

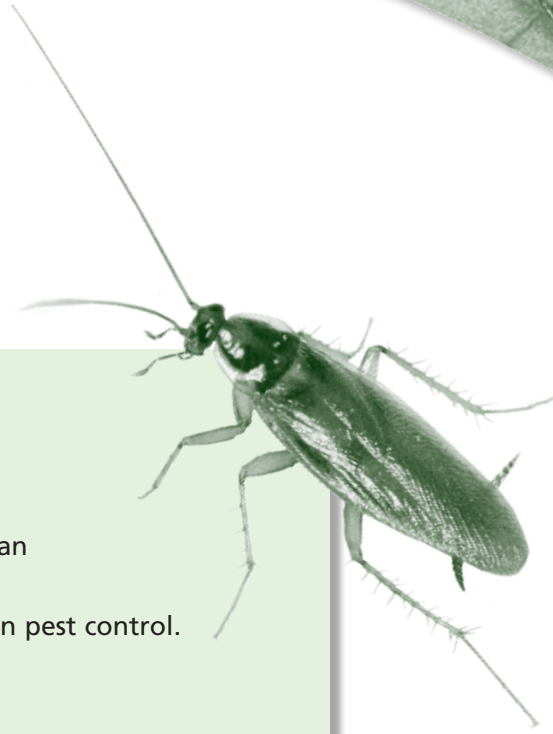
CHAPTER 1

PEST MANAGEMENT

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- Define “pest.”
- State the four main groups of pests and give an example of each.
- Discuss the importance of pest identification in pest control.
- List six general pest management methods.
- Define “integrated pest management (IPM).”
- List five benefits of using IPM.
- Discuss how using one or more control options can improve pest control.
- Describe how selectivity and persistence affect chemical controls.
- Explain how pest population levels trigger control procedures.
- Distinguish between prevention and suppression when developing pest management goals.
- Give several reasons why pesticide applications may fail.
- Explain the importance of a pesticide’s mode of action in managing pesticide resistance.
- List two tactics that will minimize the development of pesticide resistance.



Pest: Brownbanded cockroach.

Clemson University—USDA Cooperative Extension Slide Series, Bugwood.org.

Marlin E. Rice, Iowa State University Extension.

PEST PROBLEMS THROUGHOUT HISTORY

Civilization has been combating insects and other pests throughout history. Perhaps the most infamous human catastrophe was the Black Plague of Europe, when millions of

people in the 14th century died from a mysterious scourge. Centuries later, it was determined that the cause was a bacterial disease spread by rat fleas. When rats, the normal host animals,

were unavailable as a food source, the fleas sought other warm-blooded hosts—including humans. Although the plague is still present in parts of the world today, controlling rats, other rodents, and fleas can greatly reduce disease incidence.

The destruction of Ireland's potato crop by a fungal disease in the 19th century directly affected the population of the United States. Late blight essentially eliminated potatoes, the staple food crop of Ireland. Potatoes not destroyed in the field rotted in storage during the winter. Thousands of Irish starved in the resulting famine, and more than a million migrated to the United States. Late blight continues to be a major problem of potatoes, but today it is managed through the use of resistant cultivars, proper sanitation practices, and fungicides.

Malaria is a disease caused by the transmission of a parasitic microorganism (protozoan) by mosquitoes when they feed on humans. Historians credit malaria with altering the patterns of human history and causing the collapse of some civilizations. During World War II, 500,000 soldiers were infected in the South Pacific and African theaters, with 60,000 deaths recorded. In 2010, malaria cases numbered 219 million, with 660,000 people dying from this debilitating disease. Antimalarial drugs, insecticide applica-

tions, environmental modifications, and mosquito (bed) nets have brought great improvements to fighting this difficult-to-control disease.

Outbreaks of the native mountain pine beetle in the western United States and Canada in the early 21st century destroyed more than 4 million acres of lodgepole, ponderosa, Scots, and limber pines. Accidental introduction of the emerald ash borer from Asia during this same period has destroyed millions of ash trees in the midwestern United States. Preventive insecticidal treatments are being used to manage these two destructive beetles.

These examples illustrate the enormity and complexity of pest problems. But what is a pest? A **pest** is an undesirable organism that injures humans, desirable plants and animals, manufactured products, or natural substances. Many insects, **pathogens** (disease-causing organisms, such as viruses, bacteria, or fungi), plants (known as **weeds**), mollusks (slugs and snails), fish, birds, and a variety of mammals (from mice to deer) compete for our crops and livestock. In addition, some pests destroy clothing, furniture, and buildings; reduce the beauty and recreational value of the landscape; and invade our homes during the winter months. As the battle between humans and pests continues over time, so will innovative methods of control.

PEST CONTROL OVER THE YEARS

For many centuries, the causes of crop failures and human and animal diseases were shrouded in mystery. The first pest control measures were crude—weeds were pulled, rats were clubbed, and beetles were plucked from foliage. Other ancient nonchemical control methods included burning to control weeds, diseases, and insects (950 B.C.); Egyptians placing fishnets over beds to prevent mosquito bites (440 B.C.); and Romans using rat-proof grain storage bins (13 B.C.). The first known use of natural enemies is credited to Arabian growers (1000 A.D.). Arab farmers moved colonies of a predaceous ant

species from nearby mountains to an oasis to control pest ants that were damaging their date palms.

The earliest use of chemicals as pesticides dates back to 2500 B.C., when the Sumerians used sulfur compounds to control mites and insects. The Chinese used mercury and arsenic compounds in 500 B.C. to control body lice. Early plant-derived insecticides included hellebore to control body lice, nicotine to control aphids, and pyrethrins to control a wide variety of insects. In France during the late 19th century, a farmer sprayed a mixture of lime and copper sulfate on grapevines

