HORTICULTURE PEST CONTROL

Category 2b

A study guide for Commercial Applicators

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Horticulture Pest Management

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INTRODUCTION

How to Use This Manual

This manual contains the information needed to become a certified commercial applicator in Category 2b, Horticulture Pest Control. This manual is intended for use in combination with Applying Pesticides Correctly Manual (Extension bulletin 825), available through the Ohio State University Bulletin Office. However, this manual would also be useful to anyone interested in learning more about horticulture pest management.

Category 2b, Horticulture Pest Control, covers the management and control of common pests in vegetable and fruit crops. 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 2b certification exam is based on information found in this manual. 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.

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 Ohio, go to our website at www.http://Ohio Agriculture.gov or call 1-800-282-1955 and ask for Pesticide Regulation.
INTEGRATED PEST MANAGEMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

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

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

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

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

FIELD SCOUTING, MONITORING

Field scouting is an important part of any IPM program because it helps define the pest problems. Correct identification and location of each pest in a crop are necessary for a successful pest management program. Regularly scouting 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 pest population and whether it is increasing or decreasing; and the crop condition. A scouting program should include...
accurately written records of field locations, field conditions, previous pest infestations, and control measures. With this information, you can determine what control measures are appropriate.

Remember the following basic principles when scouting:

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

Insect pests can be monitored in several ways. The most common methods are actually 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). Other insect monitoring methods include collecting insects with a sweep net, shaking crop foliage and counting dislodged insects, and trapping insects. 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 OSUE county agents and other OSU personnel indicate pest pressure and outbreaks in the region and state.

**ECONOMIC THRESHOLDS**

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

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

**CONTROL STRATEGIES**

**CULTURAL CONTROL**

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

Cultural control methods work in three ways:

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

**PREVENTING COLONIZATION**

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

A. **Trap crop**—planting a small area with a preferred host to attract the pest away from the crop. Once in the trap crop, the pest can be destroyed or controlled. For example, trap crops can help control striped cucumber beetles. The beetles are attracted to the oldest, most mature crop in an area. An early planting of pumpkins or cucumbers attracts early-season striped cucumber beetles, concentrating the population and preventing movement to the primary crop.

B. **Physical barriers**—separating a pest and host with an object such as a wall or a ditch to stop the pest from infesting—for example, covering the soil with black plastic to control weeds.

C. **Crop rotation**—a cycle in which different crops are planted in a field every year; the longer the rotation between crops susceptible to the same pests, the better the pest control. A crop rotation system helps control pests such as tomato diseases. Tomatoes should not be rotated with peppers, eggplant, or any cucurbits (pumpkins, zucchini, winter squash, cucumber, watermelon or muskmelon).

D. **Delayed planting (timing)**—changing the planting date so that the host is not available when the pest is
present. Example: delaying the planting date of onions until after peak flight of onion maggot adults removes egg-laying sites and helps control onion maggots.

**E. Cover crops**—utilizing plant competition by planting a secondary crop to prevent weeds from becoming established. Example: using fall-planted rye as a living mulch for pumpkins. The rye is killed before seeding pumpkins and the rye residues suppress weeds.

Creating adverse pest conditions in the crop

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

**Destroy crop residue, alternate hosts, and volunteer crops**—eliminating the pest or pest habitat found in crop residue, or destroying alternate hosts of the pest found near or in the crop – for example, destroying corn debris after harvest to reduce overwintering European corn borers. Pests, particularly plant pathogens, can survive in a field on volunteer crops and alternate hosts. The survival of these pathogens provides a source of inoculum. For example, aster yellows and its vector survive on volunteer crops and weeds. Both the phytoplasma and the insect population can build in the primary crop, increasing the likelihood of infection.

**Tillage**—physically moving the soil around the crop. Tillage can destroy an insect and uproot and cover weeds. All of these factors can reduce pest populations.

**Water management**—Water is needed for healthy plant growth but avoid water-related conditions that promote pest problems such as disease spread. For example, Phytophthora is a water mold that is favored by saturated soil conditions. Using raised beds for squash and cucumbers helps prevent loss from Phytophthora.

**Spatial arrangement (seeding rate and row spacing)**—changing the spatial arrangement of the crop to reduce pest populations. For instance, when plant spacing and row width are reduced, plants can out compete weeds for light, water, and nutrients. On the other hand, close plant spacing may provide an environment favorable for disease development, such as white mold in snap beans.

**Allelopathy**—one plant species reducing competition from another plant species by releasing toxic chemical agents into the soil. Allelopathy has minimal potential in weed management. For example, in a conservation tillage system, leaving residues of some varieties of rye can reduce the number of weeds.

**REDUCE PEST INJURY TO CROP**

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

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

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

**Harvest timing**—changing the time when a crop is harvested to reduce pest impact on yield. For example, if a field is infested with Phytophthora, the vegetable crop should be harvested as soon as it is mature to decrease the time that the crop is exposed to the pathogen.

**Storage practices**—handling, curing, and storage practices to prevent the spread of disease during storage. For instance, controlled temperature and ventilation are essential to minimize losses in potatoes.

**BIOLOGICAL CONTROL**

Biological control is the use of living organisms to reduce a pest population. These beneficial 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.

Examples of insect biological control agents (natural enemies).

<table>
<thead>
<tr>
<th>Natural Enemy</th>
<th>Pests Controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PREDATORS</strong></td>
<td></td>
</tr>
<tr>
<td>lady beetles</td>
<td>aphids, scale insects</td>
</tr>
<tr>
<td>green lacewings</td>
<td>aphids, mites, others</td>
</tr>
<tr>
<td>spined soldier bug</td>
<td>Colorado potato beetle, Mexican bean beetle</td>
</tr>
<tr>
<td>minute pirate bug</td>
<td>corn earworm eggs, mites</td>
</tr>
<tr>
<td><strong>PARASITOIDS</strong></td>
<td></td>
</tr>
<tr>
<td>tachinid flies</td>
<td>beetles, caterpillars</td>
</tr>
<tr>
<td>ichtneumonid wasps</td>
<td>caterpillars, leafrollers, weevils, others</td>
</tr>
<tr>
<td>braconid wasps</td>
<td>caterpillars, beetles, aphids</td>
</tr>
<tr>
<td>Trichogramma wasps</td>
<td>eggs of moths, such as European corn borer</td>
</tr>
<tr>
<td><strong>PATHOGENS</strong></td>
<td></td>
</tr>
<tr>
<td><em>Bacillus thuringiensis</em></td>
<td></td>
</tr>
<tr>
<td>nuclear polyhedrosis viruses (NPV)</td>
<td></td>
</tr>
<tr>
<td><em>Beauveria bassiana</em> (fungus)</td>
<td></td>
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<tr>
<td><em>Nosema</em> (protozoan)</td>
<td></td>
</tr>
<tr>
<td><em>Streptomyces griseoviridis</em> strain K61 (Mycostop®) (fungus)</td>
<td></td>
</tr>
<tr>
<td><em>Trichoderma harzianum</em> Rifai strain KRL-AG2 (PlantShield™) (fungus)</td>
<td></td>
</tr>
</tbody>
</table>

A. Wasp lays egg in host (for example, an aphid).
B, C. As the host feeds and grows, so does the wasp larva.
D. Parasitoid kills then pupates within dead host.
E. An adult parasitoid emerges from the dead host.
**Pathogens**—disease-causing organisms such as bacteria, viruses, and fungi that infect and kill the pest. Environmental conditions such as high humidity or high pest abundance allow naturally occurring pathogens to multiply and cause disease outbreaks (epizootic), 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.

**CHEMICAL CONTROL**

Chemical control reduces a pest population through the application of pesticides. The decision to use a pesticide as part of an IPM program should be based on a scouting program, pest identification, economic thresholds, and the crop/pest life stages. When used properly, pesticides provide effective and reliable control of most pest species.

**TYPES OF PESTICIDES**

Pesticides used to control vegetable crop pests are applied either to the soil or to the plant foliage.

- **Soil-applied pesticides**
  - *Chemigation*—applying a pesticide or fertilizer to the soil by injecting it into the irrigation system.
  - *Insecticides*—applied to prevent insect damage to the roots of corn and other crops. Insecticides can be applied by broadcast soil applications and soil incorporation before planting, applied in the seed furrow at planting, or broadcast before or after crop emergence.
  - *Fungicides*—applied to soil to prevent damage to the roots caused by soil borne fungi. Fungicides can be applied by broadcast soil application and soil incorporation before planting, applied in the seed furrow at planting, or broadcast before or after crop emergence.
  - *Herbicides*—applied to the soil surface and mixed into the soil before planting (*preplant incorporated*) or applied after planting but before crop emergence and not incorporated (*preemergence*).
  - *Soil fumigants or nematicides*—applied to the soil to control nematodes before planting.

