Pests and Pest Control
Learning Objectives

After you complete your study of this module, you should be able to:

- Explain the importance of correctly identifying pests.
- Explain the importance of understanding the life cycles and habits of pests.
- Explain the factors you should consider when deciding whether control of a pest is necessary.
- Explain the three objectives of pest control — prevention, suppression, and eradication.
- Demonstrate that you know some common ways that nonchemical control methods can be used to manage pests in agricultural situations.
- Define “persistent” and “nonpersistent” pesticides.
- Distinguish the differences between contact pesticides and systemic or translocated pesticides.

Insects

- Name the two physical characteristics that all insects have in common.
- List the four primary types of insect mouthparts and give an example of an insect that has each type.
- Define “metamorphosis”.
- List the three stages of gradual metamorphosis.
- List the four stages of complete metamorphosis.
- List other types of pests that resemble insects or cause similar types of damage.
- Identify the life cycle stage in which most insects are most vulnerable and easiest to control.
- Describe the two main ways that pesticides act to poison insects and similar pests.

Plant Diseases

- Define “plant disease”.
- List the three main types of pathogens that cause plant diseases.
- Describe the factors that are necessary before a plant disease can develop.
- Describe some ways plants respond to diseases.
- List some ways plant disease agents may be spread.
- Explain how symptoms and signs can help you diagnose a plant disease.
- Explain the difference between fungicides that are protectants and those that are eradicants.

Weeds

- Name and describe the four developmental stages of weeds.
- Distinguish between the life cycle characteristics of annual, biennial, and perennial weeds.
- Name several ways weeds reproduce.
- Demonstrate that you know the common categories of land and aquatic weeds and some of their identifying characteristics.
- List several factors that affect a plant's susceptibility to herbicides.
- Define “selective” and “nonselective” herbicides.
- Demonstrate your ability to select the correct combination of herbicide characteristics for a given weed control situation.
- Identify the uses of plant growth regulators, defoliants, and desiccants.

Vertebrates

- Give some examples of vertebrate pests and the types of damage they cause.
- List some vertebrate control measures that may require approval from local or State authorities.

Terms To Know

Contact pesticide — A pesticide that kills pests simply by contacting them.
Eradi cation — Destroying an entire pest population in an area.
Foliar — Applied to the leaves of a plant.
Habitat — The places where a plant or animal lives, feeds, and breeds.
Host — The living plant or animal a pest depends on for survival.
Life cycle — The series of stages an organism passes through during its lifetime.
Metamorphosis — The series of changes through which insects and insect-like organisms pass in their growth from egg to adult.
Nonpersistent pesticide — A pesticide that breaks down quickly after it is applied.
Nonselective pesticide — A pesticide that is toxic to most plants or animals.
Parasite — An organism that lives and feeds on or in an organism of another species, which it usually injures.
Pathogen — Any disease-producing organism.
Persistent pesticide — A pesticide that remains active for a period of time after application, giving continued protection against the pest.
Plant disease — Any harmful condition that makes a plant different from a normal plant in its appearance or function.
Predator — Any animal that destroys or eats other animals.
Prevention — Keeping a pest from becoming a problem.
Selective pesticide — A pesticide that is more toxic to some kinds of plants and animals than to others.
Stomach poison — A pesticide that kills when it is eaten by the pest.
Suppression — Reducing pest numbers or damage to an acceptable level.
Systemic pesticide — A pesticide that is taken into the blood of an animal or sap of a plant. It kills the pest without harming the host.
Translocated herbicide — A pesticide that kills plants by being absorbed by leaves, stems, or roots and moving throughout the plant.
Vertebrate — An animal with a jointed backbone.
Correct identification of pests and a knowledge of their development and behavior are keys to effective pest control. In this unit, pests are grouped into four broad categories:
- insects and insect-like pests,
- weeds,
- plant diseases, and
- vertebrates.

This unit will give you some basic facts about agricultural pests, their life cycles, and how they commonly develop and spread, but it is not intended to make you an expert in pest identification. Accurate detection, identification, and diagnosis of pest problems is a science — experience is important. When you find a pest or pest problem you cannot identify, ask an expert to help you.

When you have identified a pest, you must decide how to manage it. Remember that even though a pest is present, it may not be very harmful. Consider whether the cost of control would be more than the economic loss from the pest’s damage.

If control is necessary, decide whether you need to prevent the pest from becoming a problem, suppress the numbers of pests or the level of their damage, or eradicate the entire pest population. Then, using what you have learned about integrated pest management, choose the methods that will do a cost-effective job of managing the pest while causing the least possible harm to people and the environment.

Pesticides are a valuable tool, but you should use them only when and where they are needed. Consider chemical control:
- when pest numbers or the damage the pests are causing are unacceptable, and other pest management methods will not provide effective control, or
- when your knowledge of the situation indicates that you need to use a pesticide preventively.

For example, you may know that temperature and humidity conditions make it likely that a plant disease will develop.

Remember, never try to control any pest until you know what it is. If you use a pesticide, follow the labeling directions carefully.
Insects and Insect-like Pests

Insects

There are more kinds of insects on earth than all other living animals combined. They are found in soil, hot springs, water, snow, air, and on or inside of plants and animals. They eat the choicest foods from our table. They can even eat the table.

The large number of insects can be divided into three categories according to their importance to people:
- **Species of ecological importance**—About 99 percent of all species are in this category. They do not directly help or harm people, but they are crucial in the food web. They are food for birds, fish, mammals, reptiles, amphibians, aquatic life, and other insects. Some remove animal wastes and dead plants and animals, returning nutrients to the environment. Some are considered beautiful.
- **Beneficial insects**—In this small but important group are the predators and parasites that feed on harmful insects, mites, and weeds. Examples are ladybird beetles, some bugs, ground beetles, tachinid flies, praying mantids, and many tiny parasitic wasps. Also in this category are the pollinating insects, such as bumblebees and honeybees, some moths, butterflies, and beetles.

Without pollinators, many kinds of plants could not grow. Honey from honeybees is food for people. Secretions from some insects are made into dyes and paints. Silk comes from the cocoons of silkworms.
- **Destructive insects**—Although this is the category that usually comes to mind when insects are mentioned, it includes the fewest species. These are the insects that feed on, cause injury to, or transmit disease to people, animals, plants, food, fiber, and structures. This category includes, for example, aphids, beetles, fleas, mosquitoes, caterpillars, and termites.

Physical Characteristics

All adult insects have two physical characteristics in common. They have three pairs of jointed legs, and they have three body regions — the head, thorax, and abdomen.

**Head**

The head has antennae, eyes, and mouthparts. Antennae vary in size and shape and can be a help in identifying some pest insects. Insects have compound eyes made up of many individual eyes. These compound eyes enable insects to detect motion, but they probably cannot see clear images.

The four general types of mouthparts are:
- chewing,
- piercing-sucking,
- sponging, and
- siphoning.

**Chewing mouthparts** contain toothed jaws that bite and tear. Cockroaches, ants, beetles, caterpillars, and grasshoppers are in this group.

**Piercing-sucking mouthparts** consist of a long slender tube that is forced into plant or animal tissue to suck out fluids or blood. Insects with these mouthparts include stable flies, sucking lice, bed bugs, mosquitoes, true bugs, and aphids.

**Sponging mouthparts** are tubular tongue-like structures with a spongy tip to suck up liquids or soluble food. This type of mouthpart is found in flesh flies, blow flies, and house flies.

**Siphoning mouthparts** are formed into a long tube for sucking nectar. Butterflies and moths have this type.
Thorax
The thorax contains the three pairs of legs and (if present) the wings. The various sizes, shapes, and textures of wings and the pattern of the veins can be used to identify insect species. The forewings take many forms. In the beetles, they are hard and shell-like; in the grasshoppers, they are leathery. The forewings of flies are membranous; those of true bugs are part membranous and part hardened. Most insects have membranous hindwings. The wings of moths and butterflies are membranous but are covered with scales.

Abdomen
The abdomen is usually composed of 11 segments, but 8 or fewer segments may be visible. Along each side of most of the segments are openings (called spiracles) through which the insect breathes. In some insects, the tip end of the abdomen has tail-like appendages.

Life Cycles of Insects
Most insect reproduction results from the males fertilizing the females. The females of some aphids and parasitic wasps produce eggs without mating. In some of these insect species, males are unknown. A few insects give birth to living young; however, life for most insects begins as an egg.

Temperature, humidity, and light are some of the major factors influencing the time of hatching. Eggs come in various sizes and shapes: elongate, round, oval, and flat. Eggs of cockroaches, grasshoppers, and praying mantids are laid in capsules. Eggs may be deposited singly or in masses on or near the host—in soil or water or on plants, animals, or structures.

The series of changes through which an insect passes in its growth from egg to adult is called metamorphosis.

When the young first hatches from an egg, it is called either a larva, nymph, or naiad, depending on the species. After feeding for a time, the young grows to a point where the skin cannot stretch further; the young sheds its skin (molts) and new skin is formed.

The number of these developmental stages (called instars) varies with different insect species and, in some cases, may vary with the temperature, humidity, and food supply. The heaviest feeding generally occurs during the final two instars.

The mature (adult) stage is when the insect is capable of reproduction. Winged species develop their wings at maturity. In some species, mature insects do not feed, and in some species the adults do not feed on the same material as the immature forms.

No metamorphosis
Between hatching and reaching the adult stage, some insects do not change except in size. The insect grows larger with each successive instar until it reaches maturity. Examples are silverfish, firebrats, and springtails. The food and habitats of the young (called nymphs) are similar to those of the adult.

Pests and Pest Control
Gradual metamorphosis

Insects in this group pass through three different stages of development before reaching maturity: egg, nymph, and adult. The nymphs resemble the adult in form, eat the same food, and live in the same environment. The change of the body is gradual, and the wings become fully developed only in the adult stage. Examples are cockroaches, boxelder bugs, lice, termites, aphids, and scales.