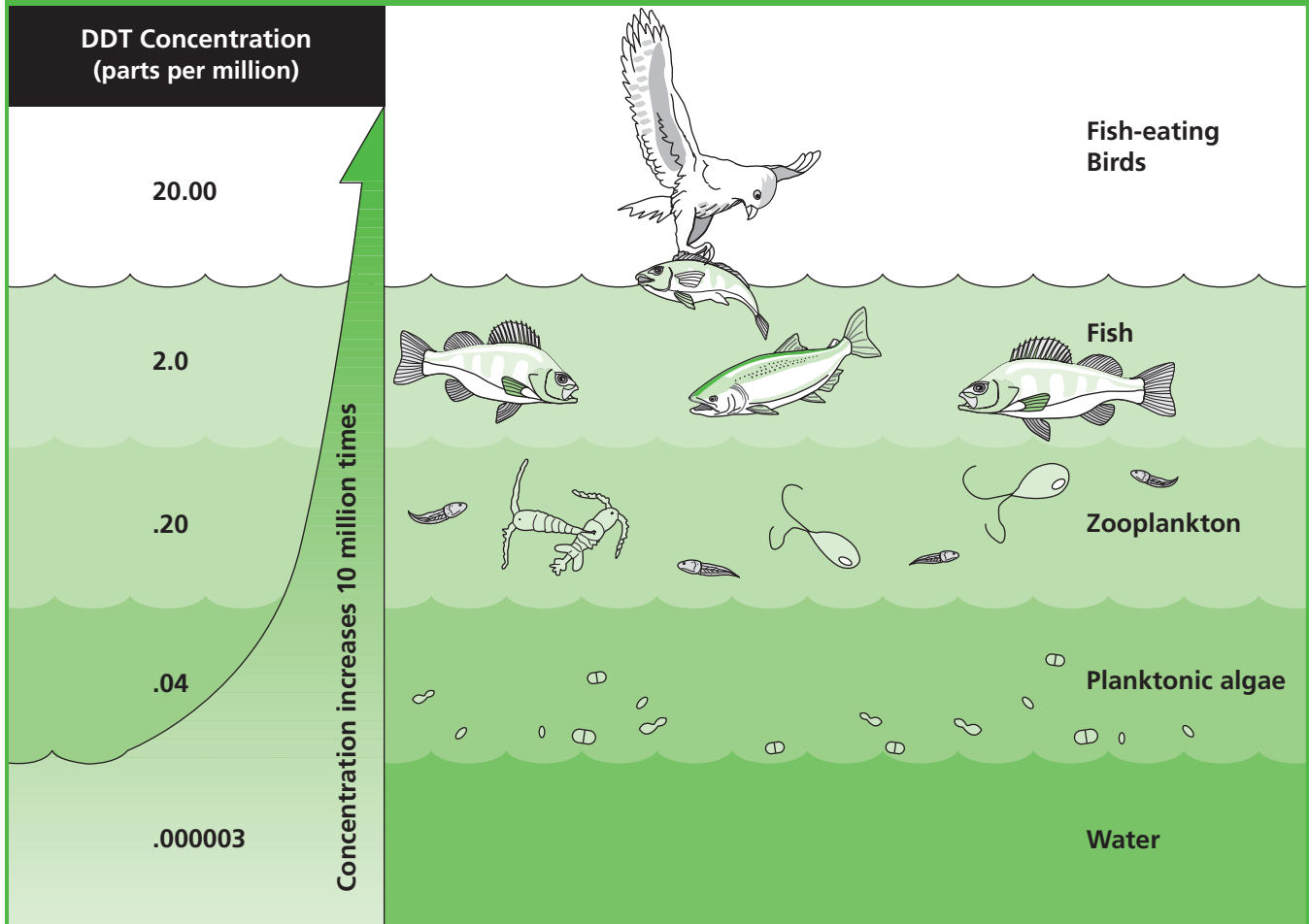
to deter passers-by from picking the grapes. The farmer found that the mixture also controlled downy mildew, a serious fungal disease of grapes. Later named Bordeaux mixture, it remains a widely used fungicide worldwide.

Until the 1940s, pest control chemicals were derived from plants and inorganic compounds. During World War II, the synthetic chemical DDT saved many Allied soldiers from insect-transmitted diseases. Synthetic pesticides launched the modern-day chemical industry and a new era in pest control. Pesticides became the primary means of solving pest problems because they were effective, relatively inexpensive, provided season-long crop protection, and could be used with fertilizers and other production practices. Modern pesticides achieved wide acceptance following their successful use in agriculture and for human health.

In recent years, however, some drawbacks of heavy dependence on pesticides have become increasingly apparent. **Pesticide resistance** to DDT was documented in 1947. Since that time, hundreds of insects have become resistant to one or more pesticides. Most notable is the Colorado potato beetle, which has developed resistance to every major group of insecticides, greatly complicating pest management efforts. Resistance also has arisen in many weeds and plant pathogens in agricultural production. (See “Pesticide Resistance” at the end of this chapter for more information.)

The impact of increasing pesticide use on the environment was graphically illustrated in 1962 by Rachel Carson. Her book, *Silent Spring*, focused on DDT and other chlorinated hydrocarbons because of their long residual activity and persistence

Figure 1.1 Biomagnification in the Food Chain



Adapted from Penn State Pesticide Education Manual

in the environment. Although these characteristics contributed to their effectiveness, chlorinated hydrocarbons also accumulated in the fatty tissue of some animals, especially those higher in the food chain (**bioaccumulation**). In certain situations, some organisms accumulated chemical residues in higher concentrations than those found in the food organisms they consumed (**biomagnification**). Ecologists refer to a **food chain** as the sequence of animals feeding in the natural environment, where a particular plant, animal, or microorganism is eaten by an animal that is in turn eaten by another animal. Animals at each level normally consume individuals from the previous level. Figure 1.1 depicts how biomagnification of a pesticide can

occur in a food chain. Organisms with pesticides in their tissues are eaten by fish, which are in turn eaten by birds. The birds at the top of the food chain accumulate the highest concentration of pesticide residues.

Since the publication of *Silent Spring*, the United States has experienced a level of environmental awareness unequal to any other period in history. The U.S. Environmental Protection Agency (EPA) was created in 1970 by Congress to implement laws passed to protect the environment and the health of humans and other animals. In 1972, EPA banned the use of DDT in the United States. Regulatory action has since been taken against many chemicals thought to pose significant environmental and health hazards.



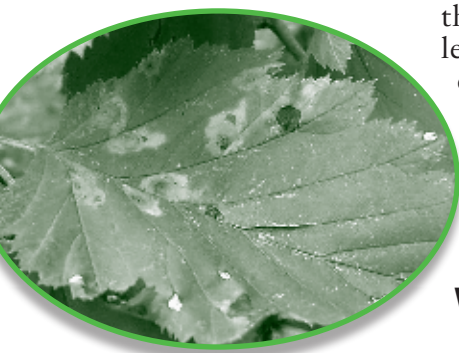
Weed pest:
Canada thistle flowers.

Kristine Schaefer, Iowa State University Extension & Outreach



Invertebrate pest:
Paper wasp.

David Cappaert, Michigan State University, Bugwood.org



Disease pathogen:
Hawthorne rust.

