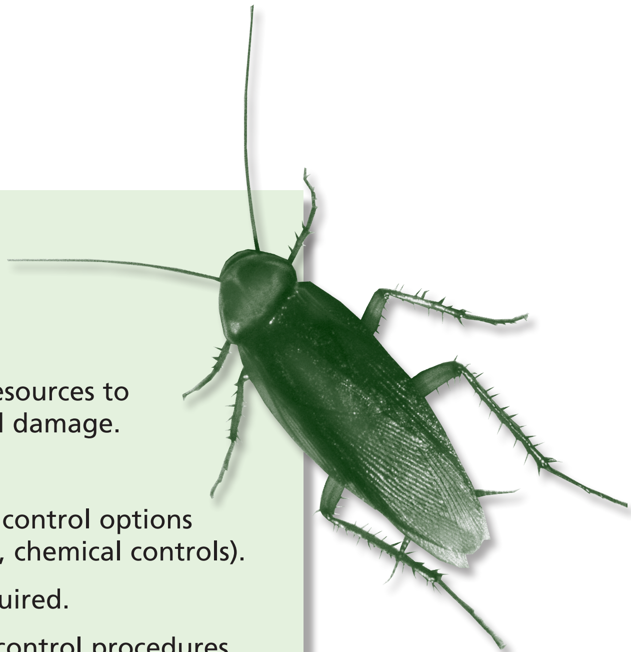
CHAPTER 1

Pest Management



LEARNING OBJECTIVES

After studying this chapter, you should:

- Know the main groups of common pests.
- Know how to use pest control references and resources to help identify pests and recognize symptoms and damage.
- Understand various pest control procedures.
- Understand integrated pest management (IPM) control options (e.g., biological, cultural, mechanical, sanitation, chemical controls).
- Understand when preventive pest control is required.
- Understand how pest population levels trigger control procedures.
- Anticipate effects on pest, hosts, and natural enemies of relevant environmental variables that influence pest populations (e.g., weather, geographic barriers, cultural practices, nutrient supply).
- Understand probable causes of non-effective pest control (e.g., incorrect pest identification, incorrect dosage, incorrect application timing, incorrect pesticide product).
- Know how to plan pest control strategies that minimize the development of pesticide resistance (e.g., rotation of pesticide types with different modes of action, application of pesticides that do not leave persistent residues, application of pesticides at below-label amounts).

Civilization has been combating insects and other pests throughout history. Records contain many examples of how pests have had major impacts on humans. Probably the most infamous was the Black Plague of Europe, when millions of people died in the 14th century from a mysterious scourge. Only centuries later was it determined that a bacterial disease spread by rat fleas was the cause. Rat fleas became infected with bacteria while feeding on diseased rats. When rats were unavailable as a food source, the fleas sought other warm-blooded hosts, often humans. Today this disease, known as bubonic plague, can be treated if properly diagnosed. Controlling rats and other rodents and fleas can reduce disease incidence.

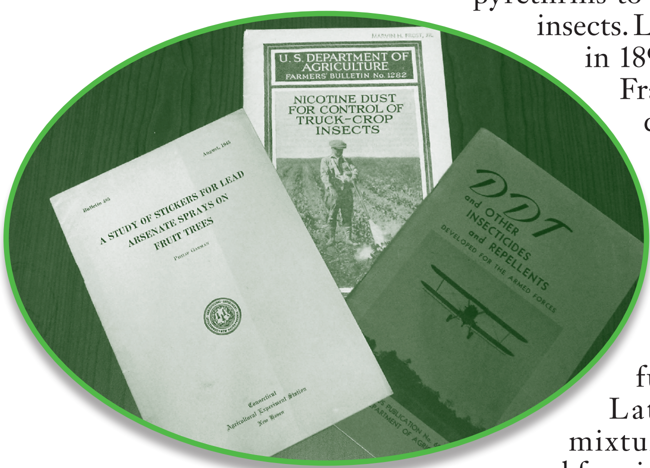
One historical occurrence that directly influenced the population of the United States was the destruction

Above lady beetle photo: Marlin E. Rice, Ph.D., Iowa State University of Ireland’s potato crop by a pest in the 19th century. A fungal disease called late blight essentially eliminated potatoes, the staple food crop. 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.

The above examples illustrate the potential enormity and complexity of pest problems. But what is a pest? Webster's Dictionary defines a pest as “any destructive or troublesome insect, small animal, weed, etc.” Many insects, **pathogens** (disease-causing organisms), weeds, mollusks (slugs and snails), fish, birds, and a variety of mammals, from rats to deer, are competitors for our livestock and crops. In addition, some pests destroy buildings and other structures and reduce the aesthetic and recreational value of the landscape. The competition between humans and pests has evolved over time, and so have the methods of control.

PEST CONTROL OVER THE YEARS

Mystery surrounded the causes of crop failures and human and animal diseases for many centuries. The first pest control measures were crude—weeds were pulled, rats were clubbed, and beetles were plucked from foliage. The earliest use of chemicals as pesticides dates back to 2500 B.C., when sulfur was burned to control insects and mites. Through the years, experimentation and good fortune led to the recognition of additional chemicals with pesticidal activity. Early plant-derived insecticides included hellebore to control body lice, nicotine to control aphids, and pyrethrins to control a wide variety of insects. Lead arsenate was first used in 1892 as an orchard spray. In France during the late 19th century, a mixture of lime and copper sulfate was sprayed on grapevines to deter passers-by from picking the grapes. The farmer found the mixture also controlled downy mildew, a serious fungal disease of grapes. Later named Bordeaux mixture, it remains a widely used fungicide worldwide.



