CHAPTER 29

Integrated Pest Management

Chapter Outcomes

After studying this chapter, you will be able to:

- Explain the concept of integrated pest management.
- Describe the different types of pests.
- Summarize the steps for pest prevention.
- Describe pest inspection and monitoring.
- Define action thresholds.
- Discuss different methods for corrective actions.
- Describe careers related to integrated pest management.

Words to Know

action threshold	integrated pest management (IPM)	pheromone
anti-transpirant	oomycete	plant pathogen
beneficial	pest	scouting
economic injury level (EIL)	pesticide	vector

Before You Read

As you read the chapter, put sticky notes next to the sections where you have questions. Write your questions on the sticky notes. Discuss the questions with your classmates or teacher.





While studying this chapter, look for the activity icon to:

- **Practice** vocabulary terms with Words to Know activities.
- **Expand** learning with identification activities.
- **Reinforce** what you learn by completing Know and Understand questions.

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From leaf-sucking aphids and root-eating nematodes to plant-smothering weeds, garden pests abound. A plant ***pest*** is any organism that damages or disrupts plant growth. Opportunities constantly arise for pests to threaten and disrupt the productivity of farms, gardens, and urban landscapes. ***Integrated pest management (IPM)*** is an environmentally sensitive approach to controlling pests. The goal of IPM is to effectively control pests with the least possible hazards to people, property, and the environment.

Using a well-planned IPM provides growers with a variety of strategies. Growers can use a combination of cultural, physical, biological, and chemical controls to help manage pests. These controls include the use of natural enemies, disease- and pest-resistant cultivars, and crop rotation. The main benefits of IPM are the minimization of hazards to people and the environment as well as effective pest management.

Creating an IPM

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Figure 29-1. Planting disease-resistant plants, such as the grape tomato cultivar 'Juliet', is one way to control pests.

Growers and gardeners use a variety of strategies to manage a given pest situation most effectively. Once the pests have been properly identified, growers can examine the environmental factors that are allowing the pests to thrive, and then shift conditions to make them unfavorable for the pests, **Figure 29-1**. Pest management decisions are based on a variety of factors, including:

- Size of the affected geographic area.
- Estimated number of pests.
- Life cycle stage of the majority of pests.
- Type of plants or crop.
- Whether the affected area is urban or rural.
- Grade or slope of the affected area.
- Time of year.
- Cost relative to the effectiveness of the strategy.

In IPM, all components are important. They should work together seamlessly and be used appropriately to prevent pests from causing too much damage to plants and crops. By understanding how to use best practices to manage pests, growers can protect natural resources and produce abundant food, fiber, and fuel crops.

Pests

Corner Question

Q

Can you name a few pests that impact human health?

As stated earlier, agricultural/horticultural pests are organisms that damage or disrupt the development of plants or crops. These same pests may damage homes or other structures. Pests may also include organisms that impact human or animal health. Pests can include weeds, birds, rodents, mammals, insects, snails, nematodes, and ***plant pathogens*** (organisms that cause disease in plants, including bacteria, fungi, viruses, and oomycetes.)

Oomycetes are filamentous protists, including water molds and downy mildews that can cause diseases, such as blights and rots. Additionally, some pests are ***vectors***, or organisms that transmit diseases or parasites from one plant to another.

Weeds

Weeds are undesirable plants in gardens, farms, orchards, lawns and landscapes, **Figure 29-2**. Weeds become a problem when they reduce crop yields, lower crop quality, or take over areas of a landscape. Weeds compete with crops and other desired plants for basic needs, including moisture, light, and nutrients. Their competitive success depends on the specific crop involved and how that crop is managed. Depending on the species, weeds can also have characteristics such as:

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Figure 29-2. English ivy may be desirable in some situations, such as in this container garden. However, it can be a prolific weed, taking over natural areas.

- Fast growth rate.
- Vigorous nutrient uptake.
- Tolerances to stresses, such as drought.
- Dormancy mechanisms that allow staggered and long-term germination.

If weeds with fast growth rate exist in a crop that has a slow growth rate, conditions are right for weeds to become a problem. Some weeds attract detrimental insects, reproduce rapidly, and persist in fields for years. Weeds ultimately reduce crop yield and quality, negatively impacting profits. Farms and gardens often have many types of weeds in one area. For this reason, growers use not just one control practice, but rather an integrated approach to management.

Insects

Insects are a class of invertebrates that can be pervasive and damaging pests to agricultural crops and ornamental plants. They have a small body size that requires minimal resources for survival, and many insects have the ability to fly to avoid predation. Most insects have the ability to produce large numbers of offspring as well as multiple generations within a growing season. These factors, as well as the development of pesticide resistance, make it challenging to manage pest populations, **Figure 29-3**. (A ***pesticide*** is a chemical that is used to control insects, weeds, fungi, rodents, and other pests.) Insects have a variety of feeding mechanisms, such as chewing, piercing, and sucking, that damage the plant by removing material or draining fluids. Many insects use plants as a place to lay their eggs, which hatch into larvae that use the plant for food. Some insects inject pathogens into the plant while feeding, causing diseases to spread quickly among and between fields of crops.

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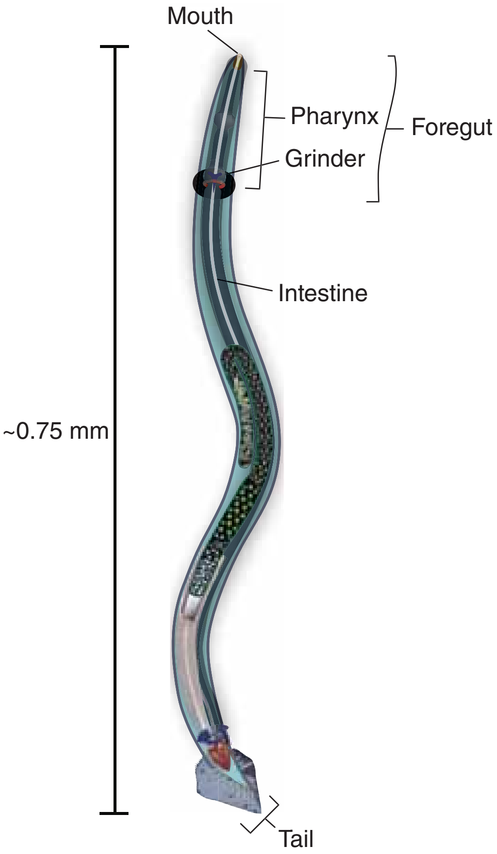
Figure 29-3. Aphids are a plant pest that can rapidly produce multiple generations in a single growing season. In addition to the physical damage they cause, aphids may also spread viruses.



