Fruit Crop Pest Management A Guide for Commercial Applicators Category 1C
Michigan State University
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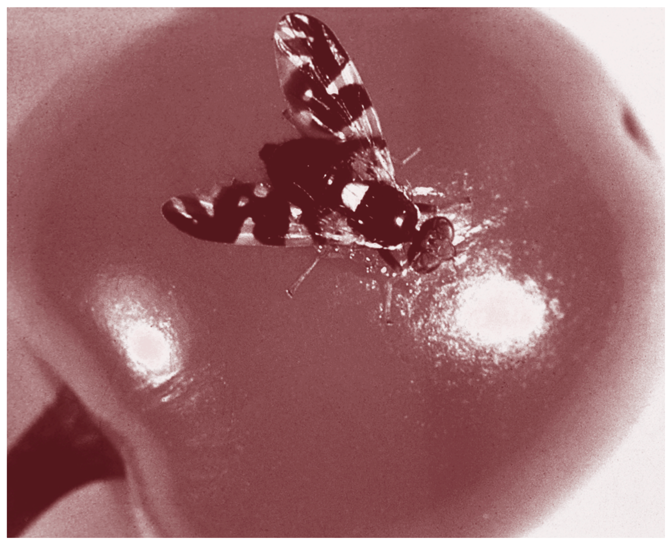

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Fruit Crop Pest Management

A Guide for Commercial Applicators
Category 1C

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MICHIGAN STATE UNIVERSITY EXTENSION

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Fruit Crop Pest Management

INTRODUCTION

How to Use This Manual

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

Category 1C, Fruit Crop Pest Management, covers the management and control of common pests in tree fruit — including apples, cherries, peaches, pears, plums and nuts — and small fruit — including blueberries, grapes, raspberries and strawberries. 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 1C 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 but 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 or 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.michigan.gov/mda>, or call the MDA at 1-800-292-3939.

CHAPTER 1

INTEGRATED PEST MANAGEMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Know the goal of integrated pest management (IPM) programs.
- Be familiar with IPM components and how they are used.
- Understand the concept and use of threshold levels.
- Be able to define and describe management methods, including cultural, biological, mating disruption and chemical methods.
- Understand the importance of preharvest interval, residues, reentry interval, phytotoxicity and pesticide resistance.

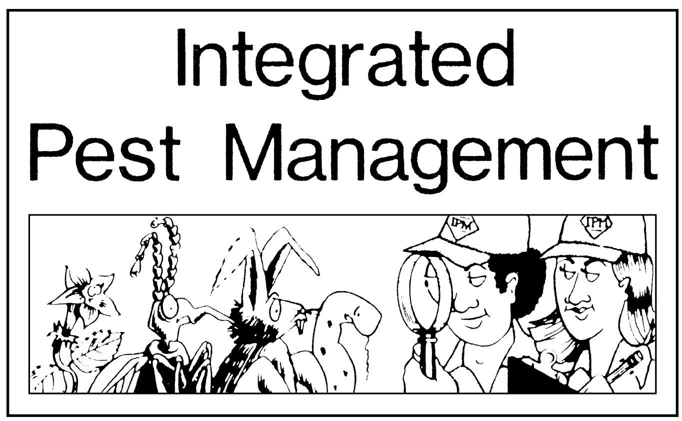
Fruit crops are vulnerable to attack by pests. Pest damage can range from leaf damage that has no effect on the value of the fruit to severe damage that kills plants, significantly reduces crop yield or reduces the crop's market value. Pests may also cause contamination of fruit at harvest, reducing its marketability. Fruit pests include insects and mites, pathogens, nematodes, weeds and vertebrates.

Effective pest management is based on thorough consideration of ecological and economic factors. The pest, its biology and the type of damage it causes 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)

Integrated pest management (IPM) is an ecological approach to pest management. In general, pest elimination is not a goal of IPM. Rather, IPM seeks to use all appropriate tools and tactics to keep pest populations below economically damaging levels while avoiding adverse effects to humans, wildlife and the environment. Based on information gathered about the pest problem and the crop, management decisions are made using a combination of control measures that best suit the problem.



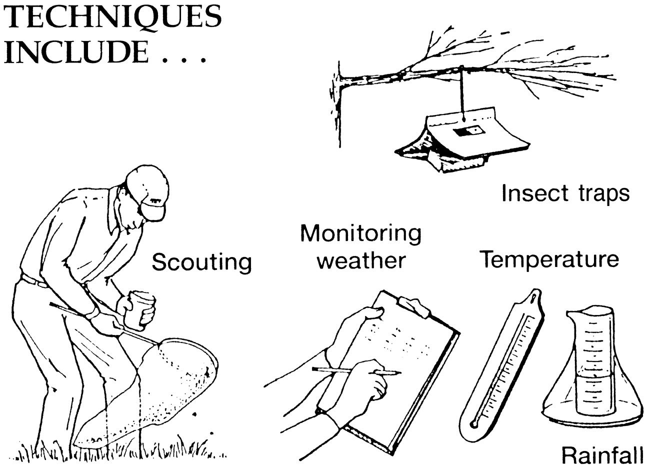
The components of IPM are:

- Monitoring (scouting).
- Forecasting.
- Thresholds.
- Choosing management methods.
- Evaluation.

MONITORING (SCOUTING)

Monitoring or scouting is the fundamental component of any IPM program. By providing the grower with timely information on pest and natural enemy populations, monitoring helps the grower determine if control methods are necessary and provides information on the effectiveness of control methods already used. Regular scouting of orchards and fields can reveal which pests are present, the growth stage of the pests and the growth stage of the crop, the location of the pests in the crop, whether the insect pests are healthy or diseased, the size of the pest population and whether it is increasing or decreasing, and the crop condition. A scouting program should include accurately written records of field or orchard locations, field conditions, previous pest infestations and control measures. With this information, you can determine what control measures are appropriate.

PEST MONITORING TECHNIQUES INCLUDE . . .



Correct identification and location of each pest in a crop are essential for precise and effective pest management decisions. The life cycle and capabilities of the pest help determine what monitoring and control choices to make. Many resources are available through Michigan State University Extension (MSUE) and Michigan State University (MSU) to assist growers in correctly identifying pests and natural enemies.

It is impossible and unrealistic to check every part of every plant or tree, so effective scouting is based on gathering information from a representative sample. Information gathered from the sample is used to make assumptions about the entire field or orchard. Correct sampling methods vary by pest and crop but usually require gathering information from several locations throughout the orchard or field and the tree or plant. Insect pests can be monitored in several ways. The most common methods used for monitoring fruit pests are described below.

1. **Visual counts**: This involves counting the number of insects present or estimating the amount of insect damage. Insect counts usually are 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 (e.g., percent leaf defoliation).
2. **Leaf brushing**: This method facilitates counting small pests and is most commonly used for mites and pear psylla. Leaves are inserted into a special machine that brushes the mites or psylla onto a glass plate with a grid, making counting easier.
3. **Beating tray**: This method involves jarring the insects from the plant by tapping limbs or shoots with a stiff rubber hose and collecting the insects on a cloth-covered tray placed beneath the plant. Insects such as pear psylla, plant bugs, large caterpillars, and predators of pear psylla and aphids can be collected and counted using this method.
4. **Pheromone traps**: Pheromones are chemical signals used by insects to communicate with others in the same species. The pheromones used in monitoring traps are usually synthetic versions of chemicals produced by females to attract males for mating. These chemicals are very specific, so the captures usually consist of males from one species of insect. Pheromone traps are available for detecting most of the major moth pests in fruit crops in Michigan. These traps can be used to:
   - Assess the time of emergence.
   - Determine the level of pest activity in a crop.
   - Determine the optimum time to apply a control measure.

   In some situations, cumulative male catch in traps can also be used to determine the need to control a pest.
5. **Other traps**: Light traps, sticky traps and bait traps all have uses in a monitoring program. Sticky spheres baited with an attractant (usually a mixture of protein hydrolysate and ammonium acetate) are used to monitor fruit flies, including the cherry fruit fly, apple maggot and blueberry maggot.

Disease monitoring can be accomplished through scouting fields weekly and examining foliage for early disease symptoms. Also, monitoring the weather can indicate when conditions are favorable for disease development. Pest alerts and newsletters provided by MSUE county agents and other MSU personnel indicate pest pressure and outbreaks in the region and state.

THRESHOLDS

An **economic injury level** is defined as the pest density at which the cost of the damage is equal to the cost of control. Economic injury levels are a function of crop value and cost of control. In general, a high-value crop will have a lower economic injury level — less pest damage will be accepted and control measures must be implemented sooner. If the control measures are expensive or the value of the crop is low, the economic injury level is usually high. High control costs means it takes more crop loss to justify the control action.

An **action threshold** is the point at which control measures are required to prevent the pest populations from increasing to the economic injury level. When the pest population reaches the threshold, action is taken to reduce the population. The action threshold is lower than the economic injury level to allow time for the control to work. For insects, an action threshold is typically expressed as the number of insects per plant or per leaf or the amount of crop damage. This threshold can vary, depending on the populations of the pest's natural enemies. If there is a high population of natural enemies, higher populations of the pest can usually be tolerated.

FORECASTING

Weather data and other information help predict when specific pests will most likely occur. Models have been developed for several important pests of fruit crops. The rate of spread and growth of many diseases is largely determined by temperature and the amount of moisture and precipitation present at vulnerable times for the crop. The adapted Mills Table that is commonly used in Michigan for predicting apple scab infection is based on air temperature and duration of wetting periods.

Growing Degree-day Models

Degree-day models, combined with monitoring, can enable the grower to determine the most effective time for treatment applications. Because insects are cold-blooded, the growth of adults, larvae and eggs is driven by the temperature of their surroundings. The dormant overwintering stages require a certain amount of heat before they reach the stage for emergence. During this development, there is a lower limit below which no growth happens, and as the temperature increases above that, the insects grow faster and faster, up to a maximum limit. Based on the understanding of how temperature affects insect growth, growing degree-day models predict when insect pests will emerge and become active. Weather varies from season to season, so applying treatments based on the stage of the pest is much more effective than using calendar dates. These models predict the appearance of insects, egg-laying activity and other important events based on the amount of heat accumulated in the vineyard, bog or orchard.

One degree day is accumulated when the average temperature for a day is 1 degree over the lower limit for development. *Growing degree-days (GDD)* are the total number of degrees for insect growth that are accumulated during one day. At the end of every day, these numbers are added to the previous daily total to create a cumulative number of GDD. The start point for accumulating degree-days is decided one of two ways — either GDD are counted from a set date, such as January 1, or they are counted from a specific biological event, called a **biofix**. This is often the first sustained capture of an adult in a pheromone or other trap. Using a biofix is usually more accurate. It also means that GDD have to be counted for a shorter period. For many of the apple and cherry pest insects, the number of GDD from first sustained moth catch to egg hatch is well known.

The MSU agricultural meteorology program has weather stations placed around the state and provides running totals of GDD at both the 42°C and 50°C thresholds on the Internet at <**http://www.agweather.geo.msu.edu/agwx/current**>. Temperature is site-specific, however, so there is no substitute for temperature measurements taken in your crop. Temperature conditions can vary greatly even within one farm, depending on the direction of the ground's slope and the presence of cold-air traps. It is not unusual for some insects to appear a week apart in different fields on the same farm. Monitoring traps should, therefore, be placed in different parts of the farm so that different timings can be followed. The easiest way to obtain a rough calculation of degree days for a specific day is to add the daily high and low temperatures (using a min-max thermometer) and divide by two. Then subtract the lower limit for growth of the target insect. By making this calculation each day, you will become more accurate in your pest management, and that should lead to better control through more accurate timing of applications.

MANAGEMENT STRATEGIES

CULTURAL PRACTICES

Cultural management manipulates the environment to make it more favorable for the plant and less favorable for the pest. Like all other control strategies, cultural control requires an understanding of the pest and the crop. Cultural control measures are usually applied at the most vulnerable stage of the pest's life cycle and are generally preventive rather than curative actions.

Cultural control methods work in three ways:

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

Examples of cultural control in fruit:

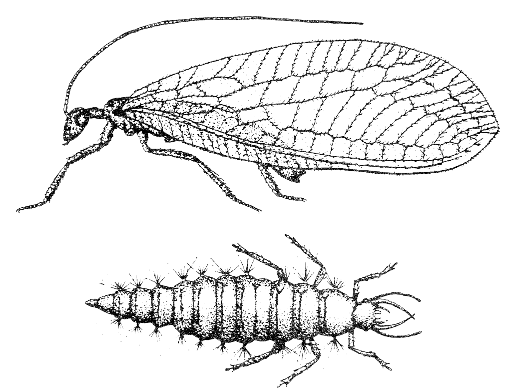
- Orient the planting to provide maximum drainage and air circulation.
- Plant insect- and disease-resistant or -tolerant varieties or rootstocks. This can be one of the simplest ways of reducing expensive treatments and negative environmental impacts.
- Remove overwintering sites — such as cull piles, mummies, suckers and damaged trees — and alternate hosts to minimize damage by insects and diseases.
- Prune to eliminate optimum sites for pests and enhance penetration of sprays.
- Manage irrigation schedules to avoid long periods of high relative humidity, which encourage some diseases to develop.
- Manage fertilizer to limit the excessive plant growth preferred by plant-sucking insects.

- Maintain a ground cover that provides habitat for beneficial insects.
- Use physical barriers to separate the pest and the host. Examples include putting netting over blueberry plantings to protect fruit from birds and covering the soil with black plastic to control weeds.
- Maintain strong, healthy plants that are well equipped to outcompete weeds, fight disease and withstand insect damage.

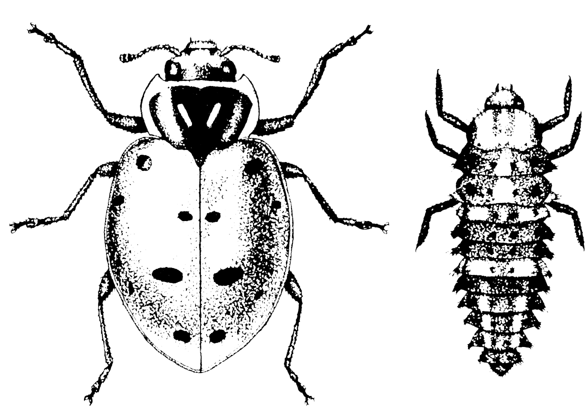
BIOLOGICAL CONTROL

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

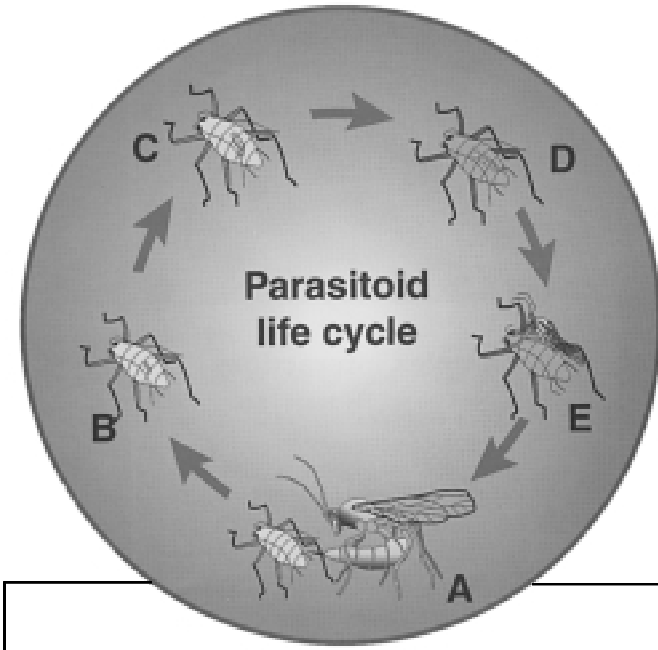
- Predators — other organisms that eat the pest. Predators are usually not specific and will eat a variety of pests.
- Parasitoids — organisms that must live in or on another organism to complete their life cycle. A parasitoid is usually an insect that develops and feeds inside another insect. An adult parasitoid lays an egg in or on a host insect. When the parasitoid egg hatches, the parasitoid larva feeds on the host insect. Eventually, the developing parasitoid kills the host insect by eating it from the inside out. Parasitoids are usually host specific and include tiny wasps and flies.



Green lacewing adult and insect-eating larva.



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



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 (epizootics), which 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 caterpillars and mosquito and beetle larvae.

MATING DISRUPTION

Mating disruption is becoming a valuable management tool for some fruit insect pests. Female insects secrete chemicals called sex pheromones to attract males of the same species for mating. Mating disruption usually involves flooding a planting or orchard with large amounts of an insect's sex pheromone to prevent potential mates from locating one another and mating. Mating disruption products are considered to be essentially nontoxic and environmentally benign.

Currently the most common products involve dispensers placed within the tree canopy or field, but new methods of dispensing pheromone, including sprayable pheromones, are being developed. Mating disruption does not kill the targeted insect but reduces the popula-

Examples of insect biological control agents (natural enemies).

Natural enemy	Pests controlled
PREDATORS	
lady beetles	aphids, other small soft-bodied insects
green lacewings	aphids, mites, mealybugs, pear psylla
syrphid flies	aphids, scale insects, thrips
minute pirate bug	mites, aphids, thrips
predatory mites	spider mites, rust mites
PARASITOIDS	
tachinid flies	caterpillars, beetle larvae and stink bugs
ichneumonid wasps	larvae and pupae of many insects
braconid wasps	caterpillars, aphids
Trichogramma wasps	eggs of many insects, including codling moth
PATHOGENS	
Bacillus thuringiensis (bacterium)	caterpillars, some beetle larvae, mosquito and blackfly larvae
codling moth granulosis virus	codling moth larvae
Agrobacterium radiobacter strain K84 (bacterium)	crown gall

tion levels of the pest by preventing mating and reproduction. Treating fruit crop environments with disruption products can help reduce broad-spectrum insecticide inputs, providing an opportunity for natural enemies of pests to establish and survive in fruit plantings.

CHEMICAL CONTROL

Chemical control reduces a pest population through the application of pesticides. In an IPM program, pesticides are used only if pest pressure, monitoring, economic thresholds or disease forecasts indicate a need. When used properly, pesticides provide effective and reliable control of many pest species. Pesticides can be man-made synthetic chemicals, naturally occurring chemicals from plants (e.g., nicotine from tobacco and pyrethrum from chrysanthemum), microorganisms (e.g., *Bacillus thuringiensis*) or minerals (e.g., copper and sulfur).

Broad-spectrum vs. Selective Insecticides

Since World War II, broad-spectrum insecticides have formed the foundation of insect management in fruit. Organochlorines, organophosphates, carbamates, and pyrethroids are all groups of broad-spectrum insecticides used in fruit pest management. They have been popular because in general they have been relatively inexpensive and fast-acting, and they provided control of many pests simultaneously. However, there are several disadvantages to these products. The wide use of these products has led to the development of resistance in many key fruit pests. Many broad-spectrum insecticides are toxic to beneficial insects and mites. This limits buildup of natural enemies and the potential for biological control of pests.

Selective or narrow-spectrum insecticides affect a specific, small group of organisms. They generally provide control of the targeted insect pest while causing minimal disruption of its natural enemies and the environment. Unlike broad-spectrum insecticides, narrow-spectrum insecticides are not contact poisons but must be ingested by the target pest to be effective. They have little or no contact toxicity. Groups of narrow-spectrum insecticides include insect growth regulators (IGRs) (which mimic or inhibit insect hormones), microbials (derived from bacteria or fungi), neonicotinoids (synthetic derivatives of botanical nicotine), insecticidal soaps and horticultural oils. Because of their selective properties, many of these products fit very well with the goal of conserving natural enemies. In an IPM program, these products should be considered when pest management is necessary.

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. Preharvest intervals are established by the Environmental Protection Agency (EPA). The preharvest interval is based partly on how long it takes the pesticide to break down. Observing the preharvest interval reduces or eliminates pesticide residues on the commodity at harvest.

Residues — the pesticide that remains on the crop after an application. Ideally, a pesticide is present to kill the pest and then breaks down when it is no longer needed. Because many pesticides do not break down completely before harvest, 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 allows increases the risk of residues exceeding legal tolerance levels.

Reentry interval (REI) — the amount of time required after a pesticide application before a person can reenter the treated area 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 personal protection equipment may enter a treated area during the reentry interval. Refer to the Worker Protection Standards 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, incompatible pesticides, adverse weather, using the wrong pesticide and improper calibration of equipment can all cause phytotoxicity. 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 to avoid this problem.

Pesticide resistance — the genetic ability of an organism to tolerate the toxic effects of a pesticide. Examples include carbaryl-resistant leafhoppers, atrazine-resistant common lamb's-quarters, Mefenoxam-resistant *Phytophthora* and ALS (acetolaclate synthase)-resistant ragweed. Resistance develops from overuse of either the same pesticide or a class of pesticides with a common mode of action, such as organophosphates or ALS herbicides. With overuse, only those pests resistant to the pesticide survive and reproduce. The result is a serious control problem. Therefore, it is important to use pesticides only when necessary and rotate pesticides and modes of action as much as possible.

EVALUATION

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

CHAPTER 1

Review Questions

Chapter 1: 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 and list the components.

2. Define economic injury level and action threshold.

3. A high-value crop will usually have a high action threshold.
   A. True.
   B. False.

4. Monitoring is important because it helps determine pest:
   A. Presence.
   B. Location.
   C. Life stage.
   D. All of the above.

5. 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.

6. Define growing degree-day models and explain what they can tell us.

7. List three ways that cultural methods work and give examples of each.

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. Describe how mating disruption works.

11. Pesticides are NEVER part of an IPM program.
   A. True.
   B. False.

12. How are tolerance and pesticide residues related?

13-15. Match the following with their definitions.

A. Predator

B. Pathogen

C. Parasitoid

13. ___ A disease-causing organism — such as bacteria, viruses and fungi — that infects the pest.

14. ___ An organism that must live in or on another organism to complete its life cycle.

15. ___ An organism that attacks, kills and feeds on other pests; usually a generalist.

16-19. Match the following management methods with their examples.

A. Cultural

B. Biological

C. Mating disruption

D. Chemical

16. ___ Placing large amounts of insect sex pheromone in a field to prevent potential mates from locating one another and mating.

17. ___ Orienting planting to provide maximum drainage and air circulation.

18. ___ Using a parasitic wasp to control a pest.

19. ___ Spraying a herbicide to control weeds.

20-23. Match the following words with their definitions.

A. Pesticide resistance

B. Reentry interval

C. Preharvest interval

D. Phytotoxicity

20. ___ Reduces unnecessary exposure of workers to pesticides.

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

22. ___ Avoids harvesting pesticide-contaminated crops.

23. ___ Can result from the continued use of the same pesticide.

CHAPTER 2

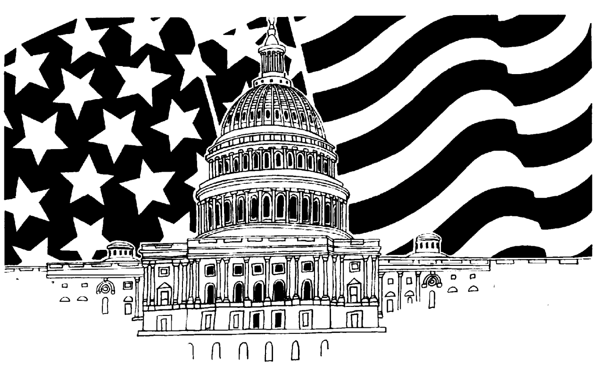
MINIMIZING PESTICIDE IMPACT

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 Michigan pesticide 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 SELECTING AND USING 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 applicators must follow. 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 labels include special local needs labels (24c), emergency exemption labels (section 18) and use information issued by the pesticide manufacturer. It 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.

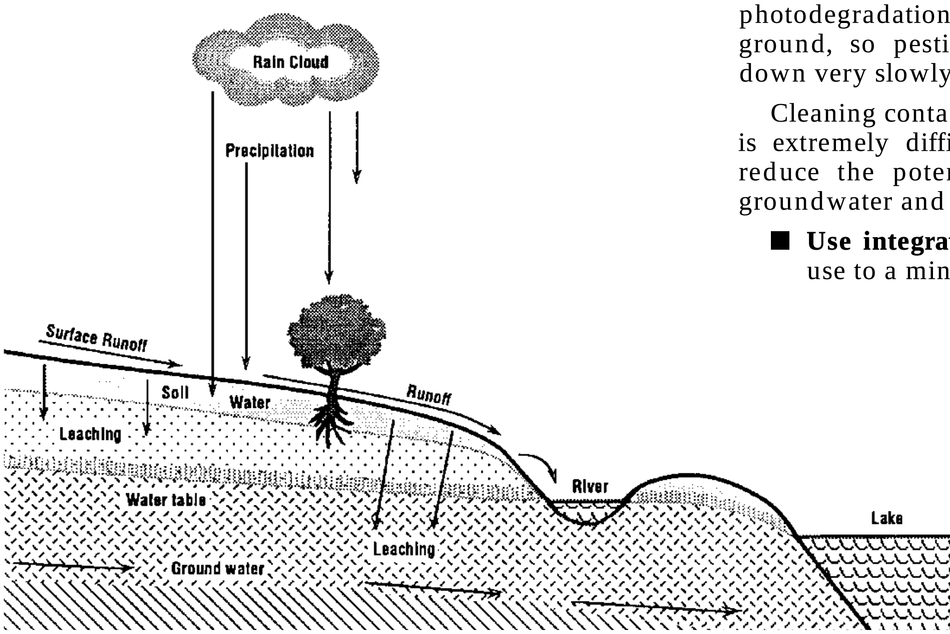
Always:

- 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 groundwater brought to the surface by 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 to 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**) or been 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 degradation 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**. Keep pesticide use to a minimum.

■ **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 through the geological layers between the soil surface and the groundwater.

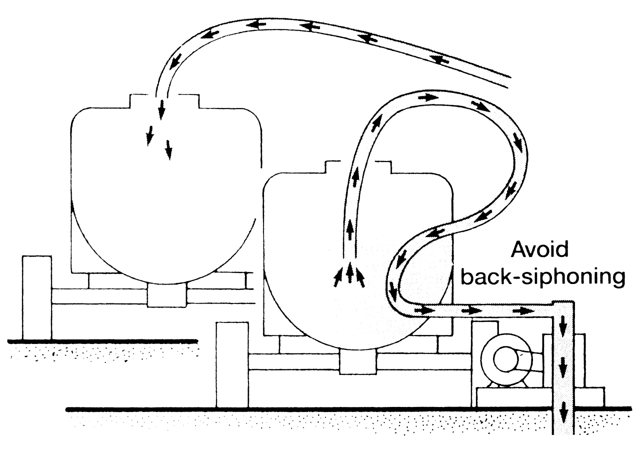
■ **Select pesticides carefully**. Choose pesticides that are not likely to leach (move downward) in the soil into groundwater or run off into surface water. Pesticides that are very water soluble and not easily bound to soil tend to be the most likely to leach. Read pesticide labels carefully, consult the MSU Extension pesticide application guides, 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.

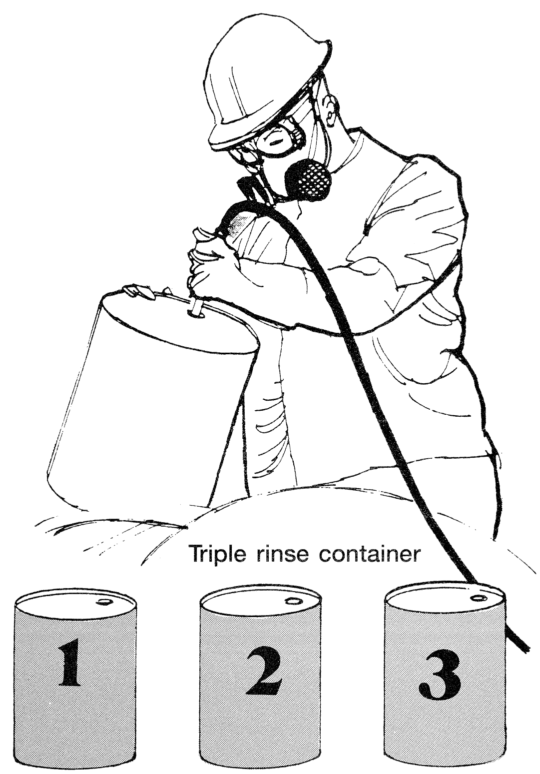
■ **Avoid back-siphoning**. Make sure that the end of the fill hose remains above the water level in the spray tank at all times. This prevents **back-siphoning** of the pesticide into the water supply. Use an anti-backflow device when siphoning water directly from a well, pond or stream. Do not leave 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 10 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 or pressure 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 or 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 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 should 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

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.

Bees are extremely important for the pollination of fruit crops. Many insecticides are highly toxic to bees. Take the following precautions to reduce the chance of bee poisoning:

- **Do not treat near beehives**. Bees may need to be moved or covered before you use pesticides near hives.
- **Select the least hazardous pesticide formulation and lowest toxicity if bees are present**. 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 for bees than midday applications.

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 or 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. Intensive use of a product may allow only resistant individuals to survive. 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 three mechanisms of resistance. Resistant individuals:

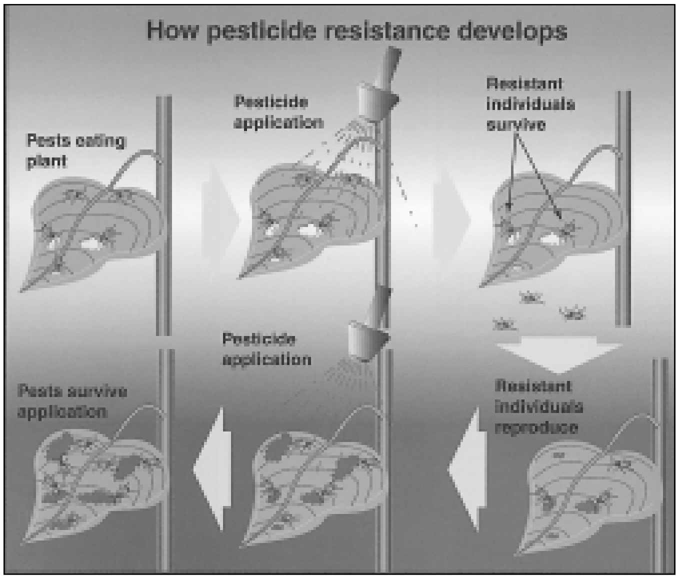
(1) May have a modified site of action so that the pesticide is no longer toxic.

(2) Metabolize (detoxify) the pesticide. **Metabolism** is a biochemical process that modifies the pesticide to less toxic compounds.

(3) Remove the pesticide from the site of action.

Resistant individuals have the genetic ability to survive when the pesticide is applied, and their offspring inherit the pesticide resistance. Because the pesticide kills most of the non-resistant individuals, the resistant organisms over time make up an increasingly larger percentage of the surviving pest population. With each use of the pesticide, this percentage increases until most of the pests are resistant and 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 the same way.



Resistance Management

Resistance management attempts to prevent or delay 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 management program. For example, crop rotation can reduce the buildup of pests in a particular crop and so reduce 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.
- **Using pesticides only when needed, and using only as much as necessary**.

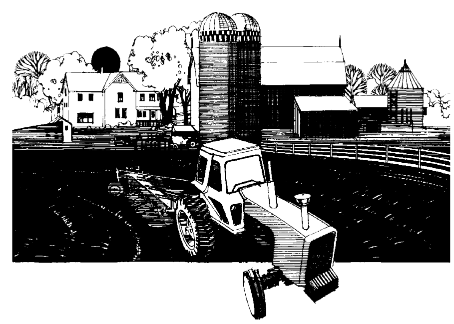
NOTIFYING NEIGHBORS

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, daycare 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 cherries to apples only if:
   A. The same pest is present on both crops.
   B. Use for apples is also on the pesticide label.
   C. A lower rate is applied to the apples.
   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 concentrate.
   B. Granular.
   C. Wettable powder.
   D. Dust.

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. Take it 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 form of:
    - 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 sprayer types and components, how they operate and what the desirable features are.
- Know special application methods that are used for fruit crop weed control and when and how they are used.
- Understand proper operation and maintenance of sprayers before, during and after spraying.

TYPES OF SPRAYERS

Spraying in fruit crop production is usually to the foliage or the ground. Foliar applications are used for disease, insect or mite control, nutrition, growth regulation and chemical thinning; ground applications are for nematode and weed control. When selecting a sprayer, be certain that it is appropriately matched to the chosen objective and will deliver the proper rate of pesticide uniformly over the target area. Most sprayers used in Michigan for pesticide applications in fruit crops use water or air as the carrier.