C. Randall, MSU

Early agricultural bulletins on pesticide application.

Until the 1940s, pest control chemicals were derived from plants and inorganic compounds. During World War II, DDT, a synthetic chemical, played a very important role, saving Allied soldiers from insect-transmitted diseases. DDT was hailed as the insecticide to solve all insect problems. The introduction of countless other synthetic organic pesticides followed. These synthetic products launched the modern-day chemical industry and began a new era in pest control. Given significant success at a relatively low cost, pesticides became the primary means of pest control. They provided season-long crop protection against pests and complemented the benefits of fertilizers and other production practices. The success of modern pesticides, particularly in agriculture and human health, encouraged widespread acceptance and eventual reliance on them.

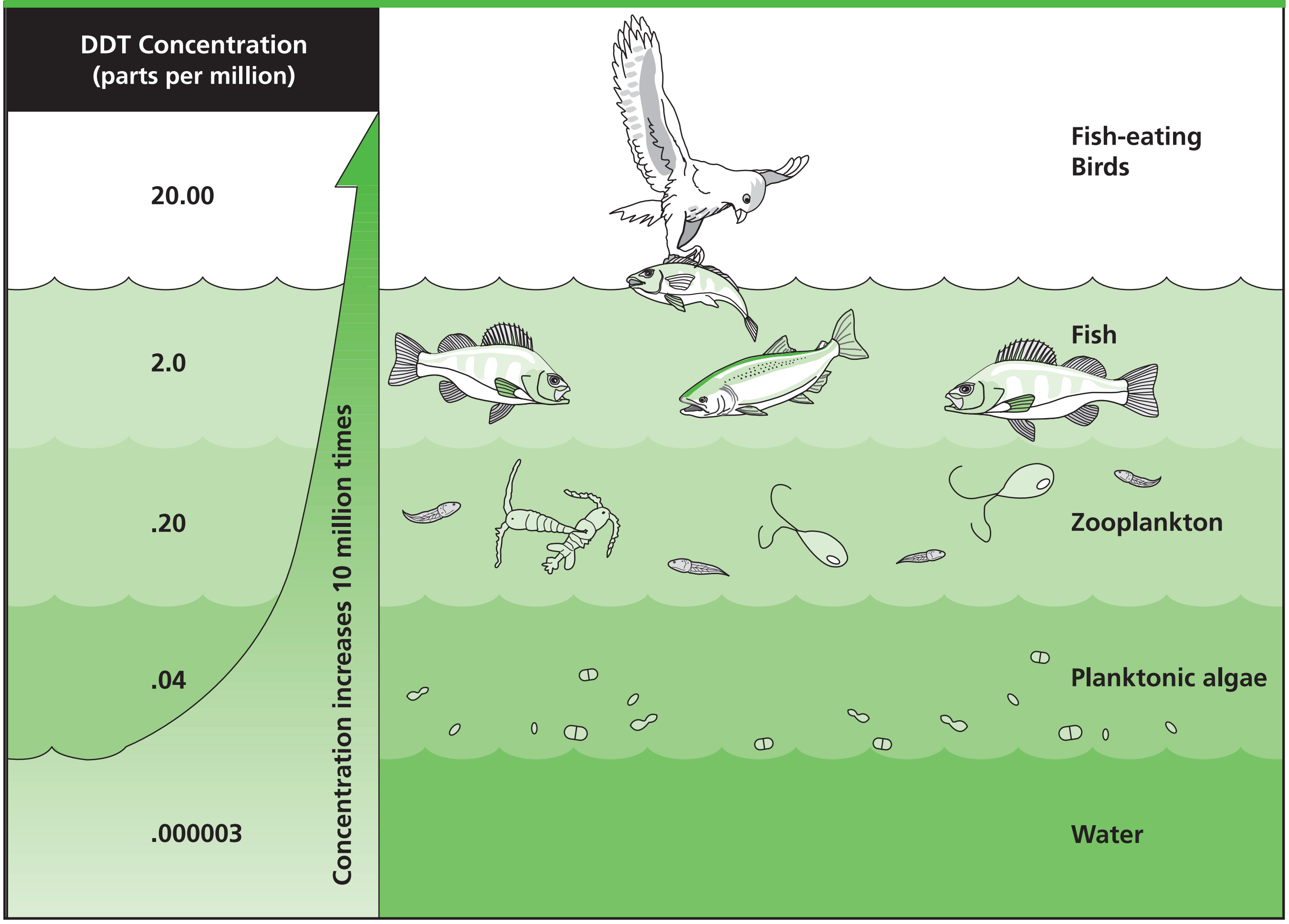
In recent years, however, some drawbacks of heavy dependence on pesticides have become increasingly apparent. One of the most disturbing is the development of **pest resistance** to pesticides. Since the resistance of the San Jose scale to lime sulfur was recognized in 1908, hundreds of insects have become resistant to one or more pesticides worldwide. Pesticide resistance also has arisen in more than 50 weeds and many plant pathogens. A dramatic example is the Colorado potato beetle in the eastern United States. This insect pest has developed resistance to every major group of insecticides, making control with chemicals difficult, if not impossible, to achieve.