Iowa State University Plant & Insect Disease Clinic

PEST RECOGNITION

There are four main groups of pest organisms: weeds, invertebrate animals, pathogens, and vertebrate animals. Never classify an organism as a pest until it is clearly determined to be one. Be certain any injury or observed damage is actually due to the identified organism and not to some other cause. Some plants, for example, can be damaged by factors in the environment. These factors include weather extremes, air pollutants, road salt, and inadequate or excessive fertilization. This damage may be mistaken for that caused by living pests.

The first step in pest management is to accurately identify the pest. Once the pest is identified, applicators can learn about its life cycle, behavior, characteristic damage, factors that favor its development, susceptible life stage(s), and known control methods. Misidentification and lack of accurate information could cause pest control failure.

Ways to Identify Pests

To identify an organism, consult reference materials: identification books, Extension bulletins, field guides, and online identification keys that contain pictures and biological information. If

you cannot pinpoint a specific plant or animal, take or send the specimen to a university diagnostic lab or a local pest management specialist. Collect several specimens, if possible. Ask the specialist to recommend the best way to collect and send samples.

It may be difficult to identify small insects and most mites, nematodes, and plant pathogens. Accurate identification requires the use of a hand lens or microscope, special tests, or careful damage

THE FOUR MAIN GROUPS OF PESTS

1. Weeds (undesirable plants).
2. Invertebrates (insects, mites, ticks, spiders, snails, and slugs).
3. Disease agents or pathogens (bacteria, viruses, fungi, nematodes [roundworms], mycoplasmas [parasitic microorganisms], and other microorganisms).
4. Vertebrates (birds, reptiles, amphibians, fish, and rodents and other mammals).

analysis. Often the pest's host (the animal or plant on which an organism lives) and location are important clues in making a correct identification. Information on the environmental conditions where you collect pests and the time of year of collection provide clues to the pest's identity.

Pest species have different physical forms depending on the life cycle stage or the time of year. Weed seedlings, for example, often do not resemble the mature plant. Many insect species undergo changes in appearance as they develop from eggs through immature stages to the adult form.

Characteristic Damage

Pests may leave signs of their presence or damage that will help you determine what they are. Birds and rodents often build characteristic nests. The type of feeding damage and excrement can help you identify many insects. Burrows, gnaw marks, tracks, trails in the grass, and/or feces are often characteristic of certain mammals. Weeds may have unique flowers, seeds, or fruits or unusual growth habits. Fungi and other pathogens often cause specific types of damage, deformation, or color changes in host tissues.



Lee Kamey, USFWS,
Bugwood.org

Vertebrate pest:
Rock dove.

PEST MANAGEMENT METHODS

Once a pest problem is identified, you can begin planning how to manage the pest. Determine what management methods are available and the benefits and limitations of each. Select methods that are most effective in controlling the pest yet the least harmful to people and the environment.

Abiotic factors are natural control measures within the environment that injure or destroy plants and animals, including pests. They include climatic factors (e.g., wind, temperature, sunshine, and rain), air or water pollution, and topographic features (rivers, lakes,

and mountains) that can affect pest movement. If such natural controls do not hold pests in check, humans must intervene and apply pest management tactics. Applied controls include biological, chemical, cultural, genetic, mechanical/physical, and regulatory methods.

Biological Control

In an undisturbed ecosystem, most organisms have one or more natural enemies or competitors that keep them from developing into large, damaging populations. When an organism is removed from one ecosystem to another, this natural check-and-balance is disturbed. The organism can become a pest in the new geographical area, especially when its natural enemies do not accompany it to the new location.

One pest management method involves reuniting the introduced pest with its natural enemies. **Biological control** is the use of natural enemies—predators, parasites, pathogens, and competitors—to control pests and their damage. These biological control (biocontrol) agents are being used successfully to manage certain insect, mite, fungal, fish, and weed pests.

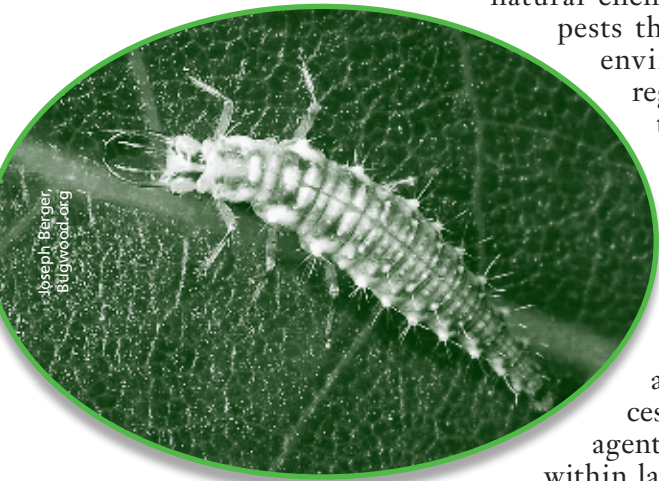
Once suitable natural enemies from the native home of an introduced pest are located, extensive testing and evaluation are necessary to ensure that these

PEST MANAGEMENT METHODS

Natural Controls

Applied Controls

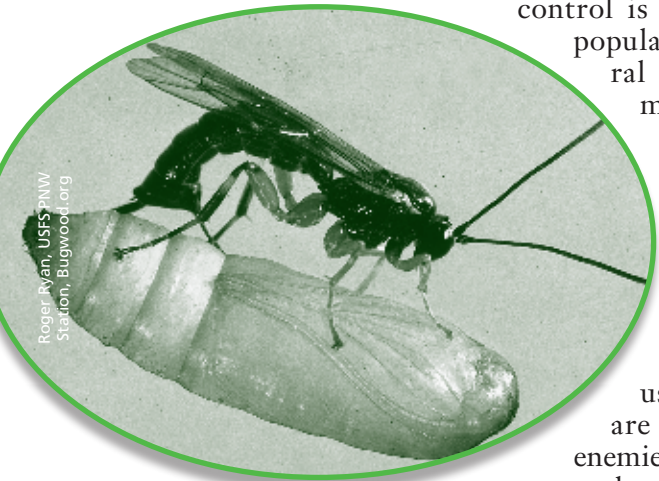
1. Biological Control
2. Chemical control
3. Cultural Control
4. Genetic control
5. Mechanical/Physical Control
6. Regulatory Control



Joseph Berger, Bugwood.org
*Biological control:
 Lacewing larva.*

natural enemies will not become pests themselves in the new environment. Laws and regulations strictly control the importation of all organisms—including biological control agents—into the United States. The selected natural enemies are imported, reared, and released. If successful, these biocontrol agents become established within large areas. Over time, they will lower target pest populations for long periods with no further human intervention.