FOLIAR APPLICATIONS

Air-blast and Air-assisted Sprayers

Sprayers used for foliage application in tree fruit commonly use water as a diluent and air as the carrier for the chemical. **Air-blast sprayers** contain a fan that can produce a high volume of airflow. Nozzles operating under low pressure deliver spray droplets directly into the high-speed airstream. The air blast shatters the drops of pesticide into fine droplets and transports them to the target. The air blast is generally directed to one or both sides as the sprayer moves forward. Make sure to match the sprayer capability to the tree size. For example, applications to large trees will require a sprayer with large air-volume capacities. Air-blast sprayers provide good penetration and coverage, but the fine spray is very susceptible to drift and may be difficult to confine to target areas. To reduce drift, applications should be made when there is little to no wind.

Airblast sprayer

Tower sprayers are also used to spray orchard trees. These sprayers are constructed to deliver air and spray material close to the top of the tree. This practice gives better spray deposition and coverage than traditional airblast sprayers, which attempt to blow the spray up into the treetops from the ground.

Low-volume spraying

Reducing the amount of water applied per acre results in low-volume spraying. For example, a low-volume application would be a reduction from 350 gallons of water per acre to 20 to 100 gallons of water. Manufacturers recommend the optimal range of water per acre for the best results from their equipment. Keep in mind that tree size, number of trees per acre and nozzles also influence how many gallons of water are needed to provide adequate coverage.

Advantages of low-volume spraying include:

- Reduced runoff.
- Reduced use of pesticide and water.

Disadvantages of low-volume spraying include:

- The importance of maintaining a constant ground speed.
- The need to take extra care when calibrating equipment.
- More noticeable application errors because of the decrease in total gallonage applied.

GROUND APPLICATIONS

In fruit crop production, ground applications are typically used to apply herbicides to control weeds. Herbicides may be applied using hydraulic sprayers, which use water and pressure to carry the chemical to the target. 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 that normally deliver low to moderate volumes at 15 to 100 pounds of pressure per square inch (psi) are typically used for herbicide applications. The spray mixture is applied through a boom equipped with nozzles. The boom usually is mounted on a tractor, truck or trailer; the nozzle(s) can also be attached to a hand-held boom.

Granular applications

Some herbicides used in fruit crop production may be applied with a granular applicator. 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. Granular applicators normally consist of a hopper for the pesticide, a mechanical 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 have an adjustable sliding gate that opens holes in the bottom of the hopper — 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 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. Both power- and hand-driven rotary spreaders are available. With any granular application, uniform distribution of the granules is important, and applications should only be made only when there is little or no wind.

PARTS OF A SPRAYER

To properly select, maintain and operate your sprayer, you need to be familiar with its components. The major parts 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 steel are easily corroded by some pesticides and liquid fertilizers. To minimize spills, the tank cover should form a watertight seal when closed. 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 (jet) 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. Agitation using a hydraulic jet is commonly called jet agitation. For jet agitators, a flow of 6 gallons per minute for each 100 gallons of tank capacity is adequate. The jet should be submerged to prevent foaming. Wettable powder suspensions can wear the inside of the tank if the jet stream passes through less than 12 inches of liquid before hitting the tank wall.

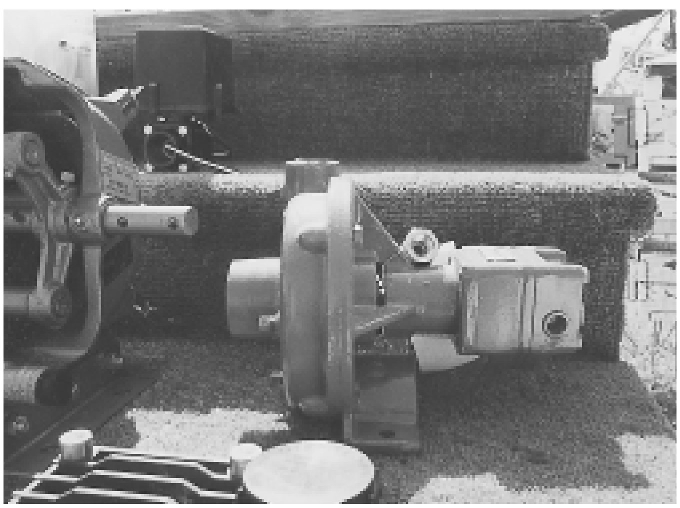
A mechanical agitator consists of a shaft with paddles and is located near the bottom of the tank. The shaft is driven by an electric motor or some other device powered by the tractor. This system is more costly than jet agitation. Mechanical agitators should operate at 100 to 200 rpm. Foaming will result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

Pumps

The 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.

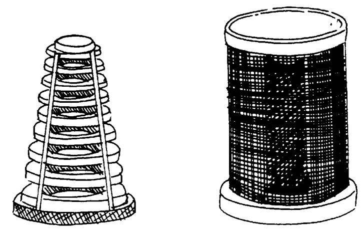
Pesticide sprayers commonly use roller, piston, diaphragm or centrifugal pumps. Each has unique characteristics that make it well adapted for particular situations. Choose a pump that best fits your pesticide application program.



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 become 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.

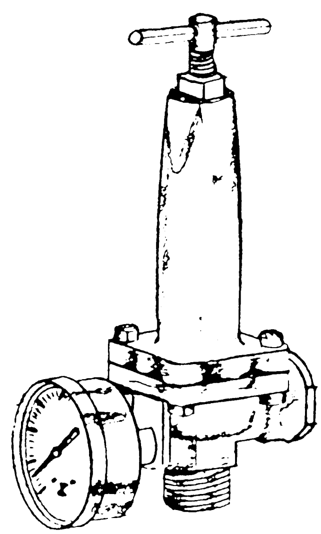
Hoses

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.



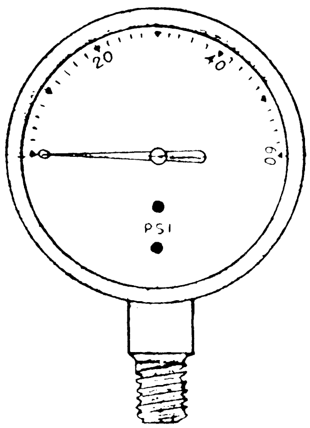
Pressure regulator.

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.

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

Pressure Gauges

A pressure gauge is essential to every sprayer system to indicate correctly 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 than other types but will last indefinitely.



Pressure gauge.

Nozzles

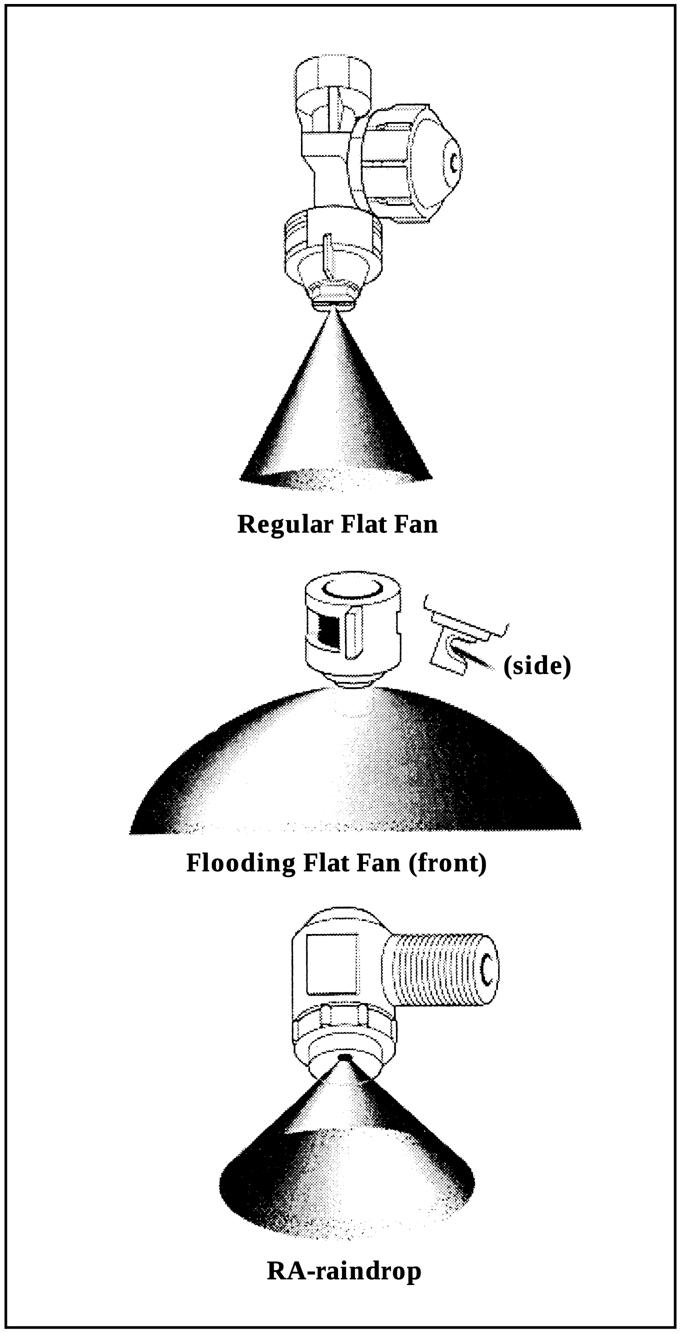
Nozzles control the volume of pesticide applied, the uniformity of application, the completeness of coverage and the degree of drift. Many types of nozzles are available, each one designed for a specific type of application. Regular flat-fan, flood and whirl chamber nozzles are preferred for weed control.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

Regular Flat-fan Nozzle

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. They are typically used for broadcast herbicide and insecticide spraying. The pattern is designed to be used on a boom and to be overlapped 30 to 50 percent to obtain uniform coverage. Spacing on the boom, spray angle and boom height determine proper overlap and should be carefully controlled.

Even Flat-fan Nozzle

The even flat-fan nozzle makes a narrow oval pattern. Spray delivery is uniform across its width. These nozzles are similar to regular flat-fan and are primarily used for band spraying over the crop row. Boom heights and nozzle spray angle determine the width of the band sprayed.



Types of nozzles.

Flooding Flat-fan Nozzle

The flooding flat-fan nozzle produces a wide-angle flat spray pattern. It operates at very low pressure and produces large spray droplets. Its pattern is not as even as the regular flat-fan nozzle pattern. If used for broadcast spraying, it should be overlapped 100 percent to provide double coverage. It is often used for applying liquid fertilizers or fertilizer-pesticide mixtures or for directing herbicide sprays under plant canopies. 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 reduce repair costs and prolong the life of the sprayer.

Before Spraying

- Read manufacturer material before purchasing a sprayer to make sure that the sprayer will fit your needs. For example, when using PTO-powered units, make sure that your tractor has enough total horsepower to operate the sprayer at the rated PTO speed.
- 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.
- Select nozzles that will provide adequate coverage for your tree size, shape and row spacing.
- Make sure all nozzles are the same type, size and fan angle.
- Measure the distance between the nozzle tip and the target, and adjust the sprayer accordingly.
- 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.

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.
- 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 pesticide 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.

C H A P T E R 3

Review Questions

Chapter 3: Application Methods and Equipment

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

1. Which of the following is an advantage of low-volume spraying?

   A. Increased runoff.

   B. Decreased runoff.

   C. Increased amount of pesticide used.

   D. Decreased amount of time spent calibrating sprayer.

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

3. The spray produced from air-blast sprayers is very susceptible to drift.

   A. True.

   B. False.

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

A. True.

B. False.

19. 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.

20. In fruit crop production, granular applicators are usually used for:

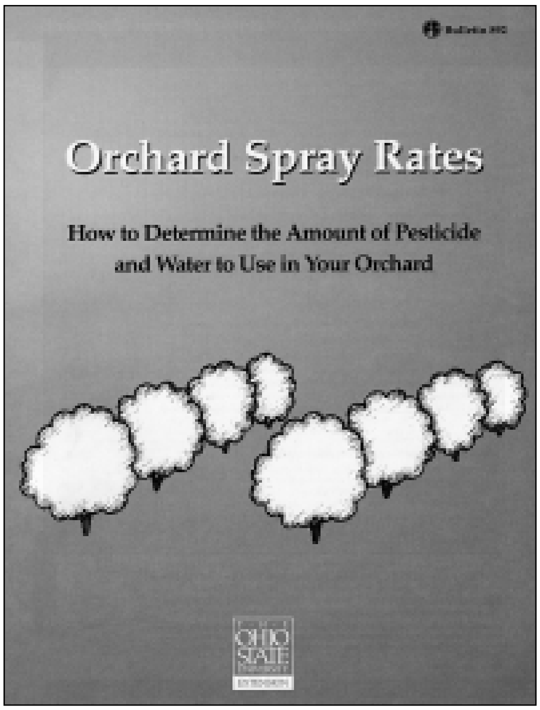
A. Foliar applications.

B. Ground applications.

C. Nutrient applications.

D. Desiccant applications.

CHAPTER 4



SPRAYING FRUIT

How to choose the amount of pesticide and water to use

Adaptation of publication "Orchard Spray Rates — How to Determine the Amount of Pesticide and Water to Use in Your Orchard"

by Celeste Welty, Extension entomologist,
The Ohio State University

BACKGROUND: TYPES OF ORCHARD PESTICIDE APPLICATIONS

Pesticide rates for fruit crops are listed in several different ways on labels for various pesticide products. These differences are sometimes confusing to novice fruit growers and even to experienced growers. How to decide which rate to use to determine appropriate amounts of pesticide and water to use for a specific orchard is explained in detail in this chapter.

Most reference books on fruit spraying show just one way of determining pesticide rates. This can leave the reader wondering if other methods are incorrect or just less preferred. In this chapter, several methods are presented that should include most of the variations in spray rate calculations that fruit growers normally hear about. The advantages and disadvantages of each method are presented along with recommendations for their use.

Orchards then and now

It helps us understand why rates are given in different ways if we consider the history of fruit growing and fruit spraying to see how pesticide rate recommendations have come about. In the early decades of the last century, apple trees were large and widely spaced within the orchard; horticulturalists still refer to large trees as *standard trees*. The old sprayers were hand-gun type sprayers that thoroughly covered the trees with the spray mix until drops began to drip from the leaves, which is what we call "to the point of runoff".

To treat large standard apple trees to the point of runoff, the general rule was to use 400 gallons of spray mix per acre. All of the older pesticide recommendations were given as a rate of product per 100 gallons of water, with the understanding that it would take 400 gallons of spray mix to treat 1 acre of apple trees or pear trees. For crops other than apple, the same principle applies but with different volumes. For peach, plum and cherry, 300 gallons per acre is the standard dilute volume. For strawberries, brambles, blueberries and grapes, 200 gallons per acre is the standard dilute volume.

Two major factors have changed since the old days. First, modern sprayers can adequately cover an acre of large trees with much less than 400 gallons per acre because coverage to the point of runoff is not needed for control of most insect pests and diseases. Second, few orchards now have large standard trees that take 400 gallons of spray mix per acre to treat to the point of runoff. Most commercial orchards now use dwarfing rootstocks. Dwarf or semidwarf trees are much smaller and more closely spaced than the old standard trees, and it takes less water to cover them.

Dilute applications

A pesticide rate per 100 gallons of water is the rate that should be used if the grower needs to make a *dilute* application with either an airblast sprayer or a handgun sprayer. When a tank of pesticide is mixed at the dilute rate, the applicator should apply it to the trees until all parts of the tree are wet. This is what we call spraying *to the point of runoff*—that is, until water begins to drip off of the leaves.

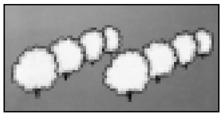
In many large commercial orchards, the only time that a dilute application is used is for sprays of superior oil in the delayed-dormant period in the spring, when the entire surface of the apple tree needs to be covered for good control of European red mite. In some smaller orchards, dilute applications are sometimes used throughout the growing season. Larger orchards usually are not treated with many dilute applications because they are more time-consuming.

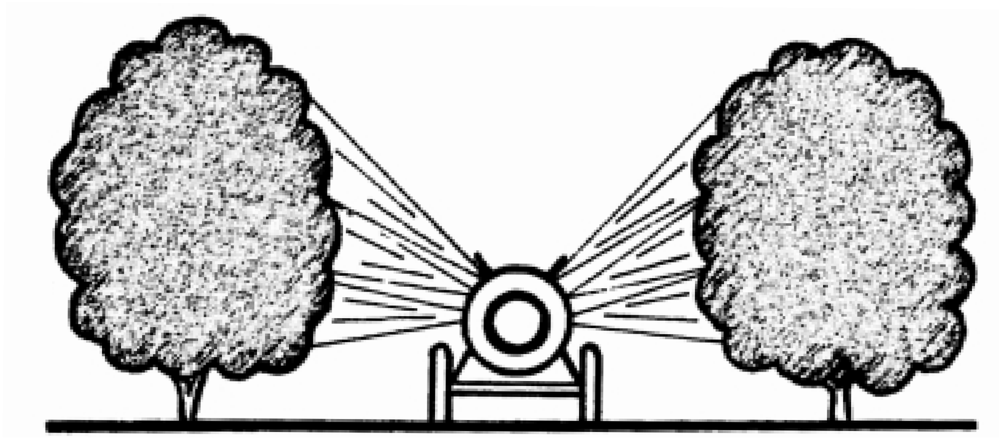
Low-volume or concentrate applications

Modern airblast sprayers, which are also known as speed sprayers, can cover fruit trees with much less than 400 gallons of spray mix per acre. Airblast sprayers produce fine droplets that cover foliage very well without the large amount of water needed to reach the point of runoff. Low-volume applications made with airblast sprayers are most commonly in the range of 40 to 80 gallons per acre.

Low-volume applications are also called *concentrate applications* because as the volume of water is decreased, there is a proportional increase in the concentration of pesticide, in order to apply the needed amount of pesticide per acre. Low-volume orchard sprays are commonly concentrated to several times the dilute rate. If the fruit grower uses what is called a 3X concentration, the volume of water is reduced to one-third of the dilute volume and therefore the pesticide is increased by three times the dilute rate. **Note**: the pesticide is increased by three times the dilute rate, not three times the concentrate rate!

When a 5X concentration is used, the volume is reduced to one-fifth of the dilute volume and therefore the pesticide concentration is increased by five times the dilute rate. Orchard sprays in the range of 2X to 5X are common.





Airblast sprayer driving between the rows.

Tree-row volume

Because dwarf and semi-dwarf types of fruit trees are smaller at maturity than the large standard types of fruit trees, a system known as tree-row volume has been developed to determine how much spray mix is needed to cover them. Although tree-row volume might sound complicated to someone who has never used it, it is well worth the effort to learn about it because it should result in more accurate coverage and likely in less pesticide per acre compared to using the full rates of water and pesticide. Tree-row volume is used to determine both the dilute volume and the related concentrate rate of pesticide per acre.

CALCULATIONS FOR DILUTE APPLICATIONS

How much water *is needed for a dilute application?*

If you want to make a *standard* dilute application, then use 400 gallons of water per acre.

Because most orchards do not need as much as 400 gallons per acre, you can *customize* the spray to a volume that is best for your orchard. Even if you never make dilute applications, you need to determine what your dilute volume should be because it is the basis for calculating the amount of pesticide to use for concentrate applications.

Determining your dilute volume per acre means *determining how many gallons of water it should take to cover 1 acre of your trees to the point of runoff*, which is when water begins to drip off of the leaves. This number is your *dilute volume*; it is likely to be in the range of 100 to 200 gallons per acre for modern types of apple trees.

You can determine your dilute volume of water per acre by any of three ways:

Method 1. Experience:

Try different volumes of water per acre with your sprayer in your orchard, and observe which volume results in runoff.

Method 2. Use a tree-row volume chart:

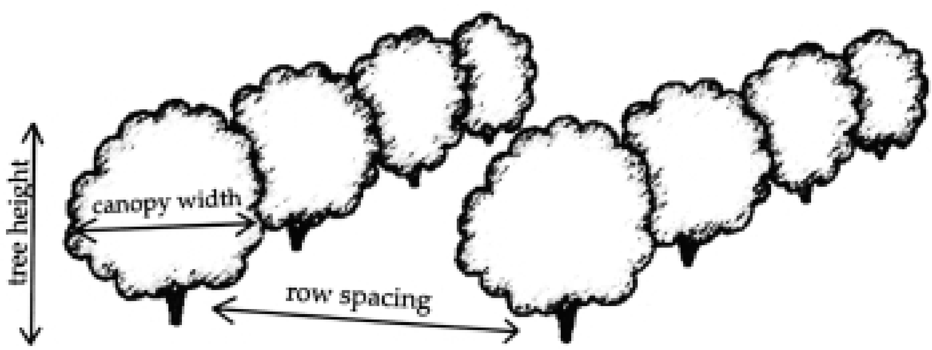
Estimates of dilute volume of water per acre are shown in the chart at the end of the chapter. The chart is based on tree size and spacing. If tree size within an orchard block is variable, then choose the measurements for the average size of the larger trees. For any combination of tree size and spacing, the chart shows what the dilute spray volume should be. The dilute spray volume is based on the rule that it takes 0.7 to 1.0 gallon to treat 1,000 cubic feet of tree canopy to the point of runoff. A canopy volume of 1,000 cubic feet is a section that is 10 feet wide by 10 feet tall by 10 feet deep. Most growers with well pruned trees can use the minimum dilute volume, which is 0.7 gallon per 1,000 cubic feet of tree canopy. The maximum dilute volume is 1.0 gallon per 1,000 cubic feet of tree canopy. The maximum dilute volume should be used in an unpruned orchard with a thick canopy.

For example, if your trees are about 12 feet wide and 10 feet tall in rows spaced 20 feet apart, the chart shows that you have a maximum of about 261,000 cubic feet of tree per acre. If these trees are relatively well pruned, then your dilute volume will be about 183 gallons of water per acre, as shown in the column for “maximum”. If these trees are not pruned, then your dilute volume will be about 261 gallons of water per acre, as shown in the column for “maximum”.

Method 3. Use tree-row volume equations:

If your tree size and spacing is not in the chart at the end of this chapter, then use the formulas below.

Tree-row volume is canopy width times tree height times row length per acre. Row length per acre is 43,560 square feet per acre divided by the distance between rows, in feet. This number can be considered the maximum volume of trees this size.



Orchard Measurements

Tree-row volume = (canopy width) x (tree height) x (row length per acre)

$$\text{Tree-row volume [cu.ft./acre]} = \left(\begin{array}{c}\text{tree canopy}\\ \text{diameter}\\ \text{[feet]}\end{array}\right) \times \left(\begin{array}{c}\text{tree}\\ \text{height}\\ \text{[feet]}\end{array}\right) \times \left(\frac{\text{43,560 square feet / acre}}{\text{distance between rows [feet]}}\right)$$

For example, for trees 10 feet wide and 8 feet tall in rows 18 feet apart:

$$\text{Tree volume} = 10\text{ ft.} \times 8\text{ ft.} \times \left(\frac{(43{,}560\text{ sq. ft. / acre})}{18\text{ ft.}}\right)$$

$$= 80 \times 2{,}420 = 193{,}600\text{ cu. ft.}$$

Minimum dilute spray volume is your tree-row volume per acre times 0.7 gallon per 1,000 cubic feet. Use this as your dilute volume of water per acre, if your trees are well pruned.

$$\begin{array}{c}\text{Minimum dilute}\\ \text{volume}\\ \text{[gal./acre]}\end{array} = \left(\begin{array}{c}\textit{your}\text{ tree-row}\\ \text{volume}\\ \text{[cu.ft./acre]}\end{array}\right) \times \left(\frac{0.7\text{ gal.}}{1{,}000\text{ cu.ft.}}\right)$$

Use this as your dilute volume of water per acre if your trees are well pruned.

Continuing the example just given:

$$\begin{array}{c}\text{Minimum}\\ \text{dilute}\\ \text{volume}\end{array} = \left(193{,}600\text{ cu.ft.}\right) \times \left(\frac{0.7\text{ gal.}}{1{,}000\text{ cu.ft.}}\right) = 136\text{ gal./acre}$$

Maximum dilute spray volume is your tree-row volume per acre times 1.0 gallon per 1,000 cubic feet. Use this as your dilute volume of water per acre if your trees are not well pruned.

$$\begin{array}{c}\text{Maximum dilute}\\ \text{spray volume}\\ \text{[gal./acre]}\end{array} = \left(\begin{array}{c}\textit{your}\text{ tree-row}\\ \text{volume}\\ \text{[cu.ft./acre]}\end{array}\right) \times \left(\frac{1.0\text{ gal.}}{1{,}000\text{ cu.ft.}}\right)$$

Use this as your dilute volume of water per acre if your trees are not well pruned.

Continuing the example just given:

$$\begin{array}{c}\text{Maximum}\\ \text{dilute}\\ \text{volume}\end{array} = \left(193{,}600\text{ cu.ft.}\right) \times \left(\frac{1.0\text{ gal.}}{1{,}000\text{ cu.ft.}}\right) = 194\text{ gal./acre}$$

Optional Adjustments for Method 3

1. *Canopy Thickness*

Canopy thickness can be factored into tree-row volume calculations. You will need to choose a density factor between 0.7 and 1.0, depending on the relative canopy density or tree shape, rather than using either the minimum or maximum volume as described previously. However, many orchardists have found that such an adjustment does not make any difference, and in most commercial orchards 0.7 is a good choice. Only in a completely unpruned orchard would the full 1.0 density factor be needed.

2. *Pesticide Type*

Pesticide type can be factored into tree-row volume calculations. Multiply the dilute volume by certain percentages because some thinners require lower volume and some stop-drop materials require higher volume.

3. *Lower Limit*

Some applicators use a lower limit of 200 gallons per acre as the minimum dilute volume even when tree-row volume calculations show that a smaller volume should be adequate. Not all orchardists agree with this, but it could be considered in cases where a smaller number of gallons is used and control is not satisfactory.

How much pesticide is needed for a dilute application?

The amount of pesticide to use per acre is the *dilute rate times the dilute volume*. The dilute rate is the amount of pesticide per 100 gallons of water. The dilute volume is either the standard (maximum) of 400 gallons per acre or a customized amount that is likely to be much smaller (100 to 200 gallons per acre) as described earlier.

$$\text{Amount of product per acre} = (\text{dilute rate}) \times (\text{dilute volume})$$

$$= \left(\frac{\text{amt. of pesticide}}{\text{100 gal.}}\right) \times \left(\frac{\text{gallons of water}}{\text{acre}}\right)$$

For example, two orchards of different sized trees need a dilute application of Guthion 50WP, which is used at a dilute rate of 0.75 pound per 100 gallons.

In the orchard of large standard trees that require 400 gallons to spray to the point of runoff, the amount of Guthion to use for a dilute spray is 0.75 pound Guthion per 100 gallons water, times 400 gallons water per acre, which equals 3.0 pounds Guthion per acre.

$$\left(\frac{\text{0.75 lb.}}{\text{100 gallons}}\right) \times \left(\frac{\text{400 gallons}}{\text{acre}}\right) = \left(\frac{\text{3.0 lb. Guthion}}{\text{acre}}\right)$$

In the orchard of small trees that require 120 gallons to spray to the point of runoff, the amount of Guthion to use for a dilute spray is 0.75 pound Guthion per 100 gallons water times 120 gallons water per acre, which equals 0.9 pound Guthion per acre.

$$\left(\frac{\text{0.75 lb. Guthion}}{\text{100 gallons water}}\right) \times \left(\frac{\text{120 gallons water}}{\text{acre}}\right) = \left(\frac{\text{0.9 lb. Guthion}}{\text{acre}}\right)$$

For another example with the same two orchards, how much superior oil per acre is needed at half-inch green if the dilute rate is 2 gallons of oil per 100 gallons of water?

For the large trees in this example:

$$\left(\frac{\text{2 gallons oil}}{\text{100 gallons water}}\right) \times \left(\frac{\text{400 gallons water}}{\text{acre}}\right) = \left(\frac{\text{8 gallons of oil}}{\text{acre}}\right)$$

For the small trees:

$$\left(\frac{\text{2 gallons oil}}{\text{100 gallons water}}\right) \times \left(\frac{\text{120 gallons water}}{\text{acre}}\right) = \left(\frac{\text{2.4 gallons of oil}}{\text{acre}}\right)$$

How much water is needed for a concentrate application?

No calculations are needed for this step. You simply need to know from experience, or from experimenting, how many gallons of water per acre your airblast sprayer uses to adequately treat your orchard for a low-volume application, for whatever speed, pressure and nozzle arrangement you prefer to use. This number of gallons of water per acre is your *concentrate volume*. It will probably be in the range of 40 to 80 gallons per acre.

A question sometimes asked is: what concentration should I use, 3X or 4X or 5X?

The answer: The exact concentration does not matter. If you want to calculate what your concentration is, you can do this without any knowledge of how much pesticide you will use. After you decide on the amount of water that is needed for dilute application and for concentrate application, then you can *calculate the concentration by taking your dilute volume of water per acre and dividing it by your concentrate volume of water per acre.*

$$\text{Concentration} = \frac{\text{dilute volume of water per acre}}{\text{concentrate volume of water per acre}}$$

For example, if you need 180 gallons to treat to the point of runoff but your airblast uses 60 gallons to make a low-volume application, then your concentration is 180 divided by 60, which equals 3; this is a 3X application.

$$\frac{\text{180 gal. water / acre}}{\text{60 gal. water / acre}} = 3 \qquad \text{This is a 3X application}$$

How much pesticide is needed for a concentrate application?

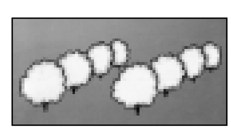
The amount of pesticide to use per acre for concentrate applications can be determined for all orchards in general, as shown in Methods 1, 2 and 3, which are explained later in the text. The amount of pesticide to use per acre for concentrate applications can be customized to a specific orchard, as explained in Methods 4 and5.

Before describing these methods, an important general point is that in concentrate spraying in a specific orchard block, *the amount of pesticide per acre stays constant even if the amount of water changes*. The rate of pesticide per acre is completely independent of the concentration used. For example, if you have an old sprayer that applies 75 gallons per acre and a new sprayer that applies 50 gallons per acre, you will use the same amount of pesticide per acre in either sprayer, although the mix in the old sprayer with 75 gallons will be a weaker concentration than the mix in the new sprayer with 50 gallons.

Method 1: Use the "amount per acre" rate as given on the label.

The easiest decision about how much pesticide to use per acre is when a pesticide label states the rate *only* as an amount of product per acre, to be used regardless of whether the spray volume is high or low.

When the label states a *range* of rates of pesticide per acre, then grower experience with factors such as pest density and tree size can be considered in deciding whether the low end of the rate range can be used or if it is necessary to go to the high end or an intermediate rate.



Advantage of Method 1: It is easy because no calculations are needed.

Disadvantage of Method 1: The rate per acre is not given on the label of many pesticide products used on fruit crops, so this method is often not possible.

Recommendation: Use this method whenever possible. Note: this method is recommended only in cases where the rate on the label is stated only as a rate per acre. On many labels, the rate is given two ways: as the rate per 100 gallons and as a full (maximum) rate per acre based on the standard conversion (as explained in Method 2, below).

Method 2: Use the full rate per acre as calculated by the standard conversion from the dilute rate.

When a pesticide label states the rate as an amount of pesticide per 100 gallons of water but you want to make a concentrate application and you need to know the equivalent amount of pesticide per acre, then you can make the standard conversion to the full rate per acre. The full rate is sometimes referred to as the *concentrate rate*. This full rate per acre should be thought of as the *maximum* amount of pesticide to use per acre.

Make the standard conversion by *multiplying the amount of pesticide per 100 gallons by the standard dilute volume of water per acre*. In the case of apples, the standard dilute volume per acre is usually defined as 400 gallons per acre. The amount of pesticide per 100 gallons times 400 gallons per acre gives you the full amount of pesticide needed per acre of apples. This is based on the old assumption, as mentioned near the beginning of this chapter, that it takes 400 gallons of spray mix for a thorough dilute application to an acre of large apple trees.

$$\left(\frac{\text{Amount of pesticide}}{\text{100 gallons of water}}\right) \times \left(\frac{\text{standard dilute volume of water}}{\text{acre}}\right) = \text{the full rate of pesticide per acre}$$

For example, if the dilute rate for Captan 50WP on apples is 1.5 pounds per 100 gallons of water, then the full rate per acre is 1.5 pounds per 100 gallons times 400 gallons water per acre, which equals 6 pounds Captan per acre.

$$\left(\frac{\text{1.5 lb.}}{\text{100 gallons}}\right) \times \left(\frac{\text{400 gallons water}}{\text{acre}}\right) = \frac{\text{6 lbs. Captan}}{\text{acre}}$$

Summary of Full Rates

$$\text{full rate of pesticide per acre of } \textbf{apples} = \left(\frac{\text{amount of pesticide}}{\text{100 gal.}}\right) \times \left(\frac{\text{400 gal. water}}{\text{acre}}\right)$$

$$\text{full rate of pesticide per acre of } \textbf{peaches} = \left(\frac{\text{amount of pesticide}}{\text{100 gal.}}\right) \times \left(\frac{\text{300 gal. water}}{\text{acre}}\right)$$

$$\text{full rate of pesticide per acre of } \textbf{berries} = \left(\frac{\text{amount of pesticide}}{\text{100 gal.}}\right) \times \left(\frac{\text{200 gal. water}}{\text{acre}}\right)$$

Advantage of Method 2: It is relatively easy to calculate.