Growing concerns about the environmental and health hazards associated with pesticides have also become significant factors challenging pesticide use. In 1962, Rachel Carson published *Silent Spring*, a book that examined pesticides and their effects on the environment. DDT and other chlorinated hydrocarbons were her primary concern because of their stability and persistence in the environment. Their long residual activity was a major factor contributing to their effectiveness, but a negative effect was their ability to accumulate in the fatty tissue of some animals (**bioaccumulation**). In certain situations, **biomagnification** of the insecticides occurred. Biomagnification is the process whereby some organisms accumulate chemical residues in higher concentrations than those found in the organisms they consume. Ecologists refer to a **food chain** as the sequence of animals feeding in the natural environment. A particular plant, animal, or microorganism is eaten by an animal, which is in turn eaten by another animal. At each succeeding level, an animal normally eats a number of 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 and interest second to no other period in history. The U.S. Environmental Protection Agency (EPA) was created in 1970 with a mandate from Congress. Its task was then, and remains today, to implement by regulation the laws passed by Congress to protect the environment and the health of humans

Adapted from Penn State *Pesticide Education Manual*

Figure 1.1 Biomagnification in the Food Chain



and other animals. Since the 1972 EPA ban on DDT use in the United States, regulatory action has been taken against many chemicals, including pesticides, thought to pose significant environmental and health hazards. Public concern has led to stringent regulation of pesticides and changes in the types of pesticides used.

PEST RECOGNITION

Larry Schulze, University of Nebraska

Weed pest.

Invertebrate pest.

Disease pest.

Pests are organisms that cause problems in various ways. Some compete with people for food or fiber. Others interfere with the raising of crops, livestock, or poultry. Certain types of pests damage property and personal belongings or disfigure ornamental plantings. Others transmit or cause plant, animal, or human diseases.

Before trying to control a pest, you need to identify it. Be certain any injury or observed damage is actually due to the identified pest and not some other cause. Once you have identified the pest and confirmed that it is causing damage, become familiar with its life cycle, growth, and reproductive habits. Then, use this information to form your pest control plans. Misidentification and lack of information about a pest could cause you to choose the wrong control method or apply the control at the wrong time. These are the most frequent causes of pest control failure.

In addition, some plants are damaged by non-living agents. These include such things as weather extremes, air pollutants, road salt, and inadequate or excessive fertilization. Sometimes this damage is mistaken for that caused by living pests.

The Four Main Groups of Pests

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

Ways to Identify Pests

Identify a pest by using the guidelines included in this chapter and then consulting reference materials such as identification books, Extension bulletins, and field guides that contain pictures and biological information on the pest. Another option is to have pests examined and identified by pest management specialists. When having pests identified, always collect several specimens. Have plastic bags, vials, or other suitable containers available when collecting samples in the field. For plant diseases, submit undamaged specimens, such as healthy foliage, along with the damaged foliage. For insects and their relatives, kill them first and send them to the specialist in a manner that will not damage body parts that aid in their identification. For weed/plant samples, it is best to submit whole plants, including roots, vegetative structures, and flowers, if possible. Plants may be pressed flat between paper or cardboard to prevent leaf crinkling or placed in plastic bags. Be sure to include the location and date of the collection.

The difficulty in identifying certain insects and most mites, nematodes, and plant pathogens in the field is their small size. Accurate identification requires the use of a hand lens or microscope, special tests, or careful analysis of damage. Often the pest's **host** (the animal or plant on which an organism lives) and location are important to making positive identifications. Information on the environmental conditions where you collect pests and the time of year of collection provides clues to the pest's identity.

Pest species may have different physical forms depending on their stage in their life cycles 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 (nymph, larva, pupa) to the adult form.

Characteristic Damage

Pests may leave signs of their presence or damage that help you determine what they are. Birds and rodents build nests that are often characteristic to each species. The type of feeding damage helps you identify many insects. Rodents and some other mammals dig distinctive burrows in the ground and often leave identifying gnaw marks on tree trunks or other objects. Sometimes trails in grass or tracks in dirt are helpful clues to rodent identification. Insect and rodent fecal materials also are distinctive and important identification aids. 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 Karney, USFWS

Vertebrate pest.

PEST MANAGEMENT METHODS

Once a pest problem is anticipated or identified, you can begin planning your pest management program. You must know what management methods are available and the benefits and limitations of each. Select methods that are the most effective and the least harmful to people and the environment. Whenever possible, combine the use of several compatible methods into an **integrated pest management (IPM)** program, and target the pest at the most susceptible stage for control.

> **Pest Management Methods**
>
> Natural controls
>
> Applied controls
>
> - Biological control
> - Mechanical control
> - Cultural control
> - Physical/environmental modification
> - Host resistance or genetic control
> - Chemical control
> - Regulatory Methods

Natural controls are the measures that check or destroy pests without depending on humans for their continuance or success. Natural controls include climatic factors such as wind, temperature, sunshine, and rain. Topographic features such as rivers, lakes, and mountains can influence pest movement. Naturally occurring predators, parasites, and pathogens can regulate pest populations.

When natural controls have not held pests in check, humans must intervene and apply pest management controls. **Applied controls** include biological, mechanical, cultural, physical, genetic, chemical, and regulatory methods.

Biological Control

Most pests have natural enemies that control or suppress them effectively in some situations. Natural enemies, including pathogens, are being used successfully as biological control agents to manage certain insect, mite, fungal, fish, and weed pests.

Biological control is often directed against pests that are not native to a geographical area. Introduced pests are often problems in their new location because they lack natural enemies to help control them. Biological control involves locating the native home of an introduced pest and finding suitable natural enemies there. After extensive testing and evaluation, selected natural enemies are imported, reared, and released. If successful, the introduced natural enemies become established within large areas and effectively lower target pest populations for long periods of time with no further need for intervention. The process is complicated because it is often difficult to locate the native home of some pests, and natural enemies cannot be released until it is proven that they will not become pests themselves. Laws have been enacted that strictly control the importation of all organisms, including biological control agents, into the United States. Other countries have similar restrictions.