- **Foliar-applied pesticides**
  - Foliar applications are applied directly to crop leaves. They can be applied before damage occurs (*preventive*) or in response to damage (*curative*).
  - *Insecticides*—generally applied to control insects that are feeding above-ground on the crop.
  - *Herbicides*—applied to the weed foliage after the crop and weeds have emerged (*postemergence*).
  - *Fungicides*—applied to the crop before the disease appears to prevent disease (*protectant*) or to control disease after it appears (*eradicant*).

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

- **Preharvest interval**—the minimum number of days needed between the last pesticide application and harvest. 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.

- **Residues**—the pesticide that remains on the crop after an application. Ideally, a pesticide is present only long enough to kill the pest and then breaks down. 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 a field without personal protective equipment (PPE). The reentry interval prevents unnecessary pesticide exposure. Only workers trained for early entry under the Worker Protection Standard (WPS) and wearing proper personal protection equipment may enter a treated area during the reentry interval. Refer to the Worker Protection Standard for the regulations on informing workers about pesticide applications.
**Phytotoxicity**—when a pesticide damages the crop to which it is applied. Pesticide drift, excessive rates, mixing incompatible pesticides, 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 avoid this problem.

**Pesticide resistance**—the genetic ability of an organism to tolerate the toxic effects of a pesticide, such as malathion-resistant Indian mealmoths, atrazine-resistant common lamb’s quarter, Mefenoxam-resistant *Phytophthora*, and ALS (acetolactate synthase)-resistant ragweed. Resistance develops from overuse of the same pesticide or from overuse of 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, leading to a serious control problem. Therefore, it is important to use pesticides only when necessary and rotate pesticides and mode of action as much as possible.
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 groundwater 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 (825) 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). Ohio pesticide laws include the Natural Resources and Environmental Protection Act. Pesticide applicators and technicians should keep up-to-date copies of the laws and review their contents periodically. Copies of Ohio pesticide laws can be obtained from Ohio Department of Agriculture (ODA). Refer to the core manual (OSU Extension bulletin 825) 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 Ohio Department of Agriculture (ODA) administer FIFRA.

Pesticide labels provide use information such as safety precautions, application rates, sites where the pesticide can be applied, and target pests. They contain information to protect the applicator, the environment, and the crop while maximizing pest control. Pesticide labels are legal documents that must be followed. Always read the entire label and all supplemental labeling before using a pesticide. Supplemental labeling includes any information you receive from the manufacturer about how to use the product. 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. Supplemental labels include special local needs labels (24c), emergency exemption labels (section 18), and (2ee) rate change exemptions use information issued by the pesticide manufacturer.
Always:

- Select pesticides labeled for use on your crop.
- Read and understand the label instructions and limitations before each use.
- Follow the application directions on the pesticide label.
- Contact your county OSU 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 Ohio get their drinking water from wells. It is easy to see why you should be concerned about keeping pesticides out of groundwater.

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

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

Keeping Pesticides Out of Groundwater and Surface Water

A pesticide that has not become a gas (volatilized), 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 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 in the geological layers between the soil surface and the groundwater.
Select pesticides carefully. Choose pesticides that are not likely to leach (move downward) in the soil into groundwater or run off into surface water. Pesticides that are very water soluble and not easily bound to soil tend to be the most likely to leach. Read pesticide labels carefully, consult the OSU Extension pesticide application guides, or seek advice from an OSU specialist or a pesticide dealer to choose the best pesticide for your situation.

Follow pesticide label directions. Container and supplemental pesticide labels are the law. Labels provide crucial information about application rates, timing, and placement of the pesticide. Consult all labels before using the pesticide.

Calibrate accurately. Calibrate equipment carefully and often to avoid over- or underapplication.

Measure accurately. Carefully measure concentrates before placing them into the spray tank. Do not “add a little extra” to ensure that the pesticide will do a better job.

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

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

Mix on an impervious pad. Mix and load pesticides on an approved impervious mix/load pad where spills can be contained and cleaned up. If mixing in the field, change the location of the mixing area regularly. A portable mix/load pad is required if you fill at the same location 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 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.

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.

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 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.

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.

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 product within its habitat.

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—pesticide 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, reducing the number of pesticide applications needed. This reduces the advantage that resistant individuals have over non-resistant individuals and delays or prevents the buildup of resistance in a population.

- **Using pesticides from different chemical families with different modes of action.** Try to do this whether you apply pesticides against a pest once a year or several times within a treatment season.

- **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.
APPLICATION EQUIPMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

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

METHODS OF APPLICATION

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

- **Broadcast application** is the uniform application of a pesticide to an entire area.
- A **directed-spray application** targets pests in a specific area in an effort to minimize pesticide contact with the crop or beneficial insects.
- **Foliar application** directs pesticide to the leafy portions of a plant.
- **Spot treatment** is application of a pesticide to small, discrete area.
- **Soil application** places pesticide directly on or in the soil rather than on a growing plant.
- **Soil incorporation** is the use of tillage equipment to mix the pesticide with the soil.
- **Soil injection** is application of a pesticide beneath the soil surface.

TYPES OF SPRAYERS

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

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

Low-pressure Sprayers

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

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

High-pressure Sprayers

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

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

PARTS OF A SPRAYER

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

Tanks

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

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

Agitators

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

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

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

Pumps

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

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

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

Strainers

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

Hoses

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

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

Pressure Regulators

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

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

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

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

Types of Nozzles

Regular Flat-fan Nozzle

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

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

Flooding Flat-fan Nozzle

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

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

Hollow-cone whirl chamber nozzle

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

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

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

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

**During Spraying**

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

**GRANULAR APPLICATIONS**

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

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

**Drop-through Spreaders**

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

**Rotary Spreaders**

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

**FIELD OPERATIONS**

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

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

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

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

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

After completely studying this chapter, you should:

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

INTRODUCTION

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

For proper calibration, you will need a few basic tools, including a stopwatch, a collection container graduated in ounces, a tape measure, and flags or stakes for marking.

Unless your sprayer is new, it will contain a certain amount of pesticide residue; therefore, a pair of chemical-proof gloves is also recommended. Additionally, a pocket calculator will help with calculations.

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

CALIBRATION OF SPRAYERS

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

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

Variables that Determine the Spray Rate

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

Nozzle Flow Rate

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

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

<table>
<thead>
<tr>
<th>Sprayer pressure (speed constant)</th>
<th>Sprayer output (gallons per acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 psi</td>
<td>10</td>
</tr>
<tr>
<td>40 psi</td>
<td>20</td>
</tr>
<tr>
<td>160 psi</td>
<td>40</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Sprayer speed (under constant pressure)</th>
<th>Sprayer output (gallons per acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mph</td>
<td>40</td>
</tr>
<tr>
<td>2 mph</td>
<td>20</td>
</tr>
<tr>
<td>3 mph</td>
<td>13.3</td>
</tr>
<tr>
<td>4 mph</td>
<td>10</td>
</tr>
</tbody>
</table>

To determine the new output after changing speed:

New output = \( \frac{\text{old output} \times \text{old speed}}{\text{new speed}} \)

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

**Precalibration Check of Nozzle Output**

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

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

<table>
<thead>
<tr>
<th>Nozzle</th>
<th>Output (ounces per minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40.0</td>
</tr>
<tr>
<td>2</td>
<td>43.0</td>
</tr>
<tr>
<td>3</td>
<td>39.5</td>
</tr>
<tr>
<td>4</td>
<td>40.5</td>
</tr>
<tr>
<td>5</td>
<td>37.5</td>
</tr>
<tr>
<td>6</td>
<td>39.5</td>
</tr>
</tbody>
</table>

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

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

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

**Spray Pattern Uniformity**

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

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

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

1. Fill the sprayer tank approximately half full with water.

2. Determine the nozzle spacing or band width in inches and stake out the appropriate distance in the field according to the following table:

<table>
<thead>
<tr>
<th>Broadcast nozzle spacing or band width (inches)</th>
<th>Travel distance (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>510</td>
</tr>
<tr>
<td>10</td>
<td>408</td>
</tr>
<tr>
<td>12</td>
<td>340</td>
</tr>
<tr>
<td>14</td>
<td>291</td>
</tr>
<tr>
<td>16</td>
<td>255</td>
</tr>
<tr>
<td>18</td>
<td>227</td>
</tr>
<tr>
<td>20</td>
<td>204</td>
</tr>
<tr>
<td>22</td>
<td>185</td>
</tr>
<tr>
<td>24</td>
<td>170</td>
</tr>
<tr>
<td>26</td>
<td>157</td>
</tr>
</tbody>
</table>

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

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

In this formula, 4,080 is a constant.

For example, if your nozzle spacing is 38 inches:

\[
\text{Travel distance} = \frac{4,080}{38} = 107 \text{ feet}
\]

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

3. With the sprayer turned off, drive the distance using the exact throttle setting and gear you plan to use during spraying. Be sure to note the throttle setting and gear; don’t rely on a speedometer. Start the spray rig about 25 feet before the staked area so that you will be at typical field speed at the beginning of the measured distance. Record your travel time in seconds.

4. Adjust the pressure to the desired setting. Use slightly higher pressure when you use nozzle check valves and nozzle strainers.