A second biological control technique is the mass release of large numbers of natural enemies into fields, orchards, greenhouses, or other locations to control specific pests. Because this method usually does not yield long-term results, the natural enemies must be released periodically. For example, predatory mites are used to control plant-feeding spider mites. Parasitic wasps are used to manage specific pests, while praying mantids, lady beetles, and lacewings are used as general predators in a garden or greenhouse. Nematodes and fungi are being studied as biological control agents for certain weeds and insects.



Roger Ryan, USFS PNW Station, Bugwood.org
*Biological control:
 Ichneumonid wasp.*

Another aspect of biological control is to maintain healthy populations of native natural enemies. This could mean planting crops or groundcovers to ensure a diverse plant community of pollen and nectar sources for adult insects. This method also requires careful selection and use of pesticides that are less toxic to natural enemies. Additionally, applicators should apply pesticides at lower-than-label rates (if recommended and effective) to lessen the impact on natural enemies.

Chemical Control

Chemical control is the pest management method that involves using naturally derived and/or synthetic chemicals to manage pests. These chemicals are often called pesticides. A **pesticide** is defined as any material that is applied to plants, soil, water, harvested crops, structures, clothing and furnishings, or animals to kill, attract, repel, or regulate or interrupt the growth and mating of pests, or to regulate plant growth.



Keith Weiler, USDA ARS, Bugwood.org
Chemical control.

Pesticides often play a key role in pest management programs and may often be the only known control method for a given pest. Major benefits associated with the use of pesticides are their effectiveness, the speed and ease of controlling pests, and their reasonable cost compared with other control options. Pesticides include a wide assortment of chemicals with specialized names and functions. They are often grouped according to the type of pest they control:

- **Avicides** control or repel pest birds.
- **Bactericides** control bacteria.
- **Chemosterilants** sterilize insects or pest vertebrates.
- **Defoliants** cause leaves (foliage) to drop from plants.
- **Desiccants** promote drying or loss of moisture from plant tissues and insects.
- **Disinfectants** (antimicrobials) control microorganisms.

- **Fungicides** control fungi.
- **Growth regulators** alter the growth or development of a plant or animal.
- **Herbicides** control weeds.
- **Insecticides** control insects and related arthropods.
- **Miticides** (acaricides) control mites.
- **Molluscicides** control snails and slugs.
- **Nematicides** control nematodes (roundworms).
- **Ovicides** destroy eggs.
- **Pheromones** attract insects.
- **Piscicides** control pest fish.
- **Predacides** control predatory vertebrates (e.g., coyotes).
- **Repellents** repel insects, mites, ticks, pest vertebrates, invertebrates, birds, and mammals.
- **Rodenticides** control rodents.

Each group of pesticides includes several classes or families. For example, the classes of insecticides include the organophosphates, organochlorines, carbamates, pyrethroids, botanicals, insecticidal soaps, and microbials, among others. The pesticides within a particular class have similar chemical structures or properties or share a common **mode of action** (how they kill the pest) or **site of action** (the specific biological system affected within the pest). The various classes of chemicals work in different ways and present different risks and problems.

Some chemicals are called **selective pesticides** because they are toxic to some pests but have little or no effect on others. For example, certain selective herbicides control broadleaf weeds but not grasses, and ovicides kill only the eggs of certain insects and mites. In contrast, fumigants are nonselective and will kill a wide variety of pests: fungi, insects, weeds, nematodes, and other organisms. Nonselective herbicides control any susceptible plant, given a sufficient dose.

Pesticides may move in various ways after they contact a host. **Systemic pesticides** are absorbed and translocated within a plant or animal. Systemic herbicides are absorbed through leaves or roots and are then transported within the treated plant. Similarly, systemic insecticides can be eaten by or injected into livestock to control insect pests. By contrast, **contact pesticides** are not absorbed by treated plants or animals. These pesticides must directly touch the pest or a site the pest frequents to be effective (see Figure 1.2).

Pesticides also vary in their **persistence**, or how long they remain active to control pests. Some **residual pesticides** control pests for weeks, months, or even years. Others provide only short-term control, sometimes lasting only a few hours.

Cultural Control

Cultural controls are practices that reduce pest establishment, reproduction, dispersal, and survival. Cultural practices and sanitation are two examples of cultural control.

Many cultural practices affect pest survival. Mowing, irrigation, aeration, and fertilization are all important ways of producing healthy turf and preventing pest buildup and damage. In agricultural production, cultivation, selection of crop plant varieties, timing of planting and harvesting, irrigation management and timing, crop rotation, and the use of trap crops help decrease populations of weeds, microorganisms, insects, mites, and other pests. Cultivation is one of the most important ways to control weeds. It is also used to manage some insects and other soil-inhabiting pests. Plows, disks, mowers, cultivators, and bed conditioners destroy weeds or

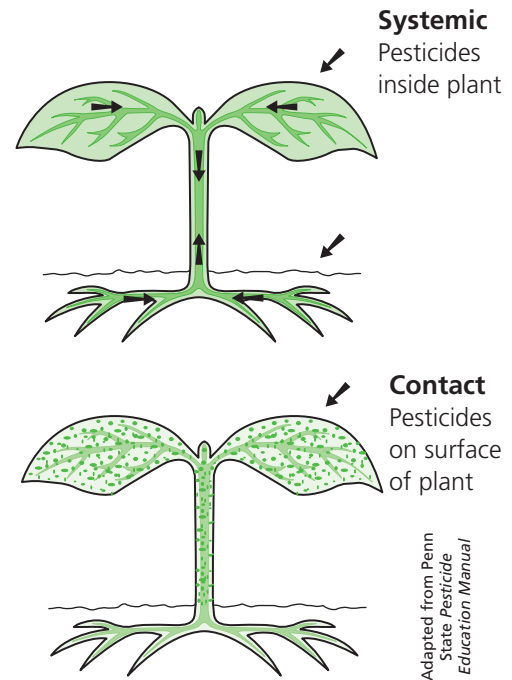
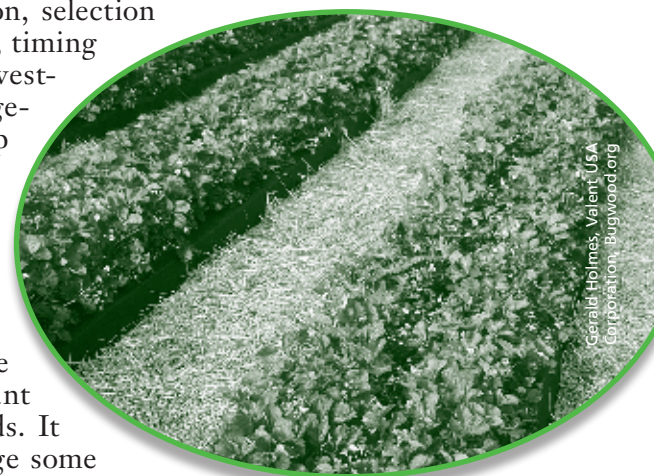


Figure 1.2
Systemic and contact pesticides on treated plants.