Biological control also involves the mass release of large numbers of natural enemies into fields, orchards, greenhouses, or other locations to control specific pests. This method usually does not have long-term results, so these natural enemies must be released periodically. Several natural enemies are reared or cultured commercially. Predatory mites are used to control plant-feeding spider mites. Parasitic wasps and lacewings are used to control various insect pests. Nematodes and fungi are being studied as biological control agents for certain weeds and some insects. General predators such as praying mantids and lady beetles are sold with claims made for biological control. In many cases, however, their effectiveness has not been established.

Maintaining populations of natural enemies by avoiding damaging cultural practices or the indiscriminate use of pesticides can be one of the most economical means of control. If pesticides are part of your control program, select types that are known to be less toxic to natural enemies or, if recommended, apply pesticides at lower-than-label rates to avoid harming natural enemies. Sometimes it is possible to modify certain parts of the environment, such as by planting crops or ground covers, to maintain or enhance natural enemies.

Scott Bauer, USDA ARS

Parasitic wasps may be used as biological control agents.

Mechanical Control

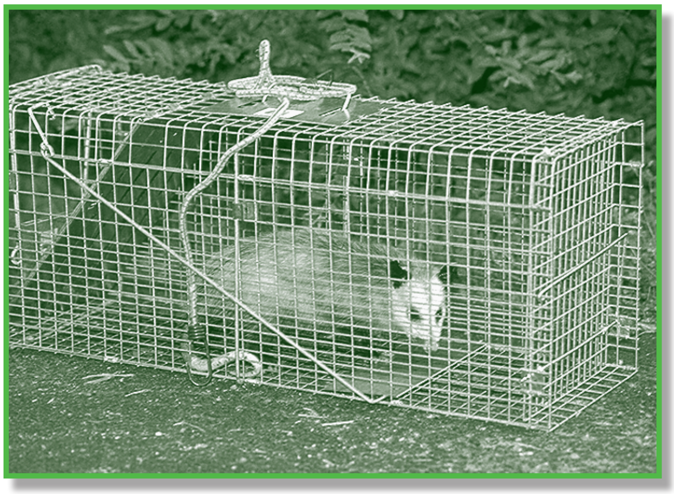
Mechanical control involves the use of devices, machines, and other physical methods to control pests or alter their environment. Traps, screens, barriers, fences, and nets are examples of devices used to prevent pest activity or remove pests from an area.

Cultivation

Cultivation is one of the most important methods of controlling weeds. It is also used for some insects and other soil-inhabiting pests. Mechanical devices such as plows, disks, mowers, cultivators, and bed conditioners physically destroy weeds or control their growth and disrupt soil conditions suitable for the survival of some microorganisms and insects.

Exclusion

Exclusion is a mechanical control technique that consists of using barriers to prevent pests from getting into an area. Window screens, for example, exclude flies, mosquitoes, and other flying insects. Patching or sealing cracks, crevices, and other small openings in buildings can exclude insects, rodents, bats, birds, or other pests. Fences and ditches make effective barriers against many vertebrate pests. Wire or cloth mesh excludes birds from fruit trees. Sticky material painted onto tree trunks, posts, wires, and other objects prevents crawling insects from crossing.



M.J. Weaver, Virginia Tech Pesticide Programs

Live trap used to control vertebrate pests.

Trapping

Traps physically catch pests within an area or building. Several types of traps are commonly used. Some kill animals that come in contact with them; others snare animals so they can then be relocated or destroyed. Traps are either mechanical devices or sticky surfaces.

Cultural Control

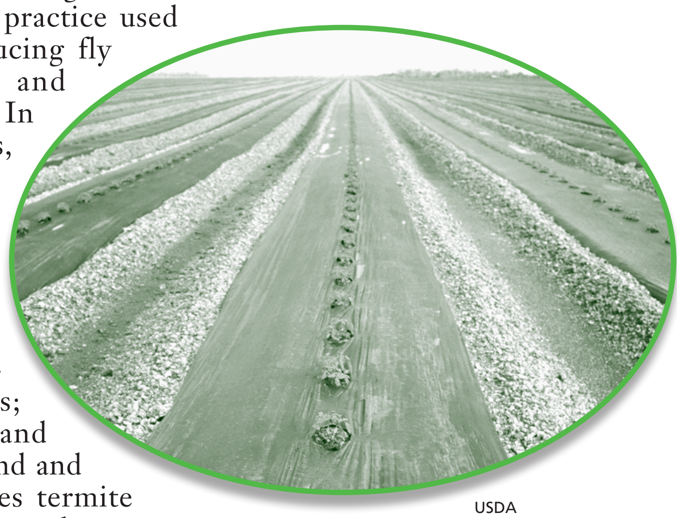
The goal of cultural control is to alter the environment, the condition of the host plant or site, or the behavior of the pest to prevent or suppress an infestation. It disrupts the normal relationship between the pest and the host plant or site and makes the pest less likely to survive, grow, or reproduce. Cultural practices and sanitation are two examples of cultural control.