K.D. Schroeder (*C.* ***elegans*** **male.svg** *from Wikimedia Commons; License: CC-BY-SA 3.0)*

Figure 29-4. Plant parasitic nematodes punctures hole in plant cells, withdrawing nutrients and diminishing plant growth.

Nematodes

Nematodes are tiny invertebrate roundworms that live in soil and water habitats. Free-living nematodes feed on bacteria, fungi, and other nematodes. Many nematodes are parasites of animals and plants. Plant parasitic nematodes are small (less than one millimeter in length) and eel-shaped with unsegmented bodies that are generally translucent and microscopic in size, **Figure 29-4**. Most plant parasitic nematodes have a hollow stylet or spear used to puncture holes in plant cells and withdraw nutrients. These holes allow the injection of damaging proteins and metabolites into the plant cells. As many nematodes live in the soil, much of their damage occurs on the roots of the plant. The nematode feeding process results in dead or distorted roots, smaller root mass, lesion formation, tissue breakdown, swellings, and galls.

Plant diseases caused by nematodes may be mistaken for other issues or conditions. For example, a root-feeding nematode species that limits the ability of plant roots to uptake water and nutrients will cause nutrient and water deficiency symptoms aboveground that are similar to those caused by other pests, diseases, or environmental conditions. When treatments for other possible causes have not worked, and midday wilting occurs, consider nematodes. Nematodes destroy vascular tissue in plants, so the plant cannot take up enough water on a hot day to keep from wilting; in the mornings and evenings, when heat is not as much of an issue, the affected plant appears fine (not wilted). The damage done by nematodes also can provide a pathway for other plant pathogens.

"Ants make up two-thirds of the biomass of all the insects. There are millions of species of organisms, and we know almost nothing about them."
—E. O. Wilson

STEM Connection Emerald Ash Borer

The emerald ash borer (EAB) is a wood-boring beetle that was accidentally introduced to the United States in 2002 from Asia. Since its arrival, this invasive pest has killed millions of ash trees (*Fraxinus* spp.). In southeast Michigan, where it was first introduced, more than 99% of ash trees with stems greater than 1″ (2.5 cm) in diameter have been killed.

The EAB lays eggs in bark cracks and crevices. The newly hatched larvae bore through the outer bark and begin feeding in galleries in the phloem and cambium. The feeding disrupts the ability of trees to transport nutrients and water, eventually girdling branches and the trunk. Scientists increasingly believe that EAB could cause local extinction of ash species across North America. Ash trees are the most widely distributed tree genera, and the loss of any ash species brings devastating economic and ecological impacts. Ecologically, ash trees are a sole food source for a number of species, making coextinction a real possibility.

Pennsylvania Department of Conservation and Natural Resources - Forestry, Bugwood.org

Plant Pathogens

Plant pathogens are organisms (including bacteria, fungi, viruses, and oomycetes) that cause disease. Note that many of these types of organisms are not plant pathogens and can be beneficial in the agricultural ecosystem. Each requires different management methods that are more fully discussed in Chapter 31, *Disease Management*. This chapter will offer a brief summary of each pathogen.

Bacteria

Bacteria are single-celled microorganisms that range from beneficial decomposers to pathogens of plants and animals. Almost all plant pathogenic bacteria develop mostly in the host plant as a parasite on the plant surface tissue or on dead or decaying organic matter in the soil. They can cause galls, cankers, wilts, leaf spots, blights, scabs and various other symptoms, **Figure 29-5**. Bacteria thrive in conditions such as high humidity, crowding of plants, and poor air circulation around plants. Bacterial diseases can be difficult to control.

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Figure 29-5. Citrus canker is caused by the bacteria *Xanthomonas axonopodis*, which causes lesions on leaves and fruit.

Fungi

More than half of all plant diseases are caused by plant pathogenic fungi, which creates significant annual losses in horticultural and agricultural production. Diseases, such as mildews and rusts, have a specialized biology. They grow only on living plants, **Figure 29-6**. Other pathogenic fungi, such as those that cause root rots and wilts, can grow on both living and dead material. These usually are soil inhabitants and cannot be reached easily for control.

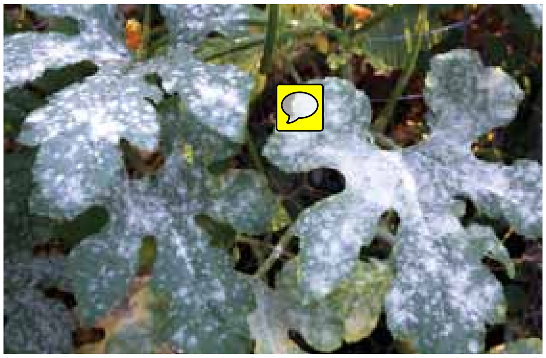

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Figure 29-6. Powdery mildew on these squash leaves is caused by fungi and is easily identifiable by its white powdery spots.

Viruses

Viruses are obligate parasites, which means they must have a suitable host to complete their life cycle. In their simplest form, they include a nucleic acid surrounded by a protein coat. Different viruses have different hosts. Some can tolerate a wide range of species as hosts, whereas others are very specific. For example, the cucumber mosaic virus has a broad range of hosts and can infect more than 85 plant families, **Figure 29-7**.

A Scot Nelson B Scot Nelson

Figure 29-7. Cucumbers are susceptible to cucumber mosaic virus; however, so are more than 1000 plant species within 85 different plant families. A—Passion fruit leaves exhibiting symptoms of the virus. B—Zinnia leaves exhibiting symptoms of the virus.

Did You Know?

Not all viruses are detrimental to plants. Some create different colors in flower petals or affect the shape of leaves, creating highly desirable ornamental characteristics.

Scot Nelson

Figure 29-8. Young, tender seedlings (such as these corn seedlings) are often susceptible to a disease called damping off, caused by the water mold *Pythium*. Avoiding overwatering can reduce risk.

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Figure 29-9. The leaves of these hostas have been damaged by slug feeding. Although the plant will survive, the ornamental value is diminished.