5. With the sprayer stationary, collect and record the output (in ounces) from at least four nozzles for the travel time recorded in step 3. Because we already determined that the output of all nozzles is within 5 percent of one another in the precalibration check, it is not necessary to collect output from all nozzles.

6. Determine the average nozzle output in ounces.

7. The spray rate in gallons per acre is equal to the average nozzle output in ounces. For example, if the average nozzle output for the recorded travel time is 20 ounces, the spray rate is 20 gallons per acre.

8. If the spray rate is not reasonable for your particular spraying job, you can change output by one of three methods: adjust pressure, change speed, or replace nozzle tips. If only a minor change in output is needed, simply make an adjustment in pressure and determine the new average nozzle output. (Remember that operating pressure must be kept within the recommended range for the nozzle type so the spray pattern is not distorted.) If a large change in output is necessary, make a change in travel speed. However, you must drive the designated field distance and determine the new travel time before calculating the average nozzle output. If it is impossible to obtain the desired output at an appropriate pressure and ground speed, you will need to change nozzle tips; in this case, you must repeat the precalibration check of nozzle output.

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

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

1. Fill the sprayer tank approximately half full with water.

2. The appropriate travel distance for 40-inch nozzle spacing is 102 feet; measure and mark this distance in the field.

3. Using the throttle setting and gear you plan to use during spraying, you find that it takes 14 seconds to drive 102 feet.

4. Adjust the pressure to the desired setting within the recommended pressure range of 15 to 30 psi for regular flat-fan nozzles; your chosen setting is 25 psi.

5. With the sprayer stationary, you collect the following outputs from four nozzles in 14 seconds:

<table>
<thead>
<tr>
<th>Nozzle</th>
<th>Output (ounces per 14 seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15.5</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>15.5</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
</tr>
</tbody>
</table>

Total = 63 ounces
6. The average output of the nozzles for 14 seconds is:
\[
\frac{63 \text{ ounces}}{4 \text{ nozzles}} = 16 \text{ ounces}
\]

7. The spray rate, therefore, is equal to 16 gallons per acre.

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

**Amount of Pesticide to Add to the Tank**

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

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

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

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

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

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

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

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

\[
\text{Amount per tank} = \text{acres per tank} \times \text{rate per acre}.
\]

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

\[
\text{Amount per tank} = 10 \times 2 = 20 \text{ quarts.}
\]

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

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

1. Calculate the area to be treated as follows:

\[
150 \times 180 = 27,000 \text{ square feet, which is equal to 0.62 acres (27,000} \div 43,560)\]

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

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

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

Cross-multiplying:

\[
(Y \times 1) = (40 \times 0.62) = 24.8 \text{ gallons to treat 0.62 acre}
\]

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

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

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

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

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

**Liquid Application on a Percentage Basis**

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

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

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

By cross multiplying:

\[
100 \times Y = 75 \times 4
\]

\[
100 \times Y = 300
\]

\[
Y = \frac{3 \text{ gallons of Pesticide C per 75 gallons of water}}{}
\]

**Granular Applicator Calibration**

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

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

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

**Drop-through Spreaders**

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

<table>
<thead>
<tr>
<th>Swath width (feet)</th>
<th>Travel distance (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>581</td>
</tr>
<tr>
<td>2</td>
<td>436</td>
</tr>
<tr>
<td>3</td>
<td>290</td>
</tr>
<tr>
<td>4</td>
<td>218</td>
</tr>
<tr>
<td>5</td>
<td>174</td>
</tr>
<tr>
<td>6</td>
<td>145</td>
</tr>
<tr>
<td>7</td>
<td>124</td>
</tr>
<tr>
<td>8</td>
<td>109</td>
</tr>
<tr>
<td>9</td>
<td>97</td>
</tr>
<tr>
<td>10</td>
<td>87</td>
</tr>
<tr>
<td>11</td>
<td>79</td>
</tr>
<tr>
<td>12</td>
<td>73</td>
</tr>
<tr>
<td>15</td>
<td>58</td>
</tr>
</tbody>
</table>

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

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

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

\[
\frac{871}{6.5} = 134 \text{ feet}
\]

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

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

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

1. Determine the amount of product in ounces that should be applied to the calibration area:
   \[
   (60 \text{ pounds}) \times (1/50) = 1.2 \text{ pounds} \times 16 \text{ ounces per pound} = 19.2 \text{ ounces}
   \]
2. Determine if the amount actually applied (16 ounces) is within 5 percent of the recommended rate (19.2 ounces):
   \[
   19.2 \text{ ounces} \times 0.05 (5\%) = 0.96 \text{ ounces}
   \]
   If your applicator was properly calibrated, it should have applied between 18.2 and 20.2 ounces of product to the calibration area. It actually applied less. You therefore need to adjust the feeder gate control to apply more material and then recalibrate.
FRUIT 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.

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 metamorphosis.

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

Development with complete metamorphosis (example: beetle).
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.

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
(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 Ohio, adult emergence begins in late June and continues until September, peaking toward the end of July. In northern Ohio, 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, dimple-like 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
American plum borer is one of several species of borers affecting tree fruit.

experienced 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 1 1/2 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.

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.

**CODLING MOTH (Cydia pomonella)**

**Crops:** apple, pear

Codling moth is the most important insect pest of apples in Ohio. 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 Ohio, 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.

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.

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.

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 parthenogenetically (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.

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 beneficial 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.

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**GRAPE BERRY MOTH** *(Endopiza viteana)*

The grape berry moth feeds only on grapes and usually has two or three generations per year in Ohio. 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.

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 rot. 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 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.

**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.

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**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 Ohio 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.
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 over-wintering 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 over-wintering 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 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.

**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.
STRAWBERRIES

MITES

Twospotted spider mites (*Tetranychus urticae*) and cyclamen mites (*Steneotarsonemus pallidus*) can cause significant damage to strawberries in Ohio. 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 OSU 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 Ohio. 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 over-winter 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.

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 dam-

**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.

**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.
FRUIT 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 Ohio, 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 Ohio State University Extension bulletin E-154, *Ohio Fruit Management Guide.*

**DISEASES OF POME FRUIT**

**FIRE BLIGHT OF APPLES AND PEARS**

**Pathogen type:** bacterium (*Erwinia amylovora*)

**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.
**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 stomata, 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, and 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.

**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*)

Disease symptoms: Powdery mildew kills vegetative shoots and flower buds and may cause russetting 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 russetting 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.

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 Ohio. 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, 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.

SOOTY BLOTCH AND FLYSPECK

Pathogen type: fungus

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.

PEACH LEAF CURL

Pathogen type: fungus (Taphrina deformans)

Disease symptoms: Peach leaf curl causes leaves and occasionally fruit to become thick, rubbery, distorted and

DISEASES OF PEACH

BACTERIAL SPOT

Pathogen type: bacterium (Xanthomonas campestris pv. pruni)

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)
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.

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 1/6 to 1/4 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 "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.
Botrytis spores on strawberry fruit.

Powdery mildew leaf symptoms appear before grape clusters become infected.

Grape leaf infected with phomopsis.

Grape cane infected with phomopsis

**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.

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 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 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.

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.

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.
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.

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 1/8 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 OSU bulletin E-2419, *Avoidance and Management of Nematode Problems in Tree Fruit Production in Ohio*.

**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 OSU 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 Ohio.

**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 nonfumigants. 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 Ohio. Please consult OSUE bulletin E-154, *Ohio Fruit Management Guide*, for specific recommendations.

Non-fumigant nematicides are also labeled for use in Ohio 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 OSUE 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.

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 (nematode-transmitted polyhedral-shaped) viruses. Nepoviruses that are commonly vectored by *X. americanum* (the most common species of dagger nematode in Ohio) 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 *Xiphinema* 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.

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**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 Ohio, 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.

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**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 vas-
cular 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.
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 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 Ohio, 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 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 Ohio.

Trapping

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

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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 Ohio 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 Ohio. 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 cannot be casually eliminated when in conflict with humans. Control methods are built around effective deer herd management. Deer are protected year round in Ohio 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 misshapen 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 Ohio Department of Natural Resources for special permit information.
LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Understand how insects grow and develop.
- Understand the difference between simple and complete metamorphosis.
- Be able to identify the major pests of asparagus, carrots, celery, cucurbits, cole crops, onions, potatoes, snap beans, sweet corn, and tomatoes.
- Be able to describe the life cycles and habitats of the major vegetable insect pests.

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

GROWTH AND DEVELOPMENT

Growth

An insect’s body is confined in a protective exoskeleton. This hard outer covering does not grow continuously. A new, soft exoskeleton is formed under the old one, and the old exoskeleton is shed in a process called molting. The new skeleton is larger and allows the insect to grow a little more. The new exoskeleton is white at first, but it 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 are divided into groups according to the way they change during their development. The technical term for this change is metamorphosis, which means “change in form.” Pests of vegetables undergo either simple or complete metamorphosis.