Cultural Practices

Many cultural practices influence the survival of pests. In turf, mowing, irrigation, aeration, and fertilization are all important ways of producing healthy turf and preventing pest buildup and damage. In agricultural crops, selection of crop plant varieties, timing of planting and harvesting, irrigation management and timing, crop rotation, and use of trap crops help reduce populations of weeds, microorganisms, insects, mites, and other pests. Weeds also can be managed by mulching (with plastic, straw, shredded bark, or wood chips) and by using cover crops.

Sanitation

Sanitation, or source reduction, involves eliminating food, water, shelter, or other necessities important to the pest's survival. 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 for preventing or reducing fly problems in poultry and livestock operations. In non-agricultural areas, certain pests are controlled by draining standing water. Closed garbage containers and frequent garbage pickup eliminate food sources for flies, cockroaches, and rodents; removing soil, trash, and other debris from around and under buildings reduces termite and fungal rot damage and prevents rodent nesting.



USDA

Use of plastic mulch to control weeds.

Physical/Environmental Modification

Pests that occur in enclosed areas may sometimes be suppressed by altering 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 either kill the insects, cause them to stop feeding, or 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 glass or plastic houses often helps to suppress fungal diseases from developing on plants.

Host Resistance or Genetic Control

Sometimes plants and animals can be bred or selected to resist specific pest problems. For example, particular livestock breeds are selected for physical characteristics that prevent attack by some pests or provide physiological resistance to disease or parasitic organisms. Resistance also is enhanced by maintaining the host's health and providing for its nutritional needs. 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 offers great promise for the future, especially when combined with new gene manipulation techniques.

Chemical Controls

Chemical controls are pesticides that are either naturally derived or synthesized. Pesticides often play a key role in pest management programs and frequently may be the only control method available. Major benefits associated with the use of pesticides are their effectiveness, the speed and ease of controlling pests, and, in many instances, their reasonable cost compared with other control options. Usually pest damage stops or pests are destroyed within a few hours (for insects) to a few days (for weeds) after application of a pesticide. Using a fungicide may provide immediate, short-term protection against microorganisms.

A **pesticide** is defined as any material that is applied to plants, the 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. Pesticides include a wide assortment of chemicals with specialized names and functions. They are commonly grouped according to the type of pest they control.

- **Avicides** control pest birds.
- **Bactericides** control bacteria.
- **Disinfectants (antimicrobials)** control microorganisms.
- **Fungicides** control fungi.
- **Herbicides** control weeds and other undesirable plants.
- **Insecticides** control insects and related arthropods.
- **Miticides (acaricides)** control mites.
- **Molluscicides** control snails and slugs.
- **Nematicides** control nematodes (roundworms).
- **Predacides** control predatory vertabrates.
- **Piscicides** control pest fish.
- **Repellents** repel insects, related invertebrates, birds, and mammals.
- **Rodenticides** control rodents.
- **Defoliants** cause leaves or foliage to drop from plants.
- **Desiccants** promote drying or loss of moisture from plant tissues.
- **Growth regulators** are substances (other than fertilizers or food) that alter the growth or development of a plant or animal.

Each group of pesticide includes several classes or families. For example, the classes of insecticides include, among others, the organophosphates, organochlorines, carbamates, pyrethroids, botanicals, insecticidal soaps, and microbials. The pesticides within a particular class have similar chemical structures or properties or share a common **mode of action**. The mode of action of a pesticide is how the pesticide works. In other words, it is what specific system(s) in the pest are affected by the pesticide. The various classes of chemicals work in different ways and present different risks and problems.

Pesticides also vary in their **selectivity**. Fumigants, for example, are non-selective, controlling a wide variety of pests—fungi, insects, weeds, nematodes, etc. Some non-selective herbicides control any plant given a sufficient dose. In contrast, selective products control only certain species of pests or affect only a certain stage of pest development. For example, certain herbicides control broadleaf weeds while not harming grasses, and ovicides kill only the eggs of certain insects, mites, and related pests.

Pesticides may move in various ways after they come in contact with a host. **Systemic pesticides** are absorbed through leaves or roots and then transported within the treated plant. Similarly, systemic insecticides can be eaten by or injected into livestock to control certain 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.

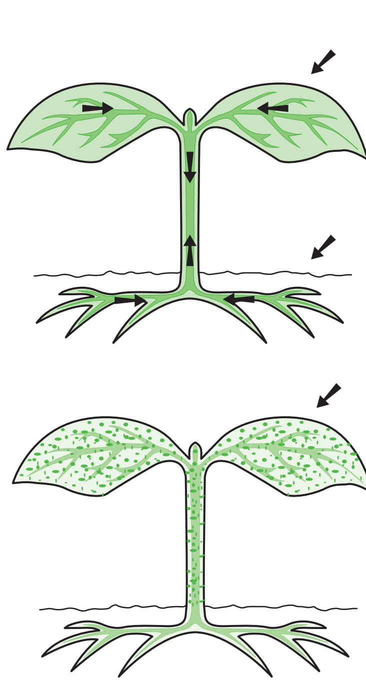
The production, sale, use, storage, and disposal of all pesticides are regulated at both the federal and state levels. The federal laws and regulations governing all aspects of pesticide use and handling are covered in Chapter 2.

Regulatory Pest Control

Some pest problems cannot be controlled successfully at a local level. These problems involve 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 are used to prevent the introduction and spread of such pests.

Quarantine is a pest control process designed to prevent entry of 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. Produce and other identified items being shipped from a quarantine area must be fumigated to destroy pests before shipment. Nursery stock, plant cuttings, and budding and grafting material are also regulated to prevent the spread of pests.

Eradication is the total 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 areawide spray program, releasing sterile insects, using mechanical and cultural practices, and intensive monitoring for pests within and around the borders of the infested area.