Incomplete metamorphosis

The insects with incomplete metamorphosis also pass through three stages of development: egg, naiad, and adult. The adult is similar to the young, but the naiads are aquatic. Examples: dragonflies, mayflies, and stoneflies.

Complete metamorphosis

The insects with complete metamorphosis pass through four stages of development: egg, larva, pupa, and adult.

The young, which may be called larvae, caterpillars, maggots, or grubs, are entirely different from the adults. They usually live in different situations and in many cases feed on different foods than adults. Examples are the beetles, butterflies, flies, mosquitoes, fleas, bees, and ants.

Larvae hatch from the egg. They grow larger by molting and passing through one to several instar stages. Moth and butterfly larvae are called caterpillars; some beetle larvae are called grubs; most fly larvae are called maggots. Caterpillars often have legs; maggots are legless. Weevil grubs are legless; other kinds of beetle larvae usually have three pairs of legs.

The pupa is a resting stage during which the larva changes into an adult with legs, wings, antennae, and functional reproductive organs. Some insects form a cocoon during this stage.

Insect-like Pests

Some other kinds of pest organisms — such as mites, ticks, spiders, sowbugs, pillbugs, centipedes, millipedes, nematodes, and mollusks — are similar to insects in many ways. Most of these pests resemble insects and have similar life cycles; all of them cause similar damage and usually can be managed with the same techniques and materials used to manage insects.

Arachnids

Mites, ticks, spiders, and scorpions have eight legs and only two body regions. They are wingless and lack antennae. The metamorphosis is gradual and includes both larval and nymphal stages. Eggs hatch into larvae (six legs) that become nympha (eight legs) and then adults. Ticks and mites have modified piercing-sucking mouthparts; spiders and scorpions have chewing mouthparts.

Crustaceans

Sowbugs and pillbugs, water fleas, and wood lice have 10 or more legs. They are wingless and contain only one segmented body region. They have two pairs of antennae and chewing mouthparts. Sowbugs and pillbugs have a hard, protective shell-like covering and are related to the aquatic lobsters, crabs, and crayfish. The metamorphosis is gradual, and there may be up to 20 instars before adulthood is reached.

Centipedes and Millipedes

Centipedes have one pair of legs per segment. They have chewing mouthparts. Some species can inflict painful bites. Millipedes have two pairs of legs per segment and are cylindr-
cyst. The cyst is the hard, leathery, egg-filled body of the dead female. It is difficult to penetrate with pesticides. A cyst may provide protection for several hundred eggs for as long as 10 years.

Mollusks
Mollusks are a large group of land and water animals including slugs, oysters, clams, barnacles, and snails. They have soft, unsegmented bodies and often are protected by a hard shell.

Snails and slugs—Land snails and slugs are soft-bodied and have two pairs of antennae-like structures. Their bodies are smooth and elongated. Snails have a spiral-shaped shell into which they can completely withdraw for protection when disturbed or when weather conditions are unfavorable. Slugs do not have a shell and must seek protection in damp places.

Snails and slugs deposit eggs in moist, dark places. The young mature in a year or more, depending on the species. Adults may live for several years. They overwinter in sheltered areas. They are active all year in warm regions and in greenhouses.

Damage Caused by Insects and Insect-like Pests
Insects, ticks, mites, and similar pests, including nematodes and mollusks, damage plants, animals, and structures in many ways. The damage often provides clues to the identity of the pest. Nematodes, for example, are too small to be seen, so their characteristic damage may be the only indication of their presence.
Even though pests are present, the level of damage they are causing may not be of enough economic importance to warrant control measures. The potential for harm may be greater at some times than others. For example, insects that damage leaves in the spring are usually more harmful to a plant than insects that damage leaves in the late summer when the plant is already about to lose its leaves.

**Plant Pests**

**Leaf-eaters**

Some insects and insect-like pests feed on plant leaves. For many plants, the loss of a few leaves will not cause reduced yield. But when pests remove most or all of the leaves from a plant, the plant is killed or is left stunted and unproductive. The larval stage (caterpillars) of some butterflies and moths can cause costly damage. Examples include gypsy moths that feed on trees and imported cabbageworms that feed on cabbage leaves. Some beetles are also leaf-eating pests, including the Colorado potato beetle and the Mexican bean beetle.

Snails and slugs feed on plants at night. They tear holes in foliage, fruits, and soft stems, using a rasp-like tongue. They may eat entire seedlings. As they move, snails and slugs leave a slime-like mucous trail that dries into silvery streaks. These streaks are undesirable on floral and ornamental crops and on the parts of crops that are to be sold for human food.
**Internal Feeders**

Some insects and insect-like pests feed and develop inside fruit, grain, or other plant parts. Usually the larval stage causes the damage during feeding. Some pests pupate inside their host. Because they are inside the plant, these pests often cause significant damage before they are detected. They are also more difficult to control when they are inside the plant. Internal feeders include boll weevils, rice weevils, birch leaf miners, and codling moths.

**Stalk or stem borers**

The larval stage of some insects and insect-like pests bore into stalks or stems. This harms the plant by weakening the stalk or stem and by preventing water and food from flowing freely within the plant. Weakened plants may blow over or wilt as a result of the damage. Examples of these borers include European corn borers, squash vine borers, and dogwood borers.

**Plant-sucking pests**

Some insects and insect-like pests have sucking mouthparts that allow them to suck juices from plants. The activity of these pests can lead to curling and stunting of leaves and stems; wilting caused by blockage of water-conducting tissues; and dead areas caused by toxins the pest injects during feeding.

As they feed, plant-sucking pests may also spread plant disease organisms. Some plant diseases can be controlled by controlling the insect pests that cause their spread.

Some of these pests also excrete a sticky fluid while they suck on the plants. The fluid is called *honeydew*. It is excreted by these common types of plant-sucking insects: leafhopper, aphid, mealybug, psyllid, soft (or unarmored) “scale”, and whitefly. Honeydew drips onto the lower parts of the plants and on objects underneath. A dark-colored fungus grows on it and forms black spots, patches, or sheets of *sooty mold*, which weakens plants and discolors fruits, landscape plants, and vehicles.

Other examples of plant-sucking pests are stink bugs and squash bugs.

**Cutworms**

Some insect pest larvae cut off plants at the soil surface. Cutworms are often hard to detect and control because they feed at night and stay under the ground during the day.

**Underground Feeders**

Many insects and insect-like pests cause damage by feeding on plant roots. Root-feeding pests interfere with the plant’s water and nutrient uptake. They can cause dead spots in turfgrass, “goose-necking” in corn, and poor color, stunting, and loss of vigor in a wide range of crops.

Some underground feeders are the larval stage of insects. They include white grubs, corn root-worm, black vine weevil, and many kinds of fly maggots. Another kind of underground maggots are nematodes. Although some types of nematodes attack above-ground plant parts, most pest nematode species feed on or in the roots. They may feed in one location, or they may constantly move throughout the roots.

Underground pests are often difficult to identify, because they cannot be seen without uprooting the plants. Nematodes are too small to see with the naked eye. Their presence is often identified from the characteristic damage they cause or from experience with previous infestations. Confirmed identification of plant pest nematodes requires sending samples of the soil, roots, and/or other affected plant parts to a laboratory.

**Pests of Animals**

The insects, ticks, mites, and similar pests that attack people and other animals have mouthparts similar to those of the plant feeders, but they suck blood and animal fluids rather than plant fluids.

Mosquitoes, lice, and ticks are bloodsucking pests. Cattle grubs, the ox warble of cows, and the bot fly of horses are internal feeding insects. Face flies, house flies, and gnats annoy and cause discomfort.

Some insects and insect-like pests inject disease-causing organisms, such as bacteria, viruses, and other parasites, into
the animals they are feeding on. In the United States, mosquitoes carry encephalitis and ticks carry Rocky Mountain spotted fever and Lyme disease.

**Pest Control Strategy**

Control of insects and similar pests may involve any of the three basic pest control objectives. Control is usually aimed at suppression of pests to a point where their presence or damage level is acceptable. Prevention and eradication are useful only in relatively small, confined areas or in programs designed to keep foreign pests out of a new area.

To successfully control insects and insect-like pests, you need a thorough knowledge of their habitats, feeding habits, and life cycle stages.

Environmental conditions, such as humidity, temperature, and availability of food, can affect the length of the life cycle by altering the growth rate of the insects. A favorable environment (usually warm and humid) can shorten the time of development from egg to adult.

You must carefully monitor pest populations and take management action at a time when you are most likely to succeed. Timing may be essential, for example, when you need to control an internal feeder before it enters the plant. It is particularly useful to know the life cycle stages in which the pests are most vulnerable:

- In the **egg and pupal stages**, insects generally are difficult to control, because these stages are inactive. The pests are not feeding, are immobile, and often are in hard-to-reach areas such as under the ground, in cocoons or cases, and in cracks or crevices.
- In the **late instar and adult stages**, insects may be controlled with moderate success. Because of their size, the insects are easiest to see in these stages and usually are causing the most destruction. However, larger insects are often more resistant to pesticides, and adults already may have laid eggs for another generation.
- The **early larval or nymphal stages**, when the insects are small, active, and vulnerable, is when you usually can achieve the best control.

Control methods used for insects and similar pests include:

- **Host resistance**
- **Biological control**
- **Cultural control**
- **Mechanical control**
- **Sanitation**, and
- **Chemical control**

**Host Resistance**

Some crops, animals, and structures resist insects and similar pests better than others. Some varieties of crops and wood are immune to certain pests. Use of resistant types helps keep pest populations below harmful levels by making the environment less favorable for the pests.

Biotechnologists and plant breeders are using genetic engineering to build pest resistance into plants. The protein crystal in *Bacillus thuringiensis* (Bt) that is toxic to many caterpillars, for example, has been incorporated into some plants. Leaf-feeding insects that feed on leaves containing the Bt protein often will die, making insecticide applications unnecessary.