Cultural control: Mulch.

control their growth. These tools also disrupt soil conditions suitable for the survival of some microorganisms and insects. Weeds also can be managed by mulching (with plastic, straw, shredded bark, or wood chips) and by using cover crops.

Sanitation involves eliminating the necessities important to a pest's survival, such as food, water or shelter. In crop production, sanitation includes such practices as removing weeds that harbor pest insects or rodents, eliminating weed plants before they produce seed, destroying diseased plant material or crop residues, and keeping field borders or surrounding areas free of pests and pest breeding sites.

Animal manure management is an effective sanitation practice used to prevent or reduce fly problems in poultry and livestock operations. Mosquitoes can be controlled by draining standing water. Closed garbage containers and frequent garbage pickup eliminate food sources for flies, cockroaches, wasps, and rodents.

Removing soil, trash, and wood debris from around and under buildings reduces termite and fungal rot damage.

Genetic Control

Sometimes plants and animals can be bred or selected to resist specific pest problems. For example, certain livestock breeds are selected for physical characteristics that prevent attack by some pests or provide physiological resistance to disease or parasitic organisms. Certain plant varieties are naturally resistant to insects, pathogens, or nematodes. Many plants actually repel various types of pests, and some contain toxic substances. Plant resistance to insect pests can sometimes be achieved by transferring genetic material from certain insect-destroying microorganisms to hybrid seed. Genetic control has been widely used in the past and may be an effective tool in the future, especially when combined with new

gene manipulation techniques. *Bacillus thuringiensis* (Bt) corn and potatoes and herbicide-resistant corn (e.g., Roundup Ready corn and Liberty Link corn), cotton (e.g., Roundup Ready cotton), and soybean (e.g., Roundup Ready soybean) are examples of genetic control. The plant is genetically modified through molecular techniques to add a small amount of genetic material from other organisms. The incorporated genetic traits provide protection from pests (e.g., Bt crops produce a protein that kills caterpillars), tolerance to herbicides, or an improvement in quality.

Mechanical/Physical Control

Mechanical and physical controls can kill a pest directly or make its environment unsuitable. Rodent traps are examples of mechanical control. Several types of traps are commonly used. Some kill animals that come across them; others snare animals that are then relocated or destroyed. Traps can be mechanical devices or sticky surfaces, some with pheromones incorporated to increase trapping efficiency.

Physical controls include mulches for weed management, steam soil sterilization for disease control, deer fences, screens to keep insects out, and cloth mesh to exclude birds from fruit trees. Another example is sealing cracks, crevices, and other small openings in buildings to exclude insects, rodents, bats, birds, and squirrels. A band of sticky material painted around tree trunks prevents crawling insects from reaching the tree's leaves.

Pests living in enclosed areas may sometimes be suppressed by altering



Sanitation: Aquatic herbicide application.



Mechanical control: Sticky trap.

physical and environmental conditions, such as water, air movement, temperature, light, and humidity. Refrigeration, for example, protects stored food products, furs, and other items from insect pests. Lowered temperatures kill the insects, cause them to stop feeding, and prevent egg hatch or development. Installing bright lights in attics sometimes discourages bats from roosting there. Lowering the humidity of stored grains and other food products reduces damage from molds and some insects. Increasing air movement in greenhouses often helps to prevent fungal diseases from developing on plants.

Regulatory Control

Some pest problems cannot be controlled successfully at a local level or by individuals. These problems are caused by pests that seriously endanger public health or are likely to cause widespread damage to agricultural crops or animals, forests, or ornamental plants. Quarantine or eradication programs directed by governmental agencies according to federal and state laws target the introduction and spread of such pests.

Quarantine is a pest control process designed to prevent entry of certain pests into pest-free areas. Some states maintain inspection stations at all major entry points to intercept pests or materials that might harbor pests. Regulatory agencies monitor airports and ocean ports. Quarantine also prevents movement of designated pests within a state. Identified items being shipped from a quarantine area must be treated to destroy pests before shipment. Nursery stock, plant cuttings, seed shipments, and budding and grafting material are also regulated to prevent the spread of pests.

Eradication is the elimination of a pest from a designated area. Often, these pests are under quarantine restrictions. When eradication is required, the geographical extent of pest infestation is determined and control measures are taken to eliminate this pest from the defined area. Procedures may include an area-wide spraying program, releasing sterile insects, and intensive monitoring for pests within and around the borders of the infested area.

Government agencies are authorized to destroy weeds and plants that cause fire hazards, harbor harmful pathogens or animals, or are noxious to people or livestock in and around agricultural areas. Similar authority applies to diseased or infected livestock or poultry and to weeds and nuisance plants in residential, commercial, and industrial areas. Mosquito abatement is an important pest control function undertaken to protect public health. Mosquito abatement laws allow state agencies to drain or treat standing water that provides breeding sites for mosquitoes.



Regulatory control: USDA inspections.

USDA APHIS

INTEGRATED PEST MANAGEMENT (IPM)

Pesticide use is a significant factor in food and fiber production, forestry, turf and landscape maintenance, and public health. In recent years, pest management has shifted from

relying heavily on pesticides to using an integrated approach based on pest assessment, decision-making, and evaluation. This pest management approach has benefited pest managers and the

environment, decreased pesticide use, and reduced the occurrence of pesticide resistance in pest populations.

Integrated pest management is a balanced, tactical approach to pest control. It defines ways to anticipate pest outbreaks and prevent pest damage. IPM is a pest management strategy that uses a wide range of pest control methods (e.g., cultural, biological, mechanical, and chemical) or tactics such as sanitation and exclusion. The goal of this strategy is to prevent pests from reaching damaging levels with the least risk to the environment. Such pest management programs enable the specialist to make intelligent, site-specific decisions about control.

INTEGRATED PEST MANAGEMENT (IPM)

A pest management strategy that utilizes a wide range of pest control methods or tactics. The goal of this strategy is to prevent pests from reaching economically or aesthetically damaging levels with the least risk to the environment.