Disadvantage of Method 2: It can result in using higher than necessary rates, especially for small trees.

Recommendation: Do not use this method if you want the most economical rate; it is better to use Method 1 or 4 or 5.

Method 3: Use the full rate per acre less 20 or 25%.

Once concentrate spraying became a common practice several decades ago, experienced fruit growers and researchers noticed that effective insect and disease control was often obtained when using a lower rate than the full rate per acre. It became a common practice to use 20 or 25% less than the full rate per acre.

For example, for an application to apples of Imidan 70WP, which has a labelled rate of 1 pound per 100 gallons:

The full rate by the standard conversion =

(1 pound / 100 gallons) x (400 gallons / acre) = 4 pounds per acre

To figure 20% less:

(4 pounds per acre) x (0.20) = 0.8 pounds

(4 pounds per acre) – 0.8 pounds = 3.2 pounds per acre

A quicker way to get the same answer is to take 80% of the full rate:

(4 pounds per acre) x 0.80 = 3.2 pounds per acre.

Advantage of Method 3: It means lower costs per acre for pesticides than if using the full rate per acre (as calculated in Method 2).

Disadvantage of Method 3: The 20% rule can work well for some products or some pest targets but not for others; research results are not available to determine exactly when this rule works and when it does not. It might mean that the rate being applied is below the rate stated on the label, thus the label directions are technically not being followed. If a below-label rate is used, the manufacturer can not be blamed if the product does not perform adequately.

Recommendation: Growers whose experience gives them confidence in using lower rates can certainly use this 20% reduction, but keep liability issues in mind if using lower than the label rate. It is better to use Method 1 or 4 or 5.

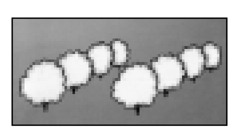
Introduction to Methods 4 and 5: Use a pesticide rate per acre customized to your fruit operation, based on tree-row volume.

When a label states the rate of pesticide per 100 gallons of water, then the rate of pesticide per acre can be customized for *your* sprayer and *your* orchard by following either of two methods based on tree-row volume. With either method, first you need to determine your dilute volume of water per acre, as described previously. Once you know your dilute volume, then you can determine your pesticide rate per acre either directly by tree-row volume (Method 4) or by the percentage-of-standard method (Method 5). Whether to use Method 4 or Method 5 is just a matter of personal preference; they are both based on the same principle.

Advantage of Methods 4 and 5: Spray costs are reduced by not applying more product than necessary.

Disadvantage of Methods 4 and 5: These are more complicated to calculate. However, most calculations can be done once per year; there is no need to recalculate for every spray.

Recommendation: Method 4 or 5 is best whenever the rate per acre is not provided on the label. In other words, these methods are best whenever Method 1 does not apply.



Method 4: Use a pesticide rate customized to your fruit operation based directly on the tree-row volume method.

Simply take *your dilute volume of water per acre* and multiply it by *the dilute rate of pesticide per 100 gallons of water*. This is a customized rate because your dilute volume is based on the size and spacing of your trees.

$$\left(\begin{array}{c}\text{the dilute rate}\\ \text{of pesticide}\\ \text{per 100 gallons of water}\end{array}\right) \times \left(\begin{array}{c}\text{your dilute}\\ \text{volume of}\\ \text{water per acre}\end{array}\right) = \begin{array}{c}\text{your}\\ \text{customized}\\ \text{pesticide rate per acre}\end{array}$$

For example, for application of Imidan 70WP at a dilute rate of 1 pound per 100 gallons, in an orchard that needs 180 gallons per acre to treat to runoff: take 1 pound per 100 gallons times 180 gallons per acre, which equals 1.8 pounds. You thus need 1.8 pounds of Imidan 70WP for each acre. You can see that this is much less product than if you had used just the full rate, which is 4 pounds of Imidan per acre.

$$\left(\frac{\text{1 pound}}{\text{100 gal. water}}\right) \times \left(\frac{\text{180 gal. water}}{\text{acre}}\right) = \text{1.8 pounds Imidan per acre}$$

Method 5: Use a pesticide rate customized to your fruit operation by tree row volume method and the percentage-of-standard method.

First, *divide your dilute volume of water per acre by the standard dilute volume of water per acre,* which gives you the percentage of standard for your trees. How to determine your dilute volume per acre was detailed on page 27. The standard dilute volume for apples is 400 gal. / A as defined on page 26.

$$\frac{\text{Your dilute volume of water per acre}}{\text{Standard dilute volume of water per acre}} = \begin{array}{c}\text{the percentage of standard}\\ \text{for your trees}\end{array}$$

For example, if you determined that it takes 180 gallons per acre for a dilute application to your apple trees, then your percentage of standard = 180 gallons per acre divided by 400 gallons per acre = 45%. Your trees are 45% of standard.

$$\frac{\text{180 gal. water per acre}}{\text{400 gal. water per acre}} = \text{0.45 Your trees are 45\% of standard.}$$

An alternate way to get the percentage of standard is to use tree size and spacing in the chart at the end of the chapter. For example, for trees 12 feet wide and 10 feet tall at 20-foot row spacing, the trees are 46% of standard if well pruned, as found in the column for minimum dilute volume, or 65% of standard if unpruned, as found in the column for maximum dilute volume.

Second, determine the amount of pesticide to use by multiplying your percentage of standard by the full rate per acre. Remember that the full rate per acre = amount of pesticide per 100 gallons times 400 gallons water per acre of apples, as explained previously in Method 2.

$$\left(\begin{array}{c}\text{your}\\ \text{percentage}\\ \text{of standard}\end{array}\right) \times \left(\begin{array}{c}\text{the full}\\ \text{pesticide rate}\\ \text{per acre}\end{array}\right) = \begin{array}{c}\text{the amount}\\ \text{of pesticide}\\ \text{to use per acre}\end{array}$$

For example, if your trees are 45% of standard and you need to apply Imidan 70WP, which has a dilute rate of 1 lb. per 100 gallons, then the full rate by the standard conversion is (1 lb. / 100 gallons) x (400 gallons / acre) = 4 lb. / acre. Take 45% of the full rate: 45% of 4 lb. / acre = 0.45 x 4 = 1.8 lb. / acre.

The full rate by the standard conversion:

$$\left(\frac{\text{1 pound}}{\text{100 gal. water}}\right) \times \left(\frac{\text{400 gal. water}}{\text{acre}}\right) = \text{4 pounds Imidan per acre}$$

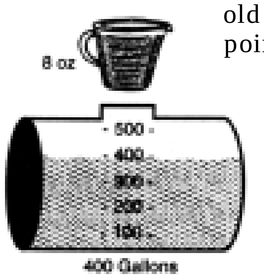
45% of the full rate:

45% of 4 pounds per acre = 0.45 x 4 = 1.8 pounds Imidan per acre

EXAMPLES FOR REVIEW

To help review the information presented in the last few pages, here are four sample calculations, all based on Provado 1.6F insecticide, which is labelled for application to apples for leafminer control at a dilute rate of 2 fluid ounces per 100 gallons. The Provado label does not state a rate per acre.

Example 1: How much Provado 1.6F should a grower use per acre for an orchard of big old apple trees, for a *dilute* application, if these trees require 400 gallons per acre to the point of runoff?

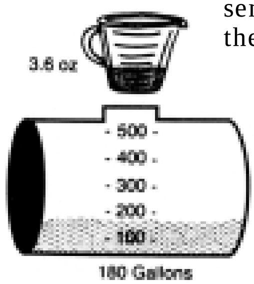


Example 1

(dilute rate) x (dilute volume) = (amount of product per acre)

$$\frac{\text{2 oz.}}{\text{100 gal. water}} \times \frac{\text{400 gal. water}}{\text{acre}} = \text{8 oz. per acre}$$

Example 2: How much Provado 1.6F should a grower use per acre for an orchard of semidwarf apple trees, for a *dilute* application, if these trees require 180 gallons per acre to the point of runoff?

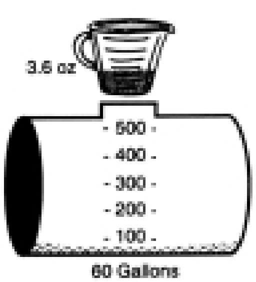


Example 2

(dilute rate) x (dilute volume) = (amount of product per acre)

$$\frac{\text{2 oz.}}{\text{100 gal. water}} \times \frac{\text{180 gal. water}}{\text{acre}} = \text{3.6 oz. per acre}$$

Example 3: How much Provado 1.6F should a grower use per acre for an orchard of semidwarf apple trees, for a *concentrate* application, if these trees require 180 gallons per acre to the point of runoff and his airblast sprayer uses 60 gallons per acre? And what concentration is this?



Example 3

(dilute rate) x (dilute volume) = (amount of product per acre)

$$\frac{\text{2 oz.}}{\text{100 gal. water}} \times \frac{\text{180 gal. water}}{\text{acre}} = \text{3.6 oz. per acre}$$

$$\frac{\text{dilute volume}}{\text{concentrate volume}} = \text{concentration}$$

$$\frac{180}{60} = 3$$

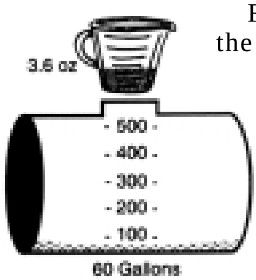
This is a 3X concentration.

You might have noticed that the block of semidwarf trees used in Examples 2 and 3 required the same amount of Provado per acre for either a dilute or a concentrate application, but the amount of *water* used per acre was different for the two types of applications.

Example 4: How much Provado 1.6F should a grower use per acre for an orchard of semidwarf apple trees, for a *concentrate* application, if these trees are in rows 18 feet apart, tree canopy width is 10 feet and tree height is 10 feet? And what spray concentration is used when an airblast sprayer applies 85 gallons per acre?

First, check the chart at the end of the chapter; for 18-foot rows and trees 10 feet wide and 10 feet tall, your dilute volume would be 169 gal./acre.

Dilute volume = 169 gal. per acre, based on the chart.



Example 4

For the final step, multiply the dilute rate by the grower's dilute volume to determine the amount of pesticide to use per acre.

(dilute rate) x (dilute volume) = (amount of product per acre)

$$\frac{\text{2 oz.}}{\text{100 gallons}} \times \frac{\text{169 gal.}}{\text{acre}} = \text{3.4 oz. per acre}$$

Another way to do the final step is to note in the tree-row volume chart that the trees are 42% of standard. Then take 42% of the full rate of Provado.

amount of pesticide per 100 gal. water x standard dilute volume of water per acre = full rate of pesticide per acre

(2 oz. per 100 gal. water) x (400 gal. water per acre) = 8 oz. per acre (the full rate)

42% of the full rate: (8 oz. per acre) x (0.42) = 3.4 ounces per acre

The concentration is 169 gallons per acre divided by 85 gallons per acre, which equals approximately 2, so it is a 2X application.

$$\frac{\text{Dilute volume}}{\text{Concentrate volume}} = \text{concentration}$$

$$\frac{\text{169 gal. per acre}}{\text{85 gal. per acre}} = \text{approximately 2}$$

This is a 2X concentration.

SPRAYING IN DIFFERENT SEASONS AND IN DIFFERENT ORCHARDS

Managing different orchard blocks

Keep in mind that if you have several blocks of fruit trees that vary in tree size and spacing, then your dilute volume, your concentrate volume and your concentration factor probably vary from block to block. You might need to adjust your application accordingly from block to block. The calculations should also be redone periodically as trees grow from year to year.

Seasonal adjustments

During the growing season, the tree canopy changes from a relatively thin canopy during the dormant and delayed dormant periods in the spring, to a moderately thick canopy by petal-fall, to a maximum density after terminal shoots are fully developed by midsummer. Thorough coverage is more difficult to achieve when the canopy is thick. The dilute volume and concentrate volume required can be adjusted to allow for these canopy changes if the grower notices that one all-purpose volume is not always adequate.

Recommendation

Be sure to evaluate fruit quality on the packing line after harvest. If the grower's spray program is not adequately controlling all insect and disease problems, then spray rates and volumes are one factor that the grower should reevaluate for the following year.

SPRAYER CALIBRATION

The purpose of sprayer calibration is to ensure that your equipment delivers the correct amount of pesticide uniformly over the target area. Because virtually every sprayer is a unique combination of pumps, nozzles and other equipment, you should refer to the sprayer's owner manual for how best to calibrate your sprayer.

VARIABLES THAT DETERMINE 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.

Tree-row volume chart.

This chart shows the dilute volume of spray mixture per acre required to spray tree fruit of various tree sizes and spacings, and equivalent percentage of standard dilute volume; assumes that trees are mature enough to fill the rows.

Distance between rows (feet)	Tree canopy width (feet)	Tree height (feet)	**Tree-row volume** per acre (cubic feet, rounded to nearest 1,000)	**Your dilute volume** (gallons per acre)		Your dilute volume as a **percentage of standard** dilute volume			
				Minimum[1]	Maximum[2]	Pome fruit (base 400 g.p.a.)		Stone fruit (base 300 g.p.a.)	
						Minimum[1]	Maximum[2]	Minimum[1]	Maximum[2]
40	22	22	527,000	369	527	92%	132%	123%	176%
30	20	20	581,000	407	581	102%	145%	136%	194%
30	20	15	436,000	305	436	76%	109%	102%	145%
26	16	12	322,000	225	322	56%	80%	75%	107%
24	14	12	305,000	213	305	53%	76%	71%	102%
22	14	12	333,000	233	333	58%	83%	78%	111%
20	15	12	392,000	274	392	69%	98%	91%	131%
20	12	14	366,000	256	366	64%	92%	85%	122%
20	12	12	314,000	220	314	55%	78%	73%	105%
20	12	10	261,000	183	261	46%	65%	61%	87%
20	10	10	218,000	152	218	38%	54%	51%	73%
19	11	10	252,000	177	252	44%	63%	59%	84%
18	12	12	348,000	244	348	61%	87%	81%	116%
18	10	10	242,000	169	242	42%	60%	56%	81%
18	8	8	155,000	108	155	27%	39%	36%	52%
17	9	9	208,000	145	208	36%	52%	48%	69%
16	8	8	174,000	122	174	30%	44%	41%	58%
15	7	8	163,000	114	163	28%	41%	38%	54%
14	6	9	168,000	118	168	29%	42%	39%	56%
14	6	8	149,000	105	149	26%	37%	35%	50%
14	6	7	131,000	91	131	23%	33%	30%	44%
13	6	7	141,000	99	141	25%	35%	33%	47%
12	6	6	131,000	91	131	23%	33%	30%	44%
12	3	8	87,000	61	87	15%	22%	20%	29%

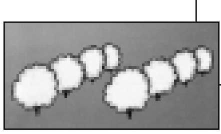
This chart shows the dilute volume of spray mixture per acre required to spray tree fruit of various tree sizes and spacings, and equivalent percentage of standard dilute volume; assuming that trees are mature enough to fill the rows.

[1] minimum: for most orchards that are regularly pruned (0.7 gal / 1000 ft^3).

[2] maximum: for unpruned orchards or unusually thick canopies (1.0 gal / 1000 ft^3).

Summary of how much water and pesticide to use for different types of spray applications to apple orchards.

Type of application	Amount of *water* per acre	Amount of *pesticide* per acre
Standard dilute application	Use 400 gallons per acre, which is enough to cover leaves of large trees to the point of runoff.	Use full rate of pesticide = (amount of pesticide per 100 gallons of water) x (400 gallons / acre).
Dilute application customized to smaller trees	Use enough to cover leaves to the point of runoff, as determined by experience and experimenting with your sprayer in your orchard.	Use (amount of pesticide per 100 gallons of water) x (your customized dilute volume of water per acre).
	OR Use amount estimated from the tree-row volume chart (see page 39).	
	OR Use amount determined by tree-row volume equations (pp. 28-29).	
Standard concentrate (low-volume) application	Use enough to provide adequate coverage of the canopy, based on experience and experimenting with your sprayer in your orchard; likely to be 40 to 80 gallons / acre.	Use amount of pesticide per acre as stated on pesticide product label.
		OR Use full rate of pesticide = (amount of pesticide per 100 gallons of water) x (400 gallons / acre).
		OR Use full rate less 20 or 25% if your experience shows that control is adequate with this adjustment.
Concentrate (low-volume) application customized to smaller trees	Use enough to provide adequate coverage of the canopy, based on experience and experimenting with your sprayer in your orchard; likely to be 40 to 80 gallons / acre.	Use the amount of pesticide per acre as stated on pesticide product label.
		OR Use amount based directly on tree-row volume = (dilute rate per 100 gallons) x (your dilute volume per acre).
		OR Use amount based on tree-row volume and percentage of standard = (full rate per acre) x (your dilute volume per acre) / (standard dilute volume per acre)



Glossary of terms

1. **'standard' trees**: fruit trees that are large (about 20 feet tall and 20 feet wide) and widely spaced (rows about 30 feet apart) within the orchard; it is the term used by horticulturalists for the type of apple trees that were grown for many years before dwarfing rootstocks became available.

2. **types of orchard pesticide applications**:

   dilute application: application of pesticide to fruit trees *to the point of runoff* — that is, until liquid begins to drip off of the leaves — by either an airblast sprayer or a handgun sprayer.

   concentrate application (also called *low-volume application*): application of pesticide to fruit trees by an airblast sprayer that produces fine droplets that cover foliage very well without the large volume needed to reach the point of runoff.

3. **spray volumes**:

   dilute volume: the number of gallons of water it takes to cover an acre of fruit trees to the point of runoff.

   standard dilute volume: the number of gallons of water it takes to cover an acre of standard (large) fruit trees to the point of runoff; for apple or pear trees, the standard dilute volume is 400 gallons of spray mix per acre. For peach, plum and cherry, 300 gallons per acre is the standard dilute volume. For strawberries, brambles, blueberries and grapes, 200 gallons per acre is the standard dilute volume.

   your customized dilute volume: the number of gallons of water it should take to cover 1 acre of your trees to the point of runoff; usually 100 to 200 gallons per acre for semi-dwarf or dwarf apple trees.

   your concentrate spray volume: the number of gallons of water per acre your airblast sprayer uses to adequately treat your orchard for a low-volume application, for whatever speed, pressure and nozzle arrangement you prefer to use; usually 40 to 80 gallons per acre.

   concentration (or concentrate factor): your dilute volume of water per acre divided by your concentrate volume of water per acre.

4. **rates of pesticide products**:

   dilute rate: the amount of pesticide that should be used to make a dilute application to the point of runoff with either a handgun sprayer or an airblast sprayer; usually expressed as an amount of pesticide to be mixed per 100 gallons of water.

   full rate: the maximum amount of pesticide to use per acre; calculated by multiplying the dilute rate (= the amount of pesticide per 100 gallons) by the standard dilute volume per acre (= 400 gallons per care for apples).

   concentrate rate: the amount of pesticide used per acre when making a concentrate (low-volume) application; this might be equal to or less than the full rate per acre.

5. **tree-row volume**: the amount of space occupied by fruit trees; calculated by tree height, tree width and tree spacing; used as the basis for determining the amount of water and pesticide needed to adequately cover the trees with spray.

CHAPTER 4

Review Questions

Chapter 4: Spraying Fruit. How to choose the amount of pesticide and water to use.

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

1. An insecticide is labeled to control aphids at a dilute rate of 5 fluid ounces per 100 gallons. How much insecticide will you need to spray a standard orchard at 400 gallons per acre?

   A. 5 fluid ounces.
   B. 10 fluid ounces.
   C. 20 fluid ounces.
   D. 50 fluid ounces.

2. Referring to question #1, how much insecticide per acre for a dilute application would you need if your orchard required 150 gallons per acre?

   A. 7.5 fluid ounces.
   B. 15 fluid ounces.
   C. 25 fluid ounces.
   D. 30 fluid ounces.

3. Referring to question #1, how much insecticide per acre would you use for a concentrate application if the trees required 150 gallons per acre and your air-blast sprayer uses 50 gallons per acre?

   A. 250 fluid ounces.
   B. 100 fluid ounces.
   C. 20 fluid ounces.
   D. 7.5 fluid ounces.

4. Referring to question #3, what is the concentration of insecticide application?

   A. 1X.
   B. 3X.
   C. 10X.
   D. 30X.

5. You should refer to the owner's manual to learn how to best calibrate your sprayer.

   A. True.
   B. False.

CHAPTER 5

INSECT MANAGEMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Understand how insects grow and develop.
- Understand the difference between gradual and complete metamorphosis.
- Be able to identify the major pests of tree fruit (apples, cherries, pears, peaches, plums and nuts) and small fruit (blueberries, grapes, raspberries and strawberries.)
- Be able to describe the life cycles and damage caused by the major fruit insect pests.

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

GROWTH AND DEVELOPMENT

Growth

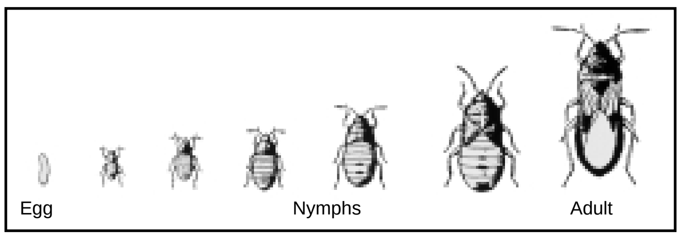
Adult insects have three body sections: head, thorax and abdomen. Six legs are attached to the thorax. Adults may have no wings or two or four wings. An insect's body is confined in a protective **exoskeleton**. This hard outer covering does not grow continuously. A new, soft exoskeleton is formed under the old one, and the old exoskeleton is shed in a process called molting. The new skeleton is larger and allows the insect to grow a little more. The new exoskeleton hardens and darkens in a few hours. After the molting process, which usually takes place in hiding, the insect resumes its normal activities.

Development

Insects can be 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." Insect pests of fruit undergo either gradual or complete metamorphosis.

Group 1. Gradual Metamorphosis

Insects developing by gradual metamorphosis hatch from eggs and 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. Several pests of fruit — such as leafhoppers, aphids, pear psylla and tarnished plant bug — develop by gradual metamorphosis. Nymphs and adults are often found together in the crop and usually eat the same food.

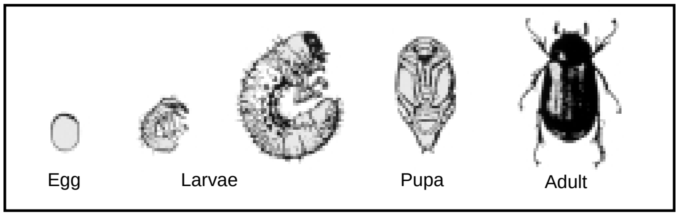


A plant bug is an example of an insect with simple metamorphosis.

Group 2. Complete Metamorphosis

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

In complete metamorphosis, newly hatched insects are called ***larvae***. Grubs, maggots and caterpillars are all types of larvae. The job of larvae is to eat and grow; they usually molt two to five times. Each larval stage between molts is called an ***instar***. After eating, molting and growing, the larvae change into ***pupae***. A pupa is an immobile stage of insect development. During pupation, the insect's body rearranges itself, resulting in a complete change in form from the immature to the adult insect. Insects undergoing complete metamorphosis have very different larval and adult stages. Larvae and adults are often so different that they do not eat the same food and need different habitats.



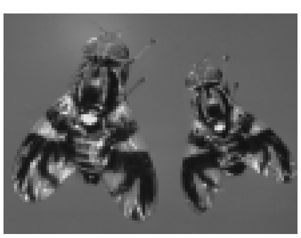
Development with complete metamorphosis (example: beetle).

CONSIDERATIONS FOR PEST MANAGEMENT

The developmental stages of insects with complete metamorphosis often support rather than compete with each other. It's as if there are two or three completely different animals with different needs and habits 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. One example is the Japanese beetle — the larva is a grub living underground and feeding on the roots of grasses, and the adult is a beetle feeding on leaves and fruit. Species with complete metamorphosis are managed differently according to life stage, where each stage lives and what each one does.

Certain stages of insects are more susceptible than others to control measures. For example, cherry fruit fly larvae feed inside fruit and are protected from sprays. Adults of this pest are much more vulnerable. During the 10-day period after emergence before adults lay eggs, carefully timed sprays can kill this pest before it lays eggs. The optimum time and part of the life cycle for most effective control are different for every pest. The following sections discuss the life cycle and behavior of each insect pest.

TREE FRUIT



Apple maggot adults female (left) and male (right).

APPLE MAGGOT

(Rhagoletis pomonella)

Crops: apple (also pear, plum, apricot, hawthorn and crabapple)

The apple maggot feeds on a variety of fruit and thrives in abandoned orchards and backyard trees. The adult fly is black, about 6 mm long, with a white spot on the thorax. The wings are clear with distinctive dark bands. The larvae are white, legless maggots and 8 mm long at maturity. The pupae look like grains of wheat.

Apple maggots have one generation per year. They overwinter in the pupal stage in the top 2 or 3 inches of soil. In southern Michigan, adult emergence begins in late June and continues until September, peaking toward the end of July. In northern Michigan, adult emergence typically begins around the second week of July. After a seven- to 10-day mating and preoviposition period, females seek out fruits. They place the eggs just under the skin through punctures made by their sharp ovipositors. The eggs usually hatch after a few days, and the maggots feed and tunnel through the fruit. Mature maggots leave the fruit and enter the soil, where they pupate.

Damage: The apple maggot causes two types of injury. The flesh surrounding a puncture where eggs are deposited in immature fruit often fails to grow with the rest of the apple, forming a sunken, dimplelike spot in the surface. Larval feeding leaves brown trails through the flesh of the apple and a distasteful flavor and odor. When several maggots are in a fruit, the interior tissues may break down and discoloration may be visible from the outside. Injured apples usually drop prematurely.

Monitoring: Adult apple maggot flies are monitored by sticky red spheres baited with apple volatile lures. Traps should be set in mid-June. They should be positioned so that they are surrounded by fruit and foliage but not touched by them or obstructed from view.

Control strategies:

Cultural:

- If possible, remove abandoned apple trees and alternate hosts for 100 yards around the orchard.
- In small orchards, infestation may be reduced by trapping out adults using unbaited sticky traps at the rate of one trap per 100 to 150 apples.

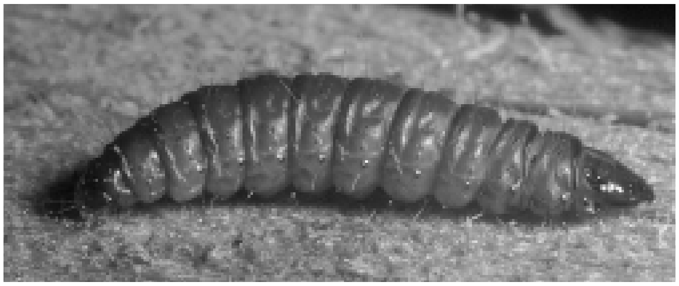
Chemical:

- Chemical control is aimed at killing the flies before they deposit eggs. Careful monitoring helps ensure correct timing for effective control. First treatments should be made seven to 10 days after the first fly is trapped. Insecticide treatments should be made if the average trap catch is more than five flies per trap.

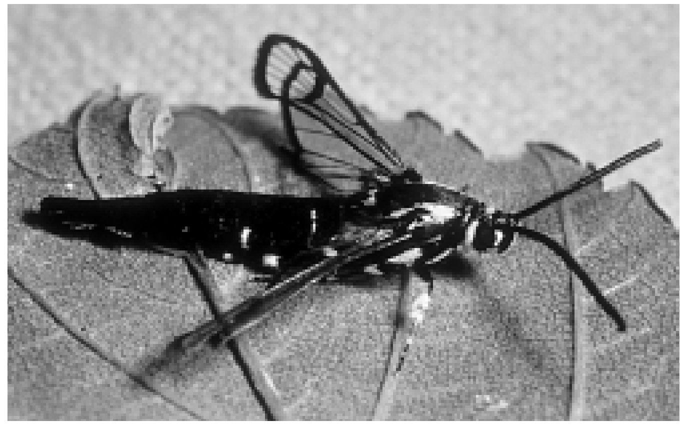
BORERS

Crops: cherry, peach, plum, apple, pear

Several species of borers affect tree fruit crops. In recent years, the American plum borer (*Euzophera semifuneralis*), lesser peachtree borer (*Synanthedon pictipes*) and peachtree borer (*Synanthedon exitosa*) have changed from minor to major pests of commercial cherry orchards in the Great Lakes region. Mechanical harvesting of cherries has largely been responsible for this by causing wounds that provide these insects with entry points through the bark and access to the underlying cambium. The highest infestations occur in older orchards that have experi-



American plum borer is one of several species of borers affecting tree fruit.



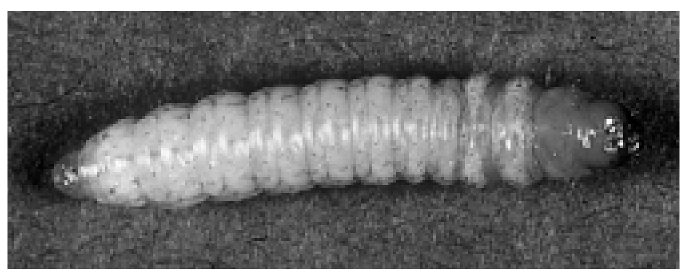
Lesser peachtree borer looks like a wasp but is actually a moth.

enced several years of wounding, especially where mechanical harvesting damage is present.

American plum borer adults are night-flying moths with dull grayish purple coloring and an irregular dark band on the forewings. They have two generations per year. The insect overwinters as a larva within a silken cocoon formed during mid- to late October. Larvae pupate as soon as cherry buds begin to open, and peak adult emergence of the first generation occurs just after full bloom. Adults live for about two weeks and lay eggs singly or in clusters in cracks near the cambium, especially in and around wounds. Larvae emerge after about nine days. Development time from first instar larva to pupa is about five weeks. The larvae feed beneath the bark. They are somewhat gregarious, and it is not uncommon for as many as 20 larvae to occur around a single wound site. Second generation adults emerge from early July to mid-September, peaking in mid-July. The second emergence and egg-laying period coincides with most mechanical harvesting schedules for cherries, which provides fresh wounds for oviposition. The following generation of larvae continues feeding until temperatures fall and trees harden off in about mid-October.

Lesser peachtree borers are day-flying moths that resemble wasps. Adults have clear wings that are fringed with blue scales. The body is blue, fringed with yellow, and the males have yellow scales on the top of the head between the eyes and black scales between the antennae. Larvae are white with a yellowish brown head and reach 1 inch at maturity. There are two generations per year; the first flight occurs during May and June, and the second during August and September. The borer overwinters as larvae. In the spring, each larva eats an exit hole nearly through the bark, spins a cocoon and pupates in a small cavity. In three or four weeks, a moth emerges, leaving an empty pupal skin protruding from the burrow. Females are active for several weeks and can lay several hundred eggs. They are especially attracted to injured, previously infected, or cankered areas. Eggs hatch in seven to 10 days, and the larvae move into the inner bark to feed.

Peachtree borer adults are also moths that resemble wasps. Males can be distinguished from the lesser peachtree borer by black scales on the top of the head between the eyes and yellow scales between the antennae. Larvae are white with brown heads and reach about 1½ inches at maturity. The peachtree borer has only a single generation per year. It overwinters in a wide range of larval stages. Larvae resume feeding in April, pupate and emerge as adults throughout the summer, usually reaching peak in July and August. Eggs hatch 10 days after deposition, and young larvae feed on the bark and move into the trunk. One sign of peachtree borers is a gum mass approximately 3 inches above to 1 foot below the soil surface.



Peachtree borer larvae feed on the tree, causing the tree to become more susceptible to other pests.

Damage: The principal damage caused by borers is done by the larvae, which feed on the cambium, or growing tissue, and inner bark of the tree. Larval feeding may girdle and kill trees. Borer damage also predisposes trees to damage by other insects, diseases and environmental stresses.

Monitoring: Pheromone traps are useful in tracking the flight of the adults and aiding in timing treatments. Trees should also be visually inspected for borer damage.