Robert Hoetink/Shutterstock.com

Figure 29-10. Moles can be significant pests, creating dirt mounds and surface tunnels, and killing plants by scraping away soil from roots and eating roots and bulbs.

Depending on the combination of virus, host, and environmental conditions (the disease triangle), a plant's response to infection may range from a symptomless condition to severe disease and plant death.

Oomycetes

Oomycetes, also known as water molds, can be both terrestrial and aquatic, with the terrestrial species primarily consisting of parasites of plants. Oomycetes, such as *Phytopthora* and *Pythium*, tend to cause plants to rot, **Figure 29-8**. Avoiding saturated soils and extremely wet conditions can minimize incidences of oomycetes.

Other Invertebrate Pests

Insects are not the only organisms that are horticultural pests. Mites, snails, and sowbugs can be damaging to plant material as well. Mites are tiny arachnids (related to spiders) that can damage a wide variety of crops, including fruit trees, vines, berries, vegetables, and ornamental plants. Spider mites cause stippling, discoloration, and leaf drop. Other pest mites cause distorted growth of leaves, shoots, buds, or fruit. Snails and slugs are mollusks that emerge at night and cause damage by chewing the leaves and flowers of many garden plants and fruit, **Figure 29-9**. Slugs and snails have similar structures and biology (slugs lack a shell). Similar management methods (eliminating moisture and hiding spots, trapping, setting up barriers, and handpicking) are used for both. Sowbugs and pillbugs are important decomposers, feeding on dead and decaying plant matter. They can, however, sometimes feed on tender young seedlings, new roots, and lower leaves.

Vertebrates

Vertebrates, such as birds, rodents, and other mammals, can be pests. Wildlife can be destructive in gardens and farms and can be a source of risk for foodborne illnesses. Vertebrate pests include deer, raccoons, rabbits, opossums, and rodents (such as squirrels, mice, rats, voles, and moles, **Figure 29-10)**. Birds can also be considered pests, feeding on fruits just as they begin to ripen. Most control methods involve keeping pests away from an area, such as using fencing, netting, devices that frighten pests away, or traps.

STEM Connection E. Coli Outbreak Linked to Deer

Pest management of deer is about preventing damage to plants and about preventing the transmission of disease to humans. In Oregon, an outbreak of E. coli (*Escherichia coli*) that sickened 15 people (one fatally) was linked to samples of deer feces found in a commercial strawberry field. Growers can keep deer from entering crop fields with effective fencing. Although deer normally will not jump a 6′ (1.8 m) fence, they can clear an 8′ (2.4 m) fence on level ground. Effective deer fences may range from 7′ to 11′ (2.1 m to 3.6 m). The type of fencing depends on cost, terrain, and other needs.

Fences can be constructed using high-tensile wire or woven mesh and are more effective than electric fences. Deer can sometimes crawl under or through a fence. The fence should be secure near the ground with no gaps. In order for the wire to remain tight, the vertical posts should be no more than 6′ to 8′ (1.8 m to 2.4 m) apart. Consulting with an agricultural fencing company is beneficial when planning fencing.

Control Measures

A number of best practices, widely considered as cultural control measures, create an environment that does not permit some pests to thrive.

Sanitation

Sanitation techniques reduce pests, their habitat, and their alternate hosts. All infected plant residues (disease and pests) should be removed from fields and gardens. This practice helps reduce helps reduce the chance of a recurring infestation. Weeds can be mowed or destroyed before they go to seed. Removing volunteer plants that are prone to pests or places that pests can overwinter is also important. Equipment and tools should be frequently cleaned to minimize the transport of any pest organisms. Pests can be excluded indoors by modifying points of entry (doors, vents, and other building openings) using screening or other barriers.

Habitat Modification

Changing conditions or environments that are suitable for pests can significantly reduce populations. For example, proper irrigation timing and delivery can reduce diseases that thrive in wet or damp environments, such as those where plants are consistently overwatered. Irrigation water should also be free of any pathogenic organisms. Removing their sources of food, water, and shelter will lessen the pests' ability to survive. For example, not planting gooseberries or currants (which serve as an alternate host for white pine blister rust) can reduce the risk of white pines becoming infected, **Figure 29-11**. Crop rotation can prevent buildup of certain pests. Scheduling the timing of planting and harvest may help to miss critical windows when pests are present.

A ©iStock/TKphotography64

B ©iStock/elzeva

C Marek Argent

Figure 29-11. Gooseberry (A) and currant (B) plantings can serve as an alternate host for white pine blister rust (C), which can be devastating for native stands of white pines.

Vadym Zaitsev/Shutterstock.com

Figure 29-12. Late blight caused by *Phytopthora*. Plant breeders have developed hybrids that have resistance to some diseases, such as late blight.

Plant Material

Growers can provide plants a stronger start for growing healthy by beginning with plant materials that are free of viruses, bacteria, fungi, or weed seeds. Growers may also use plant material that has been bred with more resistance to certain diseases. For example, a grower may choose tomato cultivars that offer resistance to minimize the incidence of late blight caused by the plant pathogen *Phytopthora*, **Figure 29-12**.

Some agronomic and horticultural crops have been genetically modified for increased resistance to certain insect pests or diseases. A genetically modified organism, or GMO, is a plant with a genome that has been transformed by genetic engineering. Crops such as corn, cotton, and soybeans have been injected with a gene that is resistant to an herbicide called glyphosate.

STEM Connection

Herbicide-Resistant Weeds

Palmer Amaranth

Native to the southwestern United States, Palmer amaranth, a type of pigweed, has become a calamitous weed problem in the south and has recently spread to the upper Midwest. Palmer amaranth is the most competitive and aggressive pigweed species and can grow as much as 2.5″ (6.4 cm) a day in southern states. Competition from Palmer amaranth can reduce soybean yields by as much as 80%.

Prolific seed production has perpetuated the establishment and spread of Palmer amaranth. A single female Palmer amaranth in the southeastern United States can produce nearly 500,000 seeds per plant, and even as much as one million seeds in optimal growing conditions. The number of seeds produced varies depending on the amount of competition the plant is experiencing and the region in which it is growing. Palmer amaranth has male and female flowers on different plants (dioecious), increasing the genetic diversity of this species by forcing cross-pollination. This also facilitates the spread of herbicide resistance in seeds. This type of

University of Delaware, Carvel

pigweed emerges throughout the growing season, requiring constant monitoring. Since the late 1980s, Palmer amaranth has evolved resistance to five different types of herbicides. As the selection pressure from other herbicides increases, multiple resistant populations will evolve.