Why Practice IPM?

IPM helps preserve a balanced ecosystem—Every ecosystem, made up of living things and their nonliving environment, has a balance: the actions of one kind of organism usually affect other species. Introducing chemicals into the ecosystem can change this balance, destroying certain species and allowing other species (sometimes other pests) to dominate. Unfortunately, pesticides can kill beneficial insects that consume pests, leaving few natural pest control mechanisms.

Pesticides can be ineffective—Chemical pesticides do not always work. As mentioned earlier, many common weeds, insects, and disease-causing fungi have developed a resistance to pesticides. Furthermore, pests may survive if the chemical does not reach them, is washed off, or is applied improperly.

IPM can save money—A good IPM program can prevent crop loss and landscape or structural damage caused by pests. IPM may also avoid the cost of purchasing unnecessary pesticides. Moreover, IPM can reduce the costs of treating chronic conditions such as asthma by controlling disease triggers.

IPM promotes a healthy environment—Using IPM strategies helps reduce environmental injury. Using fewer pesticides lowers the risk that persistent chemicals may harm living creatures and contaminate groundwater. It also lessens the need to dispose of containers and unused pesticides.

IPM helps maintain a good public image—IPM is a well-known strategy that is requested in many areas of society. IPM is used to grow food, manage turf and ornamentals, protect homes and businesses, manage school grounds, and safeguard the health of humans, pets, and livestock.

WHY PRACTICE IPM?

1. IPM helps to keep a balanced ecosystem.
2. Pesticides can be ineffective.
3. IPM can save money.
4. IPM promotes a healthy environment.
5. IPM maintains a good public image.

Components of IPM

The components of an IPM approach can be grouped into the following five steps:

1. Identify the pest and understand its biology—The first step in any pest management program is to identify the pest, whether you are dealing with an insect, weed, plant disease, or vertebrate animal.

Once you have identified the pest, you can determine its significance and the need for control. Some pests have

little impact on a plant, animal, or structure and do not require control. Others warrant immediate control because they cause serious damage or present a significant threat to human health or public safety.

Key pests may cause major damage on a regular basis unless they are controlled. Many weeds, for example, are key pests because they compete with crop or ornamental plants for resources and require regular control efforts to prevent or reduce damage. Cockroaches and rodents are also examples of key pests because their waste and body coverings (shed cockroach skins; rodent hairs) can trigger asthma in some people.

Secondary pests become a problem when a key pest is controlled or absent. For example, some weed species become pests only after key weeds, which are normally more successful in competing for resources, are controlled. Certain species of fleas, ticks, and blood-feeding bugs attack people only when their natural hosts, such as pet dogs or cats, are no longer present.

Occasional pests become troublesome only once in a while because of their life cycles, environmental influences, or as a result of human activities. For instance, ants may become occasional pests when sanitation practices change, providing them with food that previously did not exist. They also may move into buildings after a rainfall or other event destroys an outdoor food source.

2. Monitor the target pest—The key to a successful IPM program is regular monitoring. This involves measuring pest populations and/or the resulting damage or losses. Monitoring procedures vary with the pest and the situation.

Carefully looking at plants or animals over time (scouting) and trapping are often used to monitor insects and their activity. Weather and temperature data are particularly helpful in following a pest's life cycle or in predicting how long it takes a certain pest to develop. Models exist for specific insects and plant diseases that predict the need for and timing of pesticide applications.

Pest Population Thresholds

Agricultural or ornamental producers must understand the concept of economic thresholds. The presence of a pest does not always cause a loss in quality or quantity of a product. To justify the cost of control, pest populations must be large enough to cause significant damage. This is called the **economic threshold (ET)**. The economic threshold is the pest population density (number of pests per unit area) at which control measures are needed to prevent the pest from reaching the economic injury level. The **economic injury level (EIL)** is the pest population density that causes losses equal to the cost of control measures. To justify using a control method, it is necessary to set the ET below the EIL (see Figure 1.3). Otherwise, producers lose money—first from the damage caused by the pest, and then by the cost of the control method. Setting the ET below the EIL triggers the appropriate control method before pests reach the EIL.

For pest managers not directly involved in commodity production, the concept of an action threshold is more appropriate. An action threshold is the pest level at which some type of pest management action must be taken. This is a predetermined pest level that is deemed to be unacceptable. Often the action threshold is expressed as the number of pests per unit area. Below this level, IPM practitioners do not use any control measures, though they should continue to monitor the situation and do sanitation inspections as needed. Once a pest is at or above the action threshold, you should implement appropriate IPM strategies.

In some situations, the action threshold for a pest may be zero (i.e., no presence of the pest is tolerated). Examples include pests capable of transmitting a human pathogen (e.g., mosquitoes and the West Nile virus) or of creating a public health emergency (e.g., cockroaches or rodents). In an urban



Inspecting a plant for pests.

COMPONENTS OF IPM

1. Identify the pest and understand its biology.
2. Monitor the pest to be managed.
3. Develop the pest management goal.
4. Implement the IPM program.
5. Record and evaluate results.

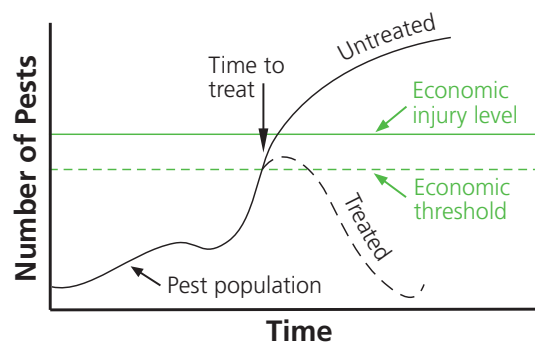


Figure 1.3
To make a control measure profitable (or at least break even), it is necessary to set the economic threshold below the economic injury level.

landscape, action thresholds consider not only the economic value of the landscape but also its ecological and aesthetic roles. A higher action threshold would be set for insect damage when no harm is done to the plant (e.g., leaf galls on a shade tree) compared to a wood-borer that may destroy the tree (action threshold of zero).

Action thresholds may vary by pest (e.g., a stinging insect in a classroom vs. a foraging ant), by site (e.g., a storage room vs. a school infirmary), and by season (e.g., pests present daily vs. two weeks of a year). Establishing action thresholds for a new IPM program will require a practical approach. First, establish an arbitrary action threshold for the major pests you encounter. Then, revise the action levels up or down as you gain understanding of a specific pest management setting.

