Chapter 18
Integrated Pest Management: Controlling Pests Safely

Paul Guillebeau, PhD UGA Entomology
Kris Braman, PhD UGA Entomology

Learning Objectives

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

Define pest, IPM and understand the concepts of IPM.

Understand the concept of scouting for pest problems.

Understand what natural controls are available and their benefits and limitations.

Be familiar with the Georgia Pest Control Handbook and how to use it.

Learn the pesticide formulations and be able to read a pesticide label and know what signal words are.

Know factors that can cause pesticide applications to fail to control pests.

Know how to calibrate a sprayer, how to properly clean pesticide equipment, and how to safely store pesticide and the importance of safety equipment.

Be able to recognize pesticide poisoning symptoms and know who to call in a pesticide emergency.

Understand the impact of pesticides on the environment and the role and benefits of beneficial insects in the landscape.

INTRODUCTION

Integrated pest management (IPM) is a program for managing pests that utilizes a variety of techniques to manage pest populations. Some components of IPM include plant health, host plant resistance, biological controls, cultural controls, and pesticides. Initially, IPM was developed in agricultural production to maximize efficiency. In more recent times, IPM is seen as the best way balance the needs of pest management with protection of human health and the environment.

IPM Basics

The basic concepts of IPM depend on knowledge of the pest's biology and the ecology of the surrounding system.

There are four components to an IPM system:

Pest Identification
Monitoring
Control Guidelines
Methods of Prevention and Control

As a gardener develops an IPM program, he or she should consider the following questions.
1. What pests are most likely to cause problems in the yard and garden?
2. When are problems with these pests most likely to arise?
3. What factors attract these pests?
4. What can I do to make my plants or area less attractive to pests?
5. What nonchemical methods can be used to avoid or correct a pest problem?
6. What natural factors (e.g., biological control agents) are present that will help to manage pest populations?
7. What can I do to encourage the development of populations of biological control agents?
8. What treatment threshold(s) will determine if and when pesticides will be applied?
9. When is the best time to control the pest(s)?
10. What pesticide choices will minimize the risks to human health and the environment?
11. How can I best combine the components of my IPM program to manage pests most effectively and minimize the risks of pesticides?

We can use a common pest, the corn earworm, to illustrate the development of an IPM program.
1. Corn earworm.
2. Anytime of the gardening season, but more likely later in the season.
3. Corn earworms locate host plants through a variety of visual cues and plant volatiles.
4. Plant diversification in the garden can dampen or confuse the cues that attract corn earworms to the garden.
5. Cultural controls (e.g., tillage), mechanical controls (e.g., tying corn silks), and biological controls can help manage corn earworm populations.
6. Many predators and parasitoids attack corn earworm larvae.
7. Plant diversification and a water supply will help build beneficial populations.
8. Depending on the plant to be protected, the threshold might be based on the number of corn earworm larvae present or the amount of plant injury.
9. Corn earworm larvae are much easier to control when they are small.
10. Corn earworm larvae are susceptible to pesticides containing Bacillus thuringiensis. If this pesticide is appropriate for the situation, B.thuringiensis has little no impact on nontarget organisms. Otherwise, apply a pesticide that breaks down quickly or apply the pesticide as spot applications to minimize the impact on nontargets.

11. In this hypothetical situation, a gardener could:
a. Plant corn early,
b. Plant a variety of food plants and flowers,
c. Till to kill corn earworm pupae in the soil,
d. Check corn plants several times each week to monitor corn earworm larvae, corn injury, and biological control populations,
e. Apply B. thuringiensis when corn earworm larvae are small.

Although simplistic, this example shows how various components are used to devise an IPM program. Other chapters in this book will help in devising an appropriate IPM program for the situation.

Pesticides play an integral role in many IPM situations. Keep in mind, however, that pesticides are only one of the tools in the IPM toolbox. Pesticides must be chosen and applied in the context of the overall IPM program. The wise use of pesticides can help manage pest populations with minimal threat to human health or the environment.

Pests

A pest is anything that:
- competes with humans, domestic animals, or desirable plants for food or water,
- injures humans, animals, desirable plants, structures, or possessions
- spreads disease to humans, domestic animals wildlife, or desirable plants
- annoys humans or domestic animals.

Types of Pests

Types of pests include:
- Insects, such as roaches, termites, mosquitoes, aphids, beetles, fleas, and caterpillars,
- Insect-like organisms, such as mites, ticks, and spiders,
- Microbial organisms, such as bacteria, fungi, nematodes, viruses, and mycoplasmas,
- Weeds, which are any plants growing where they are not wanted,
- Mollusks, such as snails, slugs, and shipworms, and
- Vertebrates, such as rats, mice, other rodents, birds, fish, and snakes.

Most organisms are not pests. A species may be a pest in some situations and not in others. An organism should not be considered a pest until it is proven to be one. Categories of pests include:
- Continuous pests that are nearly always present and require regular control.
- Sporadic, migratory, or cyclical pests that require control occasionally or intermittently.
- Potential pests that do not require control under normal conditions, but may require control in certain circumstances.

Pest Identification

Accurate identification is the first step in an effective pest management program. Never attempt a pest control program the identity of the pest has been established. The more information about the pest and the factors that influence its development and spread, the easier, more cost-effective, and more successful the pest control will be. Correct identification of a pest makes it possible to determine basic information about it, including its life cycle and the time that it is most susceptible to being controlled.

To identify and control pests, one needs to know:
- The physical features of the pests likely to be encountered,
- Characteristics of the damage they cause,
- Their development and biology,
- Whether they are continuous, sporadic, or potential pests, and
- What the control goal is.

Pest Control

In considering whether pest control is necessary, remember:
- Control a pest only when it is causing or is expected to cause more harm than is reasonable to accept.
- Use a control strategy that will reduce the pest numbers to an acceptable level.
- Cause as little harm as possible to everything except the pest.
- Even though a pest is present, it may not do much harm. It could cost more to control the pest than would be lost because of the pest's damage.

Pest Control Goals

In trying to control a pest, try to achieve one of these three goals, or some combination of them:
1. Prevention — keeping a pest from becoming a problem,
2. Suppression — reducing pest numbers or damage to an acceptable level, and
3. Eradication — destroying an entire pest population.

Prevention may be a goal when the pest's presence or abundance can be predicted in advance. Continuous pests, by definition, are usually very predictable. Sporadic and potential pests may be predictable if the circumstances or conditions are known that favor their presence as pests. For example, some plant diseases occur only under certain environmental conditions. If such conditions are present, steps can be taken to prevent the plant disease organisms from harming the desirable plants.

Suppression is a common goal in many pest situations. The intent is to reduce the number of pests to a level where the harm they cause is acceptable. Once a pest's presence is detected and control is deemed necessary, suppression and prevention often are joint goals. The right combination of control measures can often suppress the pests already present and prevent them from building up again to a level where they are causing unacceptable harm.

Eradication is a rare goal in outdoor pest situations because it is difficult to achieve. Usually the goal is prevention and/or suppression. Eradication is occasionally attempted when a foreign pest has been accidentally introduced, but is not yet established in an area. Such eradication strategies often are supported by the government. The Mediterranean fruit fly, gypsy moth, and fire ant control programs are examples. Eradication is a more common goal indoors. Enclosed environments usually are smaller, less complex, and more easily controlled than outdoor areas. In many enclosed areas, such as dwellings, schools, office buildings, and food preparation areas, certain pests cannot or will not be tolerated.

Threshold Levels

Thresholds are the levels of pest populations at which pest control action should be taken to prevent the pests in an area from causing unacceptable injury or harm.

Thresholds may be based on esthetic, health, or economic considerations. These levels, which are known as "action thresholds," have been determined for many pests.

A threshold often is set at the level where the economic losses caused by pest damage, if the pest population continued to grow, would be greater than the cost of controlling the pests. These types of action thresholds are called "economic thresholds." For example, when the number of insects on a particular crop exceeds a given quantity, an insecticide application to prevent economic damage could be justified.

In some pest control situations, the threshold level is zero: even a single pest in such a situation is unreasonably harmful. For example, the presence of any rodents in food processing facilities forces action. In homes, people generally take action to control some pests, such as rodents or roaches, even if only one or a few have been seen.

Pest Monitoring

Regular monitoring or scouting can answer several important questions:
- What kinds of pests are present?
- Are the numbers great enough to warrant control?
- When is the right time to begin control?
- Have the control efforts successfully reduced the number of pests?

Monitoring of insect, insect-like, mollusk, and vertebrate pests usually is done by trapping or by scouting. Monitoring of weed pests usually is done by visual inspection. Monitoring for microbial pests is done by looking for the injury or damage they cause. Monitoring also can include checking environmental conditions in the area. Temperature and moisture levels, especially humidity, are often important clues in predicting when a pest outbreak will occur or will hit threshold levels.

Useful tools for pest monitoring include: notebook, hand lens of at least 10x magnification, collection bags and bottles to hold specimens for identification, small forceps, sweep net, plastic coated pest flash cards and a beating sheet. Place the sheet under the leaves of the plant and tap or shake the branch or plant to dislodge the pests onto the sheet. This is helpful in determining whether or not a pest is present on the plant). Yellow and blue sticky cards are helpful in determining whether certain pest populations are increasing. Place the cards in areas of suspected infestation and change regularly (yellow for whiteflies and blue for thrips).

Steps in Pest Monitoring

1. Identify the pest.
2. Identify the current stage in the pest's life cycle.
3. Note the location(s) of the pest.
4. Determine the number of insects, weeds or disease infected plants.
5. Inventory the environment surrounding the pest, as well as the entire area that might be affected by control actions. This might include chemically sensitive family members or neighbors. Remember to look for beneficial and non-target plants, insects and animals.
6. Identify Key Hosts. These are plants or other hosts that have a history of problems or in some other way indicate the presence of the pest.
7. Identify existing damage from the pest.
8. Keep accurate records of findings and controls, if used. The same problems may appear on the same hosts year after year. Good records will help in timing future control measures.

Avoiding Harmful Effects

Pest control involves more than simply identifying a pest and using a control tactic. The treatment site, whether it is outdoors or indoors, usually contains other living organisms (such as people, animals, and plants) and nonliving surroundings (such as air, water, structures, objects, and surfaces). All of these could be affected by pest control measures. Unless the possible effects are considered on the entire system within which the pest exists, a pest control effort could cause harm or lead to continued or new pest problems. Rely on good judgment and, when pesticides are part of the strategy, on the pesticide labeling.
Most treatment sites are disrupted to some degree by pest control strategies. The actions of every type of organism or component sharing the site usually affect the actions and well-being of many others. When the balance is disrupted, certain organisms may be destroyed or reduced in number and others — sometimes the pests — may dominate.

To solve pest problems:
- identify the pest or pests and determine whether control is warranted for each,
- determine pest control goal(s),
- know what control tactics are available,
- evaluate the benefits and risks of each tactic or combination of tactics,
- choose a strategy that will be most effective and will cause the least harm to people and the environment,
- use each tactic in the strategy correctly,

- observe local, state, and federal regulations that apply to the situation.

The strategy chosen will depend on the pest identified and the kind and amount of control needed.

Natural Controls

Some natural forces act on all organisms, causing the populations to rise and fall. These natural forces act independently of humans and may either help or hinder pest control. It may not be possible to alter the action of natural forces on a pest population, but be aware of their influence and take advantage of them when possible. Natural forces that affect pest populations include climate, natural enemies, natural barriers, availability of shelter, and food and water supplies.

Climate—Weather conditions, especially temperature, day length, and humidity, affect pest activity and rate of reproduction. Pests may be killed or suppressed by rain, freezing temperatures, drought, or other adverse weather. Climate also affects pests indirectly by influencing the growth and development of their hosts. A population of plant-eating pests is related to growth of its host plants. Unusual weather conditions can change normal patterns so that increased or decreased damage results.

Natural enemies—Birds, reptiles, amphibians, fish, and mammals feed on some pests and help control their numbers. Many predatory and parasitic insect and insect-like species feed on other organisms, some of which are pests. Pathogens often suppress pest populations.

Geographic barriers—Features such as mountains and large bodies of water restrict the spread of many pests. Other features of the landscape can have similar effects.

Food and water supply—Pest populations can thrive only as long as their food and water supply lasts. Once the food source — plant or animal — is exhausted, the pests die or become inactive. The life cycle of many pests depends on the availability of water.

Shelter—The availability of shelter can affect some pest populations. Overwintering sites and places to hide from predators are important to the survival of some pests.

Applied Controls

Unfortunately, natural controls often do not control pests quickly or completely enough to prevent unacceptable injury or damage. Then other control measures must be used. Those available include: host resistance, cultural control, mechanical control, sanitation, chemical control, and biological control.

Host resistance—Some plants, animals, and structures resist pests better than others. Some varieties of plants, wood, and animals are resistant to certain pests. Use of resistant types, when available, helps keep pest populations below harmful levels by making conditions less favorable for the pests.

Host resistance works in three ways:

1. Chemicals in the host repel the pest or prevent the pest from completing its life cycle.
2. The host is more vigorous or tolerant than other varieties and thus less likely to be seriously damaged by pest attacks.
3. The host has physical characteristics that make it more difficult to attack.

Cultural control—Cultural practices sometimes are used to reduce the numbers of pests that are attacking cultivated plants. These practices alter the environment, the condition of the host plant, or the behavior of the pest to prevent or suppress an infestation. They disrupt the normal relationship between the pest and the host plant and make the pest less likely to survive, grow, or reproduce. Common cultural practices include rotating crops, cultivating the soil, varying time of planting or harvesting, planting trap crops, adjusting row width, and pruning, thinning, and fertilizing cultivated plants.

Mechanical (physical) control—Devices, machines, and other methods used to control pests or alter their environment are called mechanical or physical controls. Traps, screens, barriers, fences, and nets sometimes can be used to prevent the spread of pests into an area.

Lights, heat, and refrigeration can alter the environment enough to suppress or eradicate some pest populations. Altering the amount of water, including humidity, can control some pests, especially insects and disease agents.

Sanitation—Sanitation practices help to prevent and suppress some pests by removing the pests or their sources of food and shelter. Urban and industrial pests can be reduced by improving cleanliness, eliminating pest harborage, and increasing the frequency of garbage pickup. Carryover of agricultural pests from one planting to the next can be reduced by removing crop residues.

Other forms of sanitation that help prevent pest spread include using mulches, pest-free seeds or transplants and decontaminating equipment, animals, and other possible carriers before allowing them to enter a pest-free area or leave an infested area.

Chemical control—Pesticides are chemicals used to destroy pests, control their activity, or prevent them from causing damage. Some pesticides either attract or repel pests. Chemicals that regulate plant growth or remove foliage also are classified as pesticides. Pesticides are generally the fastest way to control pests. In some instances, they are the only tactic available.

Biological control—Biological control involves the use of natural enemies — parasites, predators, and pathogens. Supplement this natural control by releasing more of a pest's enemies into the target area or by introducing new enemies that were not in the area before. Biological control usually is not eradication. The degree of control fluctuates. There is a time lag between pest population increase and the corresponding increase in natural controls. But, under proper conditions, sufficient control can be achieved to eliminate the threat to the plant or animal to be protected.

Biological control also includes methods by which the pest is biologically altered, as in the production and release of large numbers of sterile males and the use of pheromones or juvenile hormones.

Pheromones can be useful in monitoring pest populations. Placed in a trap, for example, they can attract the insects in a sample area so that pest numbers can be estimated. Pheromones also can be a control tool. Sometimes a manufactured copy of the pheromone that a female insect uses to attract males can be used to confuse males and prevent mating, resulting in lower numbers of pests. Applying juvenile hormones to an area can reduce pest numbers by keeping some immature pests from becoming normal, reproducing adults.

Pest Control Failures

Sometimes even though a pesticide was applied, the pest has not been controlled. Review the situation to try to determine what went wrong. There are several possible reasons for the failure of chemical pest control.

Pest Resistance—Pesticides fail to control some pests because the pests are resistant to the pesticides. Consider this when planning pest control programs that rely on the use of pesticides. Rarely does any pesticide kill all the target pests. Each time a pesticide is used, it selectively kills the most susceptible pests. Some pests avoid the pesticide. Others withstand its effects. Pests that are not destroyed may pass along to their offspring the trait that allowed them to survive.

When one pesticide is used repeatedly in the same place against the same pest, the surviving pest population may be more resistant to the pesticide than the original population was. The opportunity for resistance is greater when a pesticide is used over a wide geographic area or when a pesticide is applied repeatedly to a rather small area where pest populations are isolated. A pesticide that leaves a residue that gradually loses its effectiveness over time will help select out resistance. Rotating pesticides may help reduce the development of pest resistance.

Other Reasons for Failure—Not every pesticide failure is caused by pest resistance. Make sure the correct pesticide was used and the correct dose and that it was applied correctly. Sometimes a pesticide application fails to control a pest because the pest was not identified correctly and the wrong pesticide was chosen. Other applications fail because the pesticide was not applied at an appropriate time — the pest may not have been in the area during the application or it may have been in a life cycle stage or location where it was not susceptible to the pesticide. Also remember that the pests that are present may be part of a new infestation that developed after the chemical was applied.

Georgia Pest Management Handbook

Published annually, this manual gives current information on selection, application, and safe use of pest control chemicals. The Handbook has recommendations for pest control on farms, around homes, urban areas, recreational areas, and other environments in which pests may occur. Cultural, biological, physical, and other types of control are recommended where appropriate.

Recommendations are based on information on the manufacturer's label and on performance data from Georgia research and Extension field tests. Because environmental conditions and methods of application by growers vary widely, suggested use does not imply that performance of the pesticide will always conform to the safety and pest control standards indicated by experimental data.

The Georgia Pest Management Handbook is intended to be used only as a guide. Specific rates and application methods are on the pesticide label. Refer to the label when applying any pesticide.

INTRODUCTION TO PESTICIDES

The term "pesticide" is a broad term that refers to any substance used to manage pests. Many pesticides can be identified by the "-icide" suffix. Insecticides control insects. Herbicides control plants. Fungicides control fungi. Not all pesticides carry the "-icide" suffix. Other general names include disinfectants, growth regulators (prevent or enhance development), pheromones (attractants, usually used in traps), and repellents.

Note: the use of product names as examples is not an endorsement of those products.

Grouping Pesticides Based on the Source

Inorganic pesticides come from minerals, such as boron, copper, or sulfur. Other inorganic pesticides, such as lead arsenate, were once widely used in the cotton and fruit production; this practice was discontinued as safer products became available. Compounds made with copper, sulfur, or boron (e.g., boric acid) are commonly used as pesticides today.

Naturally derived organic pesticides are natural compounds that come directly from plants or microorganisms. Pyrethrins, for example, come directly from chrysanthemums. Pyrethrins are active ingredients in wasp and hornet sprays. Neem is another common example of a plant derived organic pesticide. Spinosad is a fermentation product from actinomycete bacteria.

Synthetic organic pesticides are man-made compounds with an organic chemical structure. In some cases, synthetic organic pesticides are based on naturally occurring chemicals. For example, pyrethroids are active ingredients in many common insecticides. Their structure is modeled after pyrethrins.

Microbial pesticides include bacteria, fungi, nematodes, and viruses. Most of these products can be applied with conventional application equipment. In some situations, certain microbials can be established in the lawn or garden. Most of the time, however, repeated applications will be necessary in response to pest problems. B. thuringiensis is the most common microbial pesticide. Various strains are effective against caterpillars, mosquitoes, or beetles. In general, microbials are safer than other types of pesticides. Remember that the effectiveness of a microbial depends on a living organism. Buy fresh products and protect them from extreme temperatures.

Grouping Pesticides Based on Activity or Timing

Protectants are applied to plants, animals, structures, or products to prevent pest injury. For example, termiticides are applied to buildings before termite infestation occurs. To be effective, most fungicides must be applied before the plants or infected. In most situations, the application of prophylactic pesticides is contrary to IPM principles, but sometimes it is necessary to apply a pesticide before the pest causes damage.

Contact poisons work by simply touching the pest. Most synthetic organic insecticides work this way. Insects are killed when they walk across a leaf or other surface that has been treated with the insecticide.

Stomach poisons must be eaten by the pest. These pesticides are often more compatible with biological controls. Caterpillars have to eat B. thuringiensis before it will kill them. Baits typically contain stomach poisons.

Systemics are absorbed by the plant or animal that is being protected. The pesticide will be moved through the plant. Some systemics are only transported locally; others move throughout the entire plant or animal. The pest is killed when it feeds on the animal or plant. Systemic pesticides are often combined with fertilizers.

Translocated herbicides are moved throughout the plant after they are applied to leaves, roots, or stems. The entire plant is killed. Glyphosate (e.g., RoundUp) is a common example.

Selective pesticides are less likely to harm nontarget organisms. An herbicide that contains only 2,4 D will kill most broadleaf plants, but it will not kill grasses. Most microbial insecticides are only effective against certain kinds of insect pests.

Nonselective pesticides affect a wide range of similar organisms. Most insecticides are nonselective. For example, carbaryl (e.g., Sevin) can be used to control pest insects, but it will also kill bees and many beneficial species. Glyphosate (e.g., RoundUp) will kill or injure nearly every type of plant.

Fumigants are gases that kill pests when they are inhaled or absorbed. Very few pesticides are available as fumigants. Some "bug bombs" products are fumigants.

Preplant pesticides are applied before the crop is planted. Preplant pesticides may be part of a combination product that also contains fertilizer.

Preemergence herbicides are applied before the weeds emerge. Some preemergent herbicides are applied before the crop emerges; some are applied after the crop emerges.

Postemergence herbicides are used after the target plant emerges.

When and Where to Apply Pesticides

The timing and placement of pesticide applications are critical. Follow the label directions, the advice of the county Extension agent and the Georgia Pest Control Handbook. Many pesticides work well at very low rates. There is often great temptation to use more pesticide that the label indicates. It is illegal to exceed the label rate, and damage to nontarget plants or animals is likely to occur.

Pesticides work best when they are applied at specific times in the pests' life cycle. Most pesticides are more effective when the pests are small. Insect growth regulators have little or no effect on adult insects. It is important to be familiar with the pesticide activity and the biology of the pest.

Be careful to treat only the intended target. Some pesticides (e.g., 2,4 D) can harm nontarget organisms at very low concentrations. If an insect or mite pest occurs on the underside of leaves, pesticide applications to the upper side of leaves may be ineffective. Avoid pesticide applications when the wind speed or direction will carry the pesticide from the target area. Some pesticide labels will prohibit applications above a certain wind speed.Some pesticides are likely to leach from sandy soils. Do not apply pesticides when rain is imminent. The pesticide will be less effective, and the pesticide is more likely to run off into waterways or leach into groundwater.

Read the pesticide label and consult the appropriate Georgia Pest Control Handbook.

Factors that Affect Pesticide Activity

Human error is a common reason for pesticide failures. If the pesticide does not provide satisfactory control, review these questions.

1. Was the problem correctly identified? It may seem reasonable to attribute yellow leaves to an aphid infestation if these insects are present. However, if low soil fertility is causing the problem, an insecticide will not help. If you are unsure of the source of the problem, consult your Extension agent.
2. Did you use the appropriate pesticide? Check the label and consult Extension recommendations. B. thuringiensis is very effective against some kinds of caterpillars, but it has little or effect on mites. The homeowner edition of the Georgia Pest Control Handbook contains the recommendations of Extension specialists. Be sure to refer to the current edition.
3. Was the pesticide applied properly? Check the pesticide label to be sure you applied the proper rate. Never apply more pesticide than the label directs.
4. Was the pesticide delivered to the target site at the appropriate time? Many weeds are difficult to control if they are large. Some insect and mite pests occur in areas that are difficult to treat effectively (e.g., on the underside of leaves).

Soil type can be an important factor in pesticide decisions. You may need to use higher pesticide rates in soils high in organic matter or clay. Pesticides are more likely to leach from sandy soils. Read the pesticide label and consult your Extension agent.

Weather conditions can reduce the effectiveness of pesticides. If it rains before pesticide residues dry, the active ingredient is likely to be carried away. Sunlight breaks down some pesticides (e.g., pyrethrins) quickly. Wind increases the likelihood of drift, and it accelerates the loss of some pesticides.

Pesticide resistance occurs when resistant traits become common in the pest population. Pesticide applications rarely kill every pest. The more sensitive individuals are more likely to die, and the more resistant individuals are more likely to live and reproduce. The resistant traits may be passed to their offspring, and the next generation has fewer individuals that are sensitive to the pesticide. After repeated cycles, many individuals in the population may have the resistant traits, and the pesticide no longer provides satisfactory control. Resistance to one pesticide usually conveys some resistance to other pesticides in the same chemical class. An IPM program makes resistance less likely because the pests are subjected to a variety of control methods.

Pesticide Formulations

A pesticide formulation is a combination of active ingredients and inert ingredients.

Active ingredients are the substances that control the pest. A product may have one or more active ingredients. The active ingredients are always specified on the pesticide label.

Inert ingredients are added to make the pesticide more effective or easier to use. An inert ingredient may be added to make the pesticide mix with water or to retard breakdown by sunlight. Other inert ingredients added to make the pesticide stick or spread on leaves. The inert ingredients are usually not listed on the pesticide label.

A particular active ingredient is usually available in several different formulations. Liquid and solid formulations are both common. Some products are ready to use, and others must diluted with water or a petroleum solvent. The label will tell you how to use a pesticide formulation. Each formulation has advantages and disadvantages that make it appropriate for a particular situation. Consider which formulation is best for your circumstances before you buy the pesticide. You may have to purchase additional equipment to apply a particular formulation. The lists below include only the most common pesticide formulations. The pesticide label will provide additional information.

Liquid formulations—Emulsifiable concentrates (E or EC) are the most common liquid formulation. They are mixed with water to form an emulsion. Most ECs appear oily before they are mixed with water; the resulting water emulsion is usually white. If a number appears before the letter abbreviation, the number indicates the number of pounds of active ingredient per gallon of product. If a number appears before the letter abbreviation, the number indicates the number of pounds of active ingredient per gallon of product. For example, "4EC" indicates four pounds of active ingredient per gallon.

- Advantages: mixes well with water, requires little agitation.
- Disadvantages: more likely to injure some plants, more likely to penetrate the skin directly.

Ready to use (RTU) aerosols are prepackaged liquid pesticides. They may be a premixed EC or some other formulation.

- Advantages: no mixing or measuring required, easy disposal.
- Disadvantages: very expensive relative to most other pesticide products, many aerosols are flammable.

Dry formulations—Dusts (D) are usually ready to use without mixing or dilution. A powdered dry inert (e.g., talc, clay, or ash) is combined with the active ingredient(s). The amount of active ingredient is usually less than ten percent. The abbreviation "10D" indicates that product has ten percent active ingredient. Do not mix dust formulations with water.

- Advantages: no mixing, little or no waste.
- Disadvantages: leave a visible residue, may easily drift into a person's breathing zone (wear a dust mask).

Granular (G) formulations are made by combining the active ingredient(s) with coarse granules of an inert (e.g., ground corncobs, clay, or nutshells). The concentration of active ingredient may be as high as 40 percent. The abbreviation "20G" means the product is 20 percent active ingredient. Granules are usually applied dry.

- Advantages: no mixing, spills are usually easy to clean up.
- Disadvantages: applications usually limited to horizontal surfaces or plant whorls.

Wettable powders (WP) are finely ground particles made to mix with water. Most wettable powders are much more concentrated than dust formulations; the active ingredient(s) are commonly more than 50% of the WP formulation. The abbreviation 50WP means the product is 50% active ingredient.

- Advantages: usually safer for plants and man than EC formulations.
- Disadvantages: water mixture requires regular agitation to maintain suspension, leaves visible residue on sprayed surfaces.

Baits (B) combine a pesticide with some food or other attractive substance. Bait products are commonly used for slugs/snails, rats/mice, and some insects. The concentration of active ingredient is usually less than five percent.

- Advantages: less active ingredient usually needed, less area usually treated with pesticide.

- Disadvantages: nontarget animals may be attracted to the bait. Pets may eat slug/snail bait, and other rodents may eat baits intended for rats or mice.

Pesticide Labeling

The pesticide "label" is the information attached to the pesticide container. Other information may also come with the pesticide product, or the pesticide label may refer the user to other information. This body of information is the "labeling". Federal and state regulations require all pesticide users to follow the directions on the pesticide label. Failure to follow label directions increases the risks of the pesticide and may result in civil and/or criminal penalties.
NEVER recommend that a client ignore or deviate from the pesticide labeling.

Sometimes pesticide labeling is confusing. However, it is important to understand all of the labeling information before using a pesticide or before recommending a pesticide to someone else. If one does not understand the labeling, he or she should consult the Extension agent or the Georgia Department of Agriculture. The Georgia Department of Agriculture regulates the sale and application of pesticides in the state.

All pesticides sold in the United States must be registered with the U.S. Environmental Protection Agency (EPA). The EPA requires that certain information must appear on all pesticide products. Consider this information before deciding which pesticide product is appropriate for the situation.

Signal words indicate the acute toxicity of the pesticide product. Acute toxicity is the likelihood that a single overexposure to the pesticide will injure a person or pet. Acute toxicity is related to the weight of a person or animal. The amount of pesticide needed to injure a child or pet may be much less than the exposure that would injure an adult.

"DANGER-POISON" (along with the skull and crossbones) appears on a pesticide product that can kill a person in very low doses. The amount of a DANGER-POISON pesticide required to kill a 180-pound man may be less than 4000 milligrams (one extra-strength headache capsule is usually 500 mg). The amount to kill a child or pet would be much less.

"DANGER" without the word "POISON" indicates a pesticide that can cause irreversible eye damage and/or severe injury to the skin.

Most DANGER-POISON and DANGER pesticides are not available to the general public. The Extension Service never recommends DANGER-POISON or DANGER pesticides for use around the home.

"WARNING" indicates a pesticide of intermediate toxicity. They may still cause severe injury, but greater exposure would be required.

"CAUTION" indicates a pesticide of low toxicity. Exposure is much less likely to cause injury.

The EPA has offered some pesticide companies the option of deleting the CAUTION signal word if the acute toxicity of the product is shown to be very low. These pesticide products will have no signal word.

Brand names are the company's identifier for that particular product. Usually the brand name will be the most prominent word on the product. "RoundUp" is the brand name for one herbicide that contains the active ingredient glyphosate. Other products may have the same ingredients with a different brand name and price.

Active ingredient(s) must be listed on the pesticide label along with their concentration. The ingredients may be listed by a complicated chemical name or a common name (e.g., carbaryl or glyphosate. Regulations do not require identification of the inert ingredients, but the percentage of inerts must be indicated.

The formulation will be identified on the pesticide label. It is helpful to know the common abbreviations for various formulations, but the information is also specified on the pesticide label.

Hazards to Humans (and Domestic Animals) will provide information about specific risks associated with the pesticide. Common statements include "Harmful if absorbed through skin" or "Avoid contact with skin or eyes". This section will indicate precautions and protective clothing needed to avoid injury. The protective clothing as directed by the pesticide labeling MUST be worn. If one is unable or unwilling to wear the specified protective gear, do not buy that pesticide.

Environmental hazards will also be specified. This section will caution the user about risks to birds, fish, bees, or other wildlife. The user will also be advised about other environmental concerns, such as potential leaching.

Physical and Chemical Hazards will be indicated for some pesticides. Some pesticides are highly flammable, or they may be corrosive to certain types of metals. Common statements include "Keep away from open flame" or "Do not incinerate".

Statement of Practical Treatment or First Aid instructions will be included on every pesticide label. Be familiar with these directions before using the pesticide. Quick action may be necessary if someone is exposed, and inappropriate action could exacerbate the injury. For example, the label may advise against vomiting is a person swallows the pesticide. This section may also contain important information for medical personnel. Take the label along when taking a victim to seek medical attention.

Directions for Use will tell the applicator how to use the product safely and effectively. This section contains the following information.

1. Where the pesticide may be used. It is illegal to apply a pesticide to a use site that is not indicated on the label. If a pesticide indicates beans but not corn, that pesticide may not be used on corn even if the same pest is on both crops. Some labels will indicate some specific plants and a generic group (e.g., daffodils and other flowering plants). The product may be legally used on any plant in the generic group; the manufacturer has tested the product on the specified plant. Before spraying a large number of unspecified plants, test the product on one or two plants.

2. How much pesticide may be used. The labeling will tell how to mix the pesticide and indicate a maximum rate. The directions may tell how many teaspoons are needed for a gallon or how many pounds are needed for 100 gallons. An Extension agent can help calculate how much pesticide is needed.

3. How often the pesticide may be applied. The labeling will indicate how often the pesticide may be applied and/or the maximum number of applications.

It is illegal and dangerous to apply a pesticide at a rate or frequency higher than the label maximum. The pesticide may legally be applied at a rate or frequency below the labeling directions, but the pesticide may not be effective. Do not advise a client to use less than the label rate before consulting with the Extension agent.

4. Other restrictions. Most pesticides will indicate a reentry interval and/or a preharvest interval. Do not allow anyone to enter the treated area before the reentry interval expires. If the labeling does not specify a reentry interval, stay out of the treated area until the spray dries completely. Do not consume a food treated with pesticide until the preharvest interval expires. If the labeling does not indicate a preharvest interval, the food may be eaten right away, but it should be washed thoroughly.

5. Pests that the product will control. The labeling will indicate which pests can be expected to be controlled with that product if it is applied at the specified label rate. It is legal to apply the pesticide for pests that are not on the label if the use site is indicated on the label. However, the product may not be effective.

6. Storage and disposal. Some pesticide labels will include information about proper storage and disposal. In many cases, however, the directions provide little specific advice.

Application Equipment

The proper application equipment will help in applying a pesticide safely and more effectively. A pesticide may be applied with any equipment that is not prohibited on the label. Be sure to select and maintain the appropriate application equipment.

Hand or backpack sprayers for liquid pesticides are relatively inexpensive and easy to operate. Operation of these sprayers is uncomplicated, and most applicators can repair the equipment with parts available through local retailers. Look for a tank with a large opening. Select a tank size that is appropriate for the situation. Remember that a five-gallon sprayer full of water and pesticide weighs about 40 pounds. If it is necessary to mix and carry several gallons of pesticide solution, a backpack sprayer may be a better choice.

Test the sprayer with water at the beginning of each season. Check for leaks and a regular spray pattern. Flush the tank and lines with water after each use. It may be necessary to wash the sprayer out with water and detergent when switching pesticides. Apply the wastewater to a use site indicated on the pesticide label. NEVER dump the wastes down the drain or into a sewer.

Phenoxy pesticides (e.g., 2,4 D) are active in very low concentrations. It is best not to apply other pesticides with sprayer that has been used with phenoxy herbicides. Many people keep one sprayer for phenoxy herbicides, another sprayer for other herbicides, and a third sprayer for insecticides and fungicides.

Dusters may be as simple as a shaker can. Other types of dust application equipment may include a bellows or fan to distribute the dusts. This type of equipment is usually very simple to operate and maintain. Be careful to keep the pesticide dust off of the skin and nontarget areas.

Granular applicators may be a shaker can or rolling spreader equipment. Drop spreaders distribute pesticide directly below the spreader. Rotary spreaders throw the granules over a wider area.

USING PESTICIDES SAFELY

Pesticide safety begins even before purchasing a pesticide. First, consider nonchemical options that may manage the pest problem. Sometimes nonchemical options are less effective than chemical pesticides, but the risks of pesticides are almost always greater.

Read the pesticide labeling. If one is unwilling or unable to follow the labeling directions, do not buy that product. Look for a CAUTION pesticide that is recommended for the situation. If no CAUTION product is recommended or available, it may be necessary to buy a WARNING pesticide. The Extension Service does not recommend the purchase of a DANGER pesticide for household use.

Do not transport pesticide in the passenger compartment of a vehicle. Secure the package so it will not break or leak. Do not transport pesticide near food, feed, clothing, or other household products.

Store pesticides in a secure area out of the reach of children and pets. Keep bottles of liquid pesticide in a plastic tray so that any leaks will be contained. Protect pesticides from extreme temperatures, and protect dry pesticides from excessive humidity.

Pesticide Toxicity

Acute toxicity is the likelihood of injury from a single or short-term exposure. If a person becomes ill shortly after applying a pesticide, consider acute toxicity. Common symptoms include nausea, dizziness, and headache. Refer to the pesticide label and consider how the person may have been exposed. It may be necessary to seek medical attention. Poison Control (1-800-222-1222) can advise about human or animal exposure Chronic toxicity is the likelihood of injury after repeated or long-term exposure. One cigarette or a single alcoholic drink is unlikely to cause injury, but long-term exposure can cause serious health problems. Repeated exposure to small amounts of pesticide may cause illness. There is little specific information about the long-term effects of pesticide exposure. The signal word (e.g., WARNING) on a pesticide label is based only on acute toxicity; it provides no information about chronic risks.

Pesticides are most dangerous as concentrates. Be especially careful when measuring and mixing pesticides.

The EXTOXNET web site is an excellent source for additional information about pesticide toxicity and environmental risks.

Routes of Exposure

Skin is the most common route of pesticide exposure. Some pesticide formulations (e.g., emulsifiable concentrates) can penetrate the skin directly, and many pesticides can penetrate through a wound.

Swallowing pesticide can be very serious. NEVER store any pesticide in a food or drink container. Pesticides in soft drink bottles have killed both children and adults. Be sure that implements used to measure or mix pesticides are not confused with kitchen equipment.

Inhaling pesticides can cause serious injury. Keep out of pesticide drift and pay attention to changes in wind direction.

Eye injury can occur very quickly with some pesticides. Always pour pesticides below the waist.

Inattention and poor work habits cause most pesticide exposure. When handling pesticides, always wash hands before eating, drinking, using tobacco, or using the toilet. Keep people and pets out of the spray area. Close house and car windows before applying pesticide. Be careful not to carry pesticide indoors on shoes or clothes.

First Aid for Pesticide Exposure

Act quickly if someone is exposed to pesticide. Be familiar with the first aid directions on the pesticide label.

- Skin—Rinse the exposed area with clean water immediately. Wash the area with soap and water as possible.
- Swallowed pesticide—Consult the pesticide label and call Poison Control (1-800-222-1222) immediately.
- Inhaled pesticide—Move the victim to fresh air. If the symptoms do not abate right away, seek medical attention.
- Pesticide in eye—Rinse the eye gently with clean water for at least 15 minutes. Seek medical attention.

Protecting the Body from Pesticides

The pesticide label will provide some precautions; follow these label directions. Also, use common sense to minimize pesticide exposure.

Clothing—At a minimum, wear a long-sleeved shirt, long pants, shoes, socks, and gloves. Wear a wide-brimmed hat if spraying overhead.

Gloves are the most important piece of protective equipment because most pesticide exposure occurs on the hands and forearms. Wear plastic or rubber gloves that are long enough to protect the wrists. Cloth or leather gloves do not prevent pesticide exposure. Keep shirtsleeves outside the gloves unless spraying overhead. When wearing reusable gloves, wash them before removing the gloves.

Wear rubber boots or shoe covers that repel liquids. Leather or cloth shoes will absorb pesticides. Wear pant legs outside of the boots.

Wear any additional protective clothing as directed by the pesticide label.

BENEFICIAL INSECTS AND BIOLOGICAL CONTROL OF MITES AND INSECTS

More and more emphasis is being placed on reducing the use of pesticides to prevent excess from running off landscapes into surface and groundwater in Georgia, particularly in urban areas. In addition, homeowners are becoming increasingly aware of nonchemical means of pest control. Government regulation of pesticides is becoming more and more restrictive, providing further incentive to use biologically-based pest management methods. These tactics may include the use of pest-resistant plants or the use of parasites, predators, and pathogens to reduce numbers of unwanted insect or mite pests.

Reduction of pest insects or mites below a damaging level through biological control may be achieved by conservation of existing natural enemies, augmentation of their numbers, use of products containing pathogens or nematodes, or through importation of natural enemies from the native location of an exotic pest.

Conservation

The protection of existing natural enemies may be accomplished by using management practices that favor their survival and minimize harmful effects. This includes the use of pesticides only when necessary and then, as spot sprays rather than blanket coverage of an area. Pesticide choice can be selective to reduce toxicity to beneficial insects and mites.

Avoid or be very selective in applying broad-spectrum or persistent pesticides. Often natural enemies are even more susceptible to these types of pesticides than are the pests one is trying to control. Natural enemies may be killed immediately and toxic residues will further reduce the beneficial population. Dust interferes with the activity of many natural enemies and can contribute to an outbreak of mites. Planting groundcovers and reducing dust favors the activity of beneficial insects and mites. Similarly, planting a variety of flowering species can provide additional nectar sources and sources of alternative prey for generalist predators and parasites.

Augmentation

Augmentation of natural enemies may be considered when the resident populations are insufficient to reduce pest numbers to an innocuous level. In this case, natural enemy numbers can be increased (augmented) through the purchase and release of commercially available beneficial species.

Although this method has been widely used in the management of greenhouse pests, there has been relatively little research on the use of commercially produced beneficials in landscape settings. Natural enemy releases are most likely to succeed on plant materials in areas where a certain amount of infestation and pest damage can be tolerated.

Situations where high numbers of pests and a high degree of damage are already apparent are not good candidates for natural enemy releases. Two tactics for augmenting beneficials are inoculative releases and inundative releases. An inoculative release occurs when a small number of individuals of a beneficial species is released into a low level pest infestation. The progeny of these beneficials may be sufficient to keep pest levels at or below the desired level. An inundative release is when large numbers of natural enemies are released, often several times in a season.

Importation

Importation, or classical biological control, is used most often against pests that have been accidentally introduced to the area where they are currently a problem. Insects that are not pests in their native habitat may explode in a new area where the regulation of population size by natural enemies has been removed. Natural enemies collected from the pest's native region and studied for potential to suppress the pest can be introduced in the new environment. Introduction of exotic natural enemies must be done by qualified scientists as required by law, but represents another category of natural enemies that should be recognized and conserved.

Formulated products containing entomogenous (insect-eating) nematodes or bacteria are available for the control of many insect pests. These are produced commercially and may be applied in a manner very similar to that used for conventional pesticides. These type of products, however, often require a much more restrictive set of environmental conditions to function optimally. Nematodes, for example, require a high moisture environment in order to move and locate insect hosts. If soils are too dry, the product may not work as well. In other cases, products may be sensitive to high temperatures or ultraviolet (UV) light, or may require refrigeration. Most nematodes and pathogens are relatively slow acting. Patience is required. A quick knock-down of pests should not be expected; a reduction in pest numbers will occur over time. Usually a particular life stage of the pest is the only one vulnerable to a nematode or pathogen, thus requiring repeat applications to allow for the appropriate stage or stages to be targeted.

Types of Biological Control Agents

Three general categories of natural enemies may occur or be used in managed landscapes: predators, parasites (or, more correctly, parasitoids), and pathogens or disease-causing agents.

Predators are generally insects, spiders, or mites that must find and kill several prey individuals in order to complete their life cycle. This might be a ladybird beetle that consumes hundreds of aphids as both a larva and an adult, or an insect like the minute pirate bug that feeds voraciously on thrips and insect eggs. Predators are usually larger than the prey they eat, although there are exceptions. Predators that feed on insects also occur among the birds, reptiles, amphibians, mammals, and fish. Some can cause significant reductions in insect numbers. Most often we are talking about invertebrate predators in insect and mite control.

Parasites are defined as organisms that live in or on the body of the host during some part of the parasite's life cycle. Parasitoids are a type of parasite that may consume part or all of its host's tissues—resulting in the death of the host. The most abundant parasitic insects are flies and wasps. Parasitic insects usually require only one host to complete their development in contrast to predators, which require several. Parasitic insects may be responsible for controlling several pests, however, when they oviposit, or lay eggs, on a number of new hosts.

Pathogens may be bacteria, viruses, or fungi that cause disease in insects. Nematodes that infect insects are often included in this category, too. Many pathogens that attack insects exist in the landscape and several have been formulated and are commercially available for use in agriculture, greenhouses, nurseries, and the landscape.

The first step in being able to more effectively use biological control in landscape management is to be able to identify correctly certain common natural enemies and to know what pests they may be active against. Many natural enemies are generalists, feeding on a wide variety of prey or, in the case of parasites, parasitizing several host species. Some, on the other hand, are very specialized in the type of prey or host they can successfully overcome. Knowledge of the life cycle is important, too. Many natural enemies attack only a particular stage of a pest, perhaps the egg or the larval stage.

Identification of Some Important Predators

Spiders are all predators, but have many different lifestyles. Some make webs and wait for prey to come to them while others are active hunters. Spiders are important predators in the landscape and are very common in trees, shrubs, grass, and herbaceous plant beds. Most spiders are general predators, feeding on a wide variety of prey. There are a number of spider species that may be found in the landscape. All have two body parts, an abdomen and a cephalothorax (combined head and thorax), and eight legs. Spiders tend to avoid people and most are harmless to humans. Spider complexes are believed to be important in reducing several kinds of landscape pests.

Mites are more closely related to spiders than they are to insects. Mites do not have antennae like insects do, or segmented bodies, or wings. They usually are very small and often go unnoticed. Most mites have an egg stage, a six-legged larval stage, and two eight-legged stages before becoming an adult. Phytoseiid mites are the major group of natural enemies that attack certain kinds of pest spider mites. It is especially important to conserve predatory mites in the landscape to prevent pest mite outbreaks. Other insect pests are also eaten by predatory mites, including whiteflies, thrips, and certain insect eggs.

Most predaceous mites are somewhat pear-shaped and shiny, with noticeably long legs. They may be bright red, yellow, or green depending on what they've been eating and appear transparent. Predaceous mite eggs usually are oblong; the eggs of pest mite species generally are spherical. Predaceous mites are also much more active and mobile than pest mite species.

True Bugs (Heteroptera) is a group that contains several generalist predator species. These insects all have piercing-sucking mouthparts which they use to impale their prey and extract fluid. The beak is usually carried beneath the body, but can be pointed forward or downward while feeding. The usual prey for these insects are soft-bodied insects of small to intermediate size. The next six insects are representatives of these predators:

Stink Bugs Although many stink bugs are plant feeders, there are some predaceous species, including the spined soldier bug. This is a known predator of more than 100 pest species. Adults are about 1/2 inch long, light brown, and somewhat dorsoventrally flattened. The shoulders are drawn out into the appearance of a spine, hence the name. Both the more colorful nymphs and the adults feed on and may attack prey much larger than themselves. Adults overwinter and become active in the spring when new eggs are deposited. Caterpillars and leaf beetle larvae are common prey items for stink bugs.

Predaceous Damsel Bugs are 1/8 - 3/8 inch long and may be cream colored to dark brown to black, depending on the species. The most common species are slender, elongate insects that are most active in mid-summer. They feed on eggs and immature stages of many pest insects.

Minute Pirate Bugs are 1/8 - 1/4 inch long. These insects are black and white as adults and have colorful yellow-orange-brown nymphs, depending upon instar. Gardeners notice the painful puncture that this small insect inflicts. It is an effective predator of thrips and of the eggs of many insect and mite species.

Assassin Bugs generally appear oval or elongate and are often black and orange-red or brown. They are larger than most of the other predaceous bugs, especially the giant wheel bug. Assassin bugs have a head that has a particularly long and narrow appearance. They feed on most other insects and will inflict a painful bite if handled.

Predaceous Plant Bugs are less well-known than other predaceous true bugs, but have been shown to be active predators of thrips, lace bugs, aphids, moth eggs, and other insects of importance in the landscape. See color plate in the Appendix.

Big-Eyed Bugs are stout-bodied insects, about 1/8 inch long with prominent eyes that give the insect its name. These insects are slightly larger than chinch bugs. They may have similar coloration, but are always broader across the head than the area just behind (shoulders). Chinch bugs, on the other hand, have a narrow head, never broader than the area directly behind. Often, big-eyed bugs can be found with populations of chinch bugs and it is important to be able to distinguish predator from pest. Big-eyed bugs also feed on caterpillars and insect eggs.

Lacewings (Neuroptera) Both green lacewings and brown lacewings are predators; green lacewings are more common. They often are found on weeds, shrubs, and other cultivated plants. Adult green lacewings are about 3/4 inch long; brown lacewings are smaller. Adult and larval brown lacewings and larval green lacewings feed on soft-bodied insects, especially aphids, and mites. Adult green lacewings may be pollen-feeders or they may be predaceous. Most are greenish with copper-colored eyes and the network of veins in the wings that gives them their name.

Lacewing eggs are attached to leaves by a long hair-like stalk. This raises the eggs off the surface of the leaf and helps prevent cannibalism when the young predators hatch. Larvae are oblong and soft-bodied, with distinctive sickle-shaped mandibles. They are often called aphid lions because of their habit of feeding on aphids. Some brown lacewings adhere the skins of their prey and other matter to their backs as a form of camouflage.

Praying Mantids (Mantodea) are comparatively large insects. Some may be as long as 3 inches. Our native species are much smaller, however. Usually they are green, gray, or brown. Their raptorial (prey-catching) front legs are covered with stout spines that help them grasp their prey. Mantid egg capsules contain 200 or more eggs neatly arranged in rows. The capsules are deposited on twigs and stems in a tan-colored frothy mass which hardens. It is very unlikely that praying mantids can suppress key pests in the landscape to the extent necessary.
Several families of flies (Diptera) contain predaceous members.

Robber Flies are 3/4 - 1 1/4 inch long and vary in appearance. Some are quite stout, while others are long and slender. The face is usually bearded and the head is hollowed out between the eyes. Adults are predaceous on many kinds of insects and usually capture their prey in the air. Larvae are soil-dwelling and predaceous on white grubs and other organisms.

Syrphid Flies are sometimes called flower flies because they commonly are found on flowers, or hover flies because of their behavior in flight. Most of these flies are yellow with brown or black bands on the abdomen. Some resemble wasps; many mimic bees. Syrphid larvae are maggot-like and predaceous on aphids and other soft-bodied insects. They have no legs or visible head capsule and are translucent.

Predaceous Midges Most members of this group are gall makers on plants, but there are some predaceous members of the family that feed on aphids. These larvae look much like syrphid larvae, but smaller.

Long-Legged Flies are small, about 1/4 inch with very long legs in relation to the body and usually metallic blue or green in color. Adults and larvae are predaceous and are often found near woodland streams or other wet areas.

Paper Wasps (Hymenoptera) are important predators of caterpillars. The caterpillars are paralyzed when the wasp stings them and then are transported to the nest to serve as food for the developing wasps.

Earwigs (Dermaptera) of many species are predaceous. One common species was found to eat 50 chinch bugs per day in laboratory tests. Earwigs vary in size—some of the larger species are 3/4 -1 inch long. They are usually brown and may have stripes. Earwigs have pincers, or forceps, at the end of the abdomen.

Beetles (Coleoptera) contain many families that are comprised partially or entirely of predaceous species. Some of the more common representatives are mentioned here:

Ground Beetles are predaceous as adults and as larvae. There are some seed-feeding species. They are active on the ground primarily at night. Adult beetles vary in size from 1/4 to 1 inch or longer. Many species are metallic, while others are plain brown or black. They prey on armyworms, cutworms, small mole crickets, and other insects.

Rove Beetles have shortened elytra (wing covers) that leave the segments of the abdomen visible, giving these beetles their characteristic appearance. Most species are slender and elongate from 1/16-1/2 inch long. Typically they are reddish-brown to black. Many species are predaceous, some feed on decaying organic matter helping to recycle needed nutrients in the landscape.

Lady Beetles are among our most important beneficials. Adults and larvae feed on aphids, scale insects, mites, mealybugs, other soft-bodied insects and their eggs. Lady beetle adults are oval-shaped. Most are orange or reddish with black markings.

Lady beetle larvae are elongate, covered with spines, and dorsiventrally flattened, i.e., they are wider than they are thick. Often they are brightly colored with spots. Some larvae are covered with white waxy secretion like mealybugs. Adults and larvae are voracious feeders on aphids. A single individual may consume hundreds of aphids during its lifetime.

Tiger Beetles are very active, often metallic beetles 1/2 - 3/4 inch long. They are difficult to collect because of the speed with which they run or fly. Larvae, commonly called doodlebugs, live in burrows in the soil and ambush prey as it goes by. Some species are often well represented in landscape beds.

Identification of Some Parasitic Insects

Parasitic wasps are a large group of beneficial insects and are extremely important in biological control. Although nobody knows for sure, there are likely more than 1 million species of parasites. Every insect has one or many different species of parasites that attack them. Many wasp families contain representatives of the parasitic lifestyle. Most of these wasps are very small, <1/8 inch, and are, therefore, rarely seen. A large number, in fact, attack the egg stage, completing their entire life cycle inside tiny insect eggs. Parasitic wasps lay their eggs in or on the host and the immature stage of the wasp feeds on the host's tissues. The parasitic wasp may emerge from its host to pupate, or it may pupate within the body of its host.

Wasp larvae that develop inside the host are called endoparasitic. They leave evidence of parasitism when they chew a small hole in their host's body to emerge. That small circular hole indicates that parasitism is occurring in the pest population. Insects that may be parasitized this way include scales, aphids, whiteflies, lace bug eggs, leafminers, and caterpillars. Other parasitic larvae live on the outside of the host's body and are called ectoparasites. Both endo- and ectoparasites may spin numerous white cocoons for pupation, another obvious indication of parasitism.

Field evaluation of parasitism usually has to be made on the basis of evidence of parasitism—signs that the parasites leave behind. Adults are usually too small to be seen or easily sampled, and the larvae are generally not visible inside the host insects. Often we look for evidence such as aphid "mummies" (brown, swollen, hollowed-out remains of parasitized aphids), or darkened scales or whiteflies, or exit holes to help us assess the presence and abundance of parasites.

Parasitic wasps are the best natural control for scale insects. When large numbers of armored scales have exit holes in the scale covers, it is recommended that spraying be avoided, especially if the scale population is low to moderate. Scale parasites will be very active at least twice during a scale generation. The mature female scale may be attacked and the emerging crawlers, the mobile immature stage of scale insects, are attacked by parasites. Application of a pesticide during peak crawler emergence, although our traditional recommendation, can have very negative effects on parasitism by these very susceptible wasps. Try a 3% - 4% horticultural oil during late winter. If scale populations are heavy and rate of parasitism does not appear to be high enough, follow with one or more 2% oil applications later in the summer after crawlers have ceased activity, giving parasites a chance to build. If parasites and predators appear to be absent and scale populations are heavy, an oil application targeting the crawler stage and incorporating a half rate of insecticide may be necessary for suppression.

Parasitic flies are abundantly represented by the family Tachinidae, with about 1,300 North American species. They vary tremendously in appearance. Many just resemble a common housefly, while others look like bees or wasps. These flies deposit an egg or in some cases, a live larva, on or near the body of their host. The tachinid larva burrows into its host and consumes the internal tissues. Numerous kinds of insect pests are attacked by tachinids.

Types of Pathogens

Insects get diseases just like we do. Microorganisms that cause disease in pest insects include bacteria, fungi, viruses, nematodes, and others. Disease outbreaks can cause spectacular "crashes" in large pest populations with no interference by man. Often, disease is maintained at low levels within an insect population. Representatives of each group mentioned has been developed for use as microbial insecticides.

Viruses in the Baculoviridae family have been developed for use in insect pest control because of their high virulence in insects and demonstrated safety to humans. Commercial use has been limited by high cost of production and a high degree of environmental instability of viruses. None of the few virus products that have been registered is available for use on landscape plants at this time. Infected larvae turn dark and become shiny, revealing evidence of infection. Viruses are usually quite host specific.

Bacteria are available for control of caterpillars, fly larvae, and most recently, new strains have been discovered that are effective on beetles, including leaf beetle larvae and white grub larvae. These are all strains of Bacillus thuringiensis Berliner. The original strain, B.t. kurstaki, is active against caterpillars, including many which are pests of ornamentals. B. t. israeliensis kills fly larvae, while the strains sandiego and bui-bui affect leaf beetle and grub larvae, respectively.

Fungi that attack insects belong to the Deuteromycetes and Entomophthoraceae. Fungal spores usually require water to germinate and invade new hosts. Although sudden, severe outbreaks of fungi are often involved in high insect death, the high moisture requirement has limited commercial development. Symptoms of fungal infection vary. Often the infected caterpillar's body becomes hard, brittle, and covered with first white then green powdery spores.

Nematodes are microscopic roundworms that live in the soil. Like fungi, they also require a high moisture environment for movement and survival. They have been most effective in soil or other moist habitats. Some success in controlling wood-boring caterpillars in the landscape has been reported, however.

Managing Naturally-Occurring Parasites & Predators

Natural enemies will be at their most effective if the use of broad-spectrum, high toxicity products that destroy them are avoided. The biological insecticide Bacillus thuringiensis, for example, is very effective against caterpillar pests, but leaves most natural enemies unharmed. Selective insecticides may work more slowly than broad-spectrum sprays, but long-term control is better achieved by using methods that conserve natural enemies and promote balance.

Spot treat or remove infested plants. Use resistant plant varieties that are compatible with biological control. Stop treating minor pests and focus management on key pests. Keep a garden diary; record what works well. Develop "threshold levels" for treatment; a few insects generally do not merit a pesticide application.

Monitor for beneficial insects and mites the same as for pest insects. Evidence of natural enemy activity includes diseased insects or those that have holes from which parasites have emerged. Determine whether pest numbers are increasing, decreasing, or staying the same. Make the same assessment for associated natural enemies. Predators and sometimes parasites can be sampled in much the same way as pests in the landscape are sampled. A sweep net is useful and foliage can be shaken or beaten over a white tray where dislodged insects and mites become very visible. Direct visual observation is often the most effective sampling method. Insects can be counted as number per leaf or terminal, for example, or number spotted during a three minute observation period. If the ratio of pests to natural enemies is low, spraying should be delayed. Frequent (weekly or biweekly) monitoring is necessary to take fullest advantage of natural control.

Methods to Increase Natural Enemy Populations

Judicious selection and use of pesticides to favor natural enemy survival and reproduction is critical to enhancing natural enemy activity in the landscape.

Nectar and pollen are required by many predators and parasites. Well-designed landscapes feature a variety of plant material, including a season-long bloom of perennials. Those that have been shown to be particularly attractive to beneficials include daisies, Queen Anne's Lace, yarrow, white alyssum, goldenrod, and clover.

DISCUSSION QUESTIONS

1. What are the four components of an IPM system?

2. Why is pest identification important in an IPM program?

3. Discuss the 3 goals of pest control.

4. What are the steps in pest monitoring?

5. How do natural controls affect pest populations?

6. What are some nonchemical methods of pest control?

7. Explain the action of contact pesticides, systemic pesticides, and translocated pesticides.

8. Name and explain the meaning of signal words and symbols you may see on a pesticide product.

9. Where can you find out how much pesticide to apply?

10. List some information that can be found on a pesticide label.

10. Describe actions that a pesticide user can take to avoid contamination of groundwater.

11. Where should pesticides be stored?

12. How should you dispose of excess pesticides?

13. What is the most common route of pesticide exposure and how can pesticide users protect themselves from exposure?

14. What are the 3 principles of using beneficial insects in reducing pesticide use?

15. List 10 beneficial insects you might find in the landscape.

TERMS TO KNOW

Acute effects– Illnesses or injuries that may appear immediately after exposure to a pesticide (usually within 24 hours).

Delayed effects– Illnesses or injuries that do not appear immediately (within 24 hours) after exposure to a pesticide.

Exposure– coming into contact with a pesticide.

Host– The living plant or animal a pest depends on for survival.

Labeling– the pesticide product label and other accompanying materials that contain directions that pesticide users are legally required to follow.

Parasite– an organism that lives and feeds or in another species, which it usually injures.

Pathogen– any disease-producing organism.

Pesticide– chemical used to destroy pests, control their activity, or prevent them from causing damage.

Precautionary statement– pesticide labeling statement that alerts user to possible hazards from use of the pesticide product.

Prevention– keeping a pest from becoming a problem.

Nonselective pesticide– a pesticide that is toxic to most plants and animals.

Selective pesticide– a pesticide that is more toxic to some kinds of plants and animals than others.

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– a pesticide that kills plants by being absorbed by leaves, stems, or roots and moving throughout the plant.

RESOURCES

Applying Pesticides Correctly, the General Standards manual of the Commercial Pesticide Applicators Safety Guides Series is available for purchase. Ordering information available at http://pubs.caes.uga.edu/caespubs/pubs.html

Georgia Pest Management Handbook Available online or for sale from the University of Georgia College of Agricultural and Environmental Sciences. Information at http://pubs.caes.uga.edu/caespubs/pubs.html

Suppliers of Beneficial Organisms in North America The California Environmental Protection Agency developed a publication that lists 143 commercial suppliers of 130 beneficial organisms used for biological control. It can be found at http://www.cdpr.ca.gov/docs/ipminov/bensuppl.htm or order by phone 916-324-4100. Suppliers are located in Canada, Mexico, and the United States.

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