Adapted from Penn State *Pesticide Education Manual*

Figure 1.2
Systemic and contact pesticides on treated plants.

USDA APHIS

USDA regulates and inspects imported cargo to prevent pest introduction.

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. Under the authority of mosquito abatement laws, state agencies drain or treat standing water that provides breeding sites for mosquitoes.

INTEGRATED PEST MANAGEMENT (IPM)

Pesticide use is and will continue to be significant 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. Using integrated pest management has benefited pest managers and the environment, and has reduced the occurrence of pesticide resistance in pest populations.

Integrated pest management (IPM) is a balanced, tactical approach to pest control. It involves taking action to anticipate pest outbreaks and to prevent potential damage. IPM is 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. Such pest management programs—based on the identification of pests, accurate measurement of pest populations, assessment of damage levels, and knowledge of available pest management strategies or tactics—enable the specialist to make intelligent decisions about control. IPM offers the possibility of improving the effectiveness of pest control programs while reducing some of the negative effects. Many successful IPM programs have reduced energy and pesticide use. IPM programs are very site-specific.

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?

You might be wondering why pest managers have shifted to IPM when chemical pesticides so often succeed at controlling pests. There are many reasons to broaden pest management beyond the use of chemicals.

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

Pesticides can be ineffective — Chemical pesticides are not always effective. As mentioned earlier, pests can become resistant to pesticides. In fact, some 600 cases of pests developing pesticide resistance have been documented to date, including many common weeds, insects, and disease-causing fungi. Furthermore, pests may survive in situations where the chemical does not reach pests, is washed off, is applied at an improper rate, or is applied at an improper life stage of the pest.

IPM can save money— IPM can avoid crop loss and landscape and structural damage caused by pests and prevent unnecessary pesticide expense. Applicators can save on pesticide costs because the need for control rather than the calendar is the basis for applying pesticides.

IPM promotes a healthy environment—We have much to learn about the persistence of chemicals in the environment and their effect on living creatures. Cases of contaminated groundwater appear each year, and disposal of containers and unused pesticides still pose challenges for applicators. Make sure that environmental impacts are considered in any pest management decisions. Using IPM strategies helps keep unreasonable adverse effects to a minimum.

IPM maintains a good public image—IPM is now demanded by many sectors of our society. IPM has been implemented to grow our food, to manage turf and ornamentals, to protect home and business structures, to manage school grounds, and to protect humans, pets, and livestock health.

Components of IPM

All of the components of an IPM approach can be grouped into five major steps: identify the pest and understand its biology, monitor the pest to be managed, develop a sound pest management goal, implement an IPM program, and record and evaluate results.

1. Identify the Pest and Understand its Biology— Despite our best preventive efforts, some pest outbreaks inevitably occur. The first step in any pest management program is to identify the pest. Never classify an organism as a pest or treat it as a pest until it is clearly determined to be one. Identification is important whether you are dealing with an insect, weed, plant disease, or vertebrate.

The more that you know about a pest, the easier and more successful pest management becomes. Once you have identified a pest, you can access information about its life cycle and behavior, the factors that favor development, and the recommended control procedures. You can also determine the significance of the pest and the need for control. Some pests have little impact on a plant, animal, or structure and do not require control. Other pests warrant immediate control because they cause serious damage or present a significant threat to human health or public safety.

Most pests may be classified either as key pests, occasional pests, or secondary pests.

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.

Occasional pests become troublesome only once in a while because of their life cycles or environmental influences, or as a result of human activities. For instance, ants sometimes become occasional pests when sanitation practices change, providing them with food where previously none existed. They also may move into buildings after a rainfall or other event destroys an outdoor food source.

Secondary pests become problems when a key pest is controlled or eliminated. 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.

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

Scouting and trapping are commonly used to monitor insects and their activity. Weather and temperature data

Why Practice IPM?

- IPM helps to keep a balanced ecosystem.
- Pesticides can be ineffective.
- IPM can save money.
- IPM promotes a healthy environment.
- IPM maintains a good public image.

Peggy Greb, USDA ARS

Pest monitoring by using a sweep net.

are particularly helpful in following a pest's life cycle or in predicting how long it takes a certain pest to develop. Models have been developed for a number of insects and plant diseases to predict the need for and timing of pesticide applications.

Use Pest Population Thresholds

Producers of agricultural or ornamental products must understand the concept of economic thresholds. The presence of a pest does not always cause a loss in quality or quantity of an agricultural or ornamental product. To justify the cost of control, pest populations must be large enough to cause significant damage. This population level is called the **economic threshold (ET)**. The economic threshold is the pest population density (number of pests per unit of 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 make a control practice profitable, or at least break even, 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 applying the control. Setting the ET below the EIL triggers pesticide application and other controls before pests reach the economic injury level.

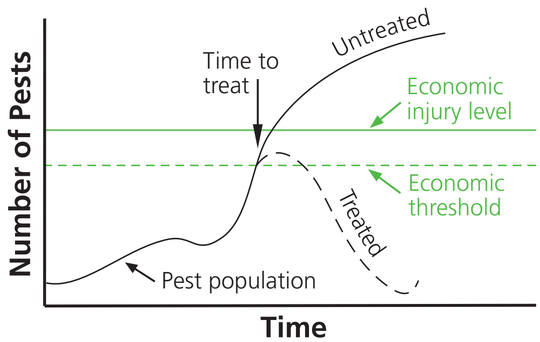


Figure 1.3
To make a control practice profitable, or at least break even, it is necessary to set the economic threshold (ET) below the economic injury level (EIL).