3. Develop the pest management goal—The goal of IPM programs is to keep pest damage at economically or aesthetically acceptable levels. Prevention and suppression techniques are often combined in an effective IPM program. As discussed above, eradication is sometimes (though rarely) the goal. The strategy for a sound IPM program is to coordinate the use of multiple tactics into a single integrated system. Pesticides are just one control method. Nonchemical methods may provide longer and more permanent pest control. Consider these first when developing a pest management strategy. Evaluate the costs, benefits, and liabilities of each tactic.

Prevention

There are economically and environmentally sound ways to prevent loss or damage from pests. Such techniques include planting weed- and disease-free seed and growing varieties of plants resistant to diseases or insects. Other choices are using cultural controls to prevent weedy plants from seeding and choosing planting and harvesting times that lessen pest problems. Sanitation methods often reduce pest buildup. Other preventive methods involve excluding pests from the target area or host and using practices

that conserve natural enemies. Making sure that plants, poultry, or livestock receive adequate water and nutrients often reduces stress and susceptibility to diseases or pests.

Pesticides are sometimes used for pest prevention. For instance, growers treat some crops and landscapes with **preplant or preemergence herbicides** because they know that weed seeds are present. If plant pathogens have already infected susceptible plants, economic damage usually cannot be prevented. For this reason, fungicides are normally applied before infection occurs whenever environmental conditions favor infection. Likewise, pesticides may be applied to structural lumber before construction to protect it from wood-destroying insects and fungi.

Suppression

Suppressive pest control methods aim to reduce pest population levels. These methods usually do not eliminate all pests but reduce their populations to a tolerable level or to a point below the EIL. Suppression sometimes lowers pest populations so that natural enemies can maintain control. Suppression is the goal of most pesticide applications. Other techniques, such as cultivation, mowing weeds, and releasing biological control agents, are also used to suppress pest populations.

Eradication

Eradication efforts are effective in buildings or other small, confined spaces where, once the pest is eliminated, it can be excluded. For example, eliminating cockroaches, rats, and mice from commercial food establishments requires eradication. Over larger areas, however, eradication is very expensive and often has limited success. Regulatory eradication programs are usually directed at exotic or introduced pests posing an area-wide public health or economic threat.

4. Implement the integrated pest management program—Once you have selected appropriate methods and have set predetermined thresholds, you can initiate the IPM program. IPM



programs are specific to each situation and can be adjusted as you learn more about the pest and the site. Observe all local, state, and federal regulations regarding the methods chosen.

5. Record and evaluate results—It is extremely important to record and evaluate the results of each pest management effort. Some control methods, especially nonchemical ones, are slow to yield measurable results. Other methods may be ineffective or even damage the target crop, animal, treated surface, or natural enemy. Objectively evaluate how well your strategies work so that you will be better prepared if you must control a specific pest again.

EFFECTIVENESS OF PEST MANAGEMENT PROGRAMS

As noted earlier, pesticides represent only one tool in the IPM toolbox. When combined with other control methods, they can help create an effective treatment plan to reduce pest populations. However, pesticides might not control the pests as expected. A good pest manager needs to find out why.

Why Pesticide Applications Fail

Pest identification—Sometimes a pesticide application fails because the pest was not identified correctly. Being able to accurately identify pests requires patience and practice. For example, knowing the difference between a caterpillar and a sawfly will result in success (control) or failure when using *Bacillus thuringiensis*. Bt is effective on caterpillars but not on sawflies. Even nonchemical tactics may fail if the pest and susceptible life stages are not accurately identified.

Dosage—Make sure that you have applied the correct pesticide at the correct dosage, according to label instructions.

Correct use—Some herbicides are formulated to kill grasses, others for broadleaf weeds, and still others can kill both types of weeds. Always read the pesticide label to see if the target pest is listed.

Application timing—Other applications fail because the pesticide was not applied at the correct time. The pest may not have been in the area during the application, or it may have been in a life cycle stage where it was not susceptible to the pesticide. Insects are usually more vulnerable when they are immature, and weeds are most easily controlled before they flower and go to seed. Also, remember that current pests may be part of a new infestation that developed long after the chemical was applied.

Application equipment—Concealed pests (under leaves or bark, in the soil, or within stems or fruits) are difficult to reach. This means that knowing the best type of application equipment to use is very important. For example, use an air-blast sprayer for pests hiding under apple tree leaves but a granular applicator during planting operations for soil-dwelling agronomic pests.

Environmental conditions—In general, do not apply pesticides just before a rainstorm. The pesticide may be washed off the target plants and away from the application site. Temperature extremes and windy conditions can move pesticides away from the target pests and site.

Pesticide degradation—Pesticides may degrade when stored. Under some

conditions, pesticides can change into a form that is ineffective. This might be due to the age of the product or the pesticide storage conditions. For example, granular pesticides stored in wet or very humid conditions will draw moisture. This may cause clumping and possible deactivation of the pesticide.

Pesticide Resistance

Pesticide resistance is the ability of a pest to tolerate a pesticide that once controlled it. Resistance develops when intensive pesticide use kills the susceptible individuals in a population but leaves the resistant ones to reproduce. Initially, higher labeled rates and more frequent applications are needed to control resistant pests. Eventually the pesticide will have little or no effect on the pest population as the resistant population grows (see Figure 1.4).

Resistance may develop to a single insecticide, fungicide, herbicide, or rodenticide. More often, however, pest populations become resistant to chemically related pesticides in a class of compounds. It is also possible for a pest to develop resistance to pesticides in two or more classes of compounds with different modes of action.