Group 1. Simple Metamorphosis

Insects developing by simple metamorphosis hatch from an egg 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. Many pests of vegetables, such as aster leafhopper, aphids, and tarnished plant bug, develop by simple metamorphosis. Nymphs and adults are often found together in the crop and usually eat the same food.

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

Group 2. Complete Metamorphosis

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

In complete metamorphosis, newly hatched insects are called larvae. Grubs, maggots, and caterpillars are types of larvae. The job of larvae is to eat and grow; they usually molt four to six times, and then they change into pupae. A pupa is an inactive stage of insect development. During pupation, the insect’s body rearranges itself, resulting in a complete change in form from the immature to an 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.
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 cabbage maggot - the larva is a maggot living and feeding in the roots of cole crops, and the adult is a fly. Species with complete metamorphosis are managed differently according to life stage, where each lives, and what each does. You will want to pay special attention to sections that discuss the life cycle and behavior of each insect pest.

INSECT PESTS OF CUCURBITS (CUCUMBER, MELON, PUMPKIN)

APHIDS

Green Peach Aphid (Myzus persicae) and

Aphids are generally characterized by a pear-shaped body with two cornicles or “tailpipes” on the hind end. Adult green peach aphids may vary in color from yellow to light green to pink. Sunflower aphids are green with black cornicles and black legs. There are wingless and winged forms of both aphids. Winged green peach aphids have dark patches on the head, thorax and abdomen.

Adult female aphids reproduce without mating, creating genetically identical offspring. They do not lay eggs but give birth to tiny aphids. Aphids overwinter as eggs on host plants or as adults in greenhouses. They also migrate into Ohio from the southern United States. There are five to ten generations per year.

Damage: Aphids use their sucking mouthparts to drink plant sap and also transmit viruses. Aphid damage can twist and distort new plant growth, and aphids can contaminate the harvested product.

Control strategies:

- Aphids have many natural enemies; lady beetles, lacewings, spiders, parasitic wasps, and fungal diseases help maintain low aphid populations.
- Chemical control for aphids is not usually necessary unless other pesticide applications have eliminated all natural enemies. Aphids can rapidly develop pesticide resistance because aphid offspring are genetically identical.

CUCUMBER BEETLES

The striped cucumber beetle (Acalymma vittatum) and the spotted cucumber beetle (Diabrotica undecimpunctata howardi) are found on cucurbits in Ohio. The striped
cucumber beetle is yellow with black stripes on its wing covers. The spotted cucumber beetle (also called the southern corn rootworm) is yellow or green with black legs, antennae, and head, and 12 black spots on its wing covers. In the spring, striped cucumber beetles emerge from overwintering sites along fencerows and ditch banks to begin feeding on new plants. Spotted cucumber beetles migrate into Ohio each year from the southern United States. Both striped and spotted female beetles lay their eggs in the soil at the base of cucurbit plants. Larvae emerge and feed on the roots and underground portions of the plant stems. Larvae pupate in the soil and when the adults emerge they feed on the foliage, flowers and fruits of cucurbits. The spotted cucumber beetle can feed on more than 200 common plants, including corn, peas, beans and tomatoes, but the striped cucumber beetle feeds only on cucurbits.

Striped cucumber beetles are easily confused with the western corn rootworm. Striped cucumber beetles have faint yellow markings on their legs; the western corn rootworm has solid black legs. Also, striped cucumber beetles have black abdomens; western corn rootworm, yellow. It is important to distinguish between these two beetles because the western corn rootworm does not injure or transmit disease to cucurbits.

**Damage:** Root feeding by striped cucumber beetle larvae can cause serious damage to undeveloped vines. Adult beetle feeding can completely defoliate young plants or girdle the stems and kill the plants. Cucumber beetle adults also transmit bacterial wilt, a major disease of cucurbits. In Ohio, the spotted cucumber beetle rarely occurs in high numbers and is not a major pest. Striped cucumber beetles, however, can be a severe problem.

**Control strategies:**

- Row covers act as a barrier and prevent striped cucumber beetle infestations. However, row covers must be removed for pollination, are not practical for large acreage, and must not have holes that could allow beetles to enter and go unnoticed.
- Trap crops help control early-season beetle infestations. Any cucurbit variety that is extremely attractive to the striped cucumber beetle can be used as a trap crop. Plant the attractive cucurbit along the field border before the primary crop. Striped cucumber beetles attack the most mature cucurbit crop in a given area, so the beetle population will build in the trap crop. This allows limited, effective insecticide applications to prevent beetle movement to the primary crop.
- Cucurbits are very sensitive to pesticides - read the label carefully. Treatment with a systemic insecticide at planting provides excellent control of early-season cucumber beetles without affecting honeybees. When cucurbit crops are in bloom, making foliar insecticide applications in the early morning or late evening reduces insecticide contact with honeybees. Yields can be reduced if the insecticide application harms pollinators.

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SQUASH BUG (*Anasa tristis*)

Squash bugs feed on all cucurbits but are more of a problem in squash and pumpkins. Adult squash bugs are dark grayish brown with gold and brown stripes on their abdomens. Females lay eggs in clusters on the undersides of leaves between leaf veins. Newly hatched squash bugs do not have wings (simple metamorphosis) and are pale green to white with reddish brown heads and legs. As they mature, they become grayish white with black legs, and look more like adult squash bugs. Immature squash bugs are commonly found in groups.

**Adult Squash bug**

**Damage:** Nymph and adult squash bugs use their sucking mouthparts to consume plant juices from leaves and fruit. Damaged leaves wilt, turn black and die. In hot, dry weather, large populations of squash bugs can cause plants to wilt. If squash bug problems are detected and controlled early, plants will recover. Late in the season, especially after a killing frost, squash bugs begin to feed on the fruit. Fruit feeding causes the tissue in damaged areas to collapse and makes the product unmarketable.

**Control strategies:**

- Plant resistant hybrids to reduce young squash bug populations.
- Cultivate immediately after harvest to remove crop debris, and eliminate overwintering sites.
- Natural enemies do not provide adequate control of the pest.
- Insecticide applications targeted at nymphs are more effective than later applications to control adults.

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INSECT PESTS OF CORN (SWEET)

**CORN FLEA BEETLE (*Chaetocnema pulicaria*)**

The adult corn flea beetle is very small—1/16 inch long—shiny, and black, with enlarged hind legs. It jumps like a flea when plants are disturbed. In Ohio, flea beetles overwinter in plant debris along field edges. In the spring, they emerge and feed on grasses and winter wheat if no corn is available. Eggs are deposited in the soil, and the larvae develop in the soil feeding on corn roots.
Flea Beetle

**Damage:** Adult corn flea beetles strip off the top layer of cells on a leaf, giving the leaf a scratched appearance. The most severe injury occurs during cold springs, when slow plant growth allows the beetle more time to feed. Corn flea beetles may also transmit a bacterial disease, Stewart’s wilt, which can dramatically reduce yields of susceptible hybrids. Disease symptoms may appear at any stage of corn development in certain corn varieties.

**Control strategies:**
- Plant wilt-resistant sweet corn hybrids.
- Avoid planting susceptible hybrids early in the season.
- Remove crop residue and control weeds to remove corn flea beetle overwintering sites.
- Areas where corn flea beetle and Stewart’s wilt have been a problem may require insecticide seed treatment. Foliar insecticides applied to control corn rootworm also offer some control of corn flea beetle. See Chapter 7, diseases of corn, for further information.

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**European Corn Borer (Ostrinia nubilalis)**

**Damage:** The European corn borer is the most serious pest of Ohio sweet corn. European corn borers overwinter as full-grown larvae in corn debris, usually field corn. Beginning in mid-June, the first generation of adult moths emerge and mate in tall grasses. The adult moths are cream to light brown. The female moth lays her eggs, which look like fish scales, on the undersides of corn leaves. The larvae hatch and feed on the leaf, eventually moving into and feeding down in the whorl. As the larvae mature, they enter the stalk to feed and pupate. Second-generation European corn borer adults mate and the females deposit eggs on the leaves in the ear zone of silking corn. The larvae feed on the developing ears, causing kernel damage, or enter the stalk, ear shank, or cob. Depending on the temperature, there are two or three generations of European corn borer per year.

**Control strategies:**
A number of factors affect the potential economic loss caused by European corn borer damage. A series of cool evenings (below 65 degrees F) or a heavy rain can reduce the number of eggs laid or the survival of small larvae. In addition, young larvae can dehydrate and blow away on hot, windy days. Thus, conditions present during European corn borer mating, egg laying, and development are critical in determining the population from year to year.

- Destruction of overwintering sites (corn debris) in the fall kills many European corn borer larvae, but, it does...
not reduce the population enough to provide adequate control the following year.

- Planting early in the season and using resistant hybrids and early-season hybrids are all useful in managing the European corn borer. Tall corn is more attractive to egg-laying females and, therefore, first-generation damage. Likewise, the second generation tends to attack late silking and pollen-shedding corn. Avoid extremely early and late plantings or plant such fields with resistant hybrids. Scouting efforts should be concentrated on fields as they begin to tassel and continue through harvest.