Check the trunk area up to 3 feet from the ground for gumming, wood chips, sawdust, frass, hibernacula and larvae near wounds or cankers. A screwdriver or wood chisel may be required to pry away dead bark near wounds. Check trees throughout the block.

Control strategies:

Cultural

- Maintain healthy trees and avoid trunk damage.

Mating disruption

- Mating disruption can be effective for lesser peachtree borer and peachtree borer. Pheromone ties should be distributed evenly throughout the orchard before the flight of the lesser peachtree borer — prebloom to petal fall. Attach ties to the tree at shoulder height. The lesser peachtree borer pheromone is effective for both peachtree borers.

Chemical

- Trunk insecticide sprays applied with a hydraulic gun are effective at controlling all three pests and result in minimal contact with fruit.

CHERRY FRUIT FLIES

Crops: cherry, plum, prune

Two species of cherry fruit flies attack stone fruits in Michigan: the cherry fruit fly (*Rhagoletis cingulata*) and the black cherry fruit fly (*Rhagoletis fausta*). Adult flies are black with a brown head and a small cream or yellow dot on their thorax. They measure about 4.5 mm, approximately two-thirds the size of a housefly. Like the apple maggot fly, cherry fruit fly adults have clear wings with distinctive black markings. The larvae are white, legless maggots that measure about 7 mm at maturity. The pupae are golden to dark brown, resemble a grain of wheat, and are approximately 4 mm long.

For practical purposes, the two species can be considered one because the life cycles and control measures for them are almost identical. They have one generation per year. They spend about 10 months of the year as pupae in the soil beneath the trees. Peak adult emergence occurs in mid-June for the black cherry fruit fly and harvest time (mid- to late July) for the cherry fruit fly. Egg laying begins after a preoviposition period of about 10 days. The female inserts eggs beneath the skin of the fruit with her ovipositor. Each female is capable of laying 300 to 400 eggs during the three to four weeks she is active. After five to seven days, legless maggots emerge from the eggs and feed for approximately two weeks in the fruit. When fully grown, each larva drops to the ground, burrows about 2 inches into the soil, constructs a pupa and overwinters.

Damage: The primary damage is caused by the maggots feeding within the fruit. Infested fruits appear normal until the maggot is nearly full grown, at which time sunken spots appear. Infested fruit cannot be sold. Damage is also caused by oviposition punctures, usually found near the bottom of the fruit.

Monitoring: In June, hang canary-yellow, sticky traps in the foliage of cherry trees. Use a feeding attractant such as ammonium acetate protein hydrolysate. Identify each species by examining the banding on the wings. The black cherry fruit fly will emerge 10 to 14 days earlier than the cherry fruit fly.

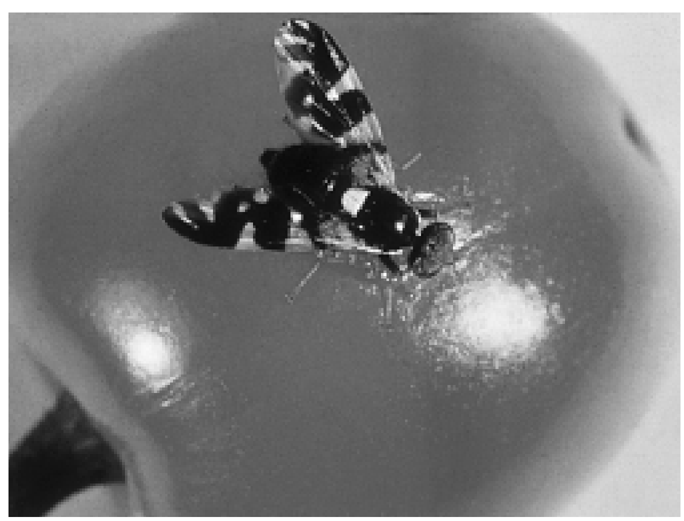
Control strategies:

Cultural

- Harvest as much fruit as possible to reduce fruit flies in the orchard.
- Remove alternate hosts, including abandoned orchards.

Chemical

- Insecticides are aimed at killing the adults before they lay eggs. Larvae inside the fruit are protected from treatments. Insecticide treatments should begin approximately five to six days after the first catch of adult flies in the sticky traps.



Cherry fruit fly larva (left) and adult (right).

CODLING MOTH

(Cydia pomonella)

Adult codling moth.

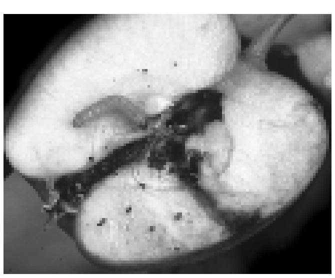
Crops: apple, pear

Codling moth is the most important insect pest of apples in Michigan. The adult moth is about 9 mm long. Wings have alternating bands of gray and white and a patch of bronze scales at the tips. Newly hatched larvae are white with black head capsules and measure about 2 mm long. The mature larva is about 15 mm long and creamy white tinged with pink.

Typically two generations of codling moth occur per year in Michigan, with a partial third generation in very warm years. The insect overwinters as a mature larva in a tightly constructed cocoon located primarily under loose bark on the tree trunk or larger limbs. The overwintering larva pupates at about first pink, and the adult emerges around full bloom. The adult lays eggs on the fruit. When an egg hatches, the larva burrows into the apple, where it creates large tunnels. After feeding within the apple for approximately three weeks, the larva emerges and seeks a pupation site. After two to three weeks in the pupal stage, the adult emerges for a second generation. Peak emergence is typically around the middle of August. Second generation larvae will leave the apples and seek an overwintering site.

Damage: Codling moth larvae cause two types of injury: deep entries and stings. A deep entry occurs when the larva burrows into the center of the fruit and feeds on seeds. Brown frass can usually be seen extruding from the entry hole. A sting is a shallow entry where the larva does some feeding but does not gain entry into the fruit. Second generation larvae cause most of the damage.

Monitoring: Pheromone traps, in conjunction with growing degree-day (GDD) models, can be used to determine the need and timing for treatment. Place pheromone traps before bloom at a density of at least one trap per 5 to 8 acres. Check traps twice a week and begin accumulating degree-days (base 50° F) on the day the first moth is trapped. The start of sustained moth capture is referred to as the **biofix**. Inspect traps weekly for the remainder of the season; count and remove captured moths. A cumulative catch of five to seven moths during the first generation or three to five moths during the second generation in any one trap may indicate the need for a spray.



Codling moth larvae damage the fruit.

Control strategies:

Mating disruption

- Mating disruption of codling moth entails placing pheromone dispensers in trees in sufficient numbers to interfere with mate location. The best sites for this approach are orchards that are relatively flat and even canopied. This allows for uniform distribution of pheromone. Mating disruption is most effective when the application is well timed and dispensers are properly positioned. Pheromone dispensers should be in place before the predicted start of the first flight. Use one trap with high load (10X) lures for every 2 to 2.5 acres. Place dispensers within 2 feet of the top of the tree canopy and near foliage to protect them from UV radiation and high temperatures. Fruit should always be visually inspected in conjunction with trapping to assess the effectiveness of a control program, especially when traps are being used for mating disruption. Concentrate visual inspections in the upper canopy and along orchard borders.

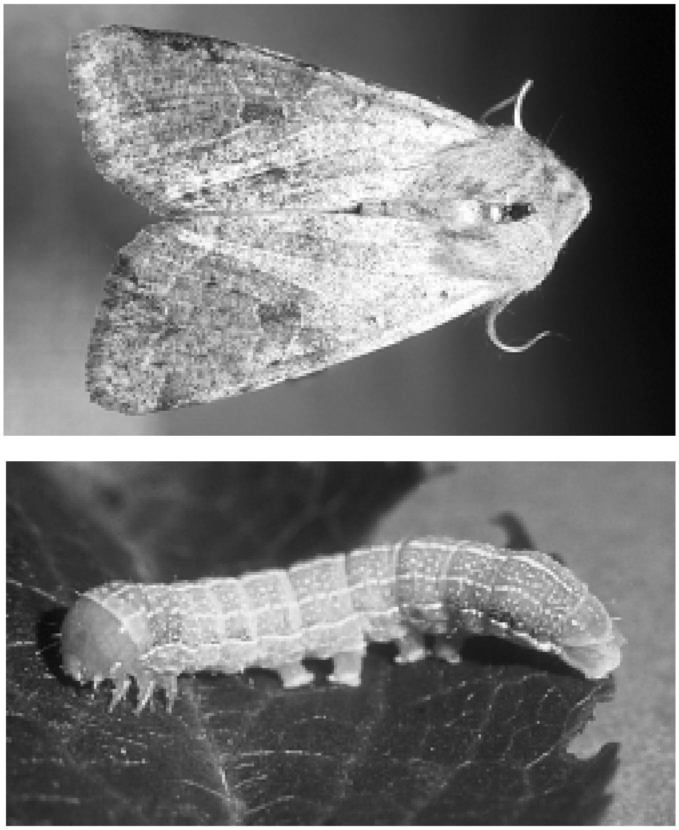
Chemical

- Growing degree-day models, not calendar dates, should be used to determine timing of pesticide applications. The first spray should be at 250 GDD, the start of egg hatch. The first spray for the second generation should be between 1,250 and 1,300 GDD. Timing of additional sprays depends on the product used. Rainfall in excess of 0.5 inch will substantially reduce the residual of most materials. The egg hatch period lasts 30 to 45 days, so several treatments may be required to control each generation.

GREEN FRUITWORMS

Crops: apple, cherry, peach, pear, plum

Fruitworms are the larval stages of moths of the family Noctuidae. The larvae are generally large and robust and various shades of green marked with yellowish or whitish lengthwise stripes. Mature larvae are 35 to 40 mm long. Several species of economic importance attack fruit. These include the speckled green fruitworm (*Orthosia hibisci*), the white-striped fruitworm (*Lithophane antennata*), the yellow-striped fruitworm (*Lithophane unimoda*) and the pyramidal fruitworm (*Amphipyra pyramidoides*). With the exception of the pyramidal fruitworm, eggs are laid in the spring when buds begin new growth. The pyramidal fruitworm overwinters as eggs that were laid in the fall. The eggs of all species start to hatch when apple buds have reached the half-inch green bud stage. The young larvae feed on the buds and leaves. They may also feed on young developing fruit. One larva can damage more than a dozen fruit. With the exception of the pyramidal fruitworm, mature larvae drop to the ground, burrow to a depth of 2 to 4 inches, pupate and overwinter as pupae. Only one generation occurs annually.



Green fruitworm adult and larva.

Damage: Most flower buds and blossoms damaged by fruitworms abort. Most fruits damaged up to and shortly after petal fall also drop prematurely. Fruits that survive exhibit deep, corky scars and indentations.

Monitoring: From pink stage to first cover, examine 20 fruit clusters per tree on five trees per orchard. On each tree, look for larvae or signs of fresh feeding on six fruit clusters on the outside of the tree, six clusters in the center and eight clusters near the top of the tree. Treatment is recommended if you find an average of two or more larvae per tree or evidence of fresh feeding.

Control strategies:

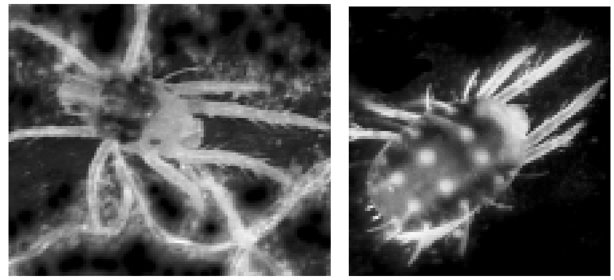
Chemical

- The biological insecticide Bt (*Bacillus thuringiensis*) is effective when applied to early instars. Timing is critical.
- Monitoring helps determine need for and timing of insecticide sprays.

MITES

Crops: apple, pear, cherry, peach, plum

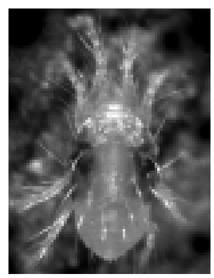
The two major mite pests of tree fruit are the European red mite (*Panonychus ulmi*) and the twospotted spider mite (*Tetranychus urticae*). Mites are not insects and undergo a different life cycle. Six-legged nymphs hatch from the eggs, molt to eight-legged protonymphs, then deutonymphs and finally eight-legged adults.



European red mite adult male (left) and female (right).

The European red mite usually overwinters as red or orange eggs on rough bark near buds and fruit spurs and in branch forks. The female adult is red or brownish red with white spots at the bases of its white bristles. The adult male is smaller than the female and reddish yellow with a tapered abdomen. Eggs begin hatching at tight cluster, and eggs are found on leaves or bark the rest of the year. Many generations occur throughout the growing season. The European red mite can reproduce by mating or parthenogenically (without mating). This contributes to the potential for the population of this pest to increase very quickly.

Twospotted spider mites have two distinct dark spots on the front half of the body behind the eyes. Males are much smaller than females and have pointed abdomens. Color varies from pale yellow to green. Overwintering adults turn orange in September. These mites can be found in the tree canopy from tight cluster through harvest. They typically construct webbing on the undersides of leaves. A complete generation from egg to adult may take as little as three weeks. Five to nine generations may occur in the orchard each season.



Twospotted spider mite.

Damage: Mites use their piercing-sucking mouthparts to suck out cell contents, including chlorophyll, from leaves and buds. This feeding turns leaves brown; the color change is referred to as bronzing. Severe infestations can cause defoliation. Moderate to heavy infestations can reduce bud formation and vigor and lead to fruit drop and decreased fruit size.

Monitoring: Orchard monitoring reduces miticide applications by determining if and when applications are required. For summer populations, examine leaves from several locations in the orchard, using 50 percent spur leaves and 50 percent shoot leaves. Treatment thresholds are two to three mites per leaf from petal fall to mid-June, five to seven mites per leaf from mid-June through July and 10 to 15 mites per leaf in August.

Control strategies:

Biological

- Several species of predatory mites can be very important at keeping pest mite populations under control.

These mites are the same size or slightly smaller than the European red mite or the twospotted spider mite and typically move rapidly across the leaf surface. Conservation of predator mites is essential.

- Another important predator of mites, the black lady beetle (*Stethorus punctum*), can provide excellent biological control of mites.

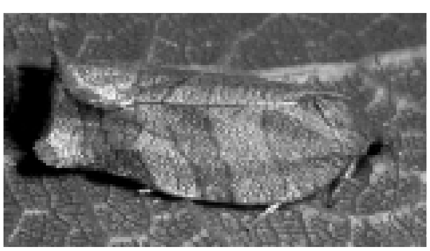
Cultural

- Ground cover and habitat management are important. Black lady beetle adults overwinter in the orchard in leaf litter around the base of trees. To conserve this natural enemy, the area in the strip near the trunk of the tree should not be disturbed from November until mid-April, when the adults become active.

Chemical

- Large populations and the high number of generations per season make mites especially good at developing resistance to miticides. Rotate miticides with different modes of action within a season or from season to season to delay the development of resistance.
- Use selective miticides and avoid the use of chemicals that are known to harm benefical predators.
- Carefully select insecticides and fungicides that are applied for other pests. In general, predator mites are not as resistant to the standard pesticides that growers use as their spider mite prey.

OBLIQUEBANDED LEAFROLLER
(Chloristoneura rosaceana)



Obliquebanded leafroller larva and adult.

Crops: apple, blueberry, pear, cherry, plum, peach, raspberry, strawberry

The obliquebanded leafroller is the most common of several leafrollers found in Michigan. It has been found on more than 80 plant species. Adults are moths about 18 to 25 mm long with brown and tan bands on the wings. Larvae are green with brown to black head capsules and about 25 mm long at maturity. The pest overwinters as second or third instar larvae within cocoons. Cocoons are found under old bud scales or bark fragments, within cracks or roughened areas, and in twig crotches.

Two generations occur per year in Michigan. Overwintering larvae feed inside bud clusters before bloom, begin feeding on fruit after petal fall and mature in late May and June. When the leaves get large enough, the larvae form them into tubular chambers where they stay except when feeding. Pupation occurs within the feeding site, and moths emerge from mid-June to mid-July. One female can lay up to 900 eggs on the leaves during her seven- to eight-day oviposition period. Newly hatched larvae crawl to new leaves or lower themselves by silk strands to other leaves. Winds can transport larvae on these strands for some distance. Summer larvae are present from about late June into August. A degree-day model can be used to predict larval activity periods.

Damage: Feeding by first generation larvae destroys floral parts and buds, causes fruit to drop and damages fruit. Summer feeding injury can leave fruit disfigured and unmarketable.

Monitoring: Check for overwintering larvae in terminals after petal fall. Summer controls will likely be needed if larvae are found in 1 to 2 percent of the shoots. Use pheromone traps to determine the biofix point for adult flight. Trap catches are usually not accurate indicators of population size because the pheromone lures are very attractive to adult moths.

Control strategies:

Cultural

- Pruning out water sprouts can limit food for the summer generation.

Chemical

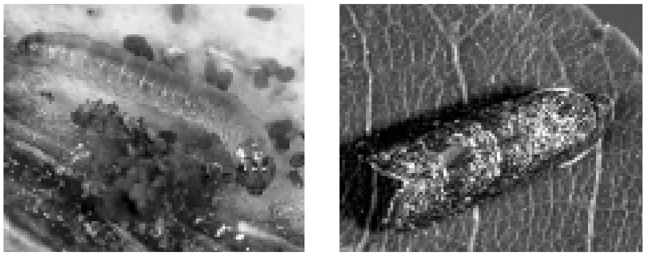
- This pest has a history of developing resistance to insecticides. Rotate insecticides with different modes of action to discourage the development of resistance.
- Biorational pesticides, including Bt, are available for leafroller control. The larvae need to ingest Bt, so applications are most effective if they are applied when the larvae are actively feeding. A general recommendation is to apply Bt when daytime high temperatures are expected to be at least 65° F for a day or two following the spray.

ORIENTAL FRUIT MOTH *(Grapholitha molesta)*

Crops: peach, cherry, plum, apple, pear

The Oriental fruit moth has traditionally been a pest of stone fruits, but in recent years it has also become a pest of apples and pears. Three full generations and sometimes a partial fourth generation occur in Michigan. Adults are gray moths with wavy, light lines on their wings; they measure about 5 mm long. Mature larvae are about 10 mm long and creamy white to pink with brown head capsules and anal combs.

The Oriental fruit moth overwinters as full-grown larvae in cocoons in tree bark crevices, weed stems, trash on the ground, fruit containers and packing sheds. On peach trees, most overwintering larvae are found on the lower 2 feet of the tree. Pupation usually begins around mid-March, with adults emerging around the pink stage for



Oriental fruit moth larva and adult.

peaches. Adults lay eggs on leaves in May and June, and after hatching, most first generation larvae bore into the twigs. First generation larvae may feed in two to three twigs for two to 10 weeks before reaching maturity. Second generation larvae feed in both twigs and fruit, often feeding in three or four twigs before they reach maturity. Third generation larvae start appearing in mid-August and are responsible for most of the wormy fruit at harvest.

Damage: The feeding of larvae in shoots injures twigs and causes leaves to wilt. Severe shoot feeding can lead to bushy trees, especially in peach. Larval feeding in fruit causes fruit drop and makes fruit unmarketable. Larvae may enter fruit through the stem or the side. In apples, codling moth and Oriental fruit moth larvae cause similar types of fruit damage. Both will enter fruit from either the calyx (blossom) end or from the side of the apple. In general, Oriental fruit moth larvae feed away from the center of the fruit, unlike codling moth larvae, which feed on flesh and seeds in the center of the fruit.

Monitoring: Pheromone traps and growing degree-day models should be used to monitor this pest. Use one trap per 10 acres to determine the biofix for each generation.

Control strategies:

Biological

- Natural parasites such as *Trichogramma minutum* (an egg parasite) and *Macrocentrus ancylivorus* (a larval parasite) may parasitize 50 to 90 percent of eggs and larvae.

Mating disruption

- Mating disruption can be achieved with pheromone ties or pheromone sprays. Ties should be placed in the mid- to upper level of the tree canopy at pink at the rate on the label. Visual monitoring should always accompany mating disruption to evaluate effectiveness.

Chemical

- Use degree-day models to determine timing of insecticide treatments.

PEAR PSYLLA *(Cacopsylla pyricola)*

Crop: pear

The pear psylla is a serious pest of pears. Unlike many tree fruit insects, it feeds only on pears. Adults are approximately 3 mm long and dark reddish brown. They resemble tiny cicadas. Adults overwinter on the trunks in crevices and under bark. Adults emerge from their winter location on bright, sunny days when the temperature is above 50° F, usually in March or April. Most of the eggs are laid before the buds open. Eggs hatch between 11 and 30 days later, depending on the temperature, with most typically hatching by petal fall. The nymphs migrate immediately to the axils of the leaf petioles and stems. They use their sucking mouthparts to feed on sap. The sap is converted within their bodies to honeydew, which is given off as droplets. There are five nymphal stages and usually three generations per year. Females of the later generations are smaller and lighter colored than those of the first generation and usually deposit their eggs along the midribs and in the notches at the edges of leaves.

Damage: Sooty mold, a fungus, grows on the honeydew secreted by the pear psylla and can cover fruit. Leaves may wilt, and partial or complete defoliation can occur. Fruit growth is impaired, and fruit may drop. The tree may show signs of “psylla shock,” believed to be caused by the toxin the psylla injects. Prolonged infestations can cause trees to decline and die.

Monitoring: In the prebloom period, use a beating tray early in the morning to sample for adults. Dislodge adult pear psylla by tapping a limb with a rubber hose and holding the tray underneath the limb. In the very early spring, yellow sticky traps used for monitoring other pests can also be used to monitor overwintering pear psylla adults.

Control strategies:

Cultural

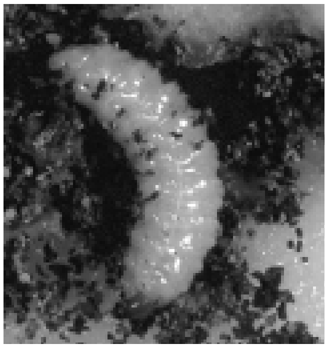
- Minimize heavy pruning. Heavy pruning encourages the proliferation of terminal shoots, which provide more feeding sites for the psylla.
- Avoid overfertilization. Overfertilization can cause extended terminal growth and delay hardening off, providing excellent feeding conditions for this pest.
- Pruning water sprouts around mid-July can greatly reduce populations because nymphs find it difficult to feed on old leaves.

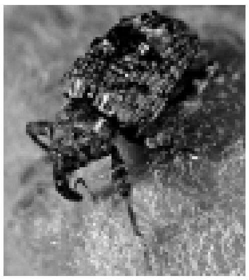
Chemical

- Pear psylla can develop resistance to chemicals quickly. Rotate insecticides with different modes of action within a season to delay the development of resistance.
- Use monitoring to determine when and if sprays are necessary.

PLUM CURCULIO *(Conotrachelus nenuphar)*

Crops: apple, blueberry, cherry, pear, peach, plum





Both adult and larval plum curculio damage tree fruit in Michigan.

Plum curculio is one of the most important insects attacking fruit. In addition to commercial tree fruit and blueberries, this pest has many hosts, including wild plum, hawthorn and native crabapple, and it is commonly present in 100 percent of backyard fruit trees. Plum curculio adults usually migrate into orchards from adjacent woodlots and hedgerows in the spring around bloom time. Moisture and temperature regulate plum curculio activity. The most reliable predictor of movement from overwintering sites to orchards is either a maximum daily temperature of 75° F for two or three days or a mean daily temperature of 55 to 60° F for three to six days. Spring migration lasts about six weeks.

The adult curculio is a small, mottled black, gray and brown beetle about 5 mm long with a large curled snout. After migrating into orchards, adults mate, and females deposit eggs into the fruit. Each female can lay 100 to 500 eggs. After about a week, the eggs hatch, and the small, white, legless grubs burrow and feed in the developing fruit. After feeding for about two weeks, the grown larvae leave the fruit and pupate in the ground about 1 inch below the soil surface. The complete life cycle takes about 50 to 55 days from egg to adult. Adults emerge from the soil in late summer, feeding on maturing fruit until they seek a hibernation spot in the fall.

Damage: Larval feeding causes internal injury in the fruit and often leads to premature fruit drop. Adult feeding and oviposition cause scarring and deformity in the fruit.

Monitoring: Visually inspect fruit for signs of feeding or egg laying. Concentrate sampling on trees or bushes adjacent to hedgerows and woodlands, especially where previous damage occurred. When curculio pressure is known to be high, multiple fruit per tree or bush should be monitored as often as daily. Beating trays can be used to determine the presence of this pest.

Control strategies:

Cultural

- For small-scale plantings, removing dropped fruit and mass trapping in hedgerows may help decrease the population but will not provide complete control.

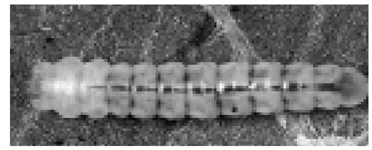
Chemical

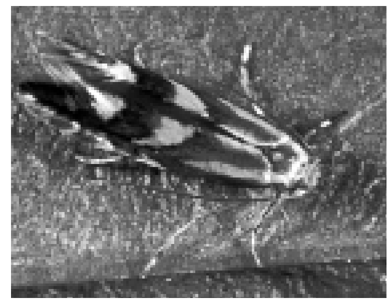
- Insecticide application should be timed to correspond with the petal-fall stage for apples and blueberries, and the petal-fall and shuck-split stages for peaches and cherries.

SPOTTED TENTIFORM LEAFMINER

(Phyllonorycter blancardella)

Crop: apple



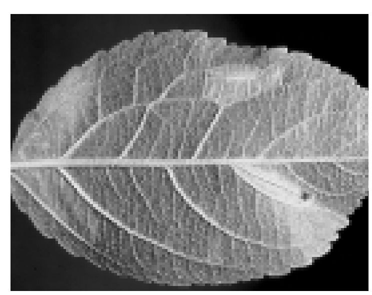


Spotted tentiform leafminer larva (top) and adult (bottom).

The spotted tentiform leafminer has three generations a year in Michigan. First generation adults emerge around bud break and lay eggs on the undersides of leaves. First egg hatch occurs two to three weeks later. Adult moths are small, about 3 mm long, with distinctive gold, black and white wing patterns. Mature larvae are white to pale green and measure about 5 mm long. Larvae feed on foliage within larval mines that cover 4 to 5 percent of the leaf area.

Adults emerge from late April until mid-June. Females lay eggs, which hatch after about one week. First instar larvae cut an opening in the leaf and feed on the contents of cells. The next two instars extend the mine and also feed on the liquid contents of the cells. These first three instars are called sap feeders. The fourth and fifth instars feed on whole cells and are called tissue feeders. The larvae pupate within the mine. First generation adult emergence occurs about 60 to 70 days after the spring generation adult emergence. In the warmer summer, the time between first generation adult emergence and second generation adult emergence is only 30 to 40 days. The third generation begins in August and continues until cold weather, overwintering as pupae in leaves on the ground.

Damage: A heavy infestation can cause stunting of fruit growth, reduced terminal growth, early leaf drop, premature ripening, fruit drop and reduced fruit set for the following season. Drought conditions can worsen damage by extensive mining.



Damage caused by spotted tentiform leafminer larvae.

Monitoring: Pheromone traps can be used to determine first moth emergence.

Control strategies:

Biological

- On unsprayed trees, this insect is controlled 100 percent by natural enemies, especially a group of parasitic wasps. These beneficial insects are very susceptible to organophosphate, carbamate and synthetic pyrethroid broad-spectrum insecticides used for other pests. Careful monitoring and timing of sprays can help conserve natural enemies.

Chemical

- This pest has been successful at developing resistance to insecticides. Rotating the mode of action in sprays for other pests can help prevent the development of resistance.
- Careful monitoring should be used to determine if sprays are necessary. If possible, use selective insecticides if sprays are needed around petal fall to conserve the beneficial parasitic wasps.

WHITE APPLE LEAFHOPPER *(Typhlocyba pomaria)*

Adult white apple leafhopper

Crop: apple

Adults and nymphs suck juices, including chlorophyll, out of mature leaves. Unlike potato leafhoppers (*Empoasca fabae*), white apple leafhoppers do not tend to feed at the leaf edge. Another behavioral difference between the two types of leafhoppers is that the potato leafhopper moves forwards, backwards and sideways, but the white apple leafhopper does not move sideways. The feeding of white apple leafhoppers causes a whitish stippling effect on foliage and leaves hard-to-remove excrement on fruit. In Michigan two generations occur. Nymphs and adults are present from spring to harvest. Nymphs are white to yellow, with early instars having red eyes. Adults are about 3 mm long and pale yellow-white.

Overwintering eggs hatch anytime from pink stage to petal fall. Nymphs begin feeding on the lower sides of leaves and petioles, and near the midvein and larger veins. Second generation eggs begin to hatch in late July, and hatching may continue into September. Second generation adults begin to emerge in late August or early September. These adults lay the overwintering eggs in the bark of apple trees.

Damage: Leafhoppers damage leaves by sucking out juices and chlorophyll, leaving a stippling effect on the leaves. Excrement on fruit is sticky and difficult to remove, and it can reduce the quality of the fruit. Large populations are a nuisance at harvest.

Leafhoppers damage leaves by sucking out plant juices.

Monitoring: Estimate the number per leaf. Examine five trees per block, 20 leaves per tree, and check the undersides of leaves for nymphs. More first generation leafhoppers will be on spur leaves. Most summer generation leafhoppers will be on midshoot leaves. Thresholds vary. Trees with a sparse canopy and a heavy crop can tolerate fewer leafhoppers than trees with luxurious canopies.

Control strategies:

- Nymphs are easier to control than adults. Controlling the first generation is usually more effective because they are more likely to be at the same growth stage, and there is less leaf area to cover. Good control of the first generation directly reduces the population size of the second generation. Thorough coverage of both sides of the leaves is essential.

BLUEBERRIES

PLUM CURCULIO *(Conotrachelus nenuphar)*

(See Tree Fruit Pests)

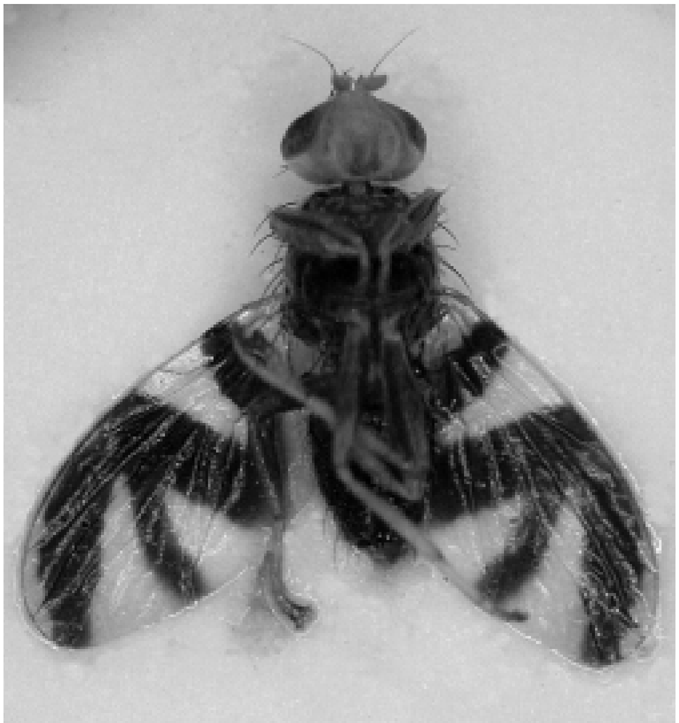
BLUEBERRY MAGGOT *(Rhagoletis mendax)*

The blueberry maggot has one generation per year. The adult fly is black, about 5 mm long, slightly smaller than a housefly, with a white spot on the thorax. The wings are clear with a W-shaped dark pattern. The larvae are white, legless maggots and 7 mm long at maturity. The pupae look like grains of wheat.

The blueberry maggot overwinters as pupae in the soil. Adults emerge anytime from late June to early August. Females begin to lay eggs about 10 days after emergence. This delay before egg laying is called the preoviposition period. One egg per fruit is inserted just under the skin of ripening or ripe berries. Two to seven days later, a tiny maggot emerges and tunnels through the fruit, liquefying the flesh. Smaller larvae are colorless and almost impossible to detect. Older larvae are whitish and easier to find. After about 20 days of feeding in the fruit, the larvae drop to the ground and pupate.

Damage: Maggot feeding makes berries soft, mushy and unmarketable. Buyers have zero tolerance for infested berries, and entire shipments can be refused. When preserves are made from infested berries, maggots rise to the top and can be found near the lid.