IPM is very important in managing Palmer amaranth. Herbicides need to be used in combination with other methods, such as deep tilling of the soil to bury the seeds, which are very short-lived. Rotating crops, hand weeding, planting a cover crop of rye, monitoring fields and ditches, and harvesting infested fields last can also help stop the spread of this plant.

When the herbicide glyphosate is sprayed on a field, the weeds die and the resistant crops remain. Another example of genetic modification is plants that have been injected with the soil-dwelling bacterium *Bacillus thuringiensis* (Bt). Bt acts as a pesticide toward any predation by insects. In some plants, the genes are "turned on" or "silenced" to promote resistance to a particular pest. In recent years, a challenge to some of these crops has been the development of resistance by the pest organisms.

Inspection and Monitoring

After doing as much as possible to prevent pests, sites should be monitored through regular observation for the appearance of insects, weeds, diseases, and other pests. This will allow growers and gardeners to locate, identify, and rank the severity of pest outbreaks. Pest populations vary between locations, and from year to year. Consistent monitoring will allow early detection of pests and provide a better chance to prevent populations from increasing.

Scouting

Scouting is the regular checking of a field, garden, orchard, lawn, greenhouse, or other area that identifies potential pest problems early while they can still be managed. This practice reduces crop loss and control costs. Scouting methods vary by situation and by crop. Scouting should occur throughout the season. Notes should be taken on environmental conditions, beneficial insects, pest insects, diseases, weeds, crop growth stage, and crop health. This information can be collected over years, creating a field history that tracks common pest problems. Scouting methods include the use of sweep nets, insect traps, soil sampling, weed counts, and visual observations.

Sweep Nets

Sampling with a sweep net is a common practice used to inventory fields for various agricultural and horticultural pests, **Figure 29-13**. To use a sweep net, swing it in an arc so the net rim sweeps the top 6″ to 15″ (15 cm to 40 cm) of plant growth, depending on the type of crop. After a few sweeps, the net is inspected for pests.

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Figure 29-13. Sweep nets are tools that allow fields to be surveyed for both pest and beneficial insects.

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Figure 29-14. Sticky traps are commonly used in greenhouses and nurseries as a monitoring tool for pest presence and populations.

Insect Traps

Several types of insect traps can be used to monitor and control pests. The data gathered with these traps is valuable for making decisions about pest management. Some examples include sticky traps, pheromone traps, pitfall traps, and light traps.

- Sticky traps use a material coated with glue to trap and hold insects. They are used in floriculture and nursery industries to catch and monitor insects and other pests. Sticky traps provide a relative measure of insect populations and can allow early detection of pests before damage is observed in crops, **Figure 29-14**.
- Pheromone traps are baited with sex ***pheromones***, the chemicals released by female insects to attract mates, **Figure 29-15**. (Pheromones may also be synthetically produced for use in traps.) Pheromone traps are valuable tools for monitoring pest populations. They allow early pest detection, identify areas of pest infestations, and help growers record the population size and increase. Pheromone traps can be used in a variety of situations, including orchards, crop fields, and forests.

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Figure 29-15. Pheromone traps are another method for luring pest insects, observing populations levels, and gathering data used to make decisions regarding pest management.

- Pitfall traps help growers detect early activity. They are used to monitor walking and crawling soil and litter arthropods, particularly those that are active at night. A container is sunk into the ground so that its rim is even with the soil surface. Insects and other organisms are captured when they fall into the trap. To prevent escape, the traps usually contain a killing/preserving agent, such as soapy water or ethyl alcohol.
- Light traps use a funnel with a light source. The light is attractive to some insects, such as moths. The insects become trapped, allowing for inventory. Light traps are less commonly used than other methods.

Soil Sampling

Soil cores are pulled from fields, usually to a depth of 12″ (30 cm), and surveyed for populations of plant parasitic nematodes, plant pathogens, and other soil-dwelling insect pests. Management decisions can be made after proper identification and population counts of pests. Depending on the pest being sampled, soils may be collected at different times of the year.

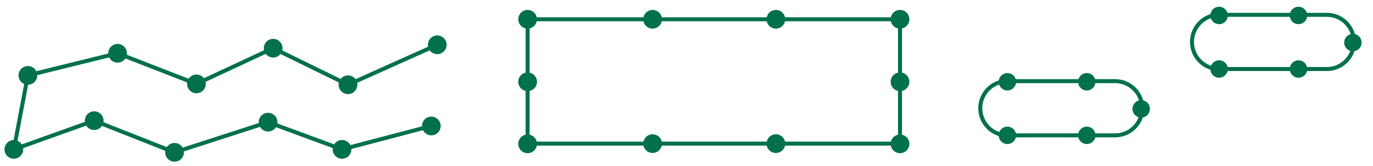
Weed Counts

Scouting for weeds allows growers to accurately determine weed diversity and populations. Some weeds are not competitive with specific crops, and their presence does not need to be managed. Others weeds are highly competitive and may be best controlled at a certain stage in their life cycle. Growers use scouting methods established for specific crops to monitor weed populations.

Generally, scouting occurs throughout the season at regular intervals. Approximately 10 stops may be made in each field. At each stop, weeds are counted in a section 12″ (30 cm) wide. The number of stops can vary depending on the size of the field, **Figure 29-16**. It is important to obtain enough representative samples to understand the situation. Additionally, fields that have different environmental conditions such as wet, dry, and shady areas should be sampled. The number and size of broadleaf weeds and grassy weeds are recorded separately. If weeds are present in only a concentrated area of the field, the locations should be marked to be managed separately.

Visual Observation

As fields are scouted for weeds or insects, disease should also be monitored. Stunting, discoloration, poor stands, and girdling are examples of visual symptoms of diseases. Experienced scouts will understand the



Goodheart-Willcox Publisher

Figure 29-16. Scout fields in regular intervals throughout the season to get an accurate understanding of pest levels.

growing conditions and management and should be able to rule out nutrient deficiencies or other environmental stressors. If growers suspect that plants are infected with a disease, samples can be collected for research or testing. Many cooperative extension service offices and their affiliated land-grant universities have plant diagnostic clinics that may be able to identify the disease.

