Biological Pest Control

Overview

Many insects are accidentally introduced to environments through commerce or transportation of private goods. Although current quarantine laws are in place to prevent accidental introduction of new pests, serious new pests do find their way into the country. An example is the Russian Wheat Aphid. A non native pest arriving by mistake, without its natural enemies that kept it in check in its native country, will cause damage, once it establishes itself. The practice of biological control has resulted from the need to find and import natural enemies from other countries.

Biological Control (Biocontrol) is the application of raising and discharging natural rivals (predators and pesticides) to find and eradicate those insects and mites considered pests. These natural enemies reestablish the accepted balance of nature and are risk free to humans and don’t damage the environment. Biological control’s purpose is not to completely eliminate pests but keep the pests at low enough levels for successful crop production.

Biological Pest Control - Today

Biological control of pests and diseases is a method of controlling pests and diseases in agriculture that relies on natural predation rather than introduced chemicals.

A key belief of organic gardening is that biodiversity furthers health. The more variety a landscape has, the more sustainable it is. The organic gardener therefore works to create a system where the insects that are sometimes called pests and the pathogens that cause diseases are not eradicated, but instead are kept at manageable levels by a complex system of check and
balances within a living and vibrant ecosystem. Contrary to more conventional gardening practices which often use chemical methods to kill both useful and harmful garden life forms indiscriminately, this is a holistic approach that seeks to develop an understanding of the webs of interaction between the myriad of organisms that constitute the garden fauna and flora.

The organic gardener will often hold the view for example that the eradication of the creatures that are often described as pests is not only not possible, but also undesirable, for without them the beneficial predatory and parasitic insects which depend upon them as a food or hosts would not be able to survive.

In healthy natural woodland where there is little direct human intervention, pest and disease organisms will always be present, but, unless there is a drastic environmental change, a state of equilibrium will exist.

Therefore, biological control is about developing a range of techniques that use living organisms to maintain the beneficial equilibria in garden and agricultural landscapes without causing adverse effects to humans or the wider environment. An important part of the biological approach is to become familiar with the various life forms that inhabit the gardens and fields, predators as well as pests, and also their life cycles, patterns of feeding and the habitats that they prefer.

**Pest Control through Integrated Pest Management (IPM)**

There are 2 million farmers in the United States and crops from the United States feed the entire world. An Integrated Pest Management plan is a valuable tool for increasing pest management. The IPM plan for Agriculture must include the management of insects, weeds, and diseases that effect field crops. Biological Control is necessary and should be a part of any IPM plan. Many
University Extensions offer information to help farmers and gardeners with information and education on biological controls.

By using precaution strategies and information about pest biology it is possible to integrate less toxic and safer controls for the elimination of household, outdoor, and crop pests. IPM practices use a combination of compatible methods to either prevent or combat pests. And through the use of the IPM practices, costs are reduced and potential pesticide hazards to people and pets are reduced. Sometimes the integrated controls and precaution strategies are not enough, and pesticides will also need to be used as part of the IPM process.

**Process for Integrated Pest Management**

In order to have an effective Integrated Pest Management plan it is necessary to develop several complementary strategies or methods.

**Principles of Biological Control**

Because all insects and pests have some natural enemy, the enemies must be managed. Management of natural enemies is achieved through controlling importation, directing conservation, and monitoring growth. The goal of biological control is for the natural enemy introduced, to establish itself and continue to provide control without assistance from the gardener or farmer. Standards for biological control include:

1. One living organism is used to control another living organism.
2. Some control organisms require a limited host range and are therefore considered host specific.
3. Biological control agents affect the organism either directly or indirectly.
   - Direct – kills the pest
   - Indirect – weakens the host so they can not reproduce at a normal rate
Three types of applied Biocontrol that man can influence:

1. **Augmentation**
   Man can increase the native agents for control. Normally, there is a lack or absence of natural enemies occurring in the early pest season. Man can release the natural enemy early in the season to ensure that when the pests first appear natural enemies will not be scarce.

2. **Classical Biological control**
   Man can introduce exotic biological control agents from their native home into the areas where exotic pests have established themselves and survived and multiplied due to the absence of natural enemies. This way, the control agents will reestablish equilibrium to keep the pest under control. This method is referred to as an **old association**.

3. **Neoclassical biological control**
   Man can introduce an exotic biological control agent that previously did not have an association with the pest. The new biological control agent can establish itself and prey on the pest. This is referred to as a **new association**.
Natural Enemies

There are four types of natural enemies that can be used in biological control.