Biological:

A large number of natural enemies attack all life stages of the European corn borer.

- Generalist predators such as lady beetle larvae and adults, lacewing larvae, and minute pirate bugs feed on egg masses and small larvae. Other insects and birds eat large larvae, pupae and adults.

- Though parasitoids have been imported from Europe to control the European corn borer, only a few have been successfully established. The amount of control from these parasitoids varies from year to year and depends on the location and shape of each field.

- Two main pathogens affect European corn borer populations. *Beauvaria bassiana* is a naturally occurring fungus that can kill overwintering larvae. Dead larvae are white and furry-looking. Most epidemics of *B. bassiana* occur during and after periods of rainfall late in the season when temperatures are in the mid-80s F.

- *Nosema pyrausta* is a protozoan-like microbe that reduces European corn borer egg laying, kills some larvae, and increases overwintering mortality. An increase in stress caused by other factors increases the mortality caused by *N. pyrausta*.

Chemical:

Timing is critical to control the European corn borer because once larvae enter the stalk or ear, insecticide applications become less effective. Thus, scouting is crucial. Scout for first-generation corn borers by examining plants for shot-holing. Scout for second-generation corn borers by looking for egg masses on the undersides of leaves, especially in the ear zone. Pheromone traps in grassy field borders help determine presence and abundance of adult European corn borers.

- Insecticide applications during the whorl stage can be effective against first-generation European corn borers. Though they're not commonly used in Ohio sweet corn, research and field corn experience show that granular insecticides control first-generation corn borers more efficiently than liquid insecticides.

- *Bacillus thuringiensis* subspecies *kurstaki* (Berliner), usually known as Bt, is effective against larvae feeding in the whorl, sheath, and collar. Bt kills the corn borer only when it is ingested and is more effective on smaller larvae. Therefore, once the larvae have burrowed into the stalk, Bt is not effective. Though Bt kills the European corn borer and other caterpillars, it is much less toxic to other organisms (including beneficial insects and humans) than most broad-spectrum insecticides.

- A few varieties of transgenic Bt sweet corn are available. Transgenic Bt corn has had the gene that produces the same toxin as the bacterium *Bacillus thuringiensis* inserted into its genetic structure. When a corn borer larva feeds on a transgenic Bt corn plant, the larva ingests the toxin and dies. Like Bt insecticide applications, transgenic Bt corn is much less toxic to beneficial insects and growers than conventional insecticides.

CORN EARWORM (*Helicoverpa zea*)

The corn earworm is also known as the tomato fruitworm. Each year, sometime between June and early August, the adult moth migrates into Ohio. Female moths lay small, yellow eggs on corn silks. When the larvae hatch, they begin feeding on the tip of the ear. Corn earworm larvae vary in color from pink, green, and maroon to brown and tan and can be 1\(\frac{1}{4}\) inches long. Mature caterpillars drop from the plant and pupate in the soil. There are two to three generations per year in Ohio.

Corn earworm eggs

Corn earworm larva

Damage: Corn earworms feed on corn kernels. As they develop, they can eat the entire tip of a corn ear and then move to other parts of the plant or other ears. A fully grown larva will create a large hole in the husk of the ear it has been feeding on when it exits to pupate. Damaged ears are unmarketable, and corn earworm feeding dam-
age creates an entry point for secondary fungal infections.

**Control strategies:**

Corn earworm adults can be monitored using pheromone lures and traps placed near cornfields. Scout fields to monitor ear feeding. Correct identification is important because corn earworms are more difficult to control than European corn borers.

- Naturally occurring biological control agents such as parasitic wasps and flies, lady beetles, and other predators help control the corn earworm.
- Timing of insecticide treatments and application to the corn silks, where corn earworm eggs are laid, are critical—one corn earworms enter the ear, insecticide applications are not effective.

**FALL ARMYWORM (Spodoptera frugiperda)**

Fall armyworms cannot overwinter in areas where the ground freezes and, therefore, arrive in Ohio from the Gulf Coast states late in the growing season. The adult moth is dark gray with light and dark mottled wings and a white spot near the tip of the forewing. Eggs are deposited in clusters on leaves. The female covers her egg clusters with hairs and wing scales. The 1½-inch larvae vary in color, but all have three yellowish white lines running from head to tail and darker stripes on the sides of the body. Scattered along the body are black bumps (tubercles) with spines. A white inverted Y on the head capsule of the fall armyworm distinguishes it from other corn pests. Fall armyworm completes one to three generations per year.

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**INSECT PESTS OF ONIONS**

**ONION MAGGOT (Delia antiqua)**

Adult onion maggots emerge in mid-May and resemble houseflies. They feed on pollen from dandelions and other flowers. Female flies lay eggs in or on the soil near the bases of onion plants. When the eggs hatch, the maggots (larvae) burrow into the soil and feed on onion roots and bulbs. Onion maggots feed only on onion plants and prefer cool, wet weather. After feeding for two to three weeks, the maggots pupate in the soil. Adults emerge in a couple of weeks. There are three generations of onion maggots in Ohio each year.

**Damage:** Onion maggots feed on roots and bulbs. First-generation larvae cause the most damage, feeding on onion seedlings. Late in the season, adults prefer to lay eggs near already damaged plants. Maggots have a difficult time feeding on healthy bulbs.

**Control strategies:**

- Remove or plow under volunteer onions after harvest to reduce third-generation populations.
- Do not pile up old bulbs on field edges in the spring. This attracts adult females to lay eggs in the field.
- Plant onions as late as possible to reduce the time they are available for adult egg laying.
- Interplanting rye or barley strips in onion fields helps protect young seedlings from wind and attracts natural enemies.
- Avoid injuring plants when cultivating, fertilizing, or working in the field—onion maggots are attracted to injured plants.
- Natural enemies such as ground beetles, lady beetles, rove beetles, and tiny parasitic wasps attack and kill onion maggots. A fungal disease called Entomophthora kills adult flies.
- Onion maggots have developed resistance to nearly all available insecticides. Foliar applications aimed at armyworm populations under control and provide some suppression of fall armyworms.
- If armyworms deplete the grassy hosts and larvae migrate into a cornfield, an insecticide application may be necessary. Spot treatment of infested areas can provide sufficient control for a confined infestation.
- Timing of insecticide treatments and application to the corn silks, where eggs are laid, are critical—one fall armyworms enter the ear, insecticide applications are not effective.
killing the adults are ineffective, and, the application of foliar insecticides kills natural enemies and aids in resistance development.

- A soil insecticide application at planting protects against onion maggot.

**ONION THRIPS (Thrips tabaci)**

Thrips are small insects, measuring one mm in length, with two pairs of fringed, leathery wings. They have mouthparts developed for rasping and sucking – they shred plant tissue (rasp) and then withdraw the juices (suck). They feed on foliage, buds, and flowers of many host plants. Onion thrips prefer hot, dry conditions and require two to four weeks for complete development. There are several generations per year.

**Damage:** Thrips feed on the leaves and new growth in the center of the plant near the bulb. Damaged leaves have a silvery appearance. In heavy infestations, thrips can also be found feeding on the outer leaf surfaces, causing leaf tips to turn brown. Feeding injury reduces yield, decreases bulb size, and affects market price.

**Control strategies:**

- Thrips can be knocked off the plant or drowned by rain or overhead irrigation.
- Check plants regularly for early detection of thrips. They are usually found within the folds of leaves, where they are difficult to control with insecticides, and they have developed resistance to many common insecticides.
- When applying insecticides, use high pressures and high gallonage to improve coverage in the center of the plant.

**INSECT PESTS OF TOMATOES**

**COLORADO POTATO BEETLE**

*Leptinotarsa decemlineata*

Adult Colorado potato beetles are easily recognized by their yellow orange color and five narrow, black strips on each wing cover. Adults overwinter buried in the soil in fields and field borders. In the spring, they emerge and begin to feed, mate, and lay eggs. Typically, the yellow, oblong eggs are laid on the undersides of leaves in groups of 10 to 30. Red to orange larvae emerge and begin to feed on foliage. After two to three weeks of feeding, larvae pupate in the soil. Depending on the temperature, Ohio has one to three generations of Colorado potato beetle a year.

**Damage:** Colorado potato beetle adults and larvae feed on tomato foliage and fruit. Though they prefer to feed on potatoes, they can easily defoliate an entire tomato plant in three to four days.

**Control strategies:**

- Crop rotation helps delay and reduce spring infestations.
- Trap crops of potatoes planted along field edges attract migrating Colorado potato beetle adults and delay tomato infestation for a few days.
- Several natural enemies aid in controlling the Colorado potato beetle, though they seldom provide sufficient larval or adult control.
- Foliar insecticides can be applied to trap crops or “hot spots,” small isolated areas of infestation, to avoid treating an entire field. Insecticides are most effective on small larvae.