Monitoring: Blueberry maggot flies can be monitored effectively early in the season using baited yellow sticky boards put together to form a V, with the colored surface facing downward. During the late season, when flies



Blueberry maggot adult has a distinctive white spot on its thorax.

become sexually mature, baited sticky green spheres can be used for monitoring the adults. Spheres should be placed in the center of the bush canopy approximately 30 cm below the uppermost foliage. One trap should be placed adjacent to wild host plants or wooded areas, and the other trap should be placed in the center of the 10-acre block. Monitoring traps should be checked weekly. Fruit flies caught on monitoring traps should be counted, recorded and removed. Yellow boards should be replaced every three weeks. Sticky sphere traps should be cleaned and recoated every three weeks.

Control strategies:

Cultural

- In small plantings, trapping may be sufficient to manage this pest. For this purpose, one sticky trap per bush is recommended.
- Tillage can disrupt the pupal stage during the fall and spring.

Chemical

- Insecticide treatments should be aimed at killing adult flies before they lay eggs. This usually occurs near harvest, so growers choosing insecticides should pay careful attention to preharvest intervals listed on the labels.

CRANBERRY FRUITWORM *(Acrobasis vaccinii)*

The cranberry fruitworm is extremely common in wild blueberries and cranberries. Commercial fields near these hosts and weedy or poorly maintained plantings may have high populations of this pest.

The cranberry fruitworm has one generation per year. It overwinters as a mature larva within a cocoon of silk and soil, frequently in soil beneath the bushes. The larvae pupate in the spring, and adult moths emerge during bloom and fruit set. Adults are small, night-flying moths with dark brown-gray wings marked with white patches. Male moths typically emerge before females, and both must emerge before egg laying can start. In blueberries, the adult moth typically lays its oval, yellow eggs on the exposed calyx cup, so egg laying can start only after some petal fall. From the start of adult flight to the first egg hatch takes approximately 10 days. Larvae are green, smooth caterpillars with some brownish red coloring and dark head capsules. Larvae enter the berries at the stem end and feed on the flesh. They move from one berry to another and usually web the berries together with silk. One larva can feed on as many as eight berries in the course of its development. Fully grown larvae drop to the ground to overwinter in a cocoon of silk.

Damage: Larvae feed within berries and create masses of brown frass and silk between berries. Infested berries are unmarketable.

Monitoring: The first capture of male moths is an early warning of fruitworm activity. There is a delay of about 10 days between first moth capture and egg hatch. Any applications should be aimed at egg hatch. Looking for eggs is the most accurate way to ensure sprays are timed correctly — no degree-day model is yet available for fruitworms. These are more common on edges adjacent to woods, where high moth captures have been found.

Control strategies:

Cultural

- In small plantings with light infestations, this pest can be effectively controlled by removing infested berries, which are detected by the webbing and early ripening.
- Eliminating weeds and trash around plants and cultivation help with control.

Chemical

- Insecticide options are limited during bloom because most insecticides are toxic to bees. Exceptions are the biorational insecticide Bt (*Bacillus thuringiensis*) and an insect growth regulator that are registered for use during bloom for fruitworms. These products must be eaten by the larvae to be effective. They have their greatest impact when temperatures exceed 70° F because the larvae are more active. Bt breaks down quickly under UV exposure, so repeat applications are recommended every three to four days. The insect growth regulator kills larvae by disrupting normal development.

CHERRY FRUITWORM *(Grapholita packardi)*

The cherry fruitworm is similar in biology and management to the cranberry fruitworm.

JAPANESE BEETLE *(Popillia japonica)*

Adult Japanese beetle feeding on blueberries.

The Japanese beetle was introduced into New Jersey from Japan in 1916. Since that time, it has spread throughout the Atlantic coast and westward, and it is now firmly established in the Midwest. Adult beetles feed on a wide range of plants, including ornamentals and fruit crops. In blueberries, they remove leaf tissue and chew on the sides of fruit. This damage can increase the development of soft rots. This crop is particularly at risk of contamination because more than 60 percent of the Michigan crop is mechanically harvested, and harvesters cannot sort berries from beetles. If not detected by mechanical or human sorters, beetles may end up in fruit for sale.

The larvae are grubs that inhabit the soil and feed on grass roots. They are C-shaped, about 1 inch long and whitish with tan heads. Larvae of this species can be distinguished from those of other soil-dwelling scarabs by the V-shaped pattern of hairs on the hind end. The Japanese beetle has one generation per year in Michigan. It overwinters as larvae in the soil. In the spring, larvae move closer to the surface, resuming their growth and feeding until late June, when they pupate. Adults begin emerging about two weeks later, usually in early July, and rapidly aggregate on favorite host plants to feed and mate. This process is aided by the production of a chemical (an aggregation pheromone) that aids them in finding other individuals of their species. Females typically lay 50 to 60 eggs 2 to 4 inches under the soil surface near their food plants in batches of one to six eggs.

Damage: Adult feeding damages leaves and makes fruit susceptible to soft rots. Contamination of mechanically harvested fruit with beetles is a serious problem because buyers have zero tolerance for insect parts in the fruit.

Control strategies:

Cultural

- The majority of Japanese beetle grubs in blueberry plantings are found feeding on roots in the grassy perimeter and in row middles. Well timed rotation of row middles can significantly decrease grub populations.

Chemical

- Because adult beetles emerge from the soil during blueberry harvest time, control prior to harvest is essential to minimize contamination of blueberries, but preharvest intervals and reentry restrictions limit the utility of many insecticides during this period. To maximize the effectiveness of insecticides for Japanese beetle control, coverage should be excellent, and the full labeled rate should be used. The pH of spray water can have a significant impact on the efficacy of some insecticides.
- Well timed, targeted control of grubs in the borders and grassy areas can be effective in reducing the risk of infestation.

GRAPES

CLIMBING CUTWORMS

The common name “cutworm” refers to several nocturnal moths in the family Noctuidae. Both the adults and the larvae are active only at night, so direct observation of feeding requires a late-night trip to the vineyard. During the day, cutworms hide in the soil or leaf litter. Many of these insects feed on weeds, but some climb the stems of plants to feed on buds and other young foliage. These climbing cutworms are the ones that damage grape plants.

In Michigan grapes, the spotted cutworm, *Amathes c-nigrum*, is the main pest species. Mature larvae are gray-brown caterpillars measuring 1.2 to 1.4 inches long. The most damaging larvae feed on buds from bud swell through bud break and until the shoots are 3.9 to 5.9 inches long. Feeding on young leaves has also been reported. They pupate in the ground, 1.9 to 3.9 inches below the surface. Adult moths are brown with a heavy body, a triangular spot on each forewing and a wing span of 1.2 to 1.6 inches.

Damage: Larval feeding destroys buds. The vine can compensate for primary bud removal by producing secondary buds, but these shoots are less fruitful than those from the primary buds. Removing of both primary and secondary buds leaves tertiary buds, which produce shoots that do not fruit.

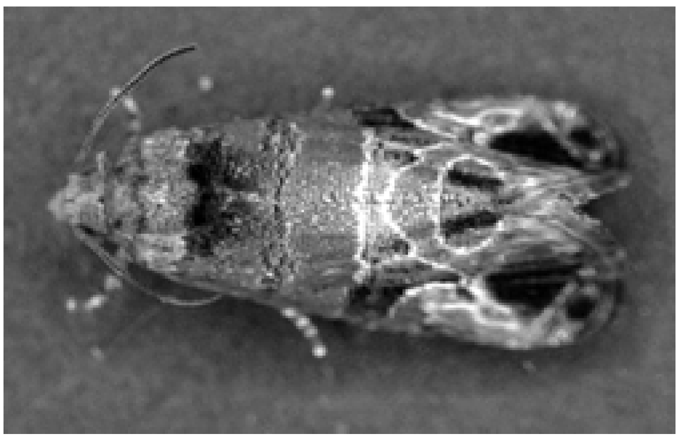
Monitoring: Careful inspection is important because this pest can cause serious bud damage in a very short time. The action threshold is 1 to 2 percent bud damage.

Control strategies:

- Insecticide treatments are warranted if bud damage reaches the action threshold.

GRAPE BERRY MOTH *(Endopiza viteana)*

The grape berry moth feeds only on grapes and usually has two or three generations per year in Michigan. This pest is common in wild grapes, and if untreated, it can destroy up to 90 percent of berries in commercial orchards. The adult is a small, brown moth with a bluish gray band in the middle of its back when it is resting. It is about .2 inch long at rest with a wingspan of approximately 1/3 inch. Adults rest during the day and can be seen flying in a zigzag pattern above the vines beginning in late afternoon through dusk.



Grape berry moth adult male.

This pest overwinters as pupae in cocoons within leaves and litter on the vineyard floor. Moths begin to emerge in late April to May, around the time of grape bloom. They mate and lay eggs on buds, young clusters or developing berries. Larvae hatch four to eight days later. Newly hatched larvae are creamy white caterpillars with dark brown heads. Larvae feed on flower buds and berries and may feed inside webbing, which can cover the whole cluster. Mature larvae reach a length of .4 inch. First generation larvae pupate within a chamber they created in a leaf or within the cluster they were feeding on. Second generation larvae tunnel and feed within the fruit. On dark grape varieties, red or purple entry points can usually be seen near where berries touch each other or join the stem. One larva may destroy as many as seven berries. Larvae in the last generation pupate in fallen leaves on the ground.

Damage: Berry moth larvae can reduce yield directly by eating grapes, and they can increase other problems by making berries susceptible to diseases such as sour rots. Large infestations late in the season can also provide conditions that increase the chance of having vinegar flies, wasps and ants in the vineyard at harvest time. Every load of juice grapes is inspected for larvae and will be rejected if too many are discovered.

Monitoring: Pheromone traps can be used for determining timing of treatments but not for predicting population size. Four traps at least 100 feet apart are recommended, with two inside the vineyard and two at the edge adjacent to wooded land. Grape berry moth infestations are spotty, and each vineyard is unique, so growers should not rely on trap data from other vineyards to time insecticide sprays. Examining fruit clusters for evidence of webbing gives an indication of the size of the overwintering population.

Control strategies:

Cultural

- Light infestations can be controlled by manually removing injured berries.
- The overwintering population can be reduced by removing and destroying leaves with pupal cells in the fall or by covering leaves with cocoons under the trellis with 1 inch of compacted soil at least three weeks before bloom.

Chemical

- Timing of treatments should be determined by pheromone trap catches.
- Choose an effective insecticide with enough residual activity that eggs and young larvae are controlled as they develop on the cluster. Short-acting products will be immediately effective but will leave the fruit at risk during the long period of egg laying if they are not reapplied. Growth regulator products should be applied at egg hatch.

GRAPE LEAFHOPPER *(Erythroneura comes)*

Leafhopper populations are usually highest during hot, dry conditions. The grape leafhopper usually has 1½ to two generations per year, depending on conditions. It overwinters as adults in debris in uncultivated, elevated, sheltered areas near vineyards. Adults begin feeding when temperatures reach the mid-60s, usually in May. The overwintering adults are 3 mm long and reddish orange; they change to yellow when they begin feeding. The leafhoppers mate and reproduce on plants including berry bushes, catnip, Virginia creeper, burdock, beech and sugar maple until new growth develops in the vineyard. Nymphs appear on the vines in late June and reach the adult stage by late July. Second generation adults and nymphs are found in late August. Adults migrate to overwintering sites in the late fall.

Nymphs are small, light green, slender insects that inhabit the undersides of leaves and walk forward when disturbed. Adults will fly when disturbed and are harder to see. The leaf tissue surrounding the feeding puncture turns white and eventually dies, and this injury is often the first sign of leafhopper activity. Damage is often highest and seen first at vineyard borders. Feeding injury first shows up along leaf veins but may eventually affect the whole leaf. Feeding is limited initially to the lower leaves, and insects can be found by turning over leaves inside the canopy.

Damage: Large populations can significantly reduce effective leaf area, leading to premature leaf drop, fruit with low Brix values, increased acidity and poor fruit color. Fruit from highly infested vineyards may therefore not earn any sugar content premium and in severe cases could be rejected by processors because of insufficient sugars. The sticky excrement ("honeydew") of the hoppers can stain the fruit and affect its appearance by supporting growth of sooty molds. Severely infested vines may be unable to produce sufficient wood for the following season. Damage to the vine can be serious if infestations are allowed to persist unchecked for two or more years, so active scouting and leafhopper management are essential for maintaining a productive vineyard.

Large populations of grape leafhoppers can lead to premature leaf drop.

Monitoring: To sample a vineyard, select two edge and two interior sample sites. In mid-July and late August, at each site, inspect five leaves (leaves three to seven) on one shoot on each of five vines to determine whether the leaves are showing any white stippling on the upper leaf surface. If they are, these leaves are counted as damaged. If more than 10 leaves from this 100-leaf sample are showing damage, the threshold has been exceeded, and an appropriate insecticide should be applied to control leafhoppers. If the vineyard interior is free of infestation but leafhoppers are present at the vineyard edges, growers could decide to spray edge areas only.

Control strategies:

Cultural

- Cultivating in the fall and cleaning up adjacent weedy areas can eliminate overwintering sites near a vineyard.
- Cold and wet weather conditions in the spring and fall and wet winters damage leafhopper populations. Populations can survive well under a blanket of snow, however.

Chemical

- Careful monitoring should be used to determine if insecticide treatment is necessary. Complete coverage of the undersides of leaves is necessary for effective control.

RASPBERRIES

APHIDS

Aphids are generally characterized by a pear-shaped body with two cornicles or "tailpipes" on the hind end. At least three genera and eight species of aphids feed on raspberries in the United States. Aphids have complex life cycles. In general, overwintering eggs hatch into wingless females in the spring. These adult female aphids reproduce without mating, creating genetically identical offspring. They do not lay eggs but give birth to tiny aphids. Populations can explode at the same time that plants are rapidly growing. Winged females are produced later in the summer and may fly to other host plants. Wingless males and egg-laying females are produced in the fall. These mate, and overwintering eggs are laid on the primary host. Some aphids overwinter as eggs on host plants; others migrate into Michigan from the southern United States. Various species have five to 10 generations per year.

Damage: Aphids use their sucking mouthparts to drink plant sap and also transmit viruses. Viruses can twist, distort and stunt new plant growth and reduce flower and fruit production. Both nymphs and adults can transmit viruses. It takes only about 15 to 30 minutes of feeding time for aphids to pick up a virus from an infected plant. They can retain this virus for several hours and are very efficient at transmitting it from plant to plant, usually requiring only one feeding for transmission.

Monitoring: To prevent the spread of viruses, monitor plantings starting at egg hatch, usually in May. The action threshold is two aphids per cane tip.

Control strategies:

Aphid control is important to stop the spread of viruses.

Cultural

- Remove wild brambles and virus-infected cultivated raspberries. Some healthy-looking plants may still harbor viruses.
- Maintain 500 to 1,000 feet between new plantings and wild brambles or infected cultivated raspberries.
- Plant certified virus-free plants. These plants remain virus-free for at least two years, but removing infected plants and controlling aphids are important to prevent local spread of virus into these plants.

- Plant aphid-resistant varieties.
- Plant virus-resistant varieties.

Chemical

- Aphids have many natural enemies — lady beetles, lacewings, spiders, parasitic wasps and fungal diseases help maintain low aphid populations. Choose insecticides that are least harmful to natural enemies, and use them only when necessary.
- Aphids can rapidly develop pesticide resistance because they reproduce quickly and most of the aphid offspring are genetically identical.

RASPBERRY CANE BORER *(Obera bimaculata)*

Raspberry cane borers are black, slender beetles about 13 mm long with bright orange markings behind the head and antennae as long as their bodies. This pest requires two years to complete its life cycle. Adult beetles emerge in June and lay eggs in the pith of new raspberry growth about 6 inches below the cane tip. The female makes two rows of puncture marks that encircle the cane, one above and one below the egg. This girdling will cause the tip of the cane to wilt. After hatching, the larvae tunnel toward the base of the cane. Larvae are white, legless borers. The larval boring weakens the cane, which usually dies before fruit matures. The larva overwinters within the cane, completes its development the following spring and pupates in the soil.

Damage: Girdling by adults causes new canes to wilt. Larval boring weakens canes and causes death and yield loss.

Monitoring: Inspect for wilted canes starting in June.

Control strategies:

- Remove wilted tips several inches below punctures and destroy them.
- Continue to check for canes with hollowed out centers, and remove and destroy any that you find.
- Remove and destroy wild brambles growing nearby.
- Regular pruning should be sufficient to manage this pest. If insecticides are necessary, they should be applied just before blossoms open.

STRAWBERRIES

MITES

Twospotted spider mites (*Tetranychus urticae*) and cyclamen mites (*Steneotarsonemus pallidus*) can cause significant damage to strawberries in Michigan. Mites are not insects. Adults have eight legs and two body sections; adult insects have six legs and three body sections.

Twospotted spider mites have a very wide host range and can be found on vegetables, shade and fruit trees, vines and ornamental plants, as well as strawberries. Eggs and adults are found on the lower surfaces of leaves. The eggs are spherical and colorless when deposited and white just before hatching. Mites typically construct webbing on the undersides of leaves. Feeding begins in the spring, and reproduction can be continuous from early spring until late fall. Mites overwinter as mature, fertile females. A complete generation from egg to adult may take as little as three weeks. Five to nine generations may occur each season. Hot, dry weather can cause rapid population increases.

Cyclamen mites are very tiny, pinkish orange to light green and shiny, and invisible to the naked eye (0.001 inch long). They overwinter as adults in the crowns and at the bases of leaf petioles. Immatures complete their development in as little as two weeks, so population increases can be very rapid. Immatures and adults are found along the midveins of young unfolded leaves and under the calyxes of new flower buds. If populations build, they are found throughout the non-expanded tissues.

Damage: Feeding by adult twospotted spider mites occurs on lower leaf surfaces, producing bronzing of leaves and leaf veins. This feeding can be particularly damaging in the months after transplanting, and with the mites' fast reproduction rate, numbers can explode very rapidly.

Cyclamen mites cause distorted leaves, blossoms and fruit because of their feeding on young tissues. Heavily infested leaves become crinkled, forming a compact bunch of distorted leaves in the center of the plant.

Monitoring: Fields should be accurately monitored to ensure that the mite population warrants applications of miticides. For twospotted spider mites, the action threshold is 25 percent of leaflets with mites. Sixty leaflets per field should be examined in a zigzag pattern. Predatory mites may also be present, and it has been found that one predatory mite per 10 twospotted spider mites provides adequate biological control. With the sampling scheme above, if 15 of 60 leaves have mites and predators are not sufficiently present, then a miticide should be applied.

Because cyclamen mites are hidden, growers should open up the newly growing tissues and look for yellowing or stunted shoots. Growers who suspect cyclamen mites as the cause of problems in their strawberries should send affected plant samples to the MSU Diagnostics Lab (517-353-9386) or to an Extension office, where the plants can be examined under a microscope for mite identification.

Control strategies:

Biological

- Mites have several natural enemies, including predatory mites and the black lady beetle. Care should be taken to preserve these natural enemies so they can build up.

Cultural

- Cyclamen mites are a common pest in greenhouses and may appear in new plantings transferred from protected propagation. Growers should ask suppliers whether they have a history of this pest in their propagation and check new transplants. Using clean transplants is the best way to reduce early plant damage.
- Annual renovation of strawberry beds can reduce the potential for twospotted mite outbreaks.

Chemical

- Most miticides kill only the motile stages, so if eggs and motiles are present, a second application may be needed a week to 10 days later to get the newly hatched mites. If the weather is warm, mites will develop faster and this application should be made earlier.
- Mites can develop resistance to miticides quickly. Alternate miticides with different modes of action to manage resistance.
- Cyclamen mites are difficult to control once they've established because of their hidden habitat. Because they are usually in small areas of the field and do not move far during the year, spot treatments can be effective. It is recommended that miticide applications for this pest be made in 400 gallons of water per acre with a wetting agent. This high application rate is used to get the pesticide into the areas where mites are hiding and is necessary for good control.

STRAWBERRY CLIPPER *(Anthonomus signatus)*

The strawberry clipper, also known as the strawberry bud weevil, is a small, dark reddish brown beetle about 3 mm long with a curved snout about one-third the length of its body. Adults overwinter in fencerows or woodlots and move to strawberries in the spring when temperatures are around 60° F, usually at the end of April. The female beetle feeds on pollen by puncturing flower buds with her snout. She then deposits an egg in the bud, girdles the bud, and clips the stem of the bud so that it hangs by a thread or falls to the ground. Eggs hatch after about a week. The white, legless grubs feed in the buds, pupate and emerge as adults in late June or July. The newly emerged adults feed on pollen of various flowers for a short time and then find overwintering sites and remain inactive for the rest of the season.

Damage: The clipping of flower buds in the spring prevents fruit from developing. Recent studies have shown that many varieties can compensate for this bud damage.

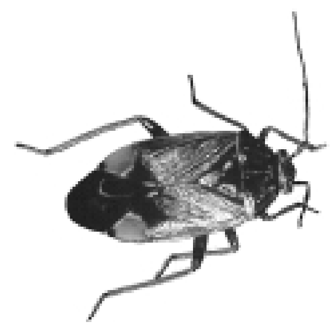
Monitoring: Scout fields beginning in early May for signs of clipped buds. Walk random rows of plants and record the number of cut buds per linear foot of row. Sample five 10-foot sections in a field and determine the number of cut buds per linear foot of row. The action threshold is one cut bud per linear row foot.

Control strategies:

- Because this pest generally migrates into the field, carefully timed treatments in field borders may be adequate for control.
- Mulches may encourage weevils to stay in the planting to overwinter. Plowing under old beds immediately after harvest helps decrease the chance of damage by this pest.
- This pest does not move great distances, so locating plantings away from woodlots and hedgerows reduces the number of adults that move into strawberry plantings in the spring.

TARNISHED PLANT BUG *(Lygus lineolaris)*

The tarnished plant bug is one of the most widespread and economically important pests of strawberries in Michigan. This insect feeds on more than 300 plant species, including weeds and crop plants and fruit, including strawberries, raspberries, apples, peaches, cherries and pears. It can also be very common in grassy fields during the spring.



Adult bugs overwinter under leaves, stones and tree bark; among the leaves of clover, alfalfa and mullein; and in other protected places. In early spring, they feed on developing foliage of many types of plants. If its habitat is disturbed by drying or cultivation, the tarnished plant bug will leave and move into more attractive vegetation. The irrigated strawberry field is highly attractive if other plants are mowed or wilted. Adults are brownish, mottled bugs about 5 to 6 mm long. Newly hatched nymphs are greenish and only about 1 mm long. Later instars resemble the adults in color but do not have wings. This pest usually has three to four generations a year, and adults and nymphs can be found from April until heavy frost.

Damage: Damage is caused by the needlelike feeding tube that the tarnished plant bug inserts into the plant to suck sap from the developing seeds. This feeding damages the developing cells of the achene, causing irregular growth known as button-berries, nubbins or catfacing. This type of damage can also be caused by poor pollination — unpollinated achenes do not enlarge. Berries with this problem will look collapsed and remain green until the fruit is almost ripe, when they turn a straw color. Damage is often on the side or top of the fruit, and large empty achenes close to one another suggest damage by this insect. This irregular development causes a loss in yield and marketability.

Monitoring: If adults are causing the damage, sampling with sweep nets has shown the action threshold to be two adults per 10 sweeps. If damage is being caused by nymphs when the buds are forming, shake sampling is more effective. At each of five sites per field, shake 10 flower clusters over a white pan or paper to dislodge the nymphs. Because of the fast development of this pest and its ability to cause damage rapidly, the action threshold for nymphs is 0.15 nymphs per blossom cluster. This is equivalent to 7.5 nymphs per field using the sampling above. At this level, control measures can be applied to maintain berry quality and yield before too much damage occurs.

Control strategies:

Cultural

- Avoiding mowing weeds in and near strawberry fields when strawberry buds are swelling and flowers are beginning to open.

Chemical

- In fields where the tarnished plant bug caused significant damage in previous years or the action threshold has been exceeded, control is justified. Applying an effective insecticide before bloom can reduce populations below the action threshold. To protect pollinators, do not spray insecticides during bloom.

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.

Match the following forms of metamorphosis with the correct statement.

A. Gradual
B. Complete
C. Both gradual and complete

4. ___Immature insects resemble adults.
5. ___Adults 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 codling moth goes through which type of metamorphosis?
    A. Gradual.
    B. Complete.

11. The tarnished plant bug goes through which type of metamorphosis?
    A. Gradual.
    B. Complete.

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

Match the following insects with the correct statement.

A. Obliquebanded leafroller
B. Japanese beetle
C. American plum borer
D. Plum curculio
E. Oriental fruit moth

13. ___Wind transports young larvae on silk strands to new leaves.
14. ___Larvae bore into shoots and fruit.
15. ___Larvae are grubs that feed on grass roots in the soil.
16. ___Larvae enter bark through wounds caused by mechanical harvesting machinery.
17. ___Larvae are grubs that feed in fruit.

18. The adult form of the following is a fly EXCEPT:
    A. Apple maggot.
    B. Blueberry maggot.
    C. Cherry fruit fly.
    D. Pear psylla.

19. Which of the following has many hosts?
    A. Grape berry moth.
    B. Pear psylla.
    C. Plum curculio.
    D. Spotted tentiform leafminer.

20. Which of the following does NOT have several generations each season?
    A. Aphids.
    B. Oriental fruit moth.
    C. Twospotted spider mite.
    D. Raspberry cane borer.

Match the following insects with the correct description of damage they cause.

A. Grape berry moth
B. Grape leafhopper
C. Mites
D. Pear psylla
E. Strawberry clipper
F. Tarnished plant bug

21. ___Bronzing of leaves
22. ___Catfacing or button berries
23. ___Decline and death of pear trees
24. ___Decreased fruit sugar levels
25. ___Webbing and larval feeding on flower buds and berries
26. ___Cut flower buds so they hang by a thread or fall to the ground

27. The fruit damage caused by which of the following is often confused with that of the codling moth?
    A. Oriental fruit moth.
    B. Plum curculio.
    C. White apple leafhopper.
    D. Strawberry clipper.

Match the following insects with the characteristics given below.

A. Grape leafhopper
B. Climbing cutworms
C. Tarnished plant bug
D. Blueberry maggot

28. ___Mowing weeds or disturbing grassy areas causes this pest to move to more desirable plants, such as strawberries.
29. ___Adults and larvae feed at night and hide in soil or leaf litter during the day.
30. ___Populations are highest during hot, dry periods.
31. ___ Adults do not lay eggs for approximately 10 days after emerging (preoviposition period).

32. Aphids must mate to produce offspring.
    A. True.
    B. False.

33. Which of the following does NOT have piercing/sucking mouthparts?
    A. Tarnished plant bug.
    B. White apple leafhopper.
    C. European red mite.
    D. Codling moth.

CHAPTER 6

WEED MANAGEMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Define a weed.
- Describe and give examples of annual, biennial and perennial weeds.
- Describe and give examples of grassy and broadleaf weeds.
- Define and identify examples of mechanical and cultural weed controls.
- Identify the characteristics of the various methods of herbicide application.
- Understand herbicide carryover and injury and ways to prevent it.
- Know what herbicide adjuvants are.

Weeds are plants growing where they are not wanted. They compete with desired plants for soil moisture and nutrients and often serve as hosts for insects, nematodes and diseases. Weeds may also provide cover for rodents that attack tree trunks during winter months. Certain noxious weeds, such as poison ivy or Canada thistle, can make harvesting fruit unpleasant. The establishment of a healthy orchard requires optimum growing conditions for the first few seasons to produce healthy trees with strong trunks. Weed control plays an important role in establishing an orchard, vineyard or small fruit planting.

LIFE CYCLES OF WEEDS

Weeds can be classified according to their 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 may germinate from seed in the spring, flower and produce seed during the summer and die in the summer or fall. Winter annuals germinate from seed in the fall and reproduce and die the following year. Annual weeds are easiest to control at the seedling stage.

Cocklebur is an annual.

BIENNIAL

Biennials complete their growth cycle 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 unmowed fencerows. 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 are **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.

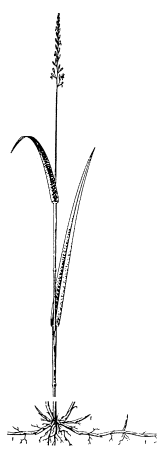
Annuals, biennials and perennials can reproduce from seed. Many weeds produce large quantities of seeds. Seeds are easily dispersed across a field by wind, rain, machinery, animals and people. Weed seeds can germinate after being dormant for long periods. They can also tolerate extremes in weather such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

COMMON WEEDS IN MICHIGAN

GRASS AND GRASSLIKE WEEDS

Annuals

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



Monocot or grass plant.

Perennials

- Johnsongrass
- Yellow nutsedge
- Quackgrass

BROADLEAF WEEDS

Annuals

- Lady's thumb
- 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

Yellow nutsedge.

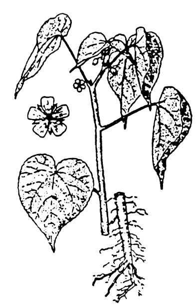
Redroot pigweed.

Biennials

- White campion
- Wild carrot
- Bull thistle

Perennials

- Milkweed
- Hemp dogbane
- Canadian thistle
- Dandelion
- Field bindweed
- Perennial sow thistle
- Swamp smartweed
- Goldenrod
- Plantain



Velvetleaf.

INTEGRATED WEED CONTROL

Objectives of a weed control program may include one or more of the following:

- Preparing the planting site.
- Increasing the survival, nutrition and growth of newly planted trees or plants by eliminating competition.
- Reducing rodent damage.
- Permitting easier pruning and harvest.
- Reducing the probability of diseases.

An integrated weed management program may include cultural, mechanical and / or chemical methods to prevent and manage weeds and will include continual evaluation. These components are described below.

CULTURAL CONTROL

Cultural weed control is simply using practices that favor the growth of the fruit crop and make it more competitive with weeds. Crop competition is a very useful method of weed control. Production practices that optimize crop growth help enable the crop plants to compete effectively with weeds. Crop management practices that can improve the competitive ability of the crop are crop and variety selection, planting date, spacing, soil fertility, drainage, etc. Recommended crop production practices are also beneficial weed control practices. Fruit trees are not usually competitive with weeds, but well maintained cover crops or sod can be.

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

MECHANICAL CONTROL

Mechanical means of weed control can include:

- Tilling or turning over soil to expose roots of weeds to drying conditions.
- Mulching.
- Mowing or removing weeds in or near fields.

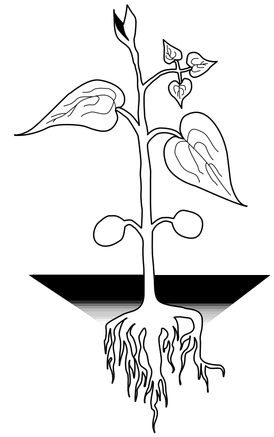
Tillage buries weeds or destroys their underground plant parts. Annual and biennial weeds are more effectively controlled with tillage in the seedling stage. Disturbing the soil, however, can bring new weed seeds near the soil surface and create more weed problems. Tillage and cultivation in orchards or plantings can also injure fruit crops. In small fields, hoes and other implements may be the safest way to control weeds through cultivation.

Mulches can limit the germination of weed seeds by shading the soil. Mulches can also provide other benefits, including decreased soil packing and crusting, conservation of soil moisture during the growing season and alteration of soil temperature. In small fruit plantings, sawdust, straw and other organic mulches are more common than plastic mulches. Be aware that straw mulches frequently contain weed seeds and can make a weed problem worse.

Mowing in orchards does not kill most weeds but can reduce competition, favor grasses and provide a sod area that supports vehicle travel and controls erosion. Removing or mowing vegetation in fencerows can help decrease the number of weed seeds introduced into the field. Well timed mowing once or twice a season can help prevent seeding, depending on the weed species that are present.

CHEMICAL CONTROL

Chemical weed control can be one component of an integrated weed control program. Pesticides used to control weeds and other plants are called herbicides. Herbicides disrupt the physiology of plants. The result is death or a severe reduction in growth. The first step in the successful use of chemical weed control is the correct identification of the weeds. Once the target weed species have been identified, the correct herbicide, formulation, rate, water volume, method of application and time of treatment must be determined. Before using any pesticide, read the entire label.



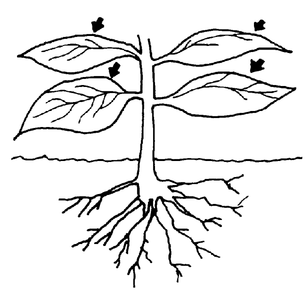
Broadleaf plant

Herbicides are generally applied as preplant incorporated, preemergence or postemergence treatments.