Economic thresholds are available for many pests and crops. Several factors can influence an economic threshold. These factors include the current value of the agricultural or ornamental product, its stage of development, the degree of damage caused under various environmental conditions, the cost and effectiveness of control measures, and the anticipated yield. For example, even slight damage to an ornamental or floricultural crop may reduce the value significantly and render it unsalable, so the economic threshold must be set quite low.

For pest managers who are not directly involved in production, the concept of **action thresholds** is more appropriate. An action threshold is the pest level at which some type of pest management action must be taken. It is a predetermined pest level that is deemed to be unacceptable. Factors besides economics come into consideration for establishing action thresholds. In some situations, the action threshold for a pest may be zero (i.e., no presence of the pest is tolerated). This is especially true when the pest is capable of transmitting a human pathogen (mosquitoes and the West Nile virus), has a venomous bite or sting (some spiders, wasps), or may create a public health emergency (cockroaches, rodents). In an urban landscape, action thresholds must consider not only the economic value of the landscape but also its ecological and aesthetic roles. Even a slight amount of pest damage may be unacceptable in such an environment. Action thresholds can vary by pest (a stinging insect in a classroom vs. an ant), by site (a storage room vs. a school infirmary), and by season (some pests are present only a few weeks out of an entire year). Often the action threshold is expressed as the number of pests per unit area. Below the action threshold level, IPM technicians 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, the technician should implement a full range of IPM strategies to control the pest.

Action thresholds are easy to understand, but establishing them is more difficult. In a new IPM program, a practical approach is to establish an arbitrary action threshold for the major pests you encounter. As you gain insight and experience into specific pest management settings, the action levels can be revised up or down.

3. Develop the Pest Management Goal — The goal of most IPM programs is to maintain pest damage at economically acceptable levels. Prevention and suppression techniques are often combined in an effective IPM program. In rare instances, eradication may be the goal of an IPM program. Once the goal of the program has been determined, the strategy for a sound IPM program is to coordinate the use of multiple tactics into a single integrated system. Pesticides are just one method for controlling pests. Non-chemical methods may provide longer and more permanent control of a pest and should always be considered when developing a pest management strategy. Evaluate the costs, benefits, and liabilities of each control tactic.

Prevention

Often economical and environmentally sound ways are available 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 minimize pest problems. Sanitation methods often reduce the buildup of pests. 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 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 are applied to structural lumber before construction to protect it from insects and fungi.

Suppression

Suppressive pest control methods are used to reduce pest population levels. The methods chosen usually do not eliminate all pests but reduce their populations to a tolerable level or to a point below an economic injury level; additional suppressive measures may be required. Suppression sometimes lowers pest populations so natural enemies are able to maintain control. Suppression is the goal of most pesticide applications. Other techniques, such as cultivation or mowing of weeds and release of biological control agents, are also used to suppress pest populations.

Eradication

Eradication is the total elimination of a pest from a designated area. This is a common objective of pest control efforts 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 involves eradication. Over larger areas, however, eradication is very expensive and often has limited success. Large eradication programs are usually directed at exotic or introduced pests posing an areawide public health or economic threat. Such programs are generally coordinated by governmental agencies. Efforts to eliminate Mediterranean fruit fly and hydrilla (an aquatic weed) in California and Florida, respectively, are examples of this type of pest management.

The pest control strategy you choose depends on the nature of the pest, the environment of the pest, and economic or tolerance considerations. Combining prevention and suppression techniques usually enhances a pest management program. Objectives sometimes differ, however, for the same pest in different situations. For example, the Mediterranean fruit fly (Med fly) is an established pest in Hawaii, so the emphasis there is to use prevention and suppression techniques to reduce crop damage. Regulatory agencies in California and Florida, however, use eradication measures to prevent the Mediterranean fruit fly from becoming permanently established in these states.

4. Implement the Integrated Pest Management Program— The following steps should be taken before implementing an IPM program:

- Identify the pest.
- Set up a monitoring program.
- Know the pest level that triggers control.
- Know what control methods are available.
- Evaluate the benefits and risks of each method.

When implementing the IPM program, try to select the methods that are the most effective and the least harmful to people and the environment. Use several methods whenever possible, and be sure to use them correctly. It is also important to 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 your control efforts. Some control methods, especially non-chemical procedures, are slow to yield measurable results. Other methods may be ineffective or even damaging to the target crop, animal, treated surface, or natural predators and parasites. Consider how well your strategies work and their impact on the environment before implementing them again.

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 integrated pest management program.
5. Record and evaluate results.

EFFECTIVENESS OF PEST MANAGEMENT PROGRAMS

Pesticides often play a significant role in pest management programs. Their use requires certain precautions be taken to avoid the development of resistant pest populations. Although pest resistance can occur, it does not cause every pesticide failure. Make sure that you have used the correct pesticide and the correct dosage, and that you have applied the pesticide according to label instructions. Sometimes a pesticide application fails to control a pest because the pest was not identified correctly and the wrong pesticide was chosen. 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 or location where it was not susceptible to the pesticide. Also, remember that the pests that are present may be part of a new infestation that developed long after the chemical was applied.

Even non-chemical pest management tactics become ineffective if the pest and the susceptible stage(s) of its life cycle are not identified correctly. Successful pest management programs do not happen by accident—they depend on careful observation, a thorough knowledge of the pest and the damage it causes, an understanding of all available pest control options, and a caring, professional attitude.