**TOMATO HORNWORM**

*Manduca quinquemaculata*

Tomato hornworms can quickly defoliate plants because the larvae are large (up to four inches long). Larvae are pale green caterpillars with white markings and a horn at the rear end. In May or June, tomato horn-
worms emerge from their overwintering sites as adult hawk moths. Single light green eggs are laid on the undersides of leaves. When eggs hatch, larvae feed on leaves and fruit before pupating in the soil. In Ohio, there may be two to three generations a year.

Tomato hornworm larva (top) and adult (bottom).

**Damage:** With their chewing mouthparts, these large caterpillars eat leaves of tomatoes, eggplants, and peppers and can also bore into tomato fruit. Tomato hornworm damage can cause 100 percent of the product to be unmarketable.

**Control strategies:**
- Small infestations of tomato hornworms can be hand picked from plants. Look closely when scouting plants for tomato hornworms—they are well camouflaged and difficult to see until they are large enough to defoliate plants.
- A number of natural enemies help control tomato hornworms. For example, caterpillars parasitized by a tiny wasp will have tiny, white wasp cocoons on them. Parasitized larvae do not develop into adult hornworms, but they do continue to feed.
- Many foliar insecticides control tomato hornworms.

**TOMATO FRUITWORM (Heliocoverpa zea)**

The tomato fruitworm is also known as the corn earworm. The adult moth migrates into Ohio each year beginning in late June. Moths are active at night, and female moths are attracted to flowering and fruiting tomato plants. Small, yellow eggs are laid near or on the tomato. Newly hatched larvae vary in color from pink and green to maroon, brown, and tan and begin at once to feed on the tomato. A fully mature larva can grow to 13/4 inches long. Mature caterpillars drop from the plant and pupate in the soil. There are two to three generations per year in Ohio.

**Damage:** Tomato fruitworm caterpillars attack green tomatoes. They bore into the fruit, creating a deep, watery cavity. The cavity creates an entry point for secondary fungal infections. Damaged fruit is unmarketable and usually falls from the vine.

**Control strategies:**
- Naturally occurring biological control agents such as parasitic wasps and flies are very important in the control of tomato fruitworm.
- Tomato fruitworm adults can be monitored using pheromone lures and traps placed near tomato plants or cornfields. Scout fields to monitor fruit feeding. It is important to treat when the larvae are small, because once they enter the fruit, insecticide applications will not be effective.

**GENERAL VEGETABLE INSECT PESTS**

**SEEDCORN MAGGOT (Delia platura)**

Seedcorn maggots have a wide host range including corn, snap beans, and cucurbits. They overwinter in the soil as small, brown pupae. Beginning in early April, adult seedcorn maggots emerge. The adult is a small, gray fly, similar to a housefly. Female flies deposit eggs in the soil and are attracted to soil high in organic matter, either plowed-down crop residue or animal manure. Larvae or maggots feed on decomposing plant material and seeds. Seedcorn maggots favor cold, wet weather. There are multiple generations a year, but only the first generation is of economic concern.

**Damage:** Larvae feed on decomposing plant matter and seeds. Seeds can be attacked before or after germination. Damaged seeds may not sprout or produce malformed, stunted plants. Attacked seedlings will wilt and die within a few days.

**Control strategies:**
- If planting into a field that has a cover crop, plow down the cover crop three to four weeks before planting. This provides enough time for decomposition.
- Insecticide seed treatments are an effective way to control seedcorn maggot.
VEGETABLE DISEASE MANAGEMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Be able to define non-infectious and infectious disease.
- Understand how fungi, bacteria, and viruses produce disease.
- Understand the disease triangle and the disease cycle.
- Understand control methods specific to disease management.
- List the major diseases affecting asparagus, carrots, celery, cole crops, cucurbits, corn (sweet), onions, potatoes, tomatoes, and snap beans.

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 non-infectious disease. Few noninfectious diseases can be corrected or avoided, and often the symptoms resemble those of infectious diseases. For example, nutrient deficiency symptoms often resemble symptoms of root rots. 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 Ohio, fungi, bacteria, and viruses are pathogens for vegetable crops. Pathogens are spread from diseased plants to healthy plants by wind, rain, soil, people, machinery and insects.

Fungi

Fungi are the largest and most familiar group of plant pathogens. The best known fungi are mushrooms and yeast. Most fungi are extremely small and 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., tomatoes, cole crops and corn 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. Hyphae absorb nutrients and water needed for fungal growth and reproduction.

Most fungi reproduce by forming microscopic spores (sometimes called conidia). Spores come in many shapes and sizes. Some spores are produced on structures called fruiting bodies. Others appear on the plant surface as mold growth (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 very small, microscopic, one-celled organisms. Some bacteria are harmful to humans and animals because they cause diseases such as pneumonia, tuberculosis, typhoid fever, and anthrax. Bacteria also cause diseases in plants but most bacteria are harmless or beneficial (for example, the nitrogen-fixing bacteria of legumes). It is important to point out that the bacteria that are plant pathogens are not human pathogens.
Bacteria enter plants through wounds, natural openings in the plant, or direct penetration, usually in the leaf but sometimes 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 may increase its numbers rapidly.

Bacteria do not produce spores or fruiting bodies; they reproduce by simple cell division. A cell splits into approximately two 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 non-living pathogen that cannot reproduce by itself. Viruses multiply by tricking the host cells into making more viruses. They are most familiar to us as the cause of human and animal diseases, such as polio, influenza, chickenpox, and warts. Viruses can also cause diseases in plants. Like 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, stunting of the leaves, early leaf fall, loss of plant vigor, mosaic patterns on leaves, deformation of plant tissues, and reduced yield. Sometimes a virus disease is mistaken for nutrient deficiency, pesticide or fertilizer injury, insect or mite activity, or other types of disease.

Because viruses can survive only in living cells, they need to enter a plant by means of a vector, usually an insect. Insect with piercing-sucking mouthparts, such as leafhoppers and aphids, are usually responsible for transmitting viruses. Pollen, soil-borne 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 (for example, potatoes).

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 side of the disease triangle, such as adding an unfavorable environment or using a disease-resistant variety, you can reduce the disease development.

HOST

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

Pathogens and host plants are also affected by moisture. 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 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 reduce the interaction between the three parts of the disease triangle.

DISEASE CYCLE

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

The basic steps are:

1. Production of inoculum. Inoculum is a source of a pathogen that infects 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 carried by the wind, rain, insects, animals, people, and machinery.

2. Spread of inoculum. The inoculum must disperse to the host plant. There are two types of spore movement:
active and passive. **Active movement** occurs when the inoculum is carried to a host by another organism (for example, insects, machinery or worker). One example is the spread of potato virus Y (PVY) by aphids from plant to plant. **Passive movement** is movement of the inoculum to a new host plant by wind or water. Most fungal and bacterial foliar pathogens disperse this way.

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

4. **Pathogen survival between susceptible crops.** In Ohio, pathogens need to survive the winter between growing seasons and periods when no host is present. Disease pathogens survive non-host periods by:
   - Surviving on crop residues left in the field.
   - Producing structures that resist microbial and environmental breakdown.
   - Infecting seeds.
   - Infecting alternate hosts. A pathogen with a large host range has an increased chance of survival. Some plant pathogens may survive in alternate hosts without causing disease.

A good example of the disease cycle can be seen by looking at the fungus that causes white mold.
DISEASE MANAGEMENT

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

Cultural Control

Changing crop production practices can help reduce the incidence and impact of many vegetable 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.

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

TILLAGE. Incorporating crop residue permits soil microorganisms to decompose the residue, prey directly on the pathogen, or outcompete the pathogen for resources, resulting in a decrease in the spacing can reduce the incidence of white mold in snap beans.

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

SEED QUALITY. Certified seed is high-quality seed selected from healthy, relatively disease-free plants of known origin and genetic makeup. Poor seed quality may be associated with fungal or bacterial pathogens that use seed for survival and dispersal. Plants infected with seed-transmitted pathogens should not be used for seed. Pathogen population. Corn residues left on the soil surface in combination with periods of high daytime temperatures and relative humidity are the favored growing conditions for the fungal pathogen Cercospora zeae-maydis, which causes corn gray leaf spot.

ROW SPACING. Soil moisture changes with row spacing. Wider row spacing allows the surface of the soil to dry out faster and increases the amount of time needed to create a closed row. For example, wider row

Biological Control

Biological control including bacteria or fungi have been developed primarily for soilborne pathogens. Once a pathogen has become established in a field, there is little opportunity to use biological control. Rotation and tillage contribute to biological control by giving natural enemies time to reduce pathogen populations.

Chemical Control

Chemical seed or foliar treatments are often used to control pathogens. Seed treatments can effectively control pathogens that live or disperse by seed. For control of diseases of vegetable crops using pesticides, see Ohio State University Extension bulletin E-312, Insect, Disease and Nematode Control for Commercial Vegetables. Foliar fungicides are important in managing rust and purple spot on asparagus fern, Cercospora and Alternaria leaf blight on carrots, and early and late blight of celery.

DISEASES OF CORN

COMMON RUST

Blisters on corn leaf infected with common rust.