Pest Identification

For pest management to be effective, pest must be accurately identified before corrective actions can be taken. A mistake in identification can lead to improper control tactics that cost time and money, and may present unnecessary risks to people or the environment. Different types of pests can cause similar damage, so unless the pest is correctly identified, the control program may target the wrong pest. As different pests are more susceptible to controls at certain life-cycle stages, proper identification will ensure the most effective control method and timing can be selected.

Although there are many online resources for pest identification, visual comparisons with online images are inadequate for accurate identification. Contact an expert from your state's cooperative extension service, land-grant university, or pest management association for assistance in identifying pests.

Recordkeeping and Evaluation

Recordkeeping is a vital component of an IPM program. Maintaining good records will help solve pest problems and offer a historical perspective of pests. Data collected through scouting can be mapped and archived to allow growers to predict seasonal pest problems and prepare for the IPM methods that will give the best control. Detailed records should also be kept on pest management methods used, including cultural, physical, biological, and chemical controls.

FFA Connection

Nursery/Landscape Pests and Disorders Identification

As part of the Nursery/Landscape CDE, students must identify certain common pests and/or the symptoms and damage they cause. The pest may be presented as an intact specimen, with a photograph, or as a preserved specimen (insect mount). Some of the common greenhouse and nursery pests that may be included on the identification list include aphids, bagworms, borers, leafhoppers, leaf miners, scale, spider mites, snails, slugs, whiteflies, and white grubs. Use the e-flashcards on your textbook's student companion website (www.g-wlearning.com/agriculture) to help you study and identify these common pests.

IPM evaluation should include a regular review of records to identify any changes in pest activity (increase or decrease) that will determine whether the management techniques are working. The review should examine the correlation between methods used and changes in pest populations. The following questions can be useful in evaluating an IPM program:

- What problems have been identified?
- Is the monitoring program adequate?
- Are all pest populations below unacceptable levels that require correction actions (action thresholds)?
- Do additional or different actions need to be taken?
- Can time and effort to control pests be reduced?
- What changes are necessary?

Action Thresholds

Identifying action thresholds is an essential part of any integrated pest management program. An ***action threshold*** is the point at which the pest reaches an unacceptable level, and where some type of corrective action to reduce its numbers is economically justified, **Figure 29-17**. Action thresholds and the corrective action taken vary depending on the pest, site, geographical location, and time of year. For example, even a few cockroaches are not tolerated in food service areas (very low action threshold). On the other hand, clover in a regularly mowed area will not crowd out the desired turf (high or no action threshold). Some pests can have an action threshold of one sighting. Other predictable and unacceptable pests may require no sighting at all to take action.

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Figure 29-17. Clover in the lawn may not be aesthetically pleasing to some people, but it rarely impacts the growth of turf. Therefore, it has a high action threshold.

An ***economic injury level (EIL)*** is the lowest population density of a pest that will cause economic damage and justify the costs of pest control. Corrective action (pest control) may result in the highest yields, but it may not necessarily be the most cost effective. Treatment at an action threshold is the most cost-effective management approach, but it may or may not result in the highest yields. Most agronomic and horticultural crops have thresholds that have been established by research. For example, codling moths in apples can cause significant economic damage if a certain population size is reached. To determine the infestation level, traps containing lures are hung in the orchard. If more than five codling moths are caught in a trap per week, there is a high risk for problems from future generations of codling moths. By applying a pesticide within five to seven days, growers can keep populations to an acceptable level.

"I do some of my best thinking while pulling weeds."
—Martha Smith

Corrective Actions

When there is a pest problem, growers consider the available cost-effective control strategies and use a combination that eliminates unacceptable pests and helps prevent future infestations. Monitoring is always necessary unless the action threshold is zero. Corrective actions include physical, mechanical, biological, and chemical controls.

Physical and Mechanical Controls

Physical and mechanical control techniques directly remove or kill pests. They may also prevent insect pests from reaching their hosts by means of a barrier or trap.

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Figure 29-18. Hoeing a garden is an easy, inexpensive way to remove weeds.

Insect Removal

Physical removal techniques are labor intensive and include hand picking, spraying with water, and cutting. For example, some aphids can be knocked off plant foliage by spraying a stream of water on the leaves. Japanese beetles can be knocked off by hand into a bucket of soapy water. Bagworm eggs overwinter inside bags. These bags can be cut from the plants in the winter months and destroyed.

Weed Removal

On a small scale, weeds can be removed through hand pulling, with hoes or string trimmers, or through tillage, **Figure 29-18**. Hand removal of weeds can be time and labor intensive, which can be expensive. Techniques known as flame cultivation or thermal weeding use propane flame torches or infrared torches to heat the plant until cellular rupture occurs and kills the plant, **Figure 29-19**. Grit blasting (shooting small and targeted amounts of grit onto plants) using ground peach pits or other material has shown early evidence as an effective method to kill weeds.

Irina Fischer/Shutterstock.com

Figure 29-19. Flame torches are used often in organic production to eradicate weeds in a quick, less labor-intensive manner.

Pest Barriers

Some pests can be prevented from reaching their host by installing a barrier. For example, a simple row cover can provide protection to solanaceous crops, such as eggplants, from the ravages of flea beetles. Putting screens in greenhouses and buildings will bar entry to many pests. Fine netting prevents birds from eating or damaging ripening fruit, **Figure 29-20**. Paper collars placed around stems of plants can prevent access by cutworms. Barriers may also be used to prevent weeds from spreading. For example, a metal border can stop the spread of bermuda grass into a garden. Landscape fabric can be laid down prior to planting to keep weeds to a minimum. An ***anti-transpirant*** spray (chemical compounds applied to the leaves of plants to reduce transpiration) can be used for some woody landscape ornamentals. This spray creates a protective barrier against infection by some plant pathogens that could cause disease.

Serkan Ogdum/Shutterstock.com

Figure 29-20. Netting placed over plants or trees prevents birds from eating or damaging fruit, but allows airflow and water to pass through.

Traps and Attractants

Traps and attractants are not only used to monitor populations, but also to trap pests to lower plant damage. For example, a sticky barrier wrapped around the trunks of trees and woody shrubs will capture crawling insects, **Figure 29-21**. Pheromone traps are primarily used in monitoring; but in some cases, such as in codling moths, the traps can be used to reduce population numbers. Traps may also be used to provide an artificial breeding or resting site. For example, small numbers of gypsy moth larvae have been effectively controlled by placing a band of folded burlap around the tree trunk to provide an artificial resting site for the caterpillars. Once caterpillars have gathered, they can be collected and destroyed.