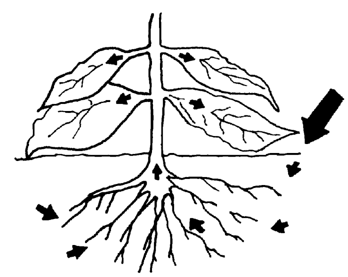
Preplant herbicide applications are applied before planting. Incorporation is required for some herbicides to prevent them from volatilizing (becoming a gas) or breaking down in the sun. This type of application is more common with annual crops than with fruit systems.

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

Postemergence herbicide applications are applied to the foliage of emerged weeds. There are two types of postemergence herbicides: contact and systemic. **Contact herbicides** kill only the plant parts that they touch and are commonly used to control annuals. Typically, the aboveground parts of a weed, such as the leaves and stems, turn brown and die. **Systemic or translocated herbicides** are absorbed by the weed's roots or leaves and moved throughout the plant. Systemic herbicides are more effective against perennial weeds because the herbicide reaches all parts of the plant. However, systemic herbicides may take up to three weeks to kill the weeds.



Contact herbicide



Translocated herbicide

EVALUATING THE RESULTS

After using any weed management method, inspect the area to evaluate the results. Keep in mind the type and species of weeds treated, soil types, and weather conditions during and after the application. Evaluation should be a continual activity. It allows you to make adjustments in rates, products and timing of applications, and to plan any additional control measures that may be needed.

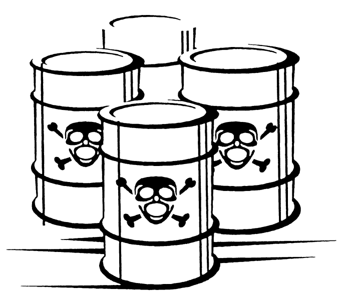
HERBICIDE ISSUES

HERBICIDE CARRYOVER AND INJURY

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. This may be an issue when starting a new fruit planting. 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 and time of application, herbicide distribution across a field and soil type. 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 or sprayer overlapping.

Fruit trees are not completely immune to herbicide injury but will often tolerate dosages much higher than those required to kill weeds. Generally, trees gain herbicide tolerance with age. Newly planted trees may be susceptible to herbicide injury, gain some tolerance when 2 to 3 years old and become very tolerant when older. Trees growing on sandy soils low in organic matter are more susceptible to soil-applied herbicides than trees growing on heavier loam soils.



To reduce the potential of herbicide carryover and injury, read and follow all directions on the pesticide label. Herbicide labels contain restrictions on the age of the crop, applications and harvest. Consult the current version of MSU Extension bulletin E-154, *Michigan Fruit Management Guide*, 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 weed control. Proper application methods must be followed for each herbicide detailed on the pesticide label. Always remember 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 a 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 adjuvants.

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

HERBICIDE COMPATIBILITY PROBLEMS

Compatibility problems in tank-mixed herbicides usually occur when applicators 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, adding 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.

Match the following terms with their definitions.

A. Annual
B. Winter annual
C. Biennial
D. Perennial

2. ______ Plants that complete their life cycle in two years.
3. ______ Plants that complete their life cycle in one year.
4. ______ Plants that complete their life cycle in one year but germinate in the fall and flower in the spring or summer.
5. ______ Plants that live for two or more years.

Match the following terms with their definitions.

A. Bulb
B. Rhizome
C. Stolon
D. Tuber

6. ______ Creeping aboveground stem
7. ______ Creeping belowground stem
8. ______ Enlarged underground stem
9. ______ Underground stem covered by fleshy leaves

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

    A. Quackgrass.
    B. Green foxtail.
    C. Wild-proso millet.
    D. Common ragweed.

11. An example of a perennial grass weed is:

    A. Quackgrass.
    B. Wild carrot.
    C. Barnyard grass.
    D. Smooth crabgrass.

Match the following examples with the type of weed control they describe. Letters may be used more than once.

A. Chemical
B. Cultural
C. Mechanical

12. _______ Maintaining healthy cover crops and sod.
13. _______ Mowing.
14. _______ Contact herbicide application.
15. _______ Using optimum spacing, site and variety selection.
16. _______ Tillage.

17. Timely mowing can help weed control by preventing seeding.

    A. True.
    B. False.

18. Preemergence herbicides generally require rainfall within a week of application to move the herbicide through the soil.

    A. True.
    B. False.

19. Systemic herbicides kill weeds on contact.

    A. True.
    B. False.

20. A grower applied a broad-spectrum herbicide to kill sod growing under his apple trees. Which type of herbicide application did he use?

    A. Preplant soil incorporated.
    B. Postemergence.
    C. Preemergence.
    D. None of the above.

21. The best way to reduce the potential of herbicide carryover is to follow the pesticide label directions.
    A. True.
    B. False.

22. Define herbicide carryover and describe conditions that increase carryover risk.

23. What is a herbicide adjuvant?

24. 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 noninfectious 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 fruit, including tree fruit (apples, cherries, pears, peaches and plums) and small fruit (blueberries, grapes, raspberries and strawberries).

Introduction

Diseases are the most difficult type of plant injury to diagnose and manage. A plant **disease** is any condition that does not allow the plant to function normally. **Noninfectious plant diseases** are caused by nonliving agents or cultural and environmental factors, such as drought, soil compaction, hail, wind, toxic chemicals, nutrient deficiency, and temperature or moisture extremes. Noninfectious disease cannot reproduce and spread from plant to plant.

Symptoms such as wilting, stunting and yellowing of leaves may appear suddenly on a plant with a noninfectious disease. Often the symptoms resemble those of infectious diseases. For example, nutrient deficiency symptoms often resemble symptoms of root rot. The remainder of the manual focuses on infectious plant diseases and their management.

An **infectious plant disease** is caused by an agent that attacks and feeds on the host plant. The disease-causing agent is called a **pathogen**. In Michigan, fungi, bacteria, nematodes and viruses are all pathogens of fruit crops. Pathogens may be 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 cannot be seen without a microscope. Fungi cannot convert sunlight into food and therefore feed on dead or decaying organic matter (dead trees) or living matter (e.g., fruit and plants).

Most fungi are made up of delicate, threadlike structures called **hyphae**. Hyphae grow and form masses called **mycelium**, which is the fuzzy growth that sometimes appears on the surface of the plant. Some fungi develop organized mycelial structures such as mushrooms. 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 on or in structures called **fruiting bodies**. Others appear on the plant surface as mold growth (e.g., powdery mildew and rust). Each fungus has a unique spore or fruiting body structure, which is often used for identification.

Wind, splashing rain, insects, workers' hands and clothing, and equipment can easily transport spores from one location to another. Harsh environmental conditions will kill some spores, but 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**, which 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.

BACTERIA

Bacteria are 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 diseases in plants. Most bacteria are harmless or even beneficial (for example, the nitrogen-fixing bacteria of legumes). It is important to point out that plant pathogenic bacteria are **not** human pathogens.

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

Bacteria infecting plants do not produce spores or fruiting bodies — they reproduce by simple cell division. A cell splits into two approximately equal halves, and 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 bacterial population may decline rapidly.

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

VIRUSES

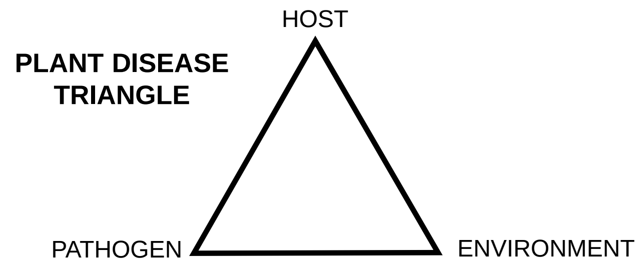
A **virus** is a very small pathogen that cannot reproduce by itself. A virus basically consists of genetic material (i.e., DNA) covered by a protein coat. Viruses multiply by tricking the host cells into making more viruses. They are most familiar to us as the cause of human and animal diseases such as polio, influenza, chicken pox and warts. Viruses can also cause diseases in plants. Like plant-pathogenic bacteria, viruses infecting plants do not infect humans.

Plants infected with a virus can show any of the following symptoms: yellow to dark green mottling, leaf stunting, 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 a 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. Insects with piercing-sucking mouthparts, such as leafhoppers and aphids, are usually responsible for transmitting viruses. 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, and can be a serious problem for crops that are propagated from cuttings or buds.

DISEASE TRIANGLE

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



The role of the environment in this interaction is important because diseases need specific conditions to develop. Temperature and moisture are two of the most important environmental conditions that influence plant diseases.

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

Pathogens and host plants are also affected by moisture. Most 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 on plant surfaces to infect the plant.

A successful disease management program takes into account the interactions of 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, and destroying or removing infected plants change one or more aspects of the disease triangle.

DISEASE CYCLE

The basic chain of events involved in disease development is called the disease cycle. The steps are:

1. **Production of inoculum. Inoculum** is a source of a pathogen that infects 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, or be carried by 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 the host by its own action (for example, growing mycelia or swimming spores). Passive movement is movement of the inoculum to a new host plant by wind, water or another organism. 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. It can be several days to months long.

DISEASE MANAGEMENT

The best available disease management strategies generally concentrate on preventing disease. Chapter 1 of this manual deals with general aspects of integrated pest management; this section will address control options specific to diseases.

Cultural Control

Production practices can help reduce the incidence and impact of many fruit 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.

SITE SELECTION. Most fruit orchards and plantings stay in the same place for many years, so site selection is extremely important. Many diseases require moisture on the plants or high humidity. Carefully selecting sites that maximize light penetration and air movement will decrease the foliage drying time and significantly decrease the severity of many diseases. Optimum soil type, fertility and drainage will help grow strong, healthy trees and plants that are more tolerant of pests.

ELIMINATE ALTERNATE HOSTS. Wild or abandoned trees and plants can serve as alternate hosts for many fruit diseases. Removing alternate hosts growing near the orchard or small fruit planting can significantly decrease the amount of inoculum for many diseases.

PLANT SPACING. Spacing and orientation of plantings should maximize light penetration and air movement and decrease drying time.

VARIETY SELECTION. The use of resistant varieties, when available, is the least expensive, easiest and most effective way to control plant diseases. Plant varieties express varying 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.

PLANT QUALITY. All planting material should be pathogen-free. Using certified virus-free or tissue-cultured stock helps prevent or delay the establishment of many diseases. Some diseases, such as all viruses and orange rust of brambles, cannot be eliminated once the plant is infected.

SANITATION. Removing diseased plants or plant parts from a planting by pruning or roguing helps eliminate disease inoculum. Diseased plant debris should be burned or buried.

Biological Control

Biological control is the use of beneficial organisms to reduce problems caused by pests. Rotation and tillage contribute to biological control by giving natural enemies opportunities to reduce pathogen populations. An example of biological control is the use of a competitive bacterium to prevent crown gall in stone fruits. This beneficial bacterium colonizes the roots and gives off an antibiotic that prevents the crown gall bacteria from establishing themselves.

Chemical Control

Chemical applications are often used to control pathogens and can be an important component of the overall disease management plan. For more information on controlling diseases of fruit crops using pesticides, see Michigan State University Extension bulletin E-154, *Michigan Fruit Management Guide.*

DISEASES OF POME FRUIT

FIRE BLIGHT OF APPLES AND PEARS

Pathogen type: bacterium (*Erwinia amylovora*)

Apple shoot infected with fire blight.

Disease symptoms: Fire blight attacks blossoms, leaves, shoots, branches, fruit and roots. Infected blossoms wilt and turn brown. Infected fruit spurs collapse and turn dark brown to black. Infected shoots turn brown to black and bend at the tip, forming a distinctive shepherd's crook. Symptoms in leaves generally start at the petioles, showing discoloration of the midvein followed by a darkening of other veins and tissue. Infected leaves often stay on the tree. Bark on infected branches appears darker than surrounding areas. Peeling away the bark reveals water-soaked tissue that has reddish streaks when newly invaded and brown as infection progresses. The margins of this canker become sunken and cracked. Active cankers exude amber or brown ooze on their surface or bark.

Infected fruit turn brown to black, shrivel and may remain on the tree. During wet weather, infected fruit and shoots may exude milky ooze containing the fire blight bacteria. Infected roots can lead to death of the entire tree in one season.

Bacterial ooze exuding from an apple infected with fire blight.

Disease cycle: The bacterial pathogen overwinters near the margins of cankers. In the spring, ooze appears on the surface of cankers around the time of bloom. The bacteria are moved by insects or splashed by rain to the flowers. Honeybees can spread the bacteria from flower to flower very quickly. Rain, high humidity and temperatures between 65 and 86° F favor infection. The pathogen is successful at infecting the tree through natural openings such as stomates, but wounds also provide important entry points. Severe storms containing hail can cause very rapid spread of this pathogen and lead to severe outbreaks of fire blight.

Control strategies:

- Plant orchards on well drained sites. Fire blight is generally worse on high fertility sites with above average soil moisture.
- Remove fire blight cankers during dormant pruning.
- Starting about 10 days after petal fall, inspect orchards weekly to remove new strikes and cankers missed earlier. Cut infected branches at least 12 inches below the lowest evidence of disease. Sterilize cutting tools between cuts using a bleach solution (1 part bleach to 10 parts water) or with 70 percent ethyl alcohol (rubbing alcohol). Prune overwintering cankers during the dormant season.
- When possible, plant fire-blight-resistant cultivars and rootstocks. Avoid combinations of highly susceptible cultivars and rootstocks.
- Use the MARYBLYT program developed by Steiner and Lightner for predicting potential infection periods. This predictive model can be very helpful in determining the need for and timing of treatments.
- Do not use antibiotics such as streptomycin or mycoshield (assuming that they are labeled for your region) when new strikes have already appeared in the orchard. Using an antibiotic once the disease is widespread will only hasten the development of resistant strains of the fire blight pathogen.
- Control sucking pests such as aphids, leafhoppers, plant bugs and pear psylla, which may spread the bacteria and create wounds where the bacteria can enter.

DISEASES OF APPLE

APPLE SCAB

Pathogen type: fungus (*Venturia inaequalis*)

Disease symptoms: Apple scab infects leaves, petioles, blossoms and fruit, but symptoms are more visible on leaves and fruit. Infections appear as velvety, olive-green to dark brown lesions. In leaves, lesions first appear on the undersides close to veins, then spread to both sides as the leaves unfold. Lesions are initially feathery at the edges but become more distinct with time. Lesions on fruit resemble those on leaves initially but become brown and corky with age. Infected leaves often fall; severe infections can result in extensive defoliation. Severe defoliation over several years can weaken the tree. Infected fruit may drop early or develop blemished or uneven growth.

Disease cycle: The apple scab fungus overwinters in infected leaves on the orchard floor. When the leaves become wet, spores are discharged and spread into surrounding trees, resulting in primary infection. Throughout the growing season, continued infection from secondary spores (conidia) occurs on foliage, blossoms, petioles and fruit during periods of sufficient wetting at given temperatures. Lesions are not visible until at least nine days after the fungus infects the leaves and fruit. Conidia are produced within these lesions. Spores require a film of moisture to germinate. Primary infection periods and time required for conidia development can be predicted by using the Adapted Mills Table.

Large scab lesions late in the season can cause fruit to crack.

Control strategies:

- Inoculum from leaves on the orchard floor can be reduced somewhat by mowing the leaves prior to bud break and/or by applying 5 percent urea just prior to leaf fall to hasten leaf decomposition.
- Plant scab-resistant cultivars. Disease-resistant apple cultivars are being developed by several breeding programs.

- Apple scab management programs usually involve fungicide sprays for much of the growing season. Fungicide choices include protectants, which need to be present on the leaf or fruit surface before the spores land, and eradicants, which can stop infection shortly after it has occurred. The apple scab fungus has developed resistance to many fungicides, so anti-resistance strategies should be part of any scab management program.

POWDERY MILDEW

Pathogen type: fungus (*Podosphaera leucotricha*)

Apple shoot infected with powdery mildew.

Disease symptoms: Powdery mildew kills vegetative shoots and flower buds and may cause russeting that reduces fruit quality. Infected buds are more susceptible to freezing than healthy buds and may be killed by low temperatures. If they are not killed by freezing, infected flower buds usually open several days later than healthy buds. When infected flower and vegetative buds open, the flowers and leaves are covered with white mycelium and spores. Infected terminal or shoot buds produce infected leaves and shoots. Infected shoots are usually shorter than healthy shoots.

Fruit showing net russeting from powdery mildew infection.

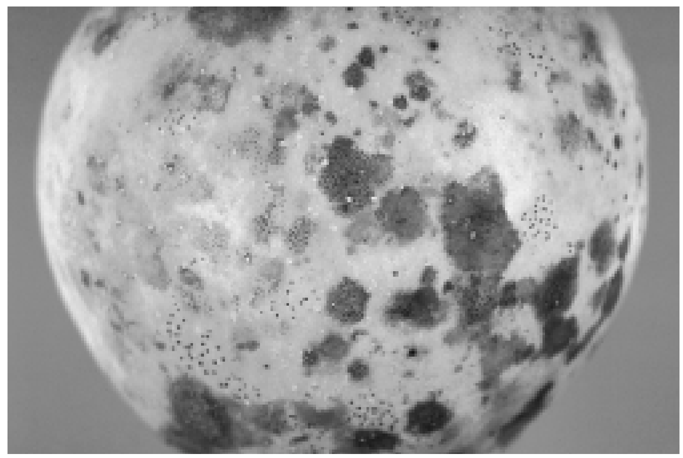
Disease cycle: The fungus overwinters as mycelium in infected buds. Spores are produced as the infected buds open in the spring. Spores are spread by wind to other buds and tissues. Powdery mildew spores do not need a film of moisture to germinate. Spores germinate well at temperatures between 60 and 80° F combined with high relative humidity. The cultivars Jonathan, Rome Beauty, Cortland, Baldwin, Monroe, Ida Red, Granny Smith and Stayman are very susceptible to powdery mildew.

Control strategies:

- Fungicide sprays may be necessary to control this disease on susceptible cultivars.

SOOTY BLOTCH AND FLYSPECK

Pathogen type: fungus



Mycelial type of sooty blotch and a few flyspeck lesions on the surface of apple.

Disease symptoms: Sooty blotch and flyspeck are fungal diseases that frequently occur together on apple fruit. Sooty blotch appears as greenish, irregular blotches or patches on the fruit surface. Individual blotches can grow together to form large infected areas. Flyspeck appears as groups of small, shiny, black dots in groups of a few to nearly a hundred on the fruit surface.

Disease cycle: The fungi that cause both diseases overwinter on twigs of many types of woody plants. Both diseases develop best under moist conditions characterized by frequent rainfall and high humidity. They infect fruit from after petal fall through late summer.

Control strategies:

- Optimizing air circulation around fruit by pruning the tree canopy and thinning fruit clusters can reduce the incidence and severity of both diseases.
- Removing reservoir hosts such as brambles in and around the orchard can reduce the overwintering inoculum.
- Fungicide treatments may be warranted.

DISEASES OF PEAR

PEAR SCAB

Pathogen type: fungus (*Venturia pirina*)

Disease symptoms: Pear scab infects leaves, shoots and fruit. Shoot infections are common in pear scab. Infections appear as velvety, olive-green to dark brown lesions. Lesions are initially feathery at the edges but become more distinct with time. Lesions on fruit and shoots become brown and corky with age. Infected fruit may drop early or develop blemished or uneven growth.

Disease cycle: The pear scab fungus overwinters in infected shoots in the trees and infected leaves on the orchard floor. When the leaves become wet, spores are discharged and spread into surrounding trees, resulting in primary infection. Spores require a film of moisture to germinate. Throughout the growing season, continued infection from secondary spores (conidia) occurs on foliage, blossoms, petioles and fruit during periods of sufficient wetting at given temperatures. Lesions are not visible for 10 to 19 days after the fungus infects the leaves, fruit or shoots. Conidia are produced within these lesions. Primary infection periods and time required for conidia development can be predicted by using the Adapted Mills Table.

Control strategies:

- Pear scab management programs usually involve fungicide sprays through much of the growing season. Fungicide choices include protectants, which need to be present on the leaf or fruit surface before the spores land, and eradicants, which can stop infection shortly after it has occurred.

DISEASES OF STONE FRUIT

BROWN ROT

Pathogen type: fungus (*Monilinia fructicola*)

Disease symptoms: Brown rot is a serious disease of all stone fruit grown in Michigan. It can drastically reduce yields by rotting fruit on the tree and after harvest. Flowers, spurs, shoots and fruit can all be infected. Infected flowers wilt and may become covered with powdery, brownish gray spores. Infected fruit develop rapidly expanding soft, brown spots that may exhibit tan masses of spores on the fruit surface. The spots quickly expand to cover the entire fruit. Under optimum conditions, it can take as little as two days from the time of infection for mature fruit to rot completely. Diseased fruit shrivel into “mummies,” which may stay on the tree or fall to the ground. Brown rot can also cause cankers on twigs. These cankers can girdle and kill the twigs.

Disease cycle: The fungus overwinters in mummies in the tree and on the orchard floor and in cankers. In the spring, spores are released into the air by water and are spread by air, rain or splashing. Warm, wet, humid weather, especially periods lasting for two to three days,

Peaches infected with brown rot.

favors disease development and progression. The fungus infects through the cuticle, natural openings and wounds. Mature fruit is more susceptible than young fruit.

Control strategies:

- Sanitation is a very important component of a brown rot management plan. Remove fruit and mummies from the trees and orchard floor after harvest, and prune out diseased twigs during the dormant season to reduce the inoculum in the orchard.
- Cultivation just before bloom can destroy inoculum sources on the orchard floor.
- Remove abandoned or wild trees that serve as a source of inoculum for the disease.
- Prune trees to increase air circulation.
- Avoid injuries to the fruit by insects, harvesting equipment or storage procedures.
- Fungicides may be warranted during bloom and as fruit ripens.

DISEASES OF CHERRY

ALTERNARIA FRUIT ROT

Pathogen type: fungus (*Alternaria* spp.)

Disease symptoms: New lesions are circular to oval and slightly sunken. Over time the lesions become firm, flattened and dark green to black, and they may cover one-third to one-half of the fruit surface. Many dark spores are often present and give the lesions a feltlike appearance. In storage, the fungus produces fluffy, white or gray mold on the surface of the lesions.

Disease cycle: Overripe, wounded or cracked fruit are most susceptible to infection by this fungus.

Control strategies:

- Harvest fruit before they become injured or overripe.

BACTERIAL CANKER

Pathogen type: bacteria (*Pseudomonas syringae*)

Bacterial canker on green cherry fruit.

Disease symptoms: Bacterial cankers form on trunks, branches, leaves and fruit. Cankers can girdle and kill branches. Cankers on trunks, limbs and branches are dark, sunken in the middle and elongate, and they exude gum during the late spring and summer. Infected leaf and flower buds may not open in the spring or may open but result in shriveled fruit or wilted leaves in the summer. In leaves, symptoms begin as dark brown, circular or angular spots that may be surrounded by yellow halos. The spots may grow together into large patches of dead tissue, especially on the edges of leaves. Symptoms on green fruit appear as brown, water-soaked lesions that cause deep, black depressions in the flesh.

The bacteria overwinter in the edges of cankers and in buds and in the tree's vascular system. Wet periods in the spring cause the bacteria to multiply and ooze from the cankers. Rain spreads the bacteria to the plant, entering and infecting through natural openings or wounds. Conditions favorable to infection include cool temperatures, frequent rains and high winds. Outbreaks are often associated with extended periods of cold, frosty, wet weather late in the spring or with severe storms that injure flowers and leaves. Frost and cold injury increase susceptibility to bacterial canker. Sweet cherries are more susceptible to this disease than tart cherries, and certain cultivars are more susceptible than others.

Bacterial cankers on branches.

Control strategies:

- Avoid planting highly susceptible cultivars, such as Hardy Giant.
- During the dormant season, prune out diseased limbs several inches below cankers.
- Disinfect tools between cuts when pruning trees known to have this disease.
- Plant trees on sites with good soil drainage to minimize cold injury.

CHERRY LEAF SPOT

Pathogen type: fungus (*Blumeriella jaapii*)

Disease symptoms: Small, circular, reddish purple spots appear on leaf surfaces. These spots enlarge to 3 to 6 mm in diameter and turn brown. During wet periods, white spores are visible in the centers of the spots on the undersides of leaves. Lack of disease control results in leaf loss in midsummer, leading to significant loss of fruit quality and yield. Premature defoliation can result in reduced tree vigor, reduced cold hardiness and death, especially when defoliation occurs prior to a cold winter.

Disease cycle: The fungus overwinters in diseased leaves on the orchard floor. Shortly after rainfall, spores are discharged and carried to leaves, resulting in primary infection. Optimum temperatures for spore discharge are between 60 and 85° F. Spore germination requires a wetting period of only a few hours. Depending on moisture and temperature, lesions on leaves appear five to 15 days after infection. Throughout the season, spores produced in these lesions are spread by rain to other leaves, resulting in secondary infections.

Control strategies:

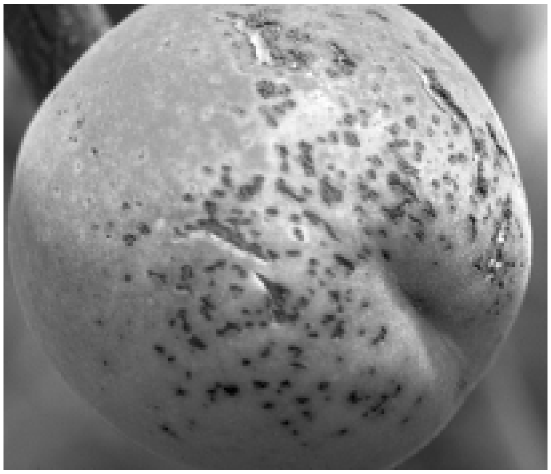
- Fungicide sprays are the primary control method for this disease.
- Rotary mowing after leaf fall can hasten leaf decomposition and help reduce the amount of overwintering fungus.

Cherry leaves showing symptoms of cherry leaf spot.

DISEASES OF PEACH

BACTERIAL SPOT

Pathogen type: bacterium (*Xanthomonas campestris* pv. *pruni*)



Bacterial spot on peach.

Disease symptoms: Lesions on the leaves first appear as small, angular, water-soaked, grayish areas on the undersides of leaves. With time they turn into brown to purplish black spots. Lesions are often concentrated along the midribs at the tips of leaves, resulting in large necrotic and tattered areas as the lesions coalesce. Infected leaves often turn yellow and drop, resulting in severe defoliation of susceptible trees. Infected fruit show gumming, pits or cracks, and/or depressed, brown to black lesions that may affect large areas. Dark, elliptical cankers can form on the shoots and twigs. Summer cankers are usually located between the nodes; spring cankers are usually found at the nodes.

Disease cycle: The bacteria overwinter in twig lesions and buds and on other plant surfaces. Windblown rain spreads the bacteria to leaves, fruit and shoots in the spring. Conditions that favor infection include driving rain, high humidity, moderate temperatures and high winds, especially on sandy sites. Symptoms are often more severe on the sides of trees exposed to winds. During wet periods in the spring and summer, bacteria ooze from cankers and leaf and fruit lesions and are spread by rain. Hot, dry weather inhibits bacterial spread and disease development.

Control strategies:

- Planting cultivars resistant to this disease is the primary control method.
- Chemical controls only suppress development — they do not eliminate the disease.
- If using susceptible cultivars, plant them where they will be protected from the wind.
- Maintain sod cover to minimize blowing sand.

PEACH LEAF CURL

Pathogen type: fungus (*Taphrina deformans*)

Disease symptoms: Peach leaf curl causes leaves and occasionally fruit to become thick, rubbery, distorted and red-yellow about a month after full bloom. The extent of symptoms may range from small areas of a leaf to almost all leaves on the entire tree. Infected leaves usually become necrotic and drop off. Infected shoots become stunted, swollen, chlorotic and rosetted. This disease may cause premature leaf drop, reduced fruit size, and reduced tree hardiness and vigor.

Disease cycle: Spores of this fungus overwinter on peach twigs. Water is required for the spores to be spread and for infection to occur. Symptoms occur 10 to 16 days after an infection period. Multiple infection periods can occur between bud swell and early leaf expansion (shortly after bloom). Optimum temperatures for infection are between 50 and 70° F.

Control strategies:

- Plant resistant cultivars. Cultivars with non-showy bloom tend to be less susceptible.
- Fungicides applied in the fall after leaves have dropped or in the spring before bud swell can prevent the disease. Once the fungus enters leaves, it cannot be controlled with fungicides.
- Cultural methods that improve tree vigor — such as thinning fruit, reducing drought stress and fertilizing — can be very helpful in reducing the impact of a peach leaf curl infection.

Peach infected with peach leaf curl.

DISEASES OF PLUM

BLACK KNOT

Pathogen type: fungus (*Apiosporina morbosa*)

Disease symptoms: This fungus causes the formation of elongated, corky knots on shoots, spurs, branches and trunks. Knots are generally longer than they are wide. Newly formed knots are greenish and corky; older knots become hard and black and are often riddled with insects and covered with pink or white mold from another fungus. The knots can stunt, girdle and eventually kill trees.

Disease cycle: In early spring, spores are produced on the knots and spread by wind and rain to new growth. Infection occurs from bud break until terminal growth stops. Free moisture is required for infection to occur, and temperatures between 55 and 77° F are best for disease development. Knots are not visible until several months after infection.

Control strategies:

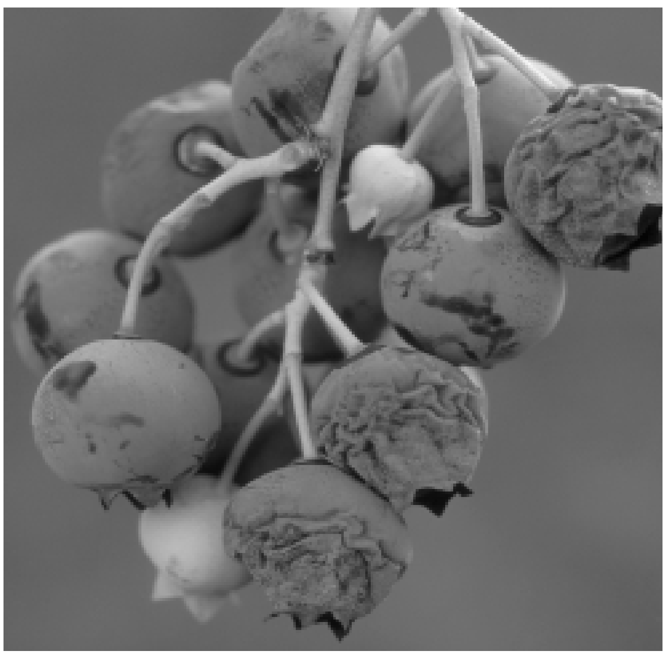
- Remove infected wild plum and cherry from fencerows and woodlots around the orchard.
- Do not put new plantings near infected older plantings.
- Prune out knots, cutting branches at least 4 inches below the knot. Remove and burn all knots from the trees and orchard floor before growth begins in the spring.

Cultural methods mentioned above are very important to black knot control. Fungicide sprays used alone may not provide effective control of this disease.

DISEASES OF BLUEBERRY

ANTHRACNOSE

Pathogen type: fungus (*Colletotrichum acutatum*)



Blueberries infected with anthracnose.

Disease symptoms: Shoot blight is usually the first symptom noticed. A few blossom clusters may turn brown or black. When fruit are ripening and turning blue, the blossom end of the fruit will soften and pucker, and the rotten berries will exhibit orange to pink spore masses.

Disease cycle: The fungus overwinters in infected twigs and starts producing spores in early spring. Spores are dispersed by rain and wind and can infect blossoms, fruit and succulent tissue. Spores can also spread from infected fruit to good fruit at harvest, resulting in postharvest losses. The disease is enhanced by hot, humid weather.

Control strategies:

- The cultivar ‘Elliott’ has some resistance to this disease.
- Prune to remove diseased twigs and increase air circulation.
- Timely harvest and rapid cooling of harvested fruit help reduce losses to fruit rot.
- A well timed fungicide program may be warranted.

PHOMOPSIS CANKER AND TWIG BLIGHT

Dead fruit cluster on a blueberry plant infected with phomopsis.

Pathogen type:

fungus (*Phomopsis vaccinii*)

Disease symptoms: The symptoms consist of dead flower and fruit clusters and a dark brown, spreading discoloration of the twig tissue. This dark brown lesion can spread an inch per week and will kill any fruit clusters along the length of the lesion. Eventually, the fungus can grow down the twig into cane tissues. Phomopsis twig blight symptoms are sometimes confused with those of botrytis blight. Botrytis infections are often characterized by a gray, fuzzy mold on the affected plant part, and there is no dark brown discoloration of the twig. Botrytis can also blight leaves; phomopsis does not.