**Biological Control**

Biological control measures for insects include:

- **Predators and parasites**
- **Sterile males**
- **Pheromones**
- **Juvenile hormones**, and
- **Microbials**

**Predators and parasites**

Most insect and insect-like pests have a variety of natural predators and parasites that help keep their numbers in check. If these natural enemies of the insect you need to control are already present in the area, you may be able to make use of them. If you use pesticides, try to use ones that are not toxic to the predators and parasites you want to encourage — or apply the pesticides at a time when the beneficial organisms are not vulnerable.

For some pests, predators and parasites can be introduced into an area where they do not naturally occur. These organisms are made available only after it is certain that they will not harm people, animals, plants, and other
beneficial organisms. Such introductions of a pest's natural enemies usually work best when done as part of a coordinated effort over a wide area, as in government-sponsored release programs.

Several kinds of parasites and predators of the alfalfa weevil, for example, have been imported from Europe and Asia and released in infested areas in this country. Several species have become established and are helping to reduce pest numbers. However, they do not always prevent serious outbreaks.

You can buy many kinds of predators (such as lady beetles) or parasites (usually various parasitic wasps) for use in your own pest management program. This technique may be of limited benefit in open fields, because the insects may not stay in the area where you release them. The use of predators and parasites can work well in enclosed areas, such as greenhouses, but you need considerable knowledge and expertise for this method of pest management.

**Sterile males**

Males of some pest insect species may be reared and sterilized in laboratories and released in large numbers into infested areas to mate with native females. These matings produce infertile eggs or sterile offspring and help reduce the pest population.

The screwworm, which attacks cattle, is one of the few insects that have the characteristics to allow this technique to be successful. The screwworm female mates only once, and screwworm populations per square mile are not dense.

**Pheromones**

Some insects (and insect-like organisms) produce natural chemicals, called pheromones, that cause responses in other insects of the same or very closely related species. Once a particular insect pheromone is identified and the chemical is synthetically produced, it can be used to disrupt the behavior of that insect species.

Synthetic pheromones may be used to disrupt normal reproduction, or they may be used to attract the pests into a trap. Pheromones in traps are often used in IPM monitoring, such as for the Mediterranean fruit fly in Florida, the boll weevil in the South, and various insect pests in orchards.

Because each pheromone affects only one specific group of insects, their use usually poses very little risk to other organisms, including people. Unfortunately, only a few synthetic pheromones are available, because it is costly to discover, produce, and market a chemical that controls only one pest species. As a result, synthetic pheromones are mainly used on high-value crops.

**Juvenile hormones**

Juvenile hormones, another type of species-specific chemical, interrupt the metamorphosis of insects (and insect-like organisms). These chemicals prevent reproduction by keeping immature insects from maturing into adults. Each chemical acts against a single pest species and has the same advantages and disadvantages as pheromones. They have been effectively used to control fleas, cockroaches, and fire ants. The pest populations slowly decline over several weeks, since they are unable to reproduce.

Juvenile hormones are seldom used in agriculture because a quick kill is usually desired.

**Microbials**

Microbial pesticides are microorganisms, such as bacteria, fungi, and viruses, that have been formulated into pest control products. Microbial pesticides are introduced into infested areas to subject pests to disease. They almost always present an extremely low hazard to people and to nontarget organisms. Most microbial pesticides are naturally occurring organisms, but some are genetically altered specifically for this purpose.

The bacterium *Bacillus thuringiensis* (*Bt*) is one of the best known microbial pesticides. Different strains of *Bt* are used to control larvae of moths, mosquitoes, and black flies.

Two species of bacteria that cause milky spore disease in Japanese beetles are effective pesticides. Another bacteria is marketed to control crown gall in trees, shrubs, and vines. An organism that causes disease in milkweed vine is sold to control that weed in certain crops.

Fungi are also used as microbial pesticides. One fungus is marketed to control certain mites and another is used to control a specific vetch weed in certain crop areas. A virus is sold to control certain moth pests and another is used to control codling moths.

Microbials are usually applied as a broadcast spray to infect as many target pests as possible. Like pheromones, microbials may be costly to develop, produce, and market, because they are often pest-specific.
Cultural Control

In general, plants that are grown under conditions that allow them to be healthy and free of stress are usually more able to resist insect attacks than are less hardy plants. Depending on the situation, there are several specific cultural techniques that may help control insects and similar pests. They include:
- crop rotation,
- trap crops,
- delay of planting, and
- harvest timing.

Crop rotation

Taking infested fields out of production and leaving them fallow or planting an alternate crop may deprive pests of host plants on which to feed and reproduce. Rotations work best against insects that have long life cycles and infest the crop during all stages of growth. Many traditional crop rotation schemes — corn and soybean rotation, for example — were developed to reduce pest problems.

Delay of planting

Delaying the planting date may reduce the population of certain pests by eliminating the plants they need for food and reproduction. For example, you can avoid Hessian fly damage in wheat by delaying planting until fly reproduction has ended for the year.

Harvest timing

Do not leave crops in the field after maturity if they are susceptible to pest attack. For example, wireworm damage to mature potatoes causes a serious quality reduction. Damage increases if the crop is left in the ground for even a short time after maturity.

Mechanical Control

Mechanical controls used on insects and similar pests are:
- screens and other barriers,
- traps,
- light, and
- heat and cold.

Screens and other barriers

Use of screens and other barriers is an important way to keep pests out of structures. Flying insects, such as mosquitoes, wasps, and flies, are kept outside by blocking any openings with screening. The effective mesh size depends on the size of the smallest flying insect pest in that environment. Crawling insects are also kept outside by screens or by other barriers such as tightly sealed doors and windows. Barriers made of sticky substances sometimes can be used to stop crawling insects from entering an area. Barriers can also be an effective control measure for snails and slugs. Moving air from fans can repel mosquitoes, eye gnats, and other small flying insects.

Traps

Traps are sometimes used to control the target pest. More often, however, they are used to survey for the presence of insect pests and to determine when the pest population has increased to the point where control is needed.
Light
Insect pests may be attracted to artificial light at night. However, since not all the pests are killed, the light attractant may actually help create infestations.

Heat and cold
In some cases, it is possible to expose insect pests to the killing effects of the heat of summer or cold of winter. Insects that feed on stored grain and flour, for example, can sometimes be controlled by ventilating grain elevators with cold winter air temperatures. Manipulation of temperature for pest management is also effective in some greenhouse situations.

Sanitation
Tilling fields and burning crop residues soon after harvest greatly aid in the control of some insect pests, as well as snails and slugs, on agricultural crops. Pink bollworm infestations in cotton, for example, can be greatly reduced by plowing the field immediately after harvest.

Removing litter from around buildings helps control pests that use it for breeding or shelter. Ants, termites, and some other indoor pests may be suppressed by using this technique.

Sanitation is important in the control of animal parasites and filth flies. Fly control in and around barns, poultry houses, and livestock pens, for example, is greatly aided by proper manure management.

Indoors, sanitation is a major method of preventing insect pest problems. Keeping surfaces clean and dry is an important factor in suppressing ant, fly, and cockroach infestations.

Chemical Control
Some problems with insects, mites, spiders, and nematodes can best be managed with the use of chemicals. Chemicals such as insecticides, acaricides, and nematicides are used to control these pests.

Mode of Action
Most of these pesticides either repel the pests or poison them:
- Repellents keep pests away from an area or from a specific host. Products designed to keep mosquitoes, chiggers, and ticks off people are an example.
- Poisons act on one or more life systems in the pest. Stomach poisons must be eaten by the pest; contact poisons act when the pest touches them.

A few insecticides kill insects by interfering mechanically with their body functions. For example, mineral oils suffocate insects; silica dusts destroy their body water balance by damaging their protective wax covering.

Persistence
Insecticides and related chemicals vary in the length of time they remain active after they are applied. Some kill the pests they contact at the time of application and then break down almost immediately. These are nonpersistent pesticides.

Others, known as persistent — or residual — pesticides, remain active for varying periods of time after they are applied. The active pesticide residue that these products leave behind gives continued protection against pests that may enter the area after the application is completed.

Applying insecticides
Thorough knowledge of the target pest helps determine what chemicals to use and how often to apply them. One well-timed application of an effective pesticide may provide the desired control. Sometimes repeated applications will be necessary as the infestation continues and pesticide residues break down.

The pesticide label, Extension Service recommendations, and other sources, such as pesticide dealers, usually indicate a range of treatment intervals and dosages. By carefully observing the pest problem and applying chemicals when the pests are most vulnerable, you often will be able to use lower doses of pesticides and apply them less often. Over a long growing period, this can mean considerable savings in time, money, and total pesticides applied.

The best control strategies take advantage of the natural controls provided by the pest’s natural enemies. When you choose a pesticide, consider what effect it will have on these beneficial organisms.

Also think about how a pesticide treatment will affect other pests in the area. If your treatment kills the predators and parasites of an insect that does not currently require control, that insect could quickly multiply to become a problem.

Ask your pesticide dealer, your Extension agent, or other experts for advice about the need for monitoring pest populations, delaying insecticide use, and choosing pest-specific products.
Plant Disease Agents

A plant disease is any harmful condition that makes a plant different from a normal plant in its appearance or function. Plant diseases caused by biological agents (pathogens) are the ones most important for you to know about, because pesticides are often used to control them. Pathogens include:
- fungi,
- bacteria, and
- viruses, viroids, and mycoplasmas.

Parasitic seed plants (discussed in the section on weeds) and nematodes (discussed in the section on insect-like pests) are sometimes considered plant disease agents because of the type of injury they cause to the host plant.

Pathogenic Plant Diseases

Pathogens that cause plant disease are parasites that live and feed on plant debris and on or in host plants. Many can be passed from one plant to another. Three factors are required before a pathogenic disease can develop — a susceptible host plant, a pathogenic agent, and an environment favorable for development of the pathogen.

A pathogenic disease depends on the life cycle of the parasite and on environmental conditions. Temperature and moisture, for example, affect the activity of the parasite, the ease with which a plant becomes diseased, and the way the disease develops.

The disease process starts when the parasite arrives at a part of a plant where infection can occur. If environmental conditions are favorable, the parasite will begin to develop. If the parasite enters the plant, the infection starts. The plant is diseased when it responds to the parasite.