Pathogen type: fungus (Puccinia sorghi)

Disease symptoms: Oval or elongated, brick-red blisters appear on the leaf surfaces, husks, leaf sheaths, and stalks. Severe infections result in leaf death. Killing the leaves of young plants reduces plant vigor and yield.

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

Control strategies: Planting resistant hybrids is the best way to control rust. Fungicides are used, especially in
**CORN SMUT**

*Ear of corn infected with corn smut.*

**Pathogen type:** fungus (*Ustilago zeae*)

**Disease symptoms:** Galls are formed on aboveground young growing parts of the plant, typically the ear, tassel, leaves, and stalk. The young galls have a greenish white covering, which turns silver-gray with age. Mature galls are full of black, powdery fungal spores that disperse into the air when the gall ruptures.

**Environmental conditions favoring disease:** Corn smut is most prevalent under dry conditions and temperatures of 78 to 94 degrees F and on stressed plants. Fungal spores overwinter in the soil and prefer high levels of soil nitrogen.

**Control strategies:**
- The best management strategy is to plant corn hybrids that have some level of resistance.
- Rotating crops and burying crop residue may be helpful.

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**STEWART’S WILT**

*Corn leaf showing symptoms of Stewart’s wilt.*

**Pathogen type:** bacterium (*Erwinia stewartii*)

**Disease symptoms:** Symptoms appear first on leaves and are more severe on young plants than on older plants. Pale green to yellow streaks with irregular margins extend the length of the leaf and turn brown. Infected young plants may show brown discoloration; cavities may form in the center of the stem near the soil line. If plants are infected after tasseling, leaf lesions develop. Light green to yellow, water-soaked streaks with wavy, irregular margins are formed parallel to leaf veins. The streaks turn tan, enlarge and coalesce (merge) with age, resulting in blighting. When these leaves are held up to the light, insect feeding scars can be observed in these lesions. The bacteria spread through the host via the vascular system and may enter the kernels. When infected stalks or leaves are cut open, droplets of yellow bacterial ooze may extrude from the vascular tissue.

**Environmental conditions favoring disease:** The bacterium overwinters in corn flea beetles and is spread to corn when corn flea beetles feed on corn plants. (Corn flea beetles carrying the bacterium can be expected if the sum of the average monthly temperatures [in degrees F] for December, January and February exceeds 90 degrees.) Stewart’s wilt is most severe when temperatures are high (88 to 98 degrees F).

**Control strategies:**
- Plant resistant hybrids.
- Control the pathogen vector, corn flea beetles.
DISEASES OF CUCURBITS (cucumbers, melons, pumpkins, squash)

ALTERNARIA LEAF SPOT

Pathogen type: fungus (*Alternaria cucumerina*)

Disease symptoms: Small, circular, tan spots with a concentric ring pattern form on the leaves. Spots coalesce, causing defoliation.

Environmental conditions favoring disease: The disease develops best under bright sunshine, frequent dews or showers, and temperatures between 60 and 90 degrees F. Fungus spores are spread by rain, wind, and splashing water. The fungus overwinters on and in seed, as well as in residue from diseased plants.

Control strategies:
- Destroy volunteer cucurbit crops and weeds that may harbor fungal spores.
- Practice crop rotation out of cucurbits to reduce the risk of Alternaria leaf spot and other diseases.
- Apply fungicides as needed.

MOSAIC VIRUSES

Pathogen type: virus

Disease symptoms: Mosaic viruses cause plant leaves to be mottled dark and light green and crinkled. The disease is more noticeable on young leaves. Older leaves have V-shaped dead areas extending from the leaf margins to the middle vein. The fruits of diseased plants are mottled, warty and misshapen.

Environmental conditions favoring disease: Many weeds act as hosts. The virus is spread primarily by aphids.

Control strategies:
- Plant disease-resistant varieties.

POWDERY MILDEW

Pathogen type: fungus (*Erysiphe cichoracearum, Sphaerotheca fuliginea*)

Disease symptoms: Powdery mildew causes a white, powdery growth on leaves and stems. The white, powdery areas may expand and merge. The crown leaves are the first to become infected and may die. Yield is reduced in infected plants, and fruit quality is poor. Powdery mildew infection renders the plant and fruit more susceptible to other diseases.

Environmental conditions favoring disease: Leaves are most susceptible 16 to 23 days after unfolding. The fun-
gus reproduces under dry conditions and will not grow when the leaf surface is wet. The optimum temperature is about 81 degrees F. Powdery mildew is spread by spores generally carried by wind.

Control strategies:
- Plant disease-resistant varieties.
- Scout for the first sign of disease and then apply a fungicide.

PHYTOPHTHORA ROOT, CROWN, AND FRUIT ROT

Cucumber field damaged by virus (top); pumpkin fruit damage by virus (bottom).

Pathogen type: fungus (Phytophthora capsici)

Disease symptoms: Phytophthora attacks fruits lying on the soil. The fungus causes partial or complete rotting of the fruit. Infected roots and stems are soft, water-soaked and brown.

Environmental conditions favoring disease: The fungus prefers moist, humid, warm conditions and is favored by saturated soil conditions. The soilborne fungus is spread readily by splashing water.

Control strategies:
- Crop rotation.
- Water management.
- Good drainage and eliminate excess moisture.

DISEASES OF ONIONS

PURPLE BLOTCH

Purple blotch on onion leaf.

Pathogen type: fungus (Alternaria porri)

Disease symptoms: Small, white, sunken lesions with purple centers appear on leaves. These spots enlarge to encircle the leaf, resulting in premature senescence. Darkened zones with the characteristic purple color appear on leaf surfaces as the plant matures.

Environmental conditions favoring disease: Fungal spores develop in high humidity, rain, or persistent dew with an optimum temperature range of 77 to 85 degrees F. Purple blotch infections are more severe following injury caused by thrips, hail, or wind-blown soil.

Control strategies:
- Plant top-quality seed and disease-free transplants.
- Dispose of onion culls by incorporating them into the soil immediately after harvest.
- Practice a three- to four-year crop rotation. Apply fungicides when weather conditions favor disease development.
DOWNY MILDEW

Disease symptoms: Disease symptoms appear on older leaves as elongated spots. Under humid conditions, the fungus produces purplish spores on the leading edge of the lesion. Eventually, affected leaves turn yellow and collapse.

Environmental conditions favoring disease: Fungal spores develop under high humidity, either from rain or persistent dew, at an optimum temperature range of 77 to 85 degrees F.

Control strategies:
- Plant high-quality seed and disease-free transplants.
- Dispose of onion culls by incorporating them into the soil immediately after harvest.
- Practice a three- to four-year crop rotation.
- Apply fungicides when weather conditions favor disease development.

SMUT

Pathogen type: fungus (Urocystis magica)

Disease symptoms: Gray streaks appear on leaves, leaf sheaths and bulbs. These streaks are filled with a dark brown, powdery mass of spores. Affected leaves become twisted and deformed and eventually may die.

Environmental conditions favoring disease: Cool weather delays plant growth, thereby extending the period an onion is susceptible to onion smut. This soilborne fungus can serve as an infection source for 15 years. Spores are spread whenever soil, water, and plant parts are moved from one place to another.

Control strategies:
- Plant disease-free seed and transplants.
- Use treated seed.
- Use an in-furrow fungicide treatment for problem fields.

BOTRYTIS LEAF BLIGHT

Pathogen type: fungus (Botrytis squamosa)

Botrytis leaf blight on plants. (top) and the onion fruit (bottom).
**Disease symptoms:** The first symptoms are numerous white specks on the leaves. The spots expand, causing the leaves to die, starting at the leaf tip.

**Environmental conditions favoring disease:** Plants may become infected where leaf tissue has been injured by thrips, blowing sand, or other agents. Fungal spores are spread by wind and develop best under warm, wet weather conditions.

**Control strategies:**
- Plant high-quality seed and transplants free of disease.
- Dispose of onion culls by incorporating them into the soil immediately after harvest.
- Practice a three- to four-year crop rotation to reduce the incidence of infestation.
- Apply fungicide when weather conditions favor disease development.

**DISEASES OF TOMATOES**

**EARLY BLIGHT OF TOMATO**

Pathogen type: fungus (*Alternaria solani*)

**Disease symptoms:** On established plants, symptoms include dark brown spots up to 1/2 inch in diameter with dark, concentric rings that develop first on oldest leaves and progress upward on the plant. Affected leaves may die prematurely, resulting in substantial early defoliation, fruit sunscald, and poor fruit color. Typically, fruit spots occur at the stem end as a rot that radiates out from the area of attachment between the calyx and the fruit. The spot is usually brown to black, up to 1 inch in diameter, firm, and depressed, with distinct concentric rings.

**Environmental conditions favoring disease:** The fungus overwinters in soil or in plant debris, where it can persist for a year or more. The fungus may also be introduced into a field on seed and transplants. Spores are disseminated by wind and running water. During periods of free moisture on the leaves, the fungus penetrates the plant. The disease occurs under a wide range of weather conditions and is favored by heavy dew and rainfall and is especially severe on plants with poor vigor.