Biological Controls

Many natural predators of pests exist in agricultural and horticultural ecosystems. These natural predators are called ***beneficials*** and may be insects, arachnids, mammals, and even microbes, **Figure 29-22**.

Gypsy Moth Larva

Peter Waters/Shutterstock.com

Adult Gypsy Moth

D. Kucharski K. Kucharska/Shutterstock.com

Figure 29-21. Gypsy moths are devastating, exotic pests that feed on many tree species. They may be controlled by trapping the larvae in burlap wrappings.

Pests	Natural Enemies	
Aphids	aphid midge aphid parasites bigeyed bugs damsel bugs lacewings lady beetles leather-winged beetles	minute pirate bugs parasitic flies parasitic wasps predatory mites soldier beetles spiders syrphid flies
Beetles	Anaphes species damsel bugs elm leaf beetle parasite	leather-winged beetles soldier beetles spiders tachinid flies
Bugs such as lygus, plant, and stink bugs	Anaphes species assassin bugs bigeyed bugs	damsel bugs lacewings
Caterpillars	alfalfa butterfly parasite assassin bugs *Bacillus thuringiensis* bigeyed bugs birds caterpillar parasite damsel bugs egg parasitic wasps	grape leaffolder parasite lacewings lady beetles minute pirate bugs parasitic flies predaceous bugs and wasps spiders tachinid flies
Elm leaf beetle	parasitic flies	parasitic wasps
Lace bugs	assassin bugs lacewings lady beetles	parasitic wasps pirate bugs spiders
Leafhoppers	assassin bugs bigeyed bugs	damsel bugs spiders
Mealybugs	citrus mealybug parasite dustywings lacewings lady beetles	mealybug destroyer lady beetle minute pirate bugs parasitic wasps

Pests	Natural Enemies	
Mites	bigeyed bugs damsel bugs dustywings lacewings lady beetles minute pirate bugs parasitic mites	predatory fly larvae) sixspotted thrips spider mite destroyer lady beetle western predatory mite
Psyllids	lacewings lady beetles parasitic wasps	pirate bugs spiders
Scale, cottony cushion	lady beetles parasitic flies	vedalia beetle
Scales	lacewings lady beetles minute pirate bugs	parasitic wasps predatory mites
Slugs, snails	birds decollate predatory snail parasitic flies	predaceous ground beetles snakes toads
Thrips	damsel bugs lacewings minute pirate bugs parasitic wasps	predatory mites predatory thrips spiders
Weevils, root or soil-dwelling	entomopathogenic nematodes	parasitic wasps
Whiteflies	bigeyed bugs dustywings lacewings lady beetles	minute pirate bugs parasitic wasps spiders whitefly parasite
Whitefly, giant	lacewings lady beetles parasitic wasps	syrphid fly larvae

Goodheart-Willcox Publisher

Figure 29-22. This table lists common natural enemies used in biological control, including predators and parasites. Natural enemies that limit pests are essential components of integrated pest management programs.

Biological control promotes and protects beneficial predators and parasites that help control pests. When scouting for pest monitoring, scouts should also monitor the presence of beneficial organisms. The presence of beneficials will impact IPM decisions. For example, tomato hornworm can be parasitized by a type of wasp. Avoiding the use of an insecticide that could kill these wasps allows predation to occur, **Figure 29-23**.

Growers may purchase and introduce parasitic beneficials as part of their IPM. One of the most common examples is the use of a ladybug or ladybird beetle as an aphid predator, **Figure 29-24**. Both the larvae and adult beetles eat aphids as well as other soft-bodied insects. Other important predators include lacewings, soldier bugs, and spiders as well as a variety of others. Parasitic beneficials are organisms that live on or inside the pest host, such as the braconid wasp. The host often dies after the parasite has completed its development. Most agricultural beneficial parasites are small wasps and flies that use caterpillars, whiteflies, aphids, and other pests as hosts.

Microbial Control

Bacteria, viruses, fungi, and nematodes can also be used as biological control measures. The naturally occurring, soil-dwelling bacterium *Bacillus thuringiensis* (Bt) is commonly used to control pests. Bt produces a protein crystal that is toxic for lepidopteran insects (butterflies and moths). The ingested Bt destroys the larvae's intestinal lining and they die within days.

The Bt toxin can be sprayed on plant foliage or genetically inserted into plant material, **Figure 29-25**. It specifically affects caterpillars and will not harm other insects in the landscape. Microbial insecticides are fairly slow acting and are most effective when applied when pest numbers are low and in early stages of their development. Bt has been used as an organic-certified pesticide.

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Figure 29-23. Tomato hornworms are often parasitized by a natural enemy, the braconid wasp.

Pavel Mikoska/Shutterstock.com

Figure 29-24. Ladybugs adults and larvae are voracious predators of aphids.

AlissalaKerr/Shutterstock.com

Figure 29-25. Cotton is commonly transformed with the Bt gene, which limits damage by any lepidopteran pest.

Chemical Controls

Pesticides are an integral part of many IPM programs, but they are not a substitute for other effective measures. When action thresholds are exceeded and non-chemical control techniques are insufficient or not practical, chemical control plays a critical role in managing pest populations. Pesticides should be used only when needed, but not only as a last resort. Small infestations of some highly-detrimental pests can quickly get out of hand. The application of a pesticide may be needed before there is time to try other methods. For example, timing an application to match pest life cycles will provide more efficient control.

Chemical methods to manage pests include many types of compounds. Some will repel or confuse pests. For example, bug spray repels mosquitoes, but it does not kill them. Some pesticides interfere with pest biology, such as interrupting weed photosynthesis or insect molting processes. Others, including some botanical and most conventional insecticides, are broadly toxic to living systems. The term *pesticide* is an inclusive term for many chemicals. Specific pesticides include insecticides (to control insects), herbicides (to control weeds), fungicides (to control fungi), rodenticides (to control rodents), and others.

Pesticide Application

Pesticides are required by law to have a detailed label and to be used according to the label to ensure maximum benefits and minimal hazard to human health and the environment. Pesticide labels describe how to use the pesticide correctly, including the best timing for application. Pesticide labels also specify what types of personal protective gear should be worn by the applicator.