The three main ways a plant responds are:
- **overdevelopment of tissue**, such as galls, swellings, and leaf curls,
- **underdevelopment of tissue**, such as stunting, lack of chlorophyll, and incomplete development of organs, and
- **death of tissue**, such as blights, leaf spots, wilting, and cankers.

The parasites that cause plant diseases may be spread by wind; rain; insects, birds, snails, slugs, and earthworms; transplant soil; nursery grafts; vegetative propagation (especially in strawberries, potatoes, and many flowers and ornamentals); contaminated equipment and tools; infected seed stock; pollen; dust storms; irrigation water; and people.

Fungi

Fungi are microorganisms that lack chlorophyll and cannot make their own food. They get food by living on other organisms. Some fungi live on dead or decaying organic matter. Most fungi are beneficial because they help release nutrients from dead plants and animals and thus contribute to soil fertility.

These fungi can be a pest problem when they rot or discolor wood. They can do considerable damage to buildings and lumber that are improperly ventilated or in contact with water or high humidity.

Most fungi that cause plant diseases are parasites on living plants. They may attack plants and plant products both above and below the soil surface. Some fungus pathogens attack many plant species, but others are restricted to only one host species.

Most fungi reproduce by spores, which function about the same way seeds do. Fungus spores are often microscopic in size and are produced in tremendous quantities.
numbers. Some spores can survive for weeks, months, or even years without a host plant. Excessive water or high humidity are nearly always essential for spore germination and active fungal growth. Spores can spread from plant to plant and crop to crop through wind, rain, irrigation water, insects, and insect-like pests, and by people through infected clothing and equipment.

Fungal infections frequently are identified by the vegetative body of the fungus (mycelium) and the fruiting bodies that produce the spores. These can usually be seen with the naked eye. Symptoms of fungal infections include soft rot of fruits, plant stunting, smuts, rusts, leaf spots, wilting, and thickening or curling of leaves. Powdery and downy mildew, smut, root and stem rots, and sooty and slime molds are examples of fungus diseases.

**Bacteria**

Bacteria are microscopic, one-celled organisms. They usually reproduce by single cell division. Each new cell is exactly like the parent cell. Bacteria can build up quickly under warm, humid weather conditions. Some can divide every 30 minutes. Bacteria may attack any part of a plant, either above or below the soil surface. Many leaf spots and rots are caused by bacteria.

**Viruses, Viroids, and Mycoplasmas**

Viruses and mycoplasmas are so small that they cannot be seen with an ordinary microscope. They are generally recognized by their effects on plants. Often it is difficult to distinguish between diseases caused by viruses or mycoplasmas and those caused by other plant disease agents such as fungi and bacteria.

Usually, the best way to identify a virus is to compare the symptoms with pictures and descriptions of diseased plants for which a positive identification has been made. Other methods require more sophisticated testing, such as inoculating indicator plants and observing the results or using specifically identified antibodies to test for the presence of the organism.

Viruses depend on other living organisms for food and to reproduce. They cannot exist separately from the host for very long. Viruses are commonly spread from plant to plant by mites and by aphids, leafhoppers, whiteflies, and other plant-feeding insects. They may be carried along with nematodes, fungus spores, and pollen, and may be spread by people through cultivation practices, such as pruning and grafting. A few are spread in the seeds of the infected plant.

Viruses can induce a wide variety of responses in host plants. Most often, they stunt plant growth and/or alter the plant's natural color. Viruses can cause abnormal formation of many parts of an infected plant, including the roots, stems, leaves, and fruit. Mosaic diseases, with their characteristic light and dark blotchy patterning, usually are caused by viruses.

Viroids are similar to viruses in many ways, but they are even smaller and lack the outer layer of protein that viruses have. Only a few plant diseases are known to be viroid-caused, but viroids are the suspected cause of many other plant and animal disorders. Viroids are spread mostly through infected plant stock. People can spread infected plant sap during plant propagation and other cultural practices. A few viroids are known to be transmitted with pollen and seeds.

Mycoplasmas are the smallest known independently living organisms. They can reproduce and exist apart from other living organisms. They obtain their food from plants. Yellows diseases and some stunts are caused by mycoplasmas. Most mycoplasmas are spread by insects, most commonly by leafhoppers. Mites may also spread them. Mycoplasmas are also readily spread among woody plants by grafting.
Diagnosis of Plant Disease

If you try to control a plant disease without having enough information about it, you usually will fail. The first step in disease management is to diagnose the disease correctly.

You can recognize diseased plants by comparing them with healthy plants. To recognize a disease condition, you must know the plant's normal growth habits. When you are trying to identify the cause of a plant disease, you need to observe:
- symptoms — the host plant's reaction to the disease agent, and
- signs — visible presence of the disease agent.

Many plant diseases cause similar symptoms in the host plants. Such things as leaf spots, wilts, galls on roots, or stunted growth may be caused by many different agents, including many that are not pathogens. For example, the symptoms may be a result of mechanical injury, improperly applied fertilizers and pesticides, or frost.

Often the only way to pinpoint the cause is by finding the observable signs that the particular disease agent is present — such as fungal spores and mycelium or bacterial ooze.

Some pathogenic diseases occur regularly on specific agricultural, ornamental, and forestry plantings. For these diseases, noticing specific symptoms may be enough to allow you to correctly identify the cause. But many less common pathogenic disease agents, including some fungi and bacteria, may have to be positively identified by an expert with access to sophisticated laboratory procedures.

Controlling Plant Disease

At present, plant disease control measures are mainly preventive. Once a plant or plant product is infected and symptoms appear, few control methods — including pesticides — are effective.

The main methods for control of plant diseases include:
- host resistance,
- cultural control,
- mechanical control,
- sanitation, and
- chemical control.

Host Resistance

The use of disease-resistant varieties is usually one of the most effective, long-lasting, and economical ways to control plant disease.

In some crop and greenhouse situations, resistant varieties are the only way to ensure continued production. For many diseases in low-value forage and field crops, for example, chemical controls are too costly. For other diseases, such as many soil-borne pathogens, no economical or effective chemical control method is available.

Cultural Control

For a plant disease to develop, a pathogen and its host must come together under the right environmental conditions. Cultural practices can prevent an infection by altering the environment, the condition of the host, or the behavior of the pathogen.

Crop rotation

Pathogenic organisms can usually carry over from one growing season to the next in the soil or in plant debris. Continual production of the same or closely related crops on the same piece of land leads to disease buildup. Crop rotation reduces the buildup of pathogens but seldom provides complete disease control.

Obviously, crop rotation is not always possible, practical, or desirable. Perennial crops such as trees, woody ornamentals, and turfgrass must remain in one location for many years. Some crops, such as corn, cotton, or wheat, often are more practical to grow on the same land year after year despite the potential for a buildup of plant disease pathogens.

Planting time

Cool-weather crops, such as spinach, peas, and some turfgrass, are subject to attack by certain diseases if planted when the temperatures are warm. They often emerge and establish poorly under such conditions. Conversely, beans, melons, and many flowers should be planted under warm conditions to avoid disease.

Seed aging

Some seed pathogens can be killed by holding the seed in storage. Proper storage conditions are essential to ensure that seed viability is not lowered.

Mechanical Control

Heat kills many pathogens. In greenhouses, soil sterilized by heat helps control some plant diseases. Hot water treatments are effective in producing clean seed and planting materials. Seed and vegetative propagation materials (such as roots, bulbs, corms, and tubers) may be treated before planting to control some fungal, bacterial, and viral diseases.
In greenhouses and other enclosed growing areas, as well as in areas where food and feed are stored, you may be able to control temperature and humidity to keep pathogens from building up rapidly enough to cause damage.

**Sanitation**
Sanitation practices help to prevent and suppress some plant diseases by removing the pathogens themselves or their sources of food and shelter.

**Pathogen-free seed stock**
Using clean seed stock is an important way to reduce the spread of plant disease. Seeds are often grown in arid areas where the amount of moisture is controlled by an irrigation system. This eliminates infection by diseases that require high moisture and humidity levels.

**Pathogen-free propagation**
Plant disease pathogens are frequently carried in or on vegetative propagation materials (such as roots, bulbs, tubers, corms, and cuttings). Use of clean planting stock is especially important in the culture of certain high-value agricultural and ornamental crops. These stock plants must be grown in pathogen-free greenhouses or in sites isolated from growing areas for these crops. When you plan for isolation, consider how far the pathogen may spread, how the pathogen is spread, and the distance between potential growing sites.

**Pathogen-free storage**
To control disease in food and feed storage areas, you must first have good sanitation in the facility before storage. Then be sure the crop is relatively pathogen-free at the time it is put into storage.

**Clean planting sites**
In some crops, you can control or reduce certain plant disease pathogens by eliminating other nearby plants that are hosts for the same disease organisms. These may be:
- plants that harbor the pathogens, such as weeds around field borders, ditch banks, and hedgerows, or
- plants the organism requires for one stage of its life cycle.
An apple grower, for example, can control cedar apple rust by eliminating nearby cedar (juniper) trees.

**Removing infected plants**
You often control diseases by systematically removing infected plants or plant parts before the disease pathogen spreads to other “clean” plants. This method is especially important for the control of some viral and mycoplasma pathogens for which no other controls are available.

**Crop residue management**
Infected crop residues often provide an ideal environment for carryover of many pathogens. In some cases the pathogens increase greatly in residues. Three basic techniques are used to manage crop residues:
- deep plowing buries pathogen-infested residues and surface soil and replaces them with soil that is relatively free from pathogens,
- fallowing reduces carryover of pathogens because their food source decays and is no longer available,
- burning kills some pathogens and removes the residue they live on. Burning may not be legal in some areas.

**Disinfecting equipment and tools**
Some plant diseases can be spread from plant to plant, field to field, and crop to crop by workers and their equipment. Disinfecting equipment, tools, and clothing with a product such as bleach (sodium hypochlorite) before moving from an infected area to a disease-free area can prevent or delay disease spread. This method of disease spread is especially important in high humidity and wet field conditions, because the pathogens are transported in the droplets of water that form on the equipment, tools, and skin.