**Control strategies:**
- Plant disease-free transplants.
- Practice crop rotation with crops other than potato, eggplant, and pepper.
- Remove or destroy crop residue immediately after harvest.
- Maintain fertility and moisture levels, but do not overfertilize with nitrogen.
- Avoid planting near windbreaks and in shady areas.
- Fungicides are essential to tomato production in Ohio and are applied on a calendar schedule or according to a disease forecaster.

**SEPTORIA LEAF SPOT**

Pathogen type: fungus (*Septoria lycopersici*)

**Disease symptoms:** Small, circular, gray spots with dark borders form on the leaves. Black specks (reproductive structures of the fungus) can be seen within the spots.

**Environmental conditions favoring disease:** The disease develops and spreads most rapidly in wet weather—spores are dispersed by splashing water. The fungus survives in crop residue and on/in seed.

**Control strategies:**
- Avoid planting near windbreaks and in shady areas.
- Remove or destroy crop residue immediately after harvest.
Practice a two- to three-year crop rotation to reduce potential outbreaks.

Apply fungicides when needed.

ANTHRACNOSE

Lesions caused by anthracnose on tomato.

Pathogen type: fungus (Colletotrichum coccodes)

Disease symptoms: Symptoms on ripening fruit are small, slightly depressed, water-soaked, circular spots that increase in size (up to 1/2 inch in diameter), become more sunken, and typically develop concentric rings. Lesions may merge, resulting in large rotted areas on the fruit. The lesions may darken and small, black fruiting structures appear in the center. These fruiting bodies exude masses of slimy, tan or salmon-colored spores during warm, humid weather.

Environmental conditions favoring disease: The fungus over-winters in soil and infected plant debris. Splashing water spreads spores. The fungus can penetrate the outer layer of the fruit directly and may also enter through wound sites. On ripe fruit, a lesion can develop within five to six days following spore contact. The fungus can cause infection when temperatures range from 55 to 95 degrees F, though lesions develop most rapidly at 80 degrees F. Wet, rainy weather increases disease development.

Control strategies:
- Practice a two- to three-year crop rotation.
- Remove or destroy crop residue immediately after harvest.
- Fungicides are essential to tomato production in Ohio and are applied on a calendar schedule or according to a disease forecaster.

BACTERIAL SPOT

Bacterial spot can affect the leaf as well as the fruit.

Pathogen type: bacterium (Xanthomonas axonopodis pv. vesicatoria)

Disease symptoms: Small, dark, greasy-looking spots develop on leaves and stems. On green fruit, small, dark, raised spots occur and may be surrounded by water-soaked margins. Spots enlarge up to 1/4 inch in diameter and are brown and scabby.

Environmental conditions favoring disease: Abundant rainfall and high humidity are requirements for spread and infection. Maximum growth of the bacteria is associated with temperatures between 75 and 86 degrees F. The bacteria can be carried on the surface of the seed and may overwinter in the soil in association with roots of non-hosts. Penetration of plant tissue occurs through wounds caused by broken plant hairs, insects, and windblown sand and soil.

Control strategies:
- Plant disease-free seed and transplants or chemically treated seed.
- Practice a three-year crop rotation with nonsusceptible hosts.
- Control solanaceous weeds, such as black nightshade.
- Apply copper-based fungicide.
LEARNING OBJECTIVES

After completely studying this chapter, you should:

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

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

DEVELOPMENT STAGES

Most crop plants and weeds have four stages of development:

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

LIFE CYCLES OF WEEDS

Weeds can 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.
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 unmoved fencerows. They are easiest to control in the seedling stage.

PERENNIAL

Perennials are plants that live for two or more years. Perennials can reproduce by seed or vegetative. The plant parts that allow perennials to spread without producing seeds are solons (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 nut sedge), and bulbs (underground stems 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.

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

COMMON WEEDS IN OHIO

GRASS AND GRASSLIKE WEEDS

Annuals
- Barnyard grass
- Large crabgrass
- Smooth crabgrass
- Giant foxtail
- Yellow foxtail
- Green foxtail
- Fall panicum
- Wild-prose millet

Perennials
- Johnson grass
- Yellow nut sedge
- Quackgrass

BROADLEAF WEEDS

Annuals
- Lady thumb
- Smartweed
- Wild buckwheat
- Lambs quarters
- Redroot pigweed
- Black nightshade
- Common cocklebur
- Jimsonweed
- Common Purslane
- Common ragweed
- Giant ragweed
- Velvetleaf
- Common chickweed
- Shepherd’s purse
- Horseweed (Mares tail)
- Prickly lettuce
- Wild mustard
- Yellow rocket

Biennials
- White champion
- Wild carrot
- Bull thistle

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

Yellow Nutsedge.

Pigweed.

Velvetleaf.

Monocot or Grass plant.
WEED CONTROL

CULTURAL CONTROL

Crop competition is a very useful method of weed control. Production practices that optimize crop growth 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, population, soil fertility, drainage, etc. Recommended crop production practices are also beneficial weed control practices.

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

MECHANICAL CONTROL

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

CHEMICAL CONTROL

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

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

TYPES OF HERBICIDES

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

Preplan Herbicide Soil Applications and Incorporation

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

Advantages of preplan soil applications and incorporation:

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

Disadvantages of preplan soil applications and incorporation:

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

Preemergence Herbicide Applications

Preemergence herbicide applications are applied to the soil surface after the crop has been planted but before the crop or weeds emerge. Typically, preemergence herbicide applications require rainfall within one week following the application to ensure that the herbicide moves into the soil.
Advantages of preemergence applications:
- Early control of weeds reduces weed competition with crop.
- They can be used in all tillage systems.
- Planting and herbicide application may be done at the same time.

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

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

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

Advantages of postemergent applications:
- Herbicide is applied after the weed problem occurs (remedial application).
- They are less susceptible to environmental conditions after the herbicide application than preemergent herbicides.
- They are useful for spot treatments.
- Postemergent herbicide applications have short or no soil residual.

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

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

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

Vegetable and ornamental crops are often more sensitive to herbicide carryover than field crops. To reduce the potential of herbicide carryover, read and follow all pesticide label directions. Herbicide labels contain restrictions on the interval between application and planting of various crops. Consult the current version of OSU Extension bulletin E-433, Weed Control Guide for Vegetable Crops, for more information on herbicides.

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

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

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

HERBICIDE COMPATIBILITY PROBLEMS

Compatibility problems in tank mixing herbicides usually occur when 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.
APPENDIX A
SELECTED BIBLIOGRAPHY

Pesticides


Selected Subject References
(subjects are in bold print)


Internet Reference Sites

Ohio Fruit IPM Links:  
http://www.OSUe.OSU.edu/ipm/fruit.htm

Ohio Fruit Management Guide:  
http://www.OSUe.OSU.edu/pestpubs/E154/TOC.htm

Ohio State University Integrated Pest Management Program:  
http://www.OSUe.OSU.edu/ipm/

Ohio State University Pesticide Education Program:  
http://www.pesterd.OSU.edu/

Ohio Department of Agriculture:  
http://www.Ohio.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:iipmworld.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 B

GLOSSARY

Glossary of Terms for Horticulture 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. LD50 and LC50 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.

BIOLGICAL 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.
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 Ohio 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 INJURY LEVEL (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.

INFECTION — The establishment of a pathogen with a host.

INFECTION — The establishment of a pathogen with a host.

INFECTION — The establishment of a pathogen with a host.

INFECTION — The establishment of a pathogen with a host.

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.

LC50 — Lethal concentration. The concentration of a pesticide, usually in air or water, that kills 50 percent of a test population of animals. LC50 is usually expressed in parts per million (ppm). The lower the LC50 value, the more acutely toxic the chemical.

LD50 — 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. LD50 is expressed in milligrams of chemical per kilogram of body weight of the test animal (mg/kg). The lower the LD50, 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.

MYCELUM — 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-INFECTIONOUS 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., caulk ing 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 meso thorax 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.

SPREOE — 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 — Along, 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 ground-water.)

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, Ohio State University Extension.


Region V Office of the EPA, Chicago, Ill.

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

American plum borer

Peachtree borer (larva)

Cherry fruit fly (adult)
Lesser peachtree borer

Cherry fruit fly (larvae)
INSECT PESTS

Codling moth (larva)

Green fruitworm (larva)

European red mite (adult male)

European red mite (adult female)

Twospotted spider mite

Obliquebanded leafroller (larva)

Obliquebanded leafroller (adult)

Codling moth (adult)

Green fruitworm (adult)
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)

Grape berry moth (adult male)

Adult Japanese beetle feeding on blueberries.

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

Blueberry shoestring disease

Black knot in plum

Anthracnose on blueberry

Mummy berries
DISEASE

Black rot on grape

Anthracnose on raspberry cane

Powdery mildew on grape

Phomopsis on grape cane
Orange rust on raspberry

Botrytis on strawberry
DISEASES

Black rot on strawberries

Leather rot on strawberries