Pesticide Resistance

Pesticide resistance can be defined as the ability of an insect, fungus, weed, rodent, or other pest to tolerate a pesticide that once controlled it. Resistance develops because intensive pesticide use kills the susceptible individuals in a population, leaving only the resistant ones to reproduce. Initially, higher labeled rates and more frequent applications are needed to control resistant pests. Eventually, however, the pesticide will have little or no effect on the pest population (see Figure 1.4).

Resistance may develop to only a single insecticide, fungicide, herbicide, or rodenticide. More often, however, pest populations become resistant to all 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 unlike modes of action.

Continual use of pesticides from the same chemical class, such as all organophosphate or all pyrethroid insecticides, increases the likelihood that resistance will develop in pest populations. Frequent applications and persistence of the chemical further increase the chances of resistance occurring. Finally, the spread of resistance through a pest population can occur much more rapidly in pests that have many generations per year and many offspring per generation, such as many insects, fungi, and rodents.

Several pest management tactics help prevent or delay the occurrence of pesticide resistance. One approach involves 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. Unfortunately, new replacement products are often quite complex, difficult to synthesize, and very costly to develop, and they have very specific modes of action, which can rapidly lead to the development of resistant pest populations even after very 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 is decreased. Applying pesticides over limited areas reduces the proportion of the total pest population exposed to the chemical, thereby maintaining a large pool of individuals still susceptible to the pesticide. This tactic has a tendency to delay the development of a resistant population because pesticide-susceptible individuals in the population 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.

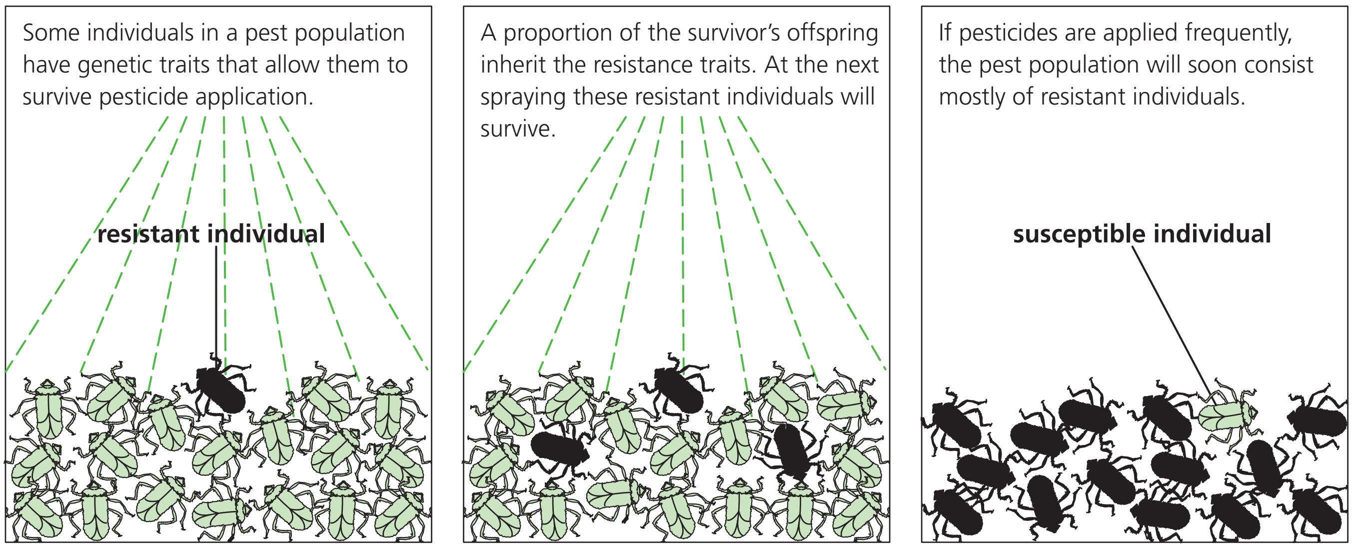
Managing pesticide resistance is a very important aspect of integrated pest management. Monitor pest populations carefully and treat only when necessary, rather than treating on a calendar basis. Good pesticide application records are

Resistance Management

- Use new or altered pesticides.
- Change pesticide use patterns.
- Treat only when necessary.

Figure 1.4 Pest resistance

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



an important component 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 and then controlled by using all available pest management techniques to extend the useful life of our current pesticides.

SUMMARY

To be successful, a pest management program must start 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 (IPM) programs attempt to balance the need for pest control with the desire to protect the environment from risks associated with pesticide use. IPM methods include both chemical and non-chemical means to prevent and control pest populations from reaching economically damaging levels. These prevention and control tactics include biological, mechanical, cultural, physical, genetic, chemical, and regulatory methods.

Monitoring techniques used in IPM programs are critical to knowing when and what type of control measures to apply. Monitoring also helps to establish pest population thresholds that may be used for deciding when pest control action should be taken. 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 also an important consideration for sustaining the effectiveness of pest management programs. Many tools and techniques are available (e.g., rotation of pesticide types with different modes of action, application of pesticides that do not leave persistent residues, application of pesticides at below-label amounts) that prevent or delay the occurrence of pesticide resistance. Whenever chemical controls are used, it is critical to read and follow all label directions correctly to avoid misapplication.

If the pest has not been properly identified, even non-chemical means of pest control will fail. It is the applicator's responsibility to consider all of the factors relevant to the pest control situation. Beyond simply identifying the pest and choosing a control strategy, the applicator must 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.