Although pesticides are valuable tools in pest management, overuse or misuse has led in some cases to resistance to the pesticide, outbreaks of secondary pests, adverse effects on non-target organisms, unwanted pesticide residues, and direct hazards to the user. Following best practices in pesticide use is a critical component of IPM. These practices include rotating types of pesticides, proper timing, safe use, and using pesticides in combination with other control tactics. Pesticides and their application are covered in more detail in Chapter 33, *Pesticide Management and Safety*.

Careers in Integrated Pest Management

Many interesting careers are related to integrated pest management. IPM methods must be researched and developed, users must be educated in their application, and chemical as well as biological components must be marketed, sold, and distributed. Three careers in IPM you may want to consider include research scientist, pesticide sales, and management in a pesticide company.

Research Scientist

Research scientists in IPM work for universities, state departments of agriculture, federal agencies such as the EPA or USDA, and other collaborating organizations, **Figure 29-26**. Researchers work to develop crop-specific IPM systems. These IPM systems include best practices and new control methods with the reduction of pesticide impact while still supporting profitable farming. Researchers often build relationships with farmers, crop associations, and farmer networks to encourage the widespread adoption of IPM systems. Researchers may write grant proposals and research papers to support their work. Higher-education degrees (master's or doctorate) are required along with at least five years of experience.

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Figure 29-26. Research scientists working on IPM methods work in labs, greenhouses, and fields. They also work with farmers and other growers to implement monitoring and control methods.

Pesticide Sales

If you have excellent communication and organization skills, a position as a sales associate for a pesticide company may be a good fit for you. Job responsibilities include explaining the company's services to existing customers as well as acquiring new customers. Sales associates must understand pesticide products, target pests, application methods, and what product would best suit a grower's operation. Most companies require some prior sales experience with a history of demonstrated sales results.

Manager

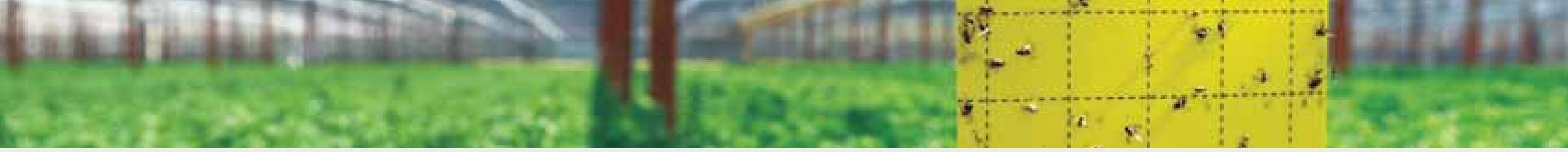
After being a sales associate, you might advance to an administrative position as a sales manager or director. In this position, you will have the opportunity to train, coach, and motivate others. You must have strong decision-making and problem-solving skills for this job. Computer skills, as well as excellent communication, interpersonal, and organizational skills, are also needed. Supervisory experience is preferred. This position generally requires a relevant college degree or equivalent experience.

CHAPTER 29

Review and Assessment

Chapter Summary

- A pest is any organism that damages or disrupts plant growth. Integrated pest management (IPM) is an environmentally sensitive approach that includes a variety of strategies (cultural, physical, biological, and chemical) to most effectively control pests.
- Pest management decisions are based on a variety of factors, such as the size of the affected area, estimated number of pests, life-cycle stage of the majority of pests, type of crop, urban or rural setting, time of year, and costs.
- Pests are organisms that damage plants or disrupt crop development. Pests include weeds, birds, rodents, mammals, insects, snails, nematodes, and plant pathogens, such as bacteria, virus, fungi, and oomycetes
- Pest prevention creates an initial environment that is unfavorable to pests and includes sanitation, habit modification, and selecting plant materials that are free of viruses, bacteria, fungi, or weed seeds.
- Inspection and monitoring of sites through regular observation for the appearance of insects, weeds, diseases, and other pests will allow growers to locate, identify, and rank the severity of any pest outbreaks that occur.
- Inspection and monitoring involves scouting sites using sweep nets, insect traps, soil samples, weed counts, and visual observations. Pest identification is important in selecting the correct control measures.
- Recordkeeping is a vital component of an IPM program. Maintaining good records will help solve pest problems and offer a historical perspective of pests.
- An action threshold is the point at which the pest reaches an unacceptable level and where corrective action to reduce its numbers is economically justified.
- Growers often take corrective measures to eliminate unacceptable pests and help prevent future infestations. Corrective actions include physical, mechanical, biological, and chemical controls.
- Physical and mechanical control techniques directly remove or kill pests or exclude insect pests from reaching their hosts by means of a barrier or trap.
- Biological control is a practice that promotes, protects, and introduces beneficial predators and parasites to help control pest populations.
- Chemical controls using pesticides are an integral part of many IPM programs, but not a substitute for other effective measures. Pesticides are required by law to have a label and to be used according to the label.
- Many interesting careers are related to integrated pest management. Three of these careers are research scientist, and sales associate or manager for a pesticide company.



Words to Know

Match the key terms from the chapter to the correct definition.

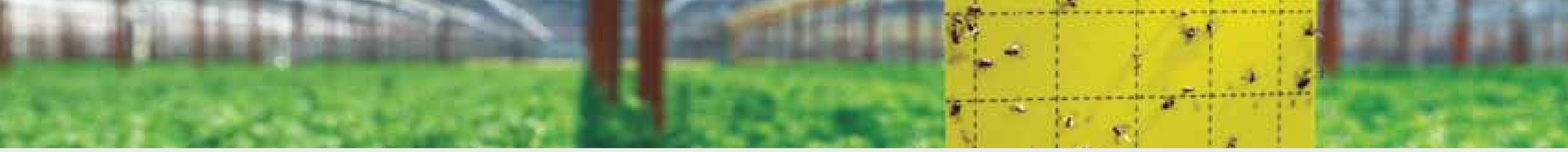
A. action threshold
B. anti-transpirant
C. beneficial
D. economic injury level (EIL)
E. integrated pest management (IPM)
F. oomycete
G. pest
H. pesticide
I. pheromone
J. plant pathogen
K. scouting
L. vector