Disease cycle: The fungus overwinters in infected canes and twigs. In the spring, the spores are rain-splashed from cankers and old twigs to the new twigs. Prolonged wet periods and wounding predispose plants to infection. ‘Jersey’ is especially susceptible.

Control strategies:

- Phomopsis twig blight incidence can be reduced by pruning out and destroying infected canes and twigs, which act as inoculum sources.
- Use cultural practices that discourage late-season growth and promote early hardening off.
- The critical period for control with fungicides is between green tip and petal fall.

SHOESTRING DISEASE

Pathogen type: virus (blueberry shoestring virus)

Disease symptoms: The most reliable symptom is narrow, elongated reddish streaks ¼ to 1 inch long or longer on current-year and one-year-old stems. Often, the fruit on infected bushes is reddish purple instead of the normal blue. Shoestring disease is named for the straplike (shoestring) leaves that this virus can cause. Many or only a few clusters of leaves in the crown will show this symptom. Some leaves will be misshapen in the form of crescents or twisted. Infected stems may develop crooked tips.

Disease cycle: The disease is spread from bush to bush by an insect vector, the blueberry aphid (*Illinoia pepperii*). The aphid spreads the virus by feeding on a healthy bush after feeding on an infected bush. There is a two- to four-year delay between infection and expression of symptoms.

Control strategies:

Once a plant is infected by a virus, it is infected forever. Control is based on prevention.

- Remove and destroy infected bushes, including wild blueberries.
- When infected bushes are present, use insecticides to control the blueberry aphid.
- Use virus-free planting stock.

Shoestring disease is easily recognized by the narrow, elongate reddish streaks on leaves.

MUMMY BERRY

Pathogen type: fungus (*Monilinia vaccinii-corymbosi*)

Disease symptoms: Shoot blight is the first symptom seen after dormancy has broken. Symptoms on blighted shoots resemble frost damage. Flowers can also become blighted. Infected fruit become malformed and pink to gray "mummies". The mummies fall to the ground, shrivel, turn dark brown and become pumpkin-shaped.

Disease cycle: The fungus overwinters in mummified fruit on the ground. In the spring, spores are produced on the mummies during cool, rainy periods and are spread by wind to shoots and flowers. The fungus can survive in the mummies for more than a year but will produce spores only when moisture is present. Spores produced on infected shoots and flowers are spread by wind, rain and insects and are responsible for secondary infection of flowers and developing fruit.

Mummy berries.

Control strategies:

- Select a resistant cultivar (e.g., Bluecrop).
- Remove or cover mummies with soil or mulch to reduce disease inoculum.
- A fungicide program can provide excellent control of this disease.

DISEASES OF GRAPE

BLACK ROT

Pathogen type: fungus (*Guignardia bidwellii*)

Disease symptoms: The fungus that causes black rot can infect all green parts of the vine — fruit, canes, leaves and tendrils. The first symptom is usually the appearance of small, yellow spots on the leaves. Over time these spots develop dark margins, become reddish brown and may reach a diameter of ⅛ to ¼ inch. Tiny, black fruiting bodies may be present in a circular pattern just within the margins of the lesions. Lesions on petioles may cause leaves to wilt. Small, round, light brown spots appear on infected grapes when they are half-grown. The entire grape rots in a few days, shrivels, and becomes hard, black and wrinkled. These shriveled fruit, or

Grapes infected with black rot eventually become "mummies".

"mummies", may remain attached to the cluster or fall to the ground.

Disease cycle: The fungus overwinters in mummies and lesions on canes and tendrils. Wind and splashing rain carry spores to young tissue in the spring. Warm, wet weather provides optimum conditions for disease development. A film of water must be present for spores to germinate and infect tissue. Most vine tissue and grapes are infected when they are young; mature leaves and ripe fruit are not susceptible.

Control strategies:

- Remove and destroy mummies and diseased tendrils and canes. Mummies and infected tendrils left on the vine serve as sources of inoculum throughout the growing season.
- Plant vineyard in site and orientation to maximize air movement.
- A carefully timed fungicide program can be a very important component for managing this disease.

POWDERY MILDEW

Pathogen type: fungus (*Uncinula necator*)

Disease symptoms: Leaf symptoms appear in early to mid-July as a white, powdery or dusty fungal growth on the upper surfaces of the leaves and other green parts of the vine. Severely affected leaves may cup, turn brown and fall. Leaves heavily infected by powdery mildew are less able to manufacture food. Plant vigor declines and chance of winter injury to the vines increases. Berries and cluster stems are infected later in the season. Infected berries turn hard and brown and fail to mature properly.

Disease cycle: The fungus overwinters in tiny, black fruiting bodies primarily in bark crevices on the grapevine. Rain in early spring causes spores to be released. The spores are carried by wind and cause primary infections on any green surface of the plant. Fungal growth and new spores give the infected plant parts a white or dusty appearance. These new spores are produced throughout the summer and cause many new secondary infections. Unlike most other grape diseases, powdery mildew spores do not need a film of moisture on the plant to infect it. Dry conditions with high relative humidity are best for the growth of this fungus.

Control strategies:

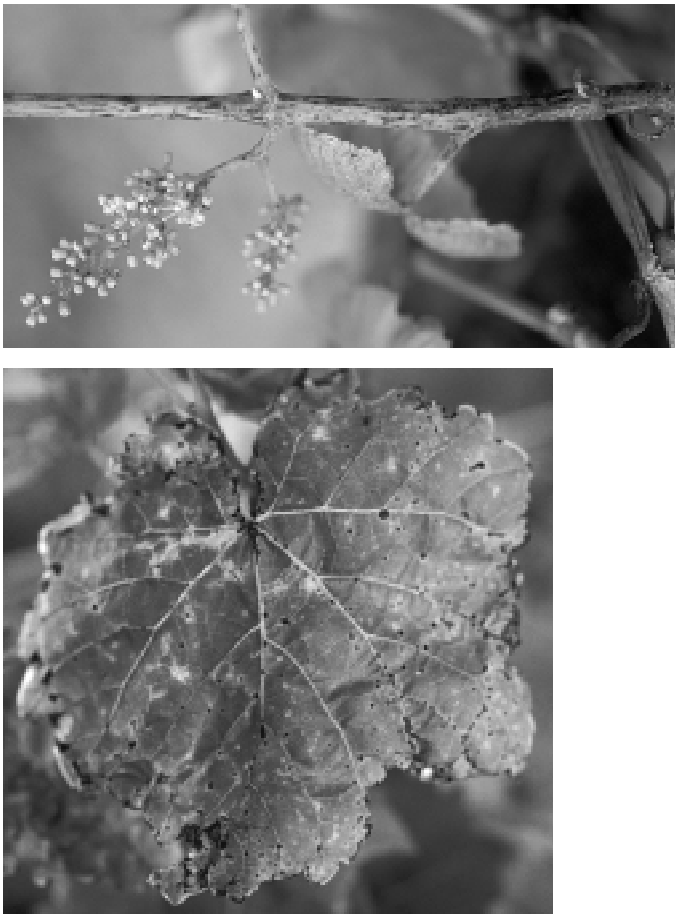
- Select a resistant cultivar (e.g., Chambourcin or Cayuga White).
- Select sites and training systems that maximize sunlight penetration and air movement through the canopy.
- On susceptible varieties, a carefully timed fungicide program may be necessary.

Powdery mildew leaf symptoms appear before grape clusters become infected.

PHOMOPSIS CANE AND LEAF SPOT

Pathogen type: fungus (*Phomopsis viticola*)

Disease symptoms: The fungus infects canes, leaves, petioles and rachises, at first causing yellowish spots with dark centers. As the spots enlarge, the tissues become dark brown to black and brittle, and long cracks may form. Shoot lesions may appear long, cracked, black and scabby. Berry infection is first noticed as the fruits begin to ripen. The berries shrivel and become brown to black and may be covered with tiny black spots, the fruiting bodies of the fungus. Under humid conditions, spores will ooze out in cream-colored droplets or tendrils. Rachis lesions contribute to premature drop of the berries.



Grape cane and leaf infected with phomopsis.

Disease cycle: The fungus overwinters in diseased canes and old fruit cluster stems that remain attached to the vine. Spores infect new leaves in the spring during rainy weather. Cool, wet weather is required for spore release and infection. Free water is required for spore germination. Shoot infection generally happens from bud break until shoots are 6 to 8 inches long. Most rachis and fruit infections take place during bloom and early fruit development. It may take weeks or months after infection for symptoms to appear.

Control strategies:

- During dormant pruning, cut out and destroy infected canes.
- Plant vineyard in site and orientation to maximize sunlight penetration and air movement.
- Good fungicide coverage during bloom and early fruit development is very important to prevent infection.

DISEASES OF RASPBERRY

ANTHRACNOSE

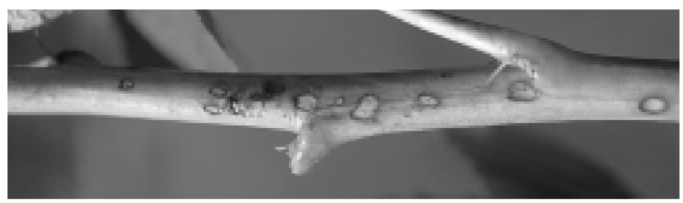
Pathogen type: fungus (*Elsinoe veneta*)

Disease symptoms: Symptoms appear on canes, leaves and, sometimes, fruit. Infected canes show tiny, purple spots, which become light gray, round spots about ⅛ inch in diameter. The spots enlarge to about ¼ inch and develop ash-gray centers and possibly purple borders. There may be so many spots that they blend together and cover large portions of the cane. This symptom is called "graybark." Leaves may develop similar small, round spots or lesions about 1/16 inch in diameter. Diseased tissue frequently drops out, giving leaves a shot-hole appearance.

Disease cycle: The fungus overwinters in infected canes. Spores are produced in the spring when leaves are emerging and throughout the summer during wet and rainy weather. The disease can become serious with abundant rain in late spring and early summer or under sprinkler irrigation.

Control strategies:

- Use disease-free plants.
- Select a resistant cultivar (e.g., Latham).
- After harvest, remove and destroy old fruiting canes and new canes that show disease symptoms.
- Use cultural techniques that improve air circulation.
- Remove wild brambles that can serve as a source of inoculum.
- Fungicides may be required when this disease is established.



Cane infected with anthracnose has light gray spots.

BOTRYTIS FRUIT ROT OR GRAY MOLD

See Strawberry Diseases.

ORANGE RUST

Pathogen type: fungus (*Arthuriomyces peckianus*)

Disease symptoms: Newly formed canes are weak and spindly and lack thorns. Infected leaves are small and yellowish with orange pustules of waxy rust spores on the undersides. Leaf symptoms often disappear by mid- to late summer. Later in the season it is harder to identify infected plants. Over the years, plants will become bushy and spindly and produce little or no fruit.

Disease cycle: Orange rust attacks black and purple raspberries and blackberries but not red raspberries. Spores on the leaves are shed and cause new infections. The fungus invades all parts of the plant, including the roots. Once plants are infected with orange rust, they are infected for life. Low temperatures and high humidity favor infection.

Orange rust fungal spores on raspberry leaf.

Control strategies:

- Plant rust-free raspberries.
- In early spring, remove and destroy any plants (including roots) that show symptoms.
- Remove wild brambles growing near the site.
- Fungicides can be used to prevent new infections.

SPUR BLIGHT

Pathogen type: fungus (*Didymella applanata*)

Disease symptoms: Small, brown or purple spots appear near leaves or buds on the lower portions of canes. These areas turn brown, and leaf and flower buds shrivel and die. Diseased canes dry out and crack as they mature. Lesions on canes turn brownish purple and enlarge to cover much of the cane. Brown, wedge-shaped lesions may occur on infected leaves.

Disease cycle: The fungus overwinters in lesions on diseased canes. Spores are released in spring and summer during rainy periods. Splashing rain and wind carry spores to new canes. The spores require a film of water to germinate and infect the canes.

Control strategies:

- Select a resistant variety (e.g., Boyne or Canby).
- Use cultural methods that improve air circulation and promote faster drying of leaves and canes.
- Remove wild brambles growing nearby.
- After harvest, remove and destroy infected canes.
- The use of fungicides may be warranted.

DISEASES OF STRAWBERRY

BOTRYTIS FRUIT ROT OR GRAY MOLD

Pathogen type: fungus (*Botrytis cinerea*)

Disease symptoms: Young blossoms may become brown and dry. Small, water-soaked areas appear on the fruit. These areas are soon covered with gray, fuzzy spore masses. Symptoms are most visible on mature fruit.

Disease cycle: The fungus overwinters on plant debris, such as dead strawberry or raspberry leaves or canes, on the ground. Rainy or humid weather favors disease development. Ideal conditions include temperatures between 70 and 80° F and moisture on the foliage from rain, dew, fog or irrigation. At the beginning of bloom, the fungus attacks the blossoms and causes a blossom blight, leading to considerable crop loss. Spores form on the blighted blossoms, and infection spreads to fruit. Spores are spread by wind and require a film of water to infect the blossoms or fruit.

Botrytis spores on strawberry fruit.

Control strategies:

- Use cultural practices and site selection that promote air circulation and penetration of sunlight.
- Use methods such as straw mulch to reduce fruit contact with the soil.
- Avoid bruising berries and refrigerate immediately after harvest.
- A carefully timed fungicide program can be very effective in controlling this disease.

BLACK ROOT ROT

Pathogen type: multiple causes including fungi (*Pythium* and *Rhizoctonia* spp.) and nematodes (*Pratylenchus penetrans*)

Disease symptoms: The first symptoms are plants with reduced vigor, often in areas of the field with compacted soil. Diseased plants often show reduced vigor the first year and become stunted and produce reduced crops of small berries in future years. Roots of diseased plants have few fine lateral roots and show irregular black patches along the length of the roots. In severe cases, the entire root system is black.

Strawberry field infected with black root rot shows areas with unhealthy plants.

Disease cycle: Black root rot is considered a disease complex. The symptoms are caused by a combination of factors, including several pathogenic soil fungi, lesion nematodes, environmental conditions (including drought, winter injury to roots, and freezing or waterlogging of soil), nutrient deficiencies, fertilizer burn and pesticide injury. Older plantings, replanted fields and sites with poor soil drainage are more likely to have this disease.

Control strategies:

- Plant healthy plants from a reputable nursery.
- Incorporate organic matter into the soil to reduce compaction.
- Avoid planting in heavy, wet soils.
- Rotate out of strawberries for two to three years (ideally five years) before replanting.

LEATHER ROT

Pathogen type: fungus (*Phytophthora cactorum*)

Disease symptoms: On green berries, the first symptom is the appearance of brown or green areas surrounded by a brown margin. As the disease progresses, the entire berry becomes brown, rough and leathery. It is more difficult to see symptoms on ripe fruit. Diseased ripe berries may show no color change or may appear brown to purple. Diseased ripe fruit are usually softer than healthy berries. Infected berries have an unpleasant odor and taste that can make jam and jelly bitter.

Disease cycle: The fungus overwinters as weather-resistant spores in mummified fruit or in the soil. These spores can live in the soil for a long time. Spores are spread to fruit by splashing or irrigation. A film of water for only one hour is required for this fungus to infect healthy tissue. This disease is commonly seen where there has been free-standing water, on berries in direct contact with the soil and in poorly drained areas.

Fruit infected with leather rot becomes brown and has an unpleasant odor.

Control strategies:

- Use straw mulch to keep berries off the soil.
- Choose a planting site with good soil drainage and air circulation.
- Remove diseased berries and take away from the field.
- A well timed fungicide program may be warranted.

Review Questions

CHAPTER 7

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. 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 certified virus-free stock.
    B. Dipping roots in a fungicide.
    C. Increasing the plant spacing.
    D. Planting orchard on a slope.

14. Which of the following requires a film of moisture on the leaves for infection to occur?
    A. Bacterial canker.
    B. Anthracnose.
    C. Apple scab.
    D. Powdery mildew.

15. Sooty blotch and flyspeck are both fungi that are frequently found infecting the same apple fruit.
    A. True.
    B. False.

16. Which of the following diseases of stone fruits produces "mummies"?
    A. Brown rot.
    B. Canker.
    C. Leaf spot.
    D. Leaf curl.

17-20. Match the following diseases with the characteristic disease symptoms.
    A. Bacterial canker.
    B. Cherry leaf spot.
    C. Powdery mildew.
    D. Peach leaf curl.

17. __ Infected plants develop thick, rubbery leaves.
18. __ Infected plant parts have a white, dusty appearance.
19. __ Sunken, dark areas appear on tree branches.
20. __ Small, circular, reddish leaf spots.

21. Which of the following diseases of blueberries results in brown discoloration of the twig?
    A. Anthracnose.
    B. Mummy berry.
    C. Shoestring disease.
    D. Phomopsis.

22. Reddish purple fruit and straplike leaves are characteristics of which blueberry disease?
    A. Anthracnose.
    B. Mummy berry.
    C. Shoestring disease.
    D. Phomopsis.

23. Which of the following diseases of blueberry is vectored by the blueberry aphid?
    A. Anthracnose.
    B. Mummy berry.
    C. Shoestring disease.
    D. Phomopsis canker.

24. Grapes do NOT need a film of moisture to become infected with powdery mildew.
    A. True.
    B. False.

25-28. Match the following raspberry diseases with the characteristic disease symptoms.
    A. Anthracnose
    B. Botrytis fruit rot
    C. Orange rust
    D. Spur blight

25. __ Small pustules on the undersides of leaves.
26. __ Infected canes have purplish spots.
27. __ Covered with a gray, fuzzy spore mass.
28. __ Infected canes have gray spots.

29. Which of the following is not a disease of strawberries?
    A. Fruit rot.
    B. Black root rot.
    C. Leather rot.
    D. Shoestring disease.

30. A strawberry plant with reduced vigor, especially in areas with compacted soil, is infected with
    A. Black root rot.
    B. Botrytis fruit rot.
    C. Leather rot.
    D. Orange rust.

31. Which of the following strawberry diseases can result in bitter-tasting jam and jelly?
    A. Black root rot.
    B. Leather rot.
    C. Leaf spot.
    D. Orange rust.

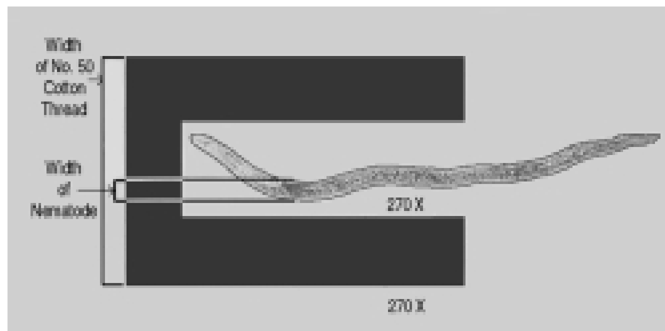
CHAPTER 8

NEMATODE MANAGEMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Understand the basic biology of plant-parasitic nematodes.
- Be familiar with nematodes of importance in fruit crop production.
- Know the importance of monitoring nematode population densities.
- Understand the strategies and tactics used to manage plant-parasitic nematodes.



Nematodes are extremely small. Here a nematode is laid on top of a cotton thread to compare size.

INTRODUCTION

Nematodes are animals. More specifically, nematodes are non-segmented roundworms. They are closely related to segmented roundworms, more commonly known as earthworms. Adult nematodes can vary in length from 1/30 inch to nearly 9 feet. Nematodes are commonly found in soil or water, including oceans. They may be the most numerous multicellular organisms on earth. A shovelful of garden soil typically includes more than 1 million nematodes.

The majority of nematode species are regarded as beneficial. They feed on bacteria, fungi, and other soil-inhabiting or aquatic animals. Some feed on very specific foods; others are considered omnivores that can feed on a wide range of foods.

Some species of nematodes are parasites of plants and animals. The focus of this chapter will be plant-parasitic nematodes. Plant-parasitic nematodes share three common characteristics. First, they are all microscopic, with adults ranging in length from about 1/30 to ¼ inch in length. Second, they are obligate parasites of plants. This means they must have living plant tissue to feed on to grow and reproduce. Finally, they all possess stylets, which are structures similar to hypodermic needles that nematodes use to puncture plant cells and obtain the cells' contents. All plant-parasitic nematodes spend at least part of their life cycles in soil, although many are principally found in root or leaf tissue.

PLANT-PARASITIC NEMATODES

Plant-parasitic nematodes are microscopic animals that attack plants. Every species of plant has at least one species of nematode that parasitizes it. The majority of plant-parasitic nematodes (about 95 percent of the described species) feed on roots, either within the root tissue as endoparasites or outside as ectoparasites. Some nematodes feed within leaves. Plant-parasitic nematodes must have living host tissue to feed on to grow and reproduce. If the host dies, nematodes will disperse and search for other plants to invade.

Poor growth of replanted trees or plants is often the most obvious indication of a nematode problem. Aboveground symptoms may include stunting, short internodes and small leaves. Root systems are small and discolored and have poorly developed feeder roots.

Infected trees or plants often become non-productive earlier than normal. Plant-parasitic nematodes can also hinder the development of beneficial fungi necessary for normal plant growth. A few types of nematodes do produce characteristic symptoms or signs; these will be discussed when specific nematodes are described.

Nematodes, like insects, have exoskeletons. This outer covering must be shed or molted for a nematode to grow. A typical plant-parasitic nematode life cycle consists of an egg, four preadult stages (referred to as juveniles) and an adult. Females are often more destructive; males typically do not feed. In many species of plant-parasitic nematodes, males are rare or not known to exist. The life cycle of a plant-parasitic nematode may be completed in as little as two weeks or as long as two years, depending on the species and the temperature.

Because of their size, plant-parasitic nematodes do not move long distances on their own. They are usually transported over long distances on machinery, in nursery stock, on transplants or seed, or by animals. Anything that moves soil moves nematodes, including water and wind. Some nematodes are known to move a few feet vertically in the soil during a growing season when environmental conditions are adverse.

SAMPLING NEMATODE POPULATIONS

Plant-parasitic nematodes are microscopic organisms with concentrated distributions in a field. Since they tend to occur in clumps, symptoms usually occur in circular or elliptical patterns. If aboveground symptoms are uniformly distributed in any given field, the cause of the problem is typically not nematodes.

Points to remember when sampling for nematodes:

- Because of their microscopic size, the only way to diagnose a plant-parasitic nematode problem is to collect soil and/or plant tissue samples and send them to a nematode diagnostic lab for analysis.
- It is impossible to provide specific recommendations for the management of plant-parasitic nematodes unless they are properly identified.
- When collecting soil samples for plant-parasitic nematodes, the more soil cores gathered, the better the sample. However, it is necessary to submit only a pint to a quart of soil to a lab.
- For more complete instructions on sampling for nematodes, please refer to MSU bulletin E-2419, *Avoidance and Management of Nematode Problems in Tree Fruit Production in Michigan.*

MANAGEMENT OF PLANT-PARASITIC NEMATODES

The best defense against nematodes is to avoid them. Once fields or plant tissues are infected with nematodes, eradication is usually impossible. Nematodes are usually transported over long distances by machinery, in plant material, on animals, or by water or wind. Natural disasters such as floods are uncontrollable, but the patterns in which machinery is moved and the sanitation of this equipment can be controlled. These tactics should be considered when trying to avoid nematodes. The bottom line is that anything that moves soil moves nematodes.

Fields often become infested with nematodes. If samples indicate the presence of pest nematodes at action threshold levels, then steps should be taken to reduce their population densities. Many tactics can be utilized to accomplish this goal.

Biological controls: The majority of nematodes present in the soil are considered beneficial. They typically feed on bacteria, fungi or small animals, including other nematodes. Research results indicate that as the abundance of beneficial nematodes increases, the numbers of plant-parasitic nematodes decrease. Steps can be taken to increase the diversity and numbers of beneficial nematodes in fields. This type of approach is outlined in other MSU bulletins on crop ecology.

Many organisms are parasites or pathogens of nematodes. Most of these occur naturally in soils but often do not provide sufficient control of plant-parasitic nematodes. Some biological nematicide products are available, but their use has not resulted in consistent control of nematodes in Michigan.

Biotechnological controls: Plants have not been genetically modified at this time to control plant-parasitic nematodes.

Chemical controls: Nematicides are chemicals that kill nematodes. Nematicides are either **fumigants** or **non-fumigants**. Fumigants are typically compounds sold as liquids that react with water in the soil to produce gases that kill a wide variety of organisms, including beneficial and pest nematodes, fungi, plants and insects. They are usually applied to the soil in the fall or spring when soil temperatures are adequate. Fumigant nematicides are labeled for use in fruit production in Michigan. Please consult MSUE bulletin E-154, *Michigan Fruit Management Guide,* for specific recommendations.

Non-fumigant nematicides are also labeled for use in Michigan fruit production. Unlike fumigants, they do not volatilize in soil water. They can be applied before, at or even after planting in some situations. These compounds typically kill a narrower spectrum of organisms than fumigants but will typically kill both beneficial and pest nematodes. See MSUE bulletin E-154 for information on use of these materials.

Cultural controls: Cultural factors that affect nematode populations include the crop, length of time planted in the same crop, soil type and cover crop. Site selection and site preparation are very important components of nematode management in orchards and small fruit plantings. Plant only nematode-free trees or plants. Pay close attention to soil condition and fertility. Use cultivation and planting practices that allow unrestricted growth and development of root systems.

Site Selection and Preparation Guidelines

Before removing an orchard or small fruit planting:

- Examine the general vigor and root condition of the plants.
- Examine the soil structure for problems such as faulty drainage and hardpan.
- Do a complete chemical analysis of soil and foliage.
- Examine the soil and roots for plant-parasitic nematodes.

Immediately after plant/tree removal:

- Work the soil and remove as many of the remaining roots as possible.
- Plant a suitable cover crop. The choice of the cover crop depends largely on the nematode species present. Increasing organic matter and biological diversity in the soil decreases the risk of nematode problems.
- Do not replant with new trees or plants until at least one year after old ones are removed.

Soil preparation during the fall before planting:

- Cultivate, removing remaining tree roots and incorporating organic matter.
- Follow appropriate pH and soil fertility recommendations.
- If the nematode population is above the action threshold, a nematicide may be recommended.

Genetic controls: Some rootstocks are resistant to certain species of nematodes. Also, cultivars vary in their tolerances to nematodes.

Physical controls: These include the use of heat, steam or water (flooding) to reduce population densities of nematodes. In field situations, these types of controls are limited. In glasshouse or polyhouse plant production, heat or steam is typically used to sterilize growing media.

NEMATODES OF IMPORTANCE IN FRUIT PRODUCTION

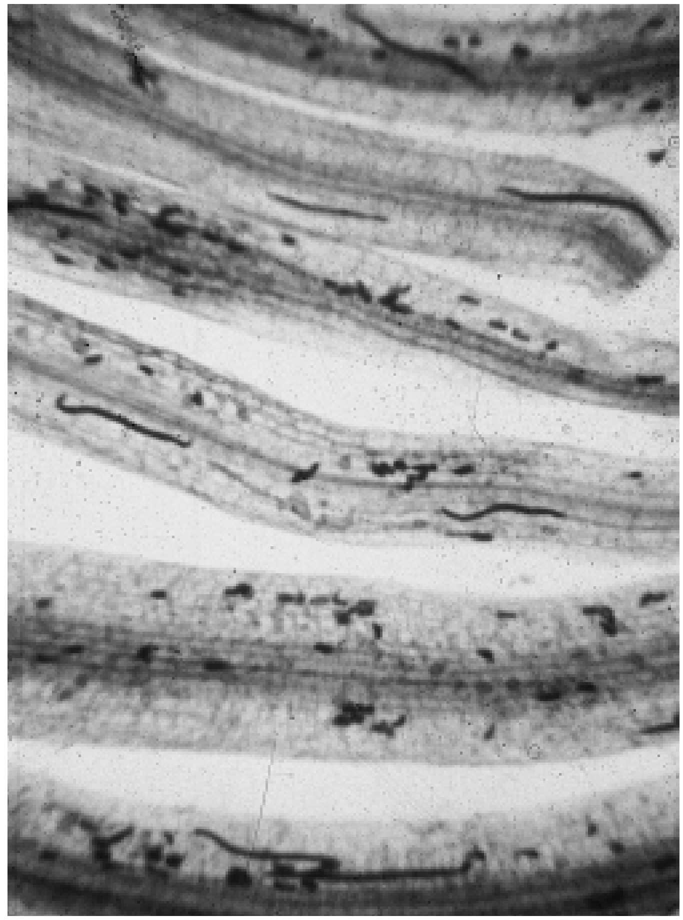
Lesion Nematode *(Pratylenchus penetrans)*

Type: Migratory endoparasite.

Host Plants: Virtually all species of cultivated plants.

Biology: Lesion nematodes overwinter as juveniles and adults within roots or in soil. These nematodes penetrate young roots. Once inside the root, they migrate between and through cells, often killing them.

Lesion nematode females lay eggs singly in root tissue or in soil. Females typically produce fewer than 100 eggs. Life cycles can be completed in three to four weeks, depending on soil temperatures. Lesion nematodes can complete multiple generations per growing season.



Lesion nematodes.

Symptoms: Penetration of roots by lesion nematodes results in very small lesions. These wounds create a point of entry for other soil pathogens, such as the fungi *Verticillium, Cylindrocarpon, Rhizoctonia, Colletotrichum* and possibly others.

Lesion nematode-infected plants typically have reduced root volumes and weights. Feeding and migration by these organisms kill cells. Feeder roots are usually destroyed.

MANAGEMENT

Avoidance:

Plant lesion nematode-free trees and plants. This is especially important in strawberry.

Population Reduction:

Cultural Controls: Lesion nematodes feed on virtually all species of cultivated plants, so they are difficult to manage with rotation. Utilizing sorghum or sudax as a rotational crop may help to reduce population densities of lesion nematode.

Chemical Controls: Nematicides may be necessary to maintain populations below the action threshold.

Dagger Nematode *(Xiphinema americanum)*

Type: Ectoparasite.

Host Plants: Most stone and small fruits.

Biology: Dagger nematodes are of concern to fruit producers because they are potential vectors of plant viruses known as nepo (**ne**matode-transmitted **po**lyhedral-shaped) viruses. Nepoviruses that are commonly vectored by *X. americanum* (the most common species of dagger nematode in Michigan) that affect small fruits and tree fruit are tomato ringspot virus (TmRSV), tobacco ringspot virus (TRSV) and peach rosette mosaic virus (PRMV). It requires only one dagger nematode to transmit a nepovirus to a host.

Dagger nematodes are large plant-parasitic nematodes that feed as ectoparasites on plant roots. All life stages overwinter, and adults can survive beyond one year. High population densities of these nematodes can injure the root systems of small fruit and tree fruit plants.

Symptoms: The feeding of this nematode often results in swollen root tips, prevents the root systems from functioning normally and often kills roots. Therefore, dagger nematodes can affect a plant's growth and yield even if they are not harboring viruses.

Tomato ringspot virus (TmRSV) causes stem pitting of peaches and cherries and brown ring union necrosis of apples and plums. Peach and cherry orchards affected by *Prunus* stem pitting exhibit an overall unthrifty appearance. Unfolding of leaf buds is delayed. The most characteristic symptom is spongy bark and pits in the trunk immediately above the soil line. Infected trees are severely stunted and die early. Prune trees infected with ring union necrosis exhibit a brown line at the scion-rootstock union. Trees are unthrifty and die early.

MANAGEMENT:

Late spring is usually a good time to check suspect trees or orchards for symptoms of these two diseases.

Avoidance:

Avoid contaminating sites with dagger nematode-infested soil. When possible, use bare-root nursery stock. Control of broadleaf weeds is imperative because these weeds often serve as hosts for nepoviruses.

Population Reduction:

Cultural Controls: Oilseed radish grown as a cover crop and incorporated into the soil will provide control.

Genetic Controls: Although apple is a host for *Xiphenema* spp., cultivars vary in their resistance or susceptibility to nepoviruses. Some rootstocks are tolerant to TmRSV (tomato ringspot virus), and some fruiting varieties are resistant, including Red Delicious and Jonathan.

Chemical Controls: Dagger nematodes are relatively easy to control with nematicides.

Ring Nematode *(Criconemella xenoplax)*

Type: Ectoparasite.

Host Plants: Hosts include stone, pome and small fruits. This species is more common on woody perennials than on annuals.

Biology: The life cycle of this species takes 25 to 34 days at 75° F under laboratory conditions. Females lay eight to 15 eggs over a two- to three-day period. Males are rare. Ring nematodes feed on cortical cells along roots as well as at the root tips. Once feeding is established, they do not move for extended periods of time.