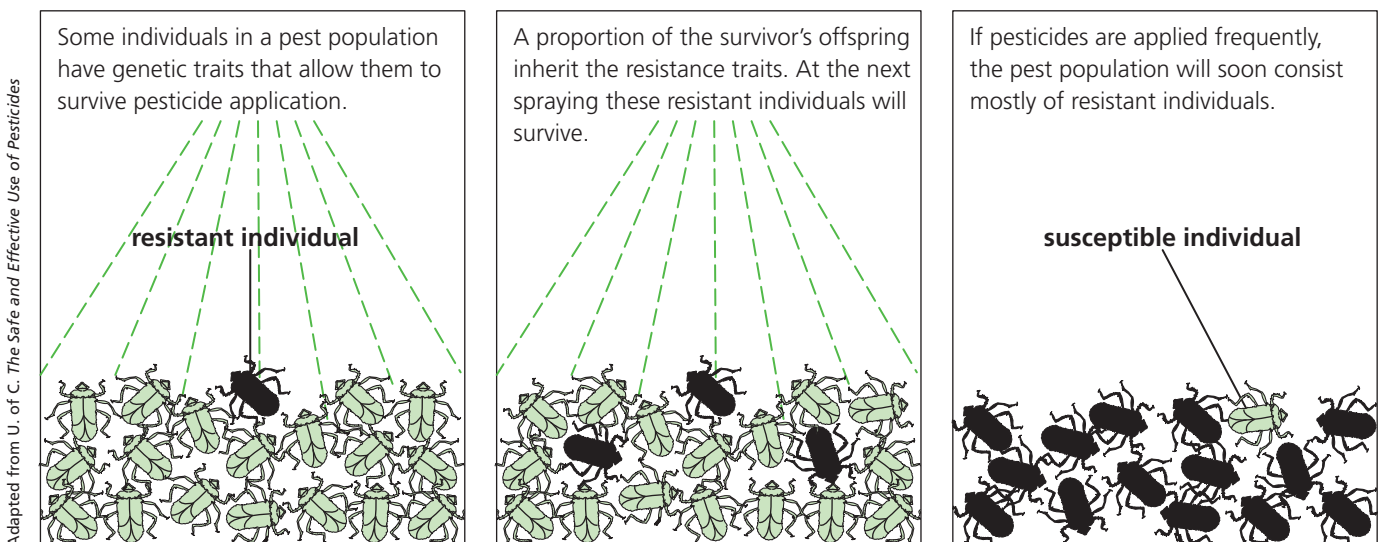
Continual use of pesticides from the same chemical class, such as all growth regulator herbicides or all pyrethroid insecticides, increases the likelihood that resistance will develop in

a pest population. Frequent applications and greater persistence of the chemical further increase the chances of pesticide resistance. Finally, resistance can spread through a pest population much more rapidly in pests that have many generations per year and many offspring per generation, such as many insects, mites, fungi, and rodents.

Several pest management tactics help prevent or delay the occurrence of pesticide resistance. One approach is the use of new or altered pesticides. Using new compounds with different modes of action will lessen the likelihood of resistance developing in a population. Most pesticides have a code number at the top of the label indicating the mode of action (e.g., Group 4A Insecticides—Neonicotinoids, or Group 2 Herbicides—ALS Inhibitors). Unfortunately, new replacement products are often quite complex, difficult to synthesize, and very costly to develop. Moreover, they have very specific modes of action, which can rapidly lead to the development of resistant pest populations even after limited use in the field. No longer can we expect to respond to pesticide resistance by merely substituting one pesticide for another.

Changing pesticide use patterns is an important step in preventing resistance. When dosages are reduced, fewer pests are killed, so the pressure to develop resistant pest populations

Figure 1.4 Pesticide resistance



Adapted from U. of C. *The Safe and Effective Use of Pesticides*

is decreased. Applying pesticides over limited areas reduces the proportion of the total pest population exposed to the chemical. The result is a large pool of individuals still susceptible to the pesticide. This tactic tends to delay the development of a resistant population because pesticide-susceptible individuals continue to interbreed with resistant ones, thus diluting the resistance in the population. Also, treating alternate generations of pests with pesticides that have different modes of action decreases the selection pressure for resistance.

Managing pesticide resistance is a critical aspect of integrated pest management. Monitor pest populations carefully and treat only when necessary instead of on a schedule. Good pesticide application records are another important part of resistance management. Pesticides are more effectively managed when treatment history is known. Resistance must be detected when it is at a very low level. It should then be controlled by using all available pest management techniques to extend the useful life of our current pesticides.

SUMMARY

A successful pest management program begins with the proper identification of the pest. Choosing the appropriate pest control method depends on recognizing and understanding the pest, its life cycle, habits, and habitat. Integrated pest management programs attempt to balance the need for pest control with the desire to protect the environment from pesticide contamination.

Monitoring is critical to knowing where pests are located, when to act against growing pest populations, and what type of control measures to use. Evaluation and recording results help to determine how well the IPM program is working and whether there are any harmful human or environmental effects.

Minimizing pesticide resistance is critical for sustaining the effectiveness of pest management programs. Using a variety of tools and techniques will help prevent or delay the occurrence of pesticide resistance.

If the pest has not been properly identified, even nonchemical control tactics will fail. It is your responsibility to consider the effects of pest control actions on the entire treatment site, whether an outdoor area or inside a structure. Use good judgment—especially when pesticides are part of the control strategy—to avoid harmful effects to other living organisms and the environment.



Review Questions

CHAPTER 1: PEST MANAGEMENT

Write the answers to the following questions, and then check your answers with those in Appendix A.

- Using barriers to prevent pests from getting into an area is an example of which type of pest management method?**
 - Biological.
 - Mechanical.
 - Genetic.
- Making use of plant varieties that are naturally resistant to insect feeding is an example of which type of pest management method?**
 - Biological.
 - Genetic.
 - Regulatory.
- Which statement about biological control methods is *true*?**
 - Modifying the environment to enhance natural enemies is recommended in biological control.
 - Biological control involves importing exotic pests to control natural enemies.
 - Using several cultural practices and a wide variety of pesticides works best in biological control.
- Sealing cracks and crevices and small openings in buildings is an example of which type of pest management method?**
 - Physical.
 - Genetic.
 - Biological.
- Which statement about cultural control practices is *true*?**
 - They reduce pest establishment, reproduction, and survival.
 - They use naturally derived and/or synthesized chemicals to control pests.
 - They involve the release of parasites and predators found in foreign countries.
- Monitoring pests at airports and ocean ports that pose a serious threat to public health or widespread damage to crops or animals is an example of which type of pest management method?**
 - Regulatory.
 - Genetic.
 - Biological.
- Which statement about pest management strategies in IPM is *true*?**
 - The goal is to prevent pests from reaching damaging levels.
 - Eradication is never the goal of an IPM program.
 - Nonchemical methods are short-term solutions to control pests.
- Which would be considered a preventive pest management strategy?**
 - Planting weed- and disease-free seed on an athletic field.
 - Releasing natural enemies to help reduce pest populations.
 - Removing a pest that is a public health concern from an area.

continued ►

9. Which statement about action thresholds is *true*?
- A. The IPM technician needs to implement control measures below the action threshold level.
 - B. The action threshold for a pest may be set at a zero pest population density.
 - C. In an urban landscape, action thresholds are usually more related to economics than aesthetics.
10. Which would increase the likelihood of pesticide resistance?
- A. An insect that has one generation per year.
 - B. Continual use of pesticides from the same chemical class.
 - C. Applying a pesticide that has little or no residual effect.