**Chemical Control**
Chemicals used to control plant disease pathogens include fungicides and bactericides (disinfectants). The general term “fungicide” is often used to describe pesticides that combat both fungi and bacteria.

**Persistence**
Fungicides vary in the length of time they remain active after they are applied. A nonpersistent fungicide controls the pathogen on contact or shortly after and then is no longer chemically active against the plant disease. A persistent fungicide can retain its chemical effectiveness for a period of time after application.

The pesticide label will tell you how frequently you need to apply the product. The interval may depend not only on the persistence of the pesticide, but also on:
- environmental conditions (high humidity and warm temperatures may make more frequent applications necessary), and
- whether rainfall, irrigation, or watering washes the fungicide off plant surfaces.
Mode of action

Fungicides may be classified as protectants, eradicants, and systemics.

Protectants must be applied before or during infection of the plant by the pathogen. In order to be effective, a protectant fungicide must either be persistent or be applied repeatedly. Most chemicals now available to combat plant diseases are protectants.

Eradicants are less common and are applied after infection has occurred. They act on contact by killing the organism or by preventing its further growth and reproduction.

Secondary infections

A few fungicides prevent the plant-disease organisms from reproducing in an infected plant. The fungicides prevent spore production in existing leaf infections and reduce the likelihood of spread. These fungicides are used, for example, against new apple scab infections, and they prevent spore production in existing leaf infections.

Seed treatment

Seeds are often treated with a fungicide to control disease-causing organisms in or on the seeds. Chemical seed treatment is also used to protect seeds from disease organisms that cause seed or seedling rots and to protect seedlings from infection by damping-off fungi in the soil.

Soil applications

In-row and spot applications of soil fungicides at the time of planting protect young seedlings from many disease organisms in the soil. Soil fungicides may also be used to protect the roots of established plants from infection by pathogens. These fungicides are applied as drenches and must move down through the soil into the root zone at a concentration adequate for control.

Other pesticides

Some pesticides that are not fungicides are used for indirect control of plant diseases. Insecticides and miticides may be used to control the insects and mites that spread plant disease organisms or that damage the plant in a way that makes it more vulnerable to plant disease. Sometimes herbicides are used to eliminate weeds that may harbor disease-causing organisms.

Coverage

Almost all plant disease control chemicals are applied as cover sprays. The purpose is to reach and protect all potential sites of infection. Unlike insects and other pests, disease organisms do not move once they contact the plant. For good disease control, you need to apply fungicides and bactericides evenly over the entire plant surface.

Systemics are used to kill disease organisms on living plants. Systemic chemicals are transported in the sap stream from the application site to other plant parts. This type of chemical may act as both a protectant and an eradicant.

Timing

Successful chemical control of plant diseases requires proper timing. You usually must begin plant disease control before infection occurs. Apply the protectant chemical when environmental conditions are expected to be ideal for the development of plant disease organisms. If you do not apply the protectant in time, major crop damage may result or you may need to use the more expensive eradicant sprays.

Most fungicides prevent or inhibit disease growth for a period of time. Once the fungicide is no longer effective, the controlled disease may start to grow again or to produce spores and spread. For this reason, you may need to apply the fungicide at regular intervals. For example, sprays that control late blight of potato must be applied every few days when cool, moist conditions favor infection.

Frequent applications are common during production of some fruit and vegetable crops. Different disease threats occur throughout the growing season, and many of the disease-causing organisms are capable of causing repeated infections. Some crops, however, are vulnerable to disease only during a short time period and a single application of fungicide may provide adequate protection. Snow mold on turf is often controlled with a single fungicide application just before a snowfall.
Weeds

Any plant can be considered a weed when it is growing where it is not wanted. Weeds become a problem when they reduce crop yields, increase costs of production, and reduce the quality of crop and livestock products. In addition, some weeds cause allergic effects, such as skin irritation and hay fever, and some are poisonous to people and livestock. Weeds also spoil the beauty of turf and landscape plantings.

Weeds harm desirable plants by:
- competing for water, nutrients, light, and space,
- contaminating the product at harvest,
- harboring pest insects, mites, vertebrates, or plant disease agents, and
- releasing toxins into the soil that inhibit growth of desirable plants.

Weeds may become pests in water by:
- hindering fish growth and reproduction,
- promoting mosquito production,
- hindering boating, fishing, and swimming, and
- clogging irrigation ditches, drainage ditches, and channels.

Weeds can interfere in the production of grazing animals by:
- poisoning the animals, and
- causing an “off-flavor” in milk and meat.

In cultivated crops, the weeds usually found are those that are favored by the crop production practices. The size and kind of weed problem often depends more on the crop production method, especially the use or nonuse of cultivation, than on the crop species involved.

In noncrop areas, weed populations may be affected by factors such as:
- weed control programs used in the past,
- frequency of mowing or other traffic in the area, and
- susceptibility to herbicides.

Development Stages

All crop plants have four stages of development:
- seedling — small, delicate plantlets.
- vegetative — fast growth; production of stems, roots, and leaves. Uptake and movement of water and nutrients is fast and thorough.
- seed production — energy directed to producing flowers and seed. Uptake of water and nutrients is slow and is directed mainly to flower, fruit, and seed structures.
- maturity — little or no energy production or movement of water and nutrients.

Life Cycles of Plants

Annuals

Plants with a 1-year life cycle are annuals. They grow from seed, mature, and produce seed for the next generation in 1 year or less. They are grasslike (crabgrass and foxtail) or have broad leaves (henbit and common cocklebur).

There are two types of annual plants:
- Summer annuals are plants that grow from seeds that germinate in the spring. They grow, mature, produce seed, and die before winter. Examples: crabgrass, foxtail, common cocklebur, pigweed, and common lambsquarters.
- Winter annuals are plants that grow from seeds that germinate in the fall. They grow, mature, produce seed, and die before summer. Examples: cheat, henbit, and annual bluegrass.
Biennials

Plants with a 2-year life cycle are biennials. They grow from seed and develop a heavy root and compact cluster of leaves (called a rosette) the first year. In the second year, they mature, produce seed, and die. Examples: mullein, burdock, and bullthistle.

Perennials

Plants that live more than 2 years are perennials. Some perennial plants mature and reproduce in the first year and then repeat the vegetative, seed production, and maturity stages for several following years. In other perennials, the seed production and maturity stages may be delayed for several years. Some perennial plants die back each winter; others, such as deciduous trees, may lose their leaves, but do not die back to the ground.

Most perennials grow from seed; many species also produce tubers, bulbs, rhizomes (below-ground rootlike stems), or stolons (above-ground stems that produce roots). Examples of perennials are Johnson grass, field bindweed, dandelion, and plantain.

Simple perennials normally reproduce by seeds. However, root pieces that may be left by cultivation can produce new plants. Examples: dandelions, plantain, trees, and shrubs.

Bulbous perennials may reproduce by seed, bulblets, or bulbs. Wild garlic, for example, produces seed and bulblets above ground and bulbs below ground.

Creeping perennials produce seeds but also produce rhizomes (below-ground stems) or stolons (above-ground stems that produce roots). Examples: Johnson grass, field bindweed, and Bermuda grass.

Weed Classification

Land Plants

Most weeds on land are either grasses, sedges, or broadleaf plants.

Grasses

Grass seedlings have only one leaf as they emerge from the seed. Their leaves are generally narrow and upright with parallel veins. Grass stems are round and may be either hollow or solid. Most grasses have fibrous root systems. The growing point on seedling grasses is sheathed and located below the soil surface. Some grass species are annuals; others are perennials.

Sedges

Sedges are similar to grasses except that they have triangular stems and three rows of leaves. They are often listed under grasses on the pesticide label. Most sedges are found in wet places, but principal pest species are found in fertile, well-drained soils. Yellow and purple nutseed are perennial weed species that produce rhizomes and tubers.

Broadleaf weeds

The seedlings of broadleaf weeds have two leaves as they emerge from the seed. Their leaves are generally broad with netlike veins. Broadleaf weeds usually have a taproot and a relatively coarse root system. All actively growing broadleaf plants have exposed growing points at the end of each stem and in each leaf axil. Perennial broadleaf plants may also have growing points on roots and stems above and below the surface of the soil. Broadleaves contain species with annual, biennial, and perennial life cycles.
Aquatic Plants

Plants that are present in bodies of water may be pests in some agricultural situations. There are two types of aquatic plants — vascular plants and algae.

Vascular plants

Many aquatic plants are similar to land plants — they have stems, leaves, flowers, and roots. Most act as perennial plants, dying back and becoming dormant in the fall and beginning new growth in the spring.

Aquatic plants are classified as:
- **emergent** (emersed) — most of the plant extends above the water surface, but it is rooted to the bottom. Examples are cattails, bulrushes, arrowheads, and reeds.
- **floating** — all or part of the plant floats on the surface. Examples are duckweeds, water-little, and waterhyacinth.
- **submersed** (submersed) — most of the plant grows beneath the water surface. Examples are watermilfoil, elodea, naiads, pondweeds, and coontail.

Emergent and floating plants, like some land plants, have a thick outer layer on their leaves and stems that hinders herbicide absorption. Submergent plants have a very thin outer layer on their leaves and stems and are susceptible to herbicidal activity.

Algae

Algae are aquatic plants without true stems, leaves, or vascular systems. For control purposes, they may be classified as:
- **planktonic algae** — microscopic plants floating in the water. They often multiply rapidly and cause “blooms” in which the water appears soupy green, brown, or reddish brown, depending on the algal type.
- **filamentous algae** — long, thin strands of algae that form floating mats or long strings extending from rocks, bottom sediment, or other underwater surfaces. Examples are cladophora and spirogyra.
- **macroscopic freshwater algae** — large algae that look like vascular aquatic plants. The two should not be confused, because their control is different. Many are attached to the bottom and grow up to 2 feet tall; however, they have no true roots, stems, or leaves. Examples are chara and nitella.