1. A natural predator or parasite that controls the population of pests, such as insects, mammals, bacteria, and other microbes.
2. The regular checking of a field, garden, orchard, lawn, greenhouse, or other area that identifies potential pest problems early while they can still be managed and thereby reduce crop loss and control costs.
3. The lowest population density of a pest that will cause economic damage and justify the costs of pest control.
4. An organism that causes disease in plants.
5. A chemical compound that can be applied to the leaves of plants to reduce transpiration and provide protection from plant pathogens.
6. An organism that transmits a disease or parasite from one plant to another.
7. The point at which the volume of a pest reaches an unacceptable level, and where some type of corrective action to reduce its numbers is needed and economically justified.
8. A chemical that is emitted by insects to attract mates and which can be synthetically produced and used in lures to trap insects for monitoring.
9. An environmentally-sensitive approach to controlling pests that uses a combination of cultural, physical, biological, and chemical controls.
10. A chemical that is used to control insects, weeds, fungi, rodents, and other pests.
11. Filamentous protists, including water molds and downy mildews that can cause diseases, such as blights and rots.
12. Any organism that damages or disrupts plant growth.

Know and Understand

Answer the following questions using the information provided in this chapter.

1. What is integrated pest management (IPM)?
2. What are two main benefits of using IPM?
3. What factors are considered in making decisions for IPM?
4. What are agricultural/horticultural pests? Give several examples.
5. What impacts do weeds have in farms and gardens?
6. How do nematodes damage plants?
7. What types of damage can harmful bacteria cause in plants?



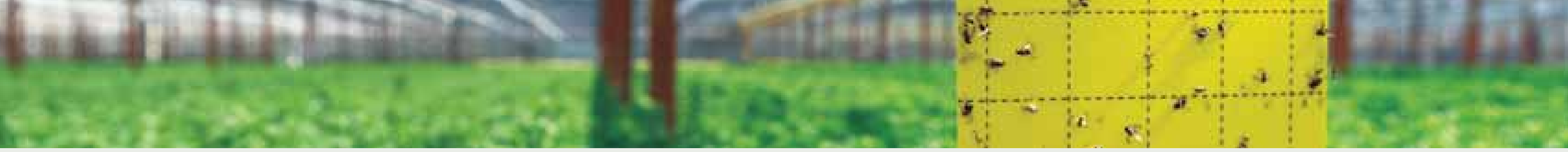
8. What are two examples of oomycetes that can cause plants to rot and how can incidents of these pathogens be minimized?
9. What risk do wildlife and other vertebrates pose as pests in the garden and what are some examples of vertebrates that can be pests?
10. Describe sanitation techniques that prevent pest infestations.
11. What are three examples of habitat modification that may prevent or reduce pests?
12. What are three common examples of plants that have been genetically modified to resist glyphosate and how does this affect pest management?
13. How does having genes from the soil-dwelling bacterium *Bacillus thuringiensis* (Bt) inserted into plants aid in pest management?
14. What is scouting (as it relates to IPM) and what are some methods for scouting?
15. Why is it important to properly identify a pest?
16. What are some questions that can be useful in evaluating an IPM program?
17. Describe physical and mechanical control techniques and two examples of these controls.
18. Explain biological control as part of IPM and give an example of a biological control.
19. Explain how pesticides can be an important part of IPM.
20. What duties are involved in a pesticide sales associate job and what skills are needed for this job?

Thinking Critically

1. One of your fields has a serious outbreak of a disease. You decide to use a pesticide. As you are getting ready to spray, the weather changes. It is windy and possibly will rain. What course of action will you take?
2. You are scouting your field and find a large area with a high population of an insect that you have never seen before. The insects are causing significant damage to your crop. What steps will you take?

STEM and Academic Activities

1. **Science.** Choose four different pests in your neighborhood that interest you. Find both the common and scientific name of each, using binomial nomenclature. Make a table with three columns: Common Name, Scientific Name, and Example. In the Example column, either draw a picture or attach a photograph of the pest.
2. **Technology.** Research recordkeeping or inventory control software for small businesses. Determine which software might be best suited for a farmer managing pests. What data fields are critical? How can this be adapted for use with field monitoring and pest management?
3. **Technology.** Investigate technologies that allow digital mapping of pest incidences. Prepare a summary that describes the process, methods, and usefulness of this application.
4. **Math.** Scouting requires observing fields in several spots. Suppose a field that is one acre is size should be scouted in 10 different locations. Create a map with marks indicating the locations for scouting that represents all parts of the field.



5. **Language Arts.** Pretend that you are a crop consultant, and you keep a daily journal to help you remember information that you might need later. Today, you scouted several different fields and made pest management decisions. Write a journal entry about these visits that includes all the information you might need in the future.

Communicating about Horticulture

1. **Reading and Speaking.** Working in groups of five students, draw a poster that illustrates the key concepts in this chapter. Use your textbook and research online for images. Take turns quizzing one another on the fundamental ideas within the chapter.
2. **Reading and Speaking.** Debate the topic of different ways to manage pests. Divide into three groups: physical and mechanical control, biological control, and chemical control. Each group should gather information to support a pro argument for their control method. Use definitions and descriptions from this chapter, as well as other resources, to support your side of the debate and to clarify word meanings as necessary. Do additional research to find expert opinions, costs associated with each method, and other relevant information.
3. **Writing.** Pick a plant pest that causes significant economic damage in your state. Use research from your local cooperative extension or land-grant university to learn about the biology and control strategies for the pest. Write a one-page summary that describes your findings.

SAE Opportunities

Jari Hindstroem/Shutterstock.com

1. **Exploratory.** Job shadow a crop consultant. What are the daily responsibilities for this job? What do you like or not like about this position? What education and experience are required to have this position?
2. **Exploratory.** Find a plant on your school campus that has an obvious pest problem. What are the options to manage the pest? How will your decision impact other plants, living organisms, and your fellow students?
3. **Exploratory.** Research what beneficials could be used to control insect pests in your school greenhouse. How does the control by beneficials compare to other methods classes may have used in the past?
4. **Exploratory.** Create a pest management plan for your school greenhouse. What preventive measures will you implement at the start? What protocols will you have in place that will allow you to make informed decisions when pest problems do arise?
5. **Exploratory.** Visit a local pesticide dealership and ask to participate in a sales call. How is this job (pesticide sales associate) different than a crop consultant job? What are the responsibilities of a sales representative? If you wanted this kind of position, what would you need to do to be marketable in the future?