Symptoms: Root systems fed on by this species generally lack feeder roots. In Michigan, ring nematodes have been implicated in increasing the susceptibility of sweet cherry trees on Mazzard rootstocks to a bacterium that causes bacterial canker (*Pseudomonas syringae* pv. *syringae*). Injured trees may become more susceptible to winter injury.

MANAGEMENT:

Avoidance:

Avoid contaminating sites with ring nematode-infested soil. When possible, use bare-root nursery stock.

Population Reduction:

Cultural Controls: Ring nematodes do not survive well in annual cropping systems, probably because of regular habitat disturbances. Tilling the soil will reduce population densities.

Using selected plants as ground covers may suppress *C. xenoplax* populations. Some marigold species (*Tagetes* spp.), for example, have demonstrated nematicidal properties against this nematode. Wheat also appears to have nematicidal properties against this species.

Genetic Controls: No resistance to this species has been identified in stone fruit. Partial tolerance in Lovell peach make it preferred over Nemaguard in locations infested with *C. xenoplax*.

Chemical Controls: Ring nematodes can be controlled with pre- and postplant nematicides.

Northern Root-knot Nematode *(Meloidogyne hapla)*

Type: Sedentary endoparasite.

Host Plants: Very wide host range includes virtually all vegetables and fruit crops.

Biology: The northern root-knot nematode (NRKN) overwinters in the soil as eggs. As soil temperatures increase in the spring, second-stage juveniles emerge, migrate through the soil and penetrate the roots of host plants. The nematodes establish feeding sites behind the root cap. As the infected root continues to grow, the vascular tissue differentiates in the area where the nematodes have fed. In otherwords, root-knot nematodes affect the plant's plumbing.

Shortly after successfully establishing a feeding site, the second-stage juvenile begins to swell and soon molts to a third-stage juvenile. Eventually, following two more molts, it matures to become an adult female or male nematode. Females are round and incapable of movement. Males are wormlike and generally exit the root because they do not feed. Female NRKN produce large numbers of eggs, up to 1,000, in a gelatinous matrix secreted by the anus.

The northern root-knot nematode can complete its life cycle in a month at optimal soil temperatures. Therefore, the nematode can complete multiple generations per growing season.

Symptoms: Northern root-knot nematodes restrict root growth by feeding directly within the vascular tissue of roots. This makes plants less efficient at taking up water and minerals from the soil. Typical symptoms are stunting, yellowing and reduced yields. Severely infested plants usually wilt during periods of hot, dry weather because the nematodes disrupt the xylem, the channels in a plant through which water moves.

NRKN invasion of roots causes small swellings on the roots called galls. Gall size depends on the number of nematodes feeding within them. On woody perennials, however, galls are not often evident.

MANAGEMENT

Avoidance:

Once established, root-knot nematodes are virtually impossible to eradicate. Therefore, attempts should be made to keep sites clean of northern root-knot nematode for as long as possible. This is accomplished primarily by using nematode-free plants and by not contaminating fields with northern root-knot nematode-infested soil.

Population Reduction:

Cultural Controls: Sites with histories of root-knot nematode problems should be kept out of fruit production for a period of two to four years. NRKN non-host crops such as corn or small grains should be grown to reduce population densities. Weed control is important because many weeds serve as hosts for the northern root-knot nematode.

Chemical Controls: Sites should be routinely sampled for plant-parasitic nematodes before establishing a new planting. If nematode population densities are recovered at action threshold levels, use of a nematicide may be advised. Root-knot nematodes are difficult to control with postplanting nematicides.

Genetic Controls: Root-knot nematode-resistant rootstocks may not necessarily be resistant to northern root-knot nematodes.

Review Questions

CHAPTER 8

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 best described as:
   A. Animals.
   B. Bacteria.
   C. Earthworms.
   D. Fungi.

2. Plant-parasitic nematodes typically range in length from approximately:
   A. 1/3000 to 1/300 inch.
   B. 1/30 to 1/4 inch.
   C. 1/4 to 4 inches.
   D. 4 inches to 4 feet.

3. Which of the following is not a characteristic shared by all plant-parasitic nematodes?
   A. Complete their life cycles in usually 7 days.
   B. Microscopic.
   C. Obligate parasites of plants.
   D. Stylet-bearing.

4. How are nematodes similar to insects?
   A. They have compound eyes.
   B. They have three primary body segments.
   C. They possess an exoskeleton.
   D. They have legs and wings.

5. To reduce population densities of northern root-knot nematodes, you should:
   A. Encourage weed growth.
   B. Do nothing.
   C. Grow corn or small grains.
   D. Fertilize crops with nitrogen.

6. Which nematode would most effectively be controlled by disturbing soil?
   A. Dagger.
   B. Lesion.
   C. Northern root-knot.
   D. Ring.

7. If root-invading fungi such as Rhizoctonia or Verticillium are a concern, which type of nematode should be avoided?
   A. Dagger.
   B. Lesion.
   C. Northern root-knot.
   D. Ring.

8. Infection by which nematode causes severe damage to the plant's vascular system, often resulting in wilting and decreased water movement throughout the plant?
   A. Dagger.
   B. Lesion.
   C. Northern root-knot.
   D. Ring.

9. To diagnose a nematode problem, you should
   A. Collect a soil sample and place the soil in a paper cup on the windowsill and count the nematodes as they migrate to the top.
   B. Collect soil and plant tissue samples and send them to a nematode diagnostic lab for analysis.
   C. Ask an expert.
   D. Consult with a fortune teller.

10. Lesion nematodes would not be transported over long distances in which of these situations?
    A. By moving machinery from field to field.
    B. By planting plant material grown in contaminated soil.
    C. By applying leaf mulch.
    D. By soil erosion caused by flooding of the local river.

Match the following words with their definitions.

A. Juvenile
B. Stylet
C. Nematode
D. Root

11. ____ The part of the plant nematodes usually feed on.
12. ____ A young nematode.
13. ____ Piercing/sucking mouthparts that allow nematodes to puncture cells and suck out the contents.
14. ____ A small non-segmented roundworm.

15. The majority of nematodes are considered beneficial.
    A. True.
    B. False.

CHAPTER 9

VERTEBRATE MANAGEMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Know the biology and types of damage caused by vertebrates in fruit crops.
- Be able to determine when it is necessary to apply management options.
- Understand the control options available to manage each vertebrate pest.

INTRODUCTION

Vertebrates rarely cause the extent of damage that insects, diseases, weeds and weather can cause in an orchard or small fruit field. In some situations and locations, however, they can pose significant problems. Management of vertebrate pests is complicated by the following factors:

- **Range.** Many vertebrates have home ranges that cover very large areas. They may use the orchard or fruit planting for food, but they may seek shelter and protection in another area where control measures are not possible.
- **Unpredictability.** Many times vertebrates cause no harm or are beneficial to the ecosystem. Under certain circumstances, however, changes in weather, population size, sources of food and other conditions can cause vertebrate damage in fruit plantings to increase dramatically.
- **Public perception.** People generally have a much higher regard for vertebrates than for insects or fungi. As a result, any management plan needs to address social and political issues.
- **Legal status.** Many federal, state and local laws protect vertebrates. Permits are required to use hunting, trapping or pesticides to deter or prevent damage from most vertebrates. Exceptions are rodents such as rats, mice, voles and chipmunks, and some birds.
- **Management options.** Integrated vertebrate management usually focuses on methods that do not kill, harm, capture or trap animals — e.g., frightening devices, such as noisemakers and scarecrows; and exclusion devices, such as fences or screening.

Three of the most common vertebrate pests in orchards and small fruit plantings are birds, voles and white-tailed deer.

BIRDS

Several species of birds — including starlings, robins, house finches, cedar waxwings and blackbirds — can cause serious damage to fruit crops. In some situations, more than half of a blueberry crop can be consumed by birds.

Many laws and regulations protect birds. Non-lethal bird management methods such as habitat modification, exclusion, and scare tactics and noise devices do not require permits and are the preferred control choices in fruit. The federal Migratory Bird Treaty Act protects all birds except pigeons, house sparrows and starlings. However, local ordinances and state laws may protect these species and/or specify the types of treatments that can be used. **ALWAYS** check local and state laws before attempting to kill or trap birds.

Damage: Birds eat and damage fruit. Many birds naturally forage for berries and find commercial fruit plantings a convenient source of food. Yield loss from bird feeding can be significant in small fruit plantings.

Management Options

Exclusion

Netting is the most effective method for controlling bird damage. The netting is placed directly over plants or bushes or over a frame. The main disadvantages of this method are the high initial cost, the time and labor involved, and the inconvenience of working around it. Its effectiveness in protecting the fruit crop usually makes the disadvantages tolerable. If carefully removed and stored, netting can last for several years.

Scare Tactics and Frightening Devices

The use of frightening devices can be effective in protecting crops from flocks of feeding birds, but their use also requires hard work and long hours for the grower. Devices need to be employed in the early morning and in late afternoon when the birds are most actively feeding. In addition, birds tend to adjust or adapt to frightening devices. It is usually best to use two or more devices or methods of bird control. Frightening devices may be auditory or visual.

Auditory frightening devices: Broadcasts of recorded distress or alarm calls have been used successfully with birds. Most calls are species-specific, so it is important to identify the birds causing damage. Noisemakers such as cannons, exploders and sirens work best if used at irregular intervals and moved frequently. These noise devices do not injure birds but may be disturbing to nearby neighbors.

Visual frightening devices: Visual devices may include eye-spot balloons, scarecrows, reflecting streamers, aluminum pie tins and others. Visual devices are most successful when they are combined with sound devices. They should be rotated and moved often so the birds do not learn that they are harmless.

VOLES

Voles (*Microtus* spp.) are sometimes called meadow mice or field mice. Three species — meadow voles, pine voles and prairie voles — damage fruit trees, Christmas trees, ornamental trees and shrubs, and grassy areas throughout the state. In general, they are compact brown or gray rodents with stocky bodies, short legs and short tails. Voles are active day and night year round. They do not hibernate. They most commonly breed in spring and summer but can breed throughout the year. Voles are very prolific and capable of huge population increases. These increases, followed by dramatic crashes, are characteristic of voles. Population levels generally peak every two to five years, but these cycles are not predictable.

Meadow voles are found statewide and make shallow (1- to 3-inch) tunnels in the soil and surface runways in the grass. They also girdle tree trunks in fall and winter, particularly in years with heavy and prolonged snow cover. Pine voles occur in scattered populations in the west half of the state and dig deep tunnels but make few surface runways. They need a certain amount of organic matter and clay content in the soil so their tunnels can hold up; as a result, they are rarely found in sandy locations. If they are present, it will be in areas with heavier soil. They girdle tree roots, sometimes as deep as 3 feet. Prairie voles are found in southwestern Michigan, and the evidence of their presence resembles that of both meadow and pine voles.

Damage: Voles may cause extensive damage by girdling seedlings and trees and damaging roots. Much of this damage occurs during the fall and winter when other food sources are scarce.

Management Options

Biological

A variety of wild animals feed on voles: hawks, owls, crows, ravens, weasels, foxes, coyotes, bobcats, raccoons, skunks, shrews, domestic cats and some species of snakes. Of these, the hawks and owls (raptors) and snakes can be encouraged to feed in orchards, tree plantations and grassy areas. Predation will not prevent large, periodic increases in vole populations but may eliminate enough individuals in normal years to prevent some damage.

Habitat Modification

Reducing or eliminating grasses and other cover is one of the best long-term options for controlling voles. Mowing and maintaining the height of ground cover between 3 and 6 inches will limit food and cover and expose the voles to predators. Long mowing intervals and mowing with a sickle-bar mower can produce a thatch layer that provides cover for voles. Flail or rotary mowers are preferred. Vegetation-free zones under the trees will discourage voles from living there. Mulch, prunings or decaying vegetation should not be allowed to accumulate around the bases of trees or in tree rows.

Exclusion

The trunks of fruit trees can be encircled with tree guards to prevent voles from gnawing the bark. This is particularly important on young trees, where small amounts of gnawing can severely damage or kill the tree. It should be noted that some tree guards will become tight around the trunk as the tree grows in diameter. A tree guard that is tight to the trunk through the fall will render that trunk more susceptible to winter injury. This is especially true with stone fruits. Removing the wraps in August and letting the trunk harden off can minimize any problems resulting from tree guards. The guards can then be reapplied just before winter sets in — late October or early November in northern Michigan.

Trapping

Trapping is not effective for controlling large vole populations but can be used for monitoring or controlling small populations. Mousetraps baited with peanut butter, oatmeal or apple slices can be placed perpendicular to runways or tunnels.

Repellents

Repellents using thiram (a fungicide) or capsaicin (the "hot" in hot peppers) as an active ingredient are registered for voles. These products may afford short-term protection, but their effectiveness is uncertain. Check with the Michigan Department of Agriculture for availability.

Rodenticides

When used in conjunction with other methods, rodenticides are an important component of a vole management program. They are the easiest and most effective way to control a large population. Broadcasting toxic baits to grassy areas can be done after harvest is complete (from September to December). It is best to broadcast baits just prior to three or more days of relatively warm, dry weather, when the voles will be most actively feeding. Do not place baits in piles or on bare soil. Research has shown that bait in piles or on bare soil is least effective in killing voles and most hazardous to non-target wildlife and pets. When voles invade an orchard by traveling under snow or when ground vegetation is sparse, bait-dispensing stations should be used. Bait stations can also be used in orchards that have a history of vole injury in just certain hot spots near the edges.

WHITE-TAILED DEER

The white-tailed deer (*Odocoileus virginianus*) is an important economic and aesthetic resource in Michigan. Each year the positive economic value of deer is realized through license fees and hunter and vacationer expenditures for food, transportation and equipment. Unlike moles, rats, voles and other rodents, deer can not be casually eliminated when in conflict with humans. Control methods are built around effective deer herd management. Deer are protected year round in Michigan except during the legal hunting season. When deer are causing persistent or severe damage, however, special permits may be issued to shoot deer at other times.

The home range of deer varies, depending on season, habitat, sex and individual characteristics, but it can be as large as several hundred acres. Most individuals use the same home range year after year. They usually use one part of the range as the feeding area and another part for resting. The orchard may be the feeding area and the adjacent woods, the resting area. Deer feed year round, but the most serious damage in orchards usually occurs in the winter when other food sources are scarce.

Damage: Deer browsing on terminal buds and fruit buds in the winter can result in stunted or mishapen growth, lower fruit production, reduced vigor or even tree death. Dwarf, semidwarf and young standard trees are the most susceptible. In the summer and fall, deer may consume fruit. White-tailed deer lack upper incisors and leave a jagged or torn surface on twigs and stems that they browse. Rubbing their antlers on trees can result in broken limbs, girdled trunks and sometimes dead trees.

Management Options

Exclusion

Fencing is often the most effective way to minimize deer damage, especially in areas where the deer populations are large. In general, fencing is expensive. Gather as much information as you can in determining what type of fence to install. **Woven-wire fences** provide excellent year-round protection from deer. They are long-lasting and easy to maintain but also very expensive. Permanent high-tensile electric fencing can provide year-round protection from deer. Electric fences work by changing the behavior of the deer. Several configurations are available. Though these fences cost less than the woven-wire fences, they require frequent monitoring, maintenance and vegetation control.

Repellents

Repellents can be one component of a deer management program that includes several types of repellents, fencing and hunting. Variable effectiveness, short activity, and high maintenance and cost over the long term limit their usefulness as stand-alone measures. Repellents are described by mode of action as "contact" or "area." Contact repellents work by taste and are applied directly to the plants, usually during the dormant season. In general, they should not be used on plant parts intended for human consumption. As always, carefully read the label to confirm that the product can be used on your crop. Examples include hot pepper sauce, thiram and putrescent egg solids. Area repellents repel by odor. They are usually less effective than contact repellents but can be used in perimeter and other situations where contact repellents cannot. Examples include putrefied meat scraps (tankage), bars of soap and human hair.

Hunting

Effective use of the legal deer hunting season can be a good way to control deer populations. Shooting permits may be issued for the removal of problem deer where they are causing damage at other times. Contact the Michigan Department of Natural Resources for special permit information.

White-tailed deer.

CHAPTER 9

Review Questions

Chapter 9: Vertebrate Management

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

1. List five factors that complicate the management of vertebrate pests.

2. Which of the following bird management methods usually requires permits?
   A. Habitat modification.
   B. Exclusion / netting.
   C. Shooting.
   D. Visual scare tactics.

3. Which of following is NOT a disadvantage of netting for bird management?
   A. High initial cost.
   B. Inconvenience to work around.
   C. Time and labor.
   D. Special permits required.

4. Recorded distress or alarm calls for bird management:
   A. Work for all birds.
   B. Are species-specific.
   C. Require federal permits.
   D. Are ineffective.

Match the following vole management methods to the appropriate examples.

A. Biological
B. Habitat modification
C. Exclusion
D. Toxic baits
E. Repellents

_____ 5. Tree guards that prevent voles from gnawing the bark.

_____ 6. Mixed grains or food pellets treated with poison to reduce populations of rodents.

_____ 7. Devices or chemicals that irritate one or more of the senses of an animal and cause it to change its behavior.

_____ 8. Placing nesting boxes for kestrels and perches for hawks and owls in or near an orchard or small fruit planting to attract predators.

_____ 9. Reducing or eliminating grasses and cover.

10. Which of the following is NOT a characteristic of voles?
    A. Capable of large population increases.
    B. Active during day and night.
    C. Hibernate during winter.
    D. Populations peak and crash.

11. Lethal controls that affect non-target species should never be used unless the alternative loss is great.
    A. True.
    B. False.

12. What factors affect the home range of deer?

Match the following deer management methods to the appropriate examples.

A. Contact repellent
B. Area repellent
C. Hunting
D. Exclusion

_____ 13. Using fencing to keep deer from harming fruit crops.

_____ 14. Substances the deer eat or taste that deter them from returning. Examples include hot pepper sauce and putrescent egg solids.

_____ 15. Substances that keep deer away by odor. Examples include bars of soap and human hair.

_____ 16. Killing deer during the legal deer hunting season or during other times with a special permit.

17. Special permits for shooting problem deer during the non-hunting season are never issued.
    A. True.
    B. False.

APPENDIX A

ANSWERS TO REVIEW QUESTIONS

Chapter 1. Integrated Pest Management

(1) Integrated pest management is an ecologically based approach to pest management that combines control strategies and tactics to keep pest populations below economically damaging levels while avoiding adverse effects to humans, wildlife and the environment. The components of IPM are monitoring (scouting), forecasting, thresholds, choosing management methods and evaluation.

(2) The economic injury level is the pest density at which the cost of the damage is equal to the cost of control. An action threshold is the point at which control measures are required to prevent the pest populations from increasing to the economic injury level.

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

(6) Growing degree-days are the total number of degrees for insect growth accumulated. Because insects are cold-blooded, the growth of adults, larvae and eggs is driven by the temperature of their surroundings. Growing degree-days represent the accumulated amount of heat and provide a more accurate model for predicting key periods of insect development.

(7) Cultural controls work by preventing the pest from colonizing the crop, creating adverse conditions that reduce the survival of the pest and reducing the impact of injury by the pest.

(8) A. (9) C.

(10) Mating disruption involves flooding a planting or orchard with a large amount of insect sex pheromone. This confuses the insects and prevents potential mates from locating one another and mating.

(11) B.

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

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

(19) D. (20) B. (21) D. (22) C. (23) 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 regarding the type of pesticide used, 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) C. (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) C. (20) B.

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

Chapter 5. Insect Management

(1) D. (2) A.

(3) Metamorphosis is defined as the change in shape or form of an animal.

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

(10) B. (11) A.

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

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

(19) C. (20) D. (21) C. (22) F. (23) D. (24) B.

(25) A. (26) E. (27) A. (28) C. (29) B. (30) A.

(31) D. (32) B. (33) D.

Chapter 6. Weed Management

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

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

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

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

(21) A.

(22) Herbicide carryover occurs when a herbicide does not break down during the season of application and persists in sufficient quantities to injure succeeding crops. Herbicide carryover is influenced by the rate and time of application, herbicide distribution across the field, soil type, and soil temperature and moisture.

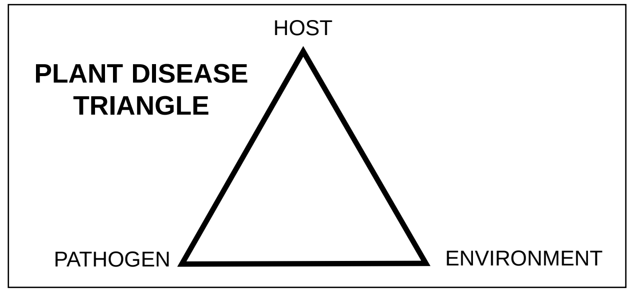
(23) A herbicide adjuvant is any substance that is added to a herbicide to enhance its effectiveness.

(24) B.

Chapter 7. Disease Management

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

(6)



(7) A.

(8) 1. Production of inoculum.
2. Spread of inoculum.
3. Infection.
4. Pathogen survival between susceptible crops.

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

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

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

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

Chapter 8. Nematode Management

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

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

(13) B. (14) C. (15) A.

Chapter 9. Vertebrate Management

(1) Range, unpredictability, public perception, legal status, management options

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

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

(12) The home range of deer varies depending on season, habitat, sex and individual characteristics. It can be as large as several hundred acres. The deer often use one part as the feeding area and another part as the resting place.

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

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 mile

Volume

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

Weight

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

APPENDIX C

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Michigan Fruit Management Guide:

http://www.msue.msu.edu/pestpubs/E154/TOC.html

Michigan State University Integrated Pest Management Program: **http://www.msue.msu.edu/ipm/**

Michigan State University Pesticide Education Program:
http://www.pested.msu.edu/

Michigan Department of Agriculture:
http://www.michigan.gov/mda

National Pesticide Information Center:
http://ace.orst.edu/info/npic/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/

University of California Statewide Integrated Pest Management Project, Pest Management and Identification:
http://www.ipm.ucdavis.edu/PMG/crops-agriculture.html

USDA Office of Pest Management Policy & Pesticide Impact Assessment Program:
http://ipmwww.ncsu.edu/opmppiap/proindex.htm
(crop profiles)

APPENDIX D

GLOSSARY

Glossary of Terms for Fruit Crop Pest Management

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.

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

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

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

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

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

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

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.

ANTIBIOSIS — A relationship between two or more organisms that negatively affects one of the organisms involved (example: plant characteristics that affect insect behavior).

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

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

ANTIXENOSIS — A relationship between two or more organisms that changes the behavior of one of the organisms involved (example: plant characteristics that drive an insect away).

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.

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

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

BACTERICIDE — Chemical used to control bacteria.

BACTERIUM (plural BACTERIA) — Microscopic one-celled organisms, some of which are capable of producing diseases in plants and animals. Others are beneficial.

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.

BARRIER APPLICATION — Application of a pesticide in a strip alongside or around a structure, a portion of a structure or any object.

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, parasites and disease-causing organisms. May be naturally occurring or introduced.

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

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

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

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

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

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

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

CARRIER — An inert liquid, solid or gas added to an active ingredient to make a pesticide dispense effectively. A carrier is also the material, usually water or oil, used to dilute the formulated product for application.

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 CONTROL — Pesticide application to kill pests.

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.

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

CHLORINATED HYDROCARBON — A pesticide containing chlorine, carbon and hydrogen. Many are persistent in the environment. Examples: chlordane, DDT, methoxychlor. Few are used in structural pest management operations today.

CHLOROPHYLL — The green pigment in plant cells that enables the plant to convert sunlight into food.

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

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

CLASSES — See ***taxonomy***.

COMMERCIAL APPLICATOR — A certified applicator who uses or supervises the use of any pesticide classified for restricted use for any purpose or on any property other than that producing an agricultural commodity.

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

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

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

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

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

COTYLEDONS — The first leaf or pair of leaves of a seedling.

CROSS-RESISTANCE — When a pest develops resistance to one type of pesticide and all other pesticides with a similar mode of action.

CULTURAL CONTROL — A pest control method that includes changing human habits — e.g., sanitation, work practices, cleaning and garbage pickup schedules, planting and harvest times, etc.

CURATIVE — The application of a control tactic after the pest has arrived.

CYST (NEMATODES) — The body of the dead adult female nematode of the genus *Heterodera* or *Globodera,* which may contain eggs.

DAMPING-OFF — A disease that destroys seedlings near the soil line, resulting in the seedlings falling over on the soil.

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

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

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

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

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

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

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

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

DISEASE — A disturbance of normal plant function; caused by bacteria, fungi, viruses 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; chemicals used to clean or surface-sterilize inanimate objects.

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 INJURY LEVEL (EIL) — The smallest pest population that will cause economic loss to the crop.

ECONOMIC THRESHOLD (ET, ACTION THRESHOLD) — The pest density at which a control tactic should be taken to prevent the pest population from increasing to the economic injury level.

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 these are added to water, a milky emulsion is formed.

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

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

ENCAPSULATED FORMULATION — A pesticide formulation with the active ingredient enclosed in capsules of polyvinyl or other materials; principally used for slow release.

ENDANGERED SPECIES — A plant or animal species whose population is reduced to the extent that it is near extinction and a federal agency has designated it as being in danger of becoming extinct.

ENTRY INTERVAL — See ***reentry interval***.

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

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

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

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

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

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

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

FAMILY — See ***taxonomy***.

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

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

FORMULATION — The pesticide product as purchased, containing a mixture of one or more active ingredients, carriers (inert ingredients) and other additives that make 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. Usually, it penetrates voids to kill pests.

FUNGICIDE — A chemical used to control fungi.

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

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

GENUS — See ***taxonomy***.

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 springwater, 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 leafhoppers.

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 thread-like structure of fungus.

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

INCUBATION PERIOD — The time between first exposure to a pathogen and the appearance of the first 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. Sometimes generalized to be synonymous with pesticide.

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

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 includes reducing pests to a tolerable level. Pesticide application is not the primary control method but is an element of IPM — as are cultural, mechanical and biological methods. IPM programs emphasize communication, monitoring, inspection and evaluation (keeping and using records).

JUVENILE — The immature or larval stage 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 does not develop into an adult but remains immature.

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

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

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

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

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

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

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

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

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

MICROBIAL DEGRADATION — Breakdown of a chemical by microorganisms.

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

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

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

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

MOLLUSCICIDE — A chemical used to control snails and slugs.

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

MONITORING — On-going surveillance. Monitoring includes inspection and record keeping. 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 hyphae; has a fuzzy appearance.

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

NEMATICIDE — A chemical used to control nematodes.

NEMATODE — A small, slender, colorless roundworm; nematodes live in soil and water or as parasites of plants or animals.

NON-INFECTIOUS DISEASE — Disease caused by non-living agents such as drought, soil compaction, temperature or moisture extremes, nutrient deficiency, etc.; cannot reproduce and spread.

NON-POINT SOURCE POLLUTION — Pollution from a generalized area or weather event.

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

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

NOZZLE FLOW RATE — The amount of material that passes through the nozzle for a specific amount of time; dependent on pressure and tip size.

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

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

ORDER — See ***taxonomy***.

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

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

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

PATHOGEN — A disease-causing organism.

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 protect from a pest.

PETIOLE — The stalk of a leaf.

pH — A measure of the acidity / alkalinity of a liquid — below pH 7 is acid; above pH 7 (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.

PHYSICAL CONTROL — Habitat alteration or changing the infested physical structure — e.g., caulking holes, sealing cracks, tightening around doors and windows, moisture reduction, ventilation, etc.

PHYTOTOXICITY — Plant injury 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).

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

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

PREHARVEST INTERVAL — The minimum amount of time (in days) between the last application and harvest.

PRONOTUM — The area just behind an insect's head (i.e., the upper plate of the ***prothorax***).

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

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) — In insects with complete metamorphosis, the developmental (resting) stage during which 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 — The length of time following a pesticide application 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) remaining 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 (RUP) — A pesticide that can be purchased and used only by certified applicators or persons under their direct supervision; 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 a 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 INCORPORATION — The mechanical mixing of a pesticide product with soil.

SOIL INJECTION — The placement of a pesticide below the surface of the soil; common application method for nematicides.

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 a fungus.

SPRAY DRIFT — Movement of airborne spray from the intended area of application.

STOLON — An aboveground creeping stem that can root and develop new shoots.

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

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 regarding the site, pest, rate, etc. Supplemental labeling may be supplied at the time of purchase or requested from the dealer.

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

SUSPENSION — Pesticide mixture 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: the poison produced by the black widow spider, the venom produced by poisonous snakes and the botulism toxin produced by bacteria.

UNCLASSIFIED PESTICIDE — See ***general-use pesticide***.

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: 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 or 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 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.

Notes

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

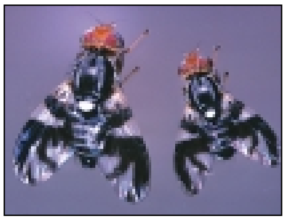
***** *Telephone Number Operated 24 Hours*

Revised by Carolyn J. Randall, *Pesticide Education Program, Michigan State University Extension*

APPENDIX E

CROP-DESTROYING PESTS

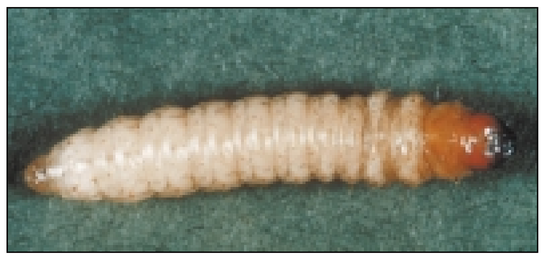
INSECT PESTS



Apple maggot adults female (left) and male (right).

American plum borer

Lesser peachtree borer



Peachtree borer (larva)

Cherry fruit fly (larvae)

Cherry fruit fly (adult)

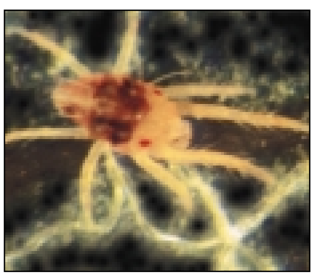
INSECT PESTS

Codling moth (larva)

Codling moth (adult)

Green fruitworm (larva)

Green fruitworm (adult)



European red mite
(adult male)

European red mite
(adult female)

Twospotted
spider mite

Obliquebanded leafroller (larva)

Obliquebanded leafroller (adult)

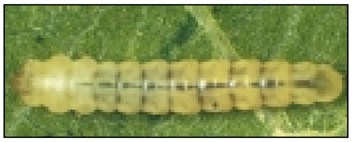
INSECT PESTS


Oriental fruit moth (larva)


Oriental fruit moth (adult)


Plum curulio (larva)


Plum curulio (adult)


Spotted tentiform leafminer (larva)


Spotted tentiform leafminer (adult)


Spotted tentiform leafminer (larvae damage)

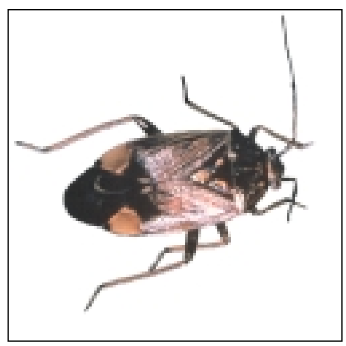

White apple leafhopper (adult)

INSECT PESTS

Blueberry maggot (adult)

Adult Japanese beetle feeding on blueberries.

Grape berry moth (adult male)



Tarnished plant bug

DISEASES

Fire blight

Powdery mildew on apple

Brown rot on peaches

Bacterial cankers on cherry

Cherry leaf spot

Bacterial cankers on peach

DISEASES

Peach leaf curl

Peach leaf curl on pear

Anthracnose on blueberry

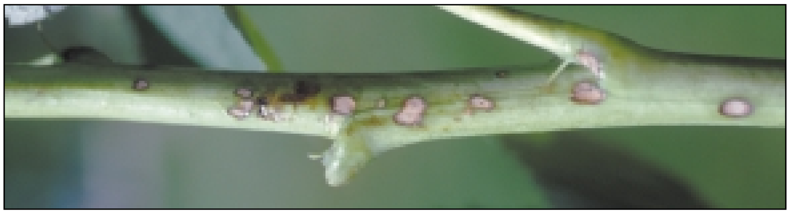
Black knot in plum

Blueberry shoestring disease

Mummy berries

DISEASES

Black rot on grape



Anthracnose on raspberry cane

Phomopsis on grape cane

Powdery mildew on grape

Orange rust on raspberry

Botrytis on strawberry

DISEASES

Black rot on strawberries

Leather rot on strawberries

New (Replaces E-2037, destroy old stock) 10:03-2M-KMF-MB, Price $13.00, for sale only. (Pesticide Applicator Certification)