Parasitic Seed Plants

Dodders, broomrape, witchweed, and some mosses are important weeds on some agricultural plants. They live on and get their food from the host plants. They can severely stunt and even kill the host plants by using the host plant’s water, food, and minerals. These plants reproduce by seeds. Some can also spread from plant to plant in close stands by vining and twining.

Weed Control Strategy

Weed control is nearly always designed to prevent or suppress a weed infestation. Eradication usually is attempted only in regulatory weed programs and in relatively small, confined areas, such as greenhouses or plant beds.

To control weeds that are growing among or close to desirable plants, you must take advantage of the differences between the weeds and the desired species. Be sure that the plants you are trying to protect are not susceptible to the weed control method you choose. Generally, the more similar the desirable plant and the weed species are to one another, the more difficult weed control becomes. For example, broadleaf weeds are usually more difficult to control in broadleaf crops, and grass weeds are often difficult to control in grass crops.

A plan to control weeds may include:
- biological control,
- cultural control,
- sanitation, and
- chemical control.
Biological Control

Biological weed control usually involves the use of insects and disease-causing agents that attack certain weed species. An example is the control of musk thistle with the thistle head weevil.

Effective biological control requires two things:
- the insect or disease must affect only the weed requiring control; otherwise, it may spread to other species—such as crops and ornamentals—and become a pest itself.
- the insects must have few natural enemies that interfere with their activity.

Grazing is another form of biological control sometimes used to control plant growth along ditches, fence rows, noncropland areas, forage crops, and roadsides. Sheep and goats are used most often, but geese are used for weeding some crops, such as strawberries.

Cultural Control

Several kinds of practices can be used in cultivated plants to make it more difficult for weeds to survive. Most of these techniques work by disrupting the normal relationship between the weed and the crop.

Tillage

Tillage is an effective and often-used method to kill or control weeds in row crops, nurseries, and forest plantings. However, tillage may bring buried seeds to the surface where they can either germinate and compete with the newly planted crop or be spread to nearby fields. Tillage can increase soil erosion and may help to spread established plant diseases to uninfected areas of the field. In some situations, weeds can be removed by hand weeding or hoeing.

Time of planting

Sometimes the planting date of crops and turfgrass can be delayed until after weeds have emerged and have been removed by cultivation or by herbicides.

Nurse crops

Plant species (usually annuals) that germinate quickly and grow rapidly are sometimes planted with a perennial crop to provide competition with weeds and allow the crop to become established. The nurse crop is then harvested or removed to allow the perennial crop to take over. For example, oats are sometimes used as a nurse crop to help establish alfalfa or clover. Annual ryegrass is sometimes used in mixtures to provide a nurse crop for perennial rye, fescue, or bluegrass.

Burning

Fire may be used to control limited infestations of annual or biennial weeds. Because fire destroys only the above-ground parts of plants, it is a good choice for control of woody plants in some situations, but usually will not control other types of perennial weeds that have underground growing points.

Mulching

By serving as a physical barrier and by keeping light from reaching weed seeds, mulching prevents weed growth between rows, around trees and shrubs, or in other areas where no plants are desired.

Mowing

Mowing may reduce competition between weeds and crops and prevent flowering and seeding of annual, biennial, and perennial weeds. Mowing is often used in orchards to control weeds and prevent soil erosion. The mower must be set at a height that will ensure control of weed plants without destroying desired plants. Mowing is an important aspect of turfgrass weed control.

Flooding

Flooding has long been used for weed control in rice. The water covers the entire weed, killing it by suffocation.

Reduced tillage

This method can reduce both weed growth and soil erosion. With limited tillage, weed seeds are not brought near the soil surface. Those that do germinate do not have as much light or space to get started. However, the remaining debris may harbor insects and plant disease agents.

Shading

Aquatic weeds are sometimes controlled by shading out the sunlight. Shading can be done, for example, by using bottom covers, adding dye to the water, or fertilizing to create plankton algae bloom that shades the bottom.

Land weeds can be shaded by planting crops so closely together that they keep the sunlight from reaching the emerging weeds.

Sanitation

Using "clean" seeds — those contaminated with few weed seeds — is a good way to reduce weed problems. If you buy seed, read the seed purity information on the label. It will indicate the approxi-
mated percent, by weight, of weed seeds and other-crop seeds in the container. If you grow your own seed, pay particular attention to weed control in the crops grown for seed production, and consider having a representative sample tested for purity.

**Chemical Control**

Some weed problems can best be controlled with the use of herbicides. Several factors affect a plant's susceptibility to herbicides:

**Growing points**

Those that are sheathed or located below the soil surface are not reached by contact herbicide sprays.

**Leaf Shape**

Herbicides tend to bounce or run off narrow, upright leaves. Broad, flat leaves tend to hold the herbicide longer.

**Waxy cuticle**

Sprays applied to leaves may be prevented from entering by a thick, waxy cuticle. The waxy surface also may cause a spray solution to form droplets and run off the leaves.

**Leaf hairs**

A dense layer of leaf hairs holds the herbicide droplets away from the leaf surface, allowing less chemical to be absorbed into the plant. A thin layer of leaf hairs causes the chemical to stay on the leaf surface longer than normal, allowing more chemical to be absorbed into the plant.

**Size and age**

Young, rapidly growing plants are more susceptible to herbicides than are larger, more mature plants.

**Deactivation**

Certain plants can stop the action of herbicides (deactivate) and so are less susceptible to injury from these chemicals. Such plants may become dominant over a period of time if similar herbicides are used repeatedly.

**Stage in life cycle**

Seedlings are very susceptible to herbicides and to most other weed control practices. Plants in the vegetative and early bud stages are generally very susceptible to translocated herbicides. Plants with seeds or in the maturity stage are the least susceptible to most chemical weed control practices.

**Timing of stages in the life cycle**

Plants that germinate and develop at different times than the crop species may be susceptible to carefully timed herbicide applications without risk of injury to the crop.

**Herbicides**

Just as there are many types of weeds, there also are many kinds of herbicides. They work in several different ways to control weeds. Some herbicides are applied to the leaves and other above-ground parts of the plant (foliar applications) and some are applied to the soil.

**Contact/Translocated**

Some herbicides kill plants on contact; others work by translocation (moving throughout the plant's system).

**Contact herbicides**

Contact herbicides kill only the parts of the plant the chemical touches. They usually are used to control annuals and biennials and are characterized by the quick dieback they cause.

**Translocated herbicides**

Translocated herbicides are absorbed by roots or leaves and carried throughout the plant. Translocated herbicides are particularly effective against perennial weeds, because the
chemical reaches all parts of the plant — even deep roots and woody stems. Translocated herbicides may take longer than contact herbicides to provide the desired results. Control may take as much as 2 or 3 weeks — even longer for woody perennials.

Selective/Nonselective

Herbicide activity is either selective or nonselective.

Selective herbicides

Selective herbicides are used to kill weeds without causing significant damage to desirable plants nearby. They are used to reduce weed competition in crops, lawns, and ornamental plantings.

Nonselective herbicides

Nonselective herbicides, if applied at an adequate rate, will kill all plants in the area. They are used where no plant growth is wanted, such as fence rows, irrigation and drainage ditch banks, and greenhouse floors and benches.

Factors affecting selectivity

Herbicide selectivity may vary according to the application rate. High rates of selective herbicides usually will injure all plants at the application site. Some nonselective herbicides can be used selectively by applying them at a lower rate.

Other factors that affect selectivity include the time and method of application, environmental conditions, and the stage of plant growth.

Persistent/Nonpersistent

Herbicides also vary in the length of time they remain active after they are applied.

Nonpersistent herbicides

Pesticides that quickly break down after application are called nonpersistent. These pesticides are often broken down easily by microorganisms or sunlight. A nonpersistent herbicide performs its control function soon after application and then is no longer active against weeds.

Persistent herbicides

The chemical structure of persistent herbicides does not change for a long time after application. Persistent herbicides may stay on or in the soil and give long-term weed control without repeated applications. If sensitive plants are later planted in the treated area, these herbicides may injure them. Persistent herbicides are sometimes called “residual” herbicides.

Choosing a Type of Herbicide

The specific pesticide products mentioned in this section are intended only as examples, not as endorsements or recommendations.

You need to choose the combination of herbicide type and application method (foliar or soil) that will provide the best control. In making the choice, use your knowledge of the weed itself, herbicide characteristics, and the crop or area to be treated. Follow the directions on the herbicide label carefully.

Foliar-contact-nonpersistent-selective

These herbicides also kill weeds by contact on the leaves and do not readily move to underground plant parts. They control seedling weeds; biennial and perennial weeds with dormant buds will regrow. Due to differences in plant structure or leaf surfaces, certain plants are not harmed by these chemicals. This makes the herbicides selective.

Acfilurofen, for example, is used for annual morningglory control in soybeans. One reason that the soybeans are unharmed is that the hairs on their leaves prevent the herbicide from reaching the leaf surface.

Bromoxynil is used to control broadleaf annual weeds in small grains. This herbicide is selective.
partly because of differences in the way the grain crop (grass-type) leaves and the broadleaf weed leaves are oriented.

**Foliar-translocated-nonpersistent-nonselective**

These herbicides are applied to the foliage and are absorbed and moved throughout the entire plant. Movement of the herbicide into the plant root system enables these compounds to control biennial and perennial weeds.

Since they are nonselective, most are used before planting and after harvesting. But if the weeds are taller than the crop, such as volunteer corn in grain, special equipment can be used to "wick" the herbicide onto the weeds without harming the crop.

These herbicides usually do not persist after application and will not control dormant weeds or weeds that germinate from seed after the herbicide is applied. Sometimes a more persistent herbicide is applied with or after these types of herbicides to give continued weed control.

Glyphosate is an example of a foliar-translocated-nonpersistent-nonselective herbicide used to control weeds in an area before or after planting (or "wicked" onto weeds that are taller than the desired plants).