1. Parasitoid

A parasitoid is an organism that spends a significant portion of its life history attached to or within a single host organism which it ultimately kills (and often consumes) in the process. They are similar to typical parasites except in the fate of the host. In a typical parasitic relationship, the parasite and host live side by side without lethal damage to the host. The parasite takes enough nutrients to thrive without preventing the host from reproducing. In a parasitoid relationship, the host is killed before it can produce offspring.

This type of relationship seems to occur only in organisms that have fast reproduction rates (such as insects or mites). Parasitoids are also often closely coevolved with their hosts.

Insects Parasitoids

An insect parasitoid is an insect parasite that destroys its host. It has an undeveloped life stage. They are valuable as natural enemies because they develop on or within a single insect host and prevent any further development of the host after initial parasitization, eventually killing the host. This typically involves a host life stage which is immobile (e.g., an egg or pupa), and
almost without exception they live inside the host. Insect parasitoids only damage a specific life stage of one or several related groups.

Characteristics of insect parasitoids

- Specific in their choice of host
- Smaller than their host
- Only females search out hosts
- Different parasitoid species attack different development stage of the host
- Adults are free living, mobile and may be predatory
- Undeveloped usually kill the host.

Usefulness as Biocontrol

An insect predator will instantly kill or immobilize their prey. A pest attacked by a parasitoid will die more gradually. The presence of parasitoids may not be obvious, even though they may be effective. In some cases, it is necessary to dissect or raise samples of pest insects to determine if any adult parasitoids appear. Because parasitoids are often more susceptible to chemical insecticides than their hosts, caution must be used.

*Bathypectes spp.* Are small, non-stinging wasps that are parasitoids of the alfalfa weevil, a serious pest of alfalfa in the Midwest and elsewhere. They were introduced to North America in 1911, from Italy by the U.S. Department of Agriculture as part of a biological control effort against the alfalfa weevil.
2. Predators

Insect predators are established in practically all agricultural and native habitats. The following are natural enemies of cabbage pests.

One of the benefits, of insect predators is that they are found all around and throughout plants, including below ground, as well as, trees and shrubs. Some predators are specific in their choice of prey, while others are not and they need a wide range of prey. Because they destroy their prey quickly, their successes are easily recognized. However, specific predators may not be identified due to their mobility. Once they feed, they move on. Major characteristics of arthropod predators:

- The adults and young are usually generalists
- Normally larger than their prey
- They destroy or consume many prey
- They will attack both immature and adult prey

Examples

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Ladybugs, and in particular their larvae which are active between May and July, are voracious predators of aphids such as greenfly and blackfly, and will also consume mites, scale insects and small caterpillars.

Hoverflies are another very welcome garden predator. Resembling slightly darker bees or wasps, they have characteristic hovering, darting flight patterns. There are over 100 species of hoverfly whose larvae principally feed upon greenfly, one larva devouring up to fifty a day, or 1000 in its lifetime. They also eat fruit tree spider mites and small caterpillars. Adults feed on nectar and pollen, which they require for egg production.

**Aphids, also known as greenfly/blackfly**

**Wax scales on a lemon tree branch**

**Female Syrphid (Hoverfly) Fly**

**Phacelia calthifolia**

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Hoverflies can be encouraged by growing attractant flowers such as the poached egg plant marigolds or *phacelia* throughout the growing season.

Dragonflies are important predators of mosquitoes, both in the water, where the dragonfly nyads eat mosquito larvae, and in the air, where adult dragonflies capture and eat adult mosquitoes. Community-wide mosquito control programs that spray adult mosquitoes also kill dragonflies, thus removing an important biocontrol agent and can actually increase mosquito populations in the long term. Other useful garden predators include lacewings, rove and ground beetles, aphid midge, centipedes, predatory mites, as well as mega fauna such as frogs, toads, hedgehogs, slow-worms and birds.

**Usefulness as Biocontrol**

Although most beneficial predators consume large amounts of pest insects during their life span some predators are more effective at controlling pests than others. Some species play an important role in the containment of pests and others provide good late season control. Some play a minor roll by themselves but their contribution greatly influences overall pest mortality.

A good example of the potential number and diversity of predators in a crop comes from an Agricultural survey on cotton crops in Arkansas. More than 600 species of predators in 45 different families of insects and 23 families of spiders and mites have been documented, in Arkansas cotton. In the northeastern United States, eighteen species of predatory insects (not including spiders and mites) have been found in potatoes. Within a single acre, there may be thousands of predators in addition to many parasitoids. Although the effect of any one species of natural enemy may be minor, the combined influence of predators, parasitoids, and insect pathogens can be significant.
3. Pathogens

A **pathogen** or **infectious agent** is a biological agent that causes disease or illness to its host. Disease causing organisms such as bacteria, viruses, protozoa and fungi can infect insects and mites. These natural occurring organisms can multiply to cause disease outbreaks or epizootics on pest populations. Under the right conditions (high humidity, high pest numbers), an outbreak of epizootics can eliminate an insect population. Diseases are an essential and normal control for some insect pests. Microbial insecticides, biorational, or bio-insectices are pathogens that have been mass produced and are accessible in commercial formulations for use in standard spray equipment.

While some microbial insecticides are still experimental, others have been available for use for several years. Gardeners and commercial growers have widely used formulations of the bacterium, **Bacillus thuringiensis** or **Bt**. One of the benefits of using microbial products is that they do not directly affect beneficial insects and none are hazardous to wildlife or humans. Most insect pathogens target certain groups of insects at certain life stages.

Chemical insecticides may bring about quicker results as microbial insecticides can take longer to destroy or weaken a target pest, which may limit their use for crops that can maintain some insect damage. In order for the use of microbial insecticides to be most effective they must be applied at the correct life stage of the pest. Because the use of microbial insecticides is compatible with the use of predators and parasitoids this aids in spreading some pathogens through the pest population. Although microbial insecticides are considered non-toxic to humans, safety precautions must be followed to minimize any exposure.
Characteristics of insect pathogens:

- Use will result in killing, reducing reproduction, slowing growth, or shortening the life of pests
- Specific to target species or specific life stages
- Effectiveness is often dependent upon other factors, such as host abundance or environmental conditions
- Degree of control may not be predictable
- Normally slow acting; adequate control may not take place for several days or longer

**Usefulness as Bio-control**

Due to the fact that effectiveness is often dependent upon other factors and the proper deployment appears to be crucial, disease control in the field is likely to be less successful than in the laboratory where ideal conditions are in place. Continued research needs to be carried out, as this may be another effective method for control.

**4. Weed-feeders**

When new exotic plant species are introduced to new locations throughout the world, problems often arise. The new species may spread rapidly because there are no effective natural enemies in the new location. It is estimated that 50% to 75% of the problem weeds in the U. S. arrived from other areas either accidentally or intentionally. An example would be purple loosestrife, a semi-aquatic herbaceous plant belonging to the loosestrife family. Purple loosestrife is native to the wetlands of Eurasia and was introduced to America in the late nineteenth century. In North America because of the lack of natural enemies, it is a nuisance choking water ways, and crowding out native North American species.
Types of Weed Feeders

Fungal products, insects, plant pathogens, nematodes and fish can be effective in controlling pest weeds. Insects feed on seeds, flower leaves, stems, roots or a combination of all of these. Insects can also pass on plant pathogens to infest the plants.

It is important to determine if the weed feeder will feed exclusively on the pest species before introducing it. Effectiveness of control, presence of a favorable host plant, harmonization with the natural enemy’s life cycle, productiveness, heartiness, and similarities in climate and ecology should also be considerations.

The fungus, *Colletotrichum gloeosporioide* has been proven effective in controlling northern joint vetch, a plant pest found in rice and soybean crops. *Colletotrichum gloeosporioide* causes plants to wilt and the crown tissues to decay. This fungus survives on infected plants and debris eventually, eliminating joint vetch from the fields.

**Other Control Success in North America**

- Nodding Thistle (Canada, Kansas U.S.)
- Ragwort (British Columbia, Canada, California and Oregon)
- Alligator Weed (Florida, Louisiana and Texas)

**Characteristics of weed-feeding natural enemies:**
• Specific to one plant species
• Negative impact on plant individuals and the population dynamics of the target weed
• Fertile
• Thrive and become widespread in all habitats and climates that the pest weed occupies
• Good colonizers

Usefulness as Biocontrol

The introduction of weed-feeding natural enemies in North America have had mixed success. In some cases, they have been extremely effective with a 99% reduction of the pest species. In other cases, it has been complete failure, as the introduced species was not able to establish itself in the new location. Some of the failure may be attributed to predators, parasitoids of the newly introduced species limiting its ability to control the pest plant.

Required Steps for Biological Control

The USDA, APHIS (U.S. Department of Agriculture’s Animal and Plant Health Inspection Services) is responsible for providing leadership in ensuring the health and care of animals and plants. PPQ (Plant Protection and Quarantine) which is part of the APHIS protects America’s agricultural and ecological resources through their pest detection program. The pest detection program provides a continuum of checks from offshore pre-clearance programs through port inspections to surveys in rural and urban sites across the U.S. Because pests, weeds and diseases are potential agent of bioterrorism, a new aspect of the Department is biological terrorism.

The APHIS grants permission for the release of any biological control agent or natural enemy. In individual states, the State Entomologist reviews requests prior to the release of any biological control agents. Research scientists conduct host specificity studies and submit the study results to federal and state agencies for their review. Once approval is obtained, exotic biological control agents may be released.
The required steps include the following:

1. Determine if the pest is appropriate for biological control.
2. Selection of suitable and effective natural enemies
3. Conduct safety tests. Make sure that the potential control agents only attack the target pests, and not turn into pests themselves.
4. Develop techniques for raising the control agents to provide sufficient distribution.
5. Conduct field establishment studies prior to the release.
6. Evaluate surveys to assess the effectiveness of the biological control agent in controlling the pest.

The website for APHIS, USDA can be accessed http://www.aphis.usda.gov

This website will provide links to identify current Plant Protection and Quarantine Plant Pest Permits and a prevalent virus list by state, as well as issues currently affecting different states.

**Predators of Pests**

**Green Lacewings**

*Green lacewings* are insects in the very large family *Chrysopidae* of the order *Neuropetra*. There are approximately 1300 species. Lacewings are widespread insects; the genus *Chrysoperla* is very common in North America. Their larvae are voracious predators, attacking most insects of suitable size, especially soft-bodied ones (aphids, caterpillars and other insect larvae, insect eggs). Adults use substrate vibrations as a form of communication, especially during courtship;
species which are nearly identical morphologically may sometimes be separated more easily based on their mating signals.

In several countries, millions of lacewings are reared for sale as biological control agents of insect and mite pests in agriculture and gardens. They are distributed as eggs, since they are highly aggressive and cannibalistic. The eggs hatch in the field, originating the predatory larvae. Their performance is variable; thus, there is a lot of interest on further improvement of the use of lacewings as biological pest control.

**Insidious Flower Bug (Orius)**

*Orius* is a predator of small insects and mites and is found on many agricultural crops including: cotton, peanuts, alfalfa, corn, pea and strawberry. It is a successful biological control agent in greenhouses. The immature stages (nymphs) and adults both feed on a variety of small prey. It is considered an excellent predator of the eggs and new larvae of the bollworm and the spotted tobacco aphid. It is believed that thrips and mites are the most basic part of its diet. It is also know the prey on corn leaf aphids potato aphids and potato leafhopper nymphs.

**Bigeyed bugs (Geocorus)**

Bigeyed bugs are the most abundant and considered the most important predaceous insects in many corps throughout the U.S. With approximately 19 species and rarely causing economic damage they offer a great benefit to biological pest control cropping systems in the U.S.
They are one of the most valuable natural enemies for cotton. They feed on eggs and small larvae of bollworm, pink bollworm, tobacco bud worm, and on the eggs and nymphs of plant bugs. They also feed on all life stages of whiteflies, mites and aphids.

**Harvestmen Spiders** also known as Daddy Long Legs or Harvest spiders feed on many soft bodied arthropods in corn, alfalfa, small grains, potatoes, strawberries and apple crops.

**Stink bugs** are names for the strong odor they emit when disturbed. It is found throughout the U. S. and feeds on immature insects including: larvae of Mexican bean beetle, European corn borer, diamondback moth, corn earworm, beet armyworm, fall armyworm, cabbage looper, imported cabbageworm, Colorado potato beetle, velvetbean caterpillar, and flea beetles.

**Persimillis** – A mite used in strawberry fields, greenhouse and warm humid habitats in which spider mites are problematic. Every fall and winter, millions of these mites are released in to the California strawberry fields and are an integral part of an IPM program of mite control.

**Californicus** – Feeds on spider mites, cyclamen and broad mites. It is able to tolerate higher temperatures and lower humidities than the perismillis mite. European growers use them in greenhouses to protect peppers and other crops from spider mites.

**Helveolus** – Is used to control the Persea mite in California avocado groves.

**Parasites of Pests**
Trichogramma

The wasps of genus *Trichogramma* are some of the most widely-studied agents of biological control in the field of entomology. *Trichogramma* wasps are tiny Hymenopteran insects, measuring 1 millimeter in length or less, that parasitize the eggs of many types of agricultural pest insects. They are easy to rear and release in fields suffering from pest outbreaks.

There are over 230 species of *Trichogramma*, and most are so similar that advanced expertise is required to tell them apart. Genetic studies are ongoing. The wasps are currently used to control at least 28 species of insect pest, including the cotton bollworm, codling moth and corn borer. Female wasps inject their own eggs into the egg of the pest, and her larva consumes the embryo and other contents of the egg.

Encarsia

*Encarsia inaron* is a tiny parasitoid, stingless wasp first collected in Italy and Israel and introduced into California in 1989 to control the ash whitefly that was collected in Italy and Israel and introduced into California in 1989 for the control of the ash whitefly. The eggs of the Encarsia develop inside the whitefly host.

Products Available

The Association of Natural Biocontrol Producers is a professional organization that represents the biological pest management industry. Through this organization it is possible to find biocontrol producers and listings of products available. A sampling of products available follows.
<table>
<thead>
<tr>
<th>Product</th>
<th>Target Pest or Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly Parasites</td>
<td>Fifth Flies</td>
</tr>
<tr>
<td>Green Lacewing</td>
<td>Immature whiteflies, mealybugs, caterpillars, other soft bodied insects</td>
</tr>
<tr>
<td>Trichogramma</td>
<td>Caterpillars</td>
</tr>
<tr>
<td>Moth Eggs:</td>
<td>Used as a food source or for host material</td>
</tr>
<tr>
<td>Fresh, Frozen</td>
<td></td>
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<tr>
<td>or Sterilized</td>
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<tr>
<td>Lady Beetles</td>
<td>Many Aphid Species</td>
</tr>
<tr>
<td>Spinned Solider bug</td>
<td>Caterpillars</td>
</tr>
<tr>
<td>Rove beetles</td>
<td>Fungus gnat larvae and pupae</td>
</tr>
<tr>
<td>Occidentalis</td>
<td>Spider mites</td>
</tr>
<tr>
<td>Longpipes</td>
<td>Spider mites</td>
</tr>
<tr>
<td>Encarsia</td>
<td>Greenhouse whitefly</td>
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</table>
Regulating Biopesticides

Before a pesticide can be marketed and used in the U.S. the EPA must evaluate the proposed pesticide to assure that it will not pose an unreasonable risk to human health and the environment. By the end of 2001, there were approximately 195 registered biopesticide active ingredients and 780 products.

This requirement results from the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and includes:

1. Naturally occurring substances the control pests (biochemical pesticides)
2. Microorganisms that control pests (microbial pesticides)
3. Pesticidal substance produced by plants containing added genetic material (Plant-Incorporate Protectants, PIPs)
**Microbial Pesticides** - Consist of microorganism such as a bacterium, fungus, virus or protozoan as the active ingredient. The most widely used are subspecies and strains of *Bacillus thuringiensis Bt*. Each strain of the bacterium produces a different mix of proteins that exclusively kills one or a few related species of insect larvae. Insect species are targeted once a determination is made as to whether the particular Bt. produces a protein that binds to a larval gut receptor, causing the insect larvae to starve.

**PIPs** – Pesticidal substances produced by a plant from genetic material that has been added to the plant. An example is when scientists take the gene for the BT pesticidal protein and introduce the gene into the plant’s own genetic material. Resulting in the plant rather than the Bt. bacterium manufacturing the substance that destroys the pest. The Bt. protein and the substance are regulated by the EPA but not the plant itself.

**Biochemical pesticides** – These are biologically occurring materials that control pests by nontoxic methods. These include insect sex pheromones that will interfere with mating, scented plant extracts that will attract insect pests to traps. Canola oil and baking soda have use as a pesticide and are considered biopesticides.

**Biocontrol Resources**

**General**

National Biological Control Institute

International Institute of Biological Control

International Organization for Biological Control

**Universities**
Auburn University's Biological Control Institute

Cornell University's Biological Control: A Guide to Natural Enemies in North America

Illinois Natural History Survey's Ecological Database of the World's Insect Pathogens (EDWIP)

Illinois Natural History Survey's Viral Diseases of Insects in the Literature (VIDIL)

Iowa State's Biological