**Foliar-translocated-nonpersistent-selective**

These herbicides are some of the oldest and most widely used weed-control chemicals. After they are applied to the foliage, they are absorbed and move throughout the plant. They are selective and can be applied to weeds while the crop is present with little or no harm to the desirable plants.

The best example of this type of herbicide is 2,4-D. It kills broad-leaf weeds in grass crops, such as oats, wheat, barley, corn, and turfgrass. Dicamba is used for hard-to-control weeds such as thistle, common milkweed, horehound, and hedge or field bindweed in corn. It is also used in grass pastures, small grains, and rangelands. Other herbicides in this group include triclopyr and 2,4-DP. These herbicides are used for brush control along fence lines and on rangelands, pastures, and rights-of-way. By selectively killing brushy-type plants without killing grass, less bare ground is left once the brush dies.

**Soil-contact-nonpersistent-nonselective**

Only a few herbicides belong to this group. The most common are soil fumigants, which kill all plants and many seeds in the treated area. These fumigants are injected deeply into the soil or are sealed into the soil with water, plastic tarps, or other gas-tight covers. The fumigant is kept sealed into the treated soil for a short "exposure" period. Then the water is allowed to evaporate, the coverings are removed, and/or the soil is aerated to allow the remaining fumigant gas to escape. Usually the treated area can be planted without injury immediately following the aeration period, making these soil fumigants one of the least persistent herbicides available.

**Soil-translocated-nonpersistent-selective**

These herbicides are applied to soil before, at, or immediately after planting and are often referred to as preplant or preemergence-type herbicides. They typically persist for 2 to 4 months. Almost all soil-applied herbicides used for weed control in vegetable, agronomic (except small grain) crops, turfgrass, ornamental, and flower crops are this type. They are applied to the soil and are primarily root or shoot absorbed, although some may be absorbed through leaves. Examples include atrazine on corn, linuron on potatoes, and EPTC on
ornamentals — all of which persist from 6 weeks to an entire growing season.

**Soil-translocated-persistent-nonselective**

These herbicides are used to control all vegetation in an area for an extended period of time. They may be used around farm buildings. For example, bromacil at high label rates, remains active for 3 to 5 years. At these high rates, bromacil will kill most brush and tree species in a treated area.

**Soil-translocated-persistent-selective**

These herbicides are used to control weeds in deeply rooted crops such as fruit, nut, and ornamental trees, cane fruits, and grapes. They may be applied to the foliage of the weeds, although most of the herbicide is eventually absorbed through the weeds' root system.

These herbicides do not dissolve readily in water and do not leach readily. Therefore, they usually do not move down to the root system of deeply rooted crops. They usually persist for more than a year. For example, simazine will control shallow-rooted weeds without injuring deeply rooted crops.

**Chemicals That Change Plant Processes**

Plant growth regulators, defoliants, and desiccants are classified as pesticides in Federal laws. These chemicals are used on plants to alter normal plant processes in some way. Overdosing will kill or seriously damage the plants.

A plant growth regulator will speed up, stop, retard, prolong, promote, start, or in some other way influence vegetative or reproductive growth of a plant. These chemicals are sometimes called growth regulators or plant regulators. They are used, for example, to thin apples, control suckers on tobacco, control the height of some floral potted plants, promote dense growth of ornamentals, and stimulate rooting.

A defoliant causes the leaves to drop from plants without killing the plants. A desiccant speeds up the drying of plant leaves, stems, or vines. Desiccants and defoliants are often called "harvest aid" chemicals. They usually are used to make harvesting of a crop easier or to advance the time of harvest. They are often used on cotton, soybeans, tomatoes, and potatoes.
Vertebrate Pests

All vertebrate animals have a jointed backbone. They include mammals, birds, reptiles, amphibians, and fish. Most vertebrate animals are not pests, but a few can be pests in some situations.

Some vertebrate pests, such as birds, rodents, raccoons, or deer, may eat or injure agricultural and ornamental crops. Birds and mammals may eat newly planted seed. Birds and rodents consume stored food and often contaminate and ruin more than they eat. Birds and mammals that prey on livestock and poultry cause costly losses to ranchers each year.

Rodents, other mammals, and some birds may carry serious diseases of humans and domestic animals such as rabies, plague, and tularemia. Rodents are an annoyance and a health hazard when they get into buildings.

Burrowing and gnawing mammals may damage dams, drainage and irrigation tunnels, turf, and outdoor wood products such as building foundations. Beavers may harm desirable plants, and they may cause flooding by building dams.

Undesirable fish species may crowd out desirable food and sport species. The few poisonous species of snakes and lizards become a problem when people, livestock, or pets are threatened. Water snakes and turtles may cause disruption or harm in fish hatcheries or waterfowl nesting reserves. Amphibians occasionally clog water outlets, filters, pipes, hoses, and other equipment associated with irrigation systems and drains.

Controlling Vertebrates

Techniques for control of vertebrate pests depend on whether the pest problem is indoors or outdoors.

Indoor vertebrate pest control usually is aimed at eradicating existing pest infestations and preventing new pests from getting in. Nearly all indoor vertebrate pests are rodents, but others, such as bats, birds, and raccoons, also may require control.

Outdoors, the strategy usually is to suppress the vertebrate pest population to a level where the damage or injury is economically acceptable.

Local and State laws may prohibit the killing or trapping of some animals such as birds, coyotes, muskrats, and beavers without special permits. Before you begin a control program, check with local authorities, such as fish and wildlife officials or the State agency responsible for pesticide regulation.

Methods of vertebrate pest control include:
- mechanical control,
- biological control,
- sanitation, and
- chemical control.

Mechanical Control

Mechanical control methods for vertebrate pests include traps, barriers, gunning, attractants, and repellents.

Traps

Traps are sometimes a good choice for vertebrate pest control. Leg-hold traps have been used traditionally, but these traps cause the trapped animal to suffer and may injure nontarget animals. Traps that quickly kill only target pests are better. Baited box traps may be a good choice; it is sometimes possible to relocate captured animals to another area. Check traps daily to maintain their effectiveness.

Barriers

Barriers are designed to prevent pests from passing through. These include fences, screens, and other barriers that cover openings, stop tunneling, and prevent gnawing. Materials used include sheet metal, hardware cloth, concrete, and similar materials. Barriers are especially effective in preventing rodents, bats, and birds from entering structures.
Gunning

Gunning is an expensive and time-consuming way to achieve vertebrate control. It works best in combination with other methods. It may be useful for large predators not controlled by traps or toxic devices. Permits may be required.

Attractants

Many techniques, such as light and sound, are used to attract pests to a trap. Predator calling is sometimes used to attract large predators when it is necessary to control them by gunning.

Repellents

Repellents are devices aimed at keeping pests from doing damage. They include such things as automatic exploders, noisemakers, recordings of scare calls, moving objects, and lights. These devices do not always provide good control. Their success often depends on where they are placed. The effectiveness of electromagnetic and ultrasonic rodent repellers is particularly questionable.

Biological Control

In some circumstances, vertebrate pests can be suppressed by increasing the presence of their predators. Developing habitats for birds that prey on rodents, using cats for rodent control, and using dogs to protect sheep from coyotes are examples of this type of control.

Sanitation

Removing sources of food and shelter helps to suppress some vertebrate pests. Sanitation techniques are used widely to manage rodents in and around structures.

Chemical Control

Pesticides for rodent pest control usually are formulated in baits. Because the chemicals may be highly toxic to people, livestock, and other animals, correct bait placement is important. To use baits effectively, you need a thorough knowledge of the pest’s habits.

Few pesticides are available for control of vertebrate pests other than rodents, and most of them require special local permits for use. The chemicals that are registered are usually bait applications. A few chemicals designed for aquatic pests or massive populations of pest birds are used as broadcast applications. The chemicals used to control vertebrate pests include rodenticides, piscicides (fish), avicides (birds), and predacides (predators).
Test Your Knowledge

Insects and Insect-like Pests

Q. Why is pest identification important?
A. You cannot make a good decision about how to manage a pest problem until you are sure what the pest is. Pests differ in their life cycles, habitats, behavior, and susceptibility to various control methods.

Q. Why do you need to understand the life cycle and habits of the pest you need to manage?
A. Knowing about a pest’s life cycle helps to:
   (i) identify it in all its growth stages,
   (ii) predict what kind of damage it is likely to cause in each stage, and
   (iii) use control measures at the times when the pest is most vulnerable.

Q. List some factors to consider when deciding whether control of a pest is necessary.
A. 1. Is the pest causing any harm?
    2. Would the cost of control be more than the economic loss from the damage the pest is causing?

Q. Explain the three primary objectives of pest control: prevention, suppression, and eradication.
A. Prevention means starting control measures before a pest becomes a problem.
   Suppression means reducing the numbers of pests or their damage to an acceptable level.
   Eradication means destroying an entire pest population in an area.

Q. List some nonchemical methods that can be used to control pests in some agricultural situations.
A. Nonchemical control methods include:
   (i) host resistance,
   (ii) biological control,
   (iii) cultural control,
   (iv) mechanical control,
   (v) sanitation.

Q. Explain what is meant by “persistent” pesticides and “nonpersistent” pesticides.
A. A persistent pesticide remains active for a period of time after application, giving continued protection against the pest.
   A nonpersistent pesticide breaks down quickly after it is applied.

Q. Explain the action of contact pesticides, systemic pesticides, and translocated herbicides.
A. Contact pesticides act when the pest touches them.
   Systemic pesticides are taken into the blood of a host animal or the sap of a host plant. The pest is killed as it feeds, but the host is not harmed by the pesticide.
   Translocated herbicides kill plants by being absorbed by leaves, stems, or roots and moving throughout the plant.

Q. What two physical characteristics do all mature insects have in common?
A. All mature insects have six legs and three body parts (head, thorax, and abdomen).

Q. What are the four main types of insect mouthparts? Give an example of each.
A. Four types of insect mouthparts are:
   (i) chewing (cockroaches, ants, beetles, caterpillars, and grasshoppers),
   (ii) piercing-sucking (stable flies, sucking lice, bed bugs, mosquitoes, true bugs, and aphids),
   (iii) sponging (flesh flies, blow flies, and house flies),
   (iv) siphoning (butterflies and moths).
[The examples listed here are those cited in this unit; you may know of others.]
Q. What is “metamorphosis”?
A. Metamorphosis is the series of changes through which an insect passes in its growth from egg to adult.

Q. What are the three stages of gradual metamorphosis?
A. The three stages of gradual metamorphosis are egg, nymph, and adult.

Q. What are the four stages of complete metamorphosis?
A. The four stages of complete metamorphosis are egg, larva, pupa, and adult.

Q. Name several other pests that resemble insects or cause similar types of damage.
A. Insect-like pests discussed in this unit include mites, ticks, spiders, scorpions, sowbugs, pillbugs, water fleas, wood lice, centipedes, millipedes, nematodes, and mollusks (snails and slugs).

Q. During what stage in the life cycle are most insects most vulnerable and easiest to control?
A. The best control generally can be achieved during the early larval or nymphal stages, when pests are small and active.

Q. What are the two main ways in which pesticides act to poison insects and similar pests?
A. Stomach poisons must be eaten by the pest; contact poisons act when the pest touches them.

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**Plant Disease Agents**

Q. What is a plant disease?
A. A plant disease is any harmful condition that makes a plant different from a normal plant in its appearance or function.

Q. What are the three main types of pathogens that cause plant diseases?
A. The three main types of pathogens that cause plant diseases are fungi, bacteria, and viruses.

Q. What three factors are required before a pathogenic plant disease can develop?
A. There must be a susceptible host plant, a pathogenic agent, and an environment favorable for development of the pathogen.

Q. How do plants respond to diseases?
A. The three main ways a plant responds to a disease are:
- overdevelopment of tissue, such as galls, swellings, and leaf curls,
- underdevelopment of tissue, such as stunting, lack of chlorophyll, and incomplete development of organs, and
- death of tissue, such as blights, leaf spots, wilting, and cankers.

Q. List several ways in which plant disease agents can be spread.
A. The parasites that cause plant diseases may be spread by wind; rain; insects, birds, snails, slugs, and earthworms; transplant soil; nursery grafts; vegetative propagation (especially in strawberries, potatoes, and many flowers and ornamentals); contaminated equipment and tools; infected seed stock; pollen; dust storms; irrigation water; and people.

Q. What are symptoms and signs? Are a plant’s symptoms and signs a sure way to diagnose a plant disease?
A. Symptoms—such as leaf spots, wilts, galls, or stunted growth—are the host plant’s reaction to the disease agent.

Signs—such as fungal spores or bacterial ooze—are the visible presence of the disease agent on the plant.

It is sometimes possible to use these signs and symptoms to identify some common diseases that occur regularly on agricultural plants. But many different diseases, as well as other conditions such as mechanical injury or frost, may cause a similar appearance in the plant. It is often necessary to get expert help with the diagnosis.
Q. Match the type of fungicide with its action:

1. Eradicant  A. Applied before or during infection of the plant by the pathogen.
2. Systemic  B. Applied after infection occurs; kills disease organisms on contact, or prevents further growth and reproduction.
3. Protectant  C. Moves in the sap from the application site to other plant parts, where it kills the disease organisms.

A. 1–B, 2–C, 3–A

Weeds

Q. What are the stages in the life cycle of a weed?

A. Weeds have four developmental stages: seedling, vegetative, seed production, and maturity.

Q. Match each stage of weed development with the correct description:

1. Seedling  A. Energy directed to producing flowers and seed.
2. Vegetative  B. Little or no energy production or movement of water and nutrients.
3. Seed production  C. Fast growth; production of stems, roots, and leaves; fast uptake of water and nutrients.
4. Maturity  D. Small, delicate plantlets.

A. 1–D, 2–C, 3–A, 4–B

Q. Match the type of plant with the correct description of its life cycle:

1. Annual  A. Plants that live more than 2 years.
2. Summer annual  B. Have a 2-year life cycle.
3. Winter annual  C. Grow from seed, mature, and produce seed for the next generation in 1 year or less.
4. Biennial  D. Have a 1-year life cycle; grow from seeds that germinate in the fall.
5. Perennial  E. Have a 1-year life cycle; grow from seeds that germinate in the spring.

A. 1–C, 2–E, 3–D, 4–B, 5–A

Q. List several ways weeds reproduce.

A. Depending on the type, weeds may reproduce by seeds, tubers, bulbs, bulblets, rhizomes, stolons, or from root pieces left by cultivation.
Q. Match these categories of land and aquatic weeds with the correct description:

1. Grasses  
   A. Aquatic plants without true stems, leaves, or vascular systems.

2. Sedges  
   B. Wide leaves with netlike veins; seedlings have two leaves.

3. Broadleaf weeds  
   C. Large algae that look like vascular plants, but have no true roots, stems, or leaves.

4. Vascular plants  
   D. Narrow, upright leaves with parallel veins; seedlings have one leaf; round stems.

5. Emergent plants  
   E. All or part of the plant floats on the water surface.

6. Floating plants  
   F. Most of the plant grows under the water surface.

7. Submergent plants  
   G. Long, thin strands of algae that extend from underwater surfaces or form floating mats.

8. Algae  
   H. Triangular stems; three rows of leaves.

9. Planktonic algae  
   I. Aquatic plants that are similar to land plants; have stems, leaves, flowers, and roots.

10. Filamentous algae  
    J. Microscopic floating plants; may cause colored “blooms” in the water.

11. Macroscopic freshwater algae  
    K. Aquatic plants that are rooted to bottom, but extend above the water surface.


Q. List several factors that affect a plant’s susceptibility to herbicides.

A. Some of the factors affecting a plant’s susceptibility to herbicides include:
   ■ location of growing points,
   ■ leaf characteristics, such as shape, waxy cuticle, and leaf hairs,
   ■ size and age of the plant,
   ■ the plant’s ability to stop the action of the herbicide,
   ■ the plant’s life cycle stage.

Q. Explain the difference between selective and nonselective herbicides.

A. Selective herbicides kill some plants without harming others. They can be used to kill weeds without harming the desirable plants nearby.
   Nonselective herbicides kill all plants in the area where they are applied.
Q. Which type of herbicide would you use in each of the following situations?

1. You need to control some weeds in an area that will be planted in about a month. The weeds are perennials, so you know that the herbicide must reach the roots to keep the weeds from growing back.
   A. Contact herbicide
   B. Translocated herbicide
   C. Defoliant

2. You need to clear all the plant growth around one of your storage buildings.
   A. Selective herbicide
   B. Desiccant
   C. Nonselective herbicide

3. You need to control the weeds along some fence rows, and you want to do the job only once during the growing season.
   A. Nonpersistent herbicide
   B. Plant growth regulator
   C. Persistent herbicide

4. You need to control a low-growing annual weed, in a field where the corn crop is waist-high.
   A. Foliar-contact-nonpersistent-nonselective herbicide, directed underneath the corn plants.
   B. Soil fumigant, injected around the corn plants.
   C. Soil-translocated-persistent-nonselective herbicide, applied at a high rate.

5. You need to kill thistle plants in a pasture where the forage crop is already growing.
   A. Soil-translocated-persistent-nonselective herbicide, applied at low rates.
   B. Foliar-translocated-nonpersistent-selective herbicide, sprayed over entire field.
   C. Plant growth regulator, “wicked” onto the thistle plants.

A. 1–B, 2–C, 3–C, 4–A, 5–B

Q. Match these names of chemicals that change plant processes with the correct description:

1. Plant growth regulator
2. Desiccant
3. Defoliant

A. Causes the leaves to drop from plants.
B. Influences the vegetative or reproductive growth of a plant.
C. Speeds up the drying of plant leaves, stems, or vines.

A. 1–B, 2–C, 3–A
Vertebrate Pests

Q. Name some vertebrate animals that may be pests in some agricultural situations and explain the type of damage they do.

A. Here are some examples of vertebrate pests and the damage they do (you may think of others):
   - Birds, rodents, raccoons, deer—eat or injure agricultural and ornamental crops.
   - Birds, mammals—eat newly planted seed.
   - Birds, rodents—eat or contaminate stored food and feed.
   - Predator birds and mammals—prey on livestock and poultry.
   - Rodents, other mammals, birds—transmit diseases to people and domestic animals.
   - Burrowing and gnawing mammals—damage dams, drainage and irrigation tunnels, turf, wood products.
   - Beavers—cause flooding.
   - Fish—Pest species may crowd out desirable species.
   - Snakes, lizards—Poisonous species may harm people, livestock, or pets.
   - Water snakes, turtles—Harm desirable animals in fish hatcheries and waterfowl nesting reserves.
   - Amphibians—Clog drains and irrigation equipment.

Q. What are some vertebrate control measures that may require approval from local or State authorities?

A. It may be necessary to get approval for:
   - Killing or trapping some animals, such as birds, coyotes, muskrats, and beavers.
   - Using pesticides to control vertebrate pests other than rodents (such as fish, birds, and predators).
Calculating Dilutions and Site Size
Learning Objectives

After you complete your study of this module, you should be able to:

- Identify factors you may need to consider when calculating how much pesticide you will need to use and how much to dilute the formulation.
- Use formulas to calculate dilutions.
- Use formulas to convert between square feet and acres.
- Use formulas to calculate the area of both regularly and irregularly shaped sites.
- Use formulas to calculate the volume of enclosed spaces.

Terms To Know

Active ingredients — The chemicals in a pesticide product that control the target pest.
Calibration — The process of measuring and adjusting the amount of pesticide that application equipment will apply to the target area.

Concentrate — Pesticide having a high percentage of active ingredient; occasionally applied full-strength, but usually diluted before application.
Diluent — Anything used to dilute a pesticide.
Dilute — To make less concentrated.

Formulation — Pesticide product as sold, usually a mixture of active and inert ingredients.
Labeling — The pesticide product label and other accompanying materials that contain directions that pesticide users are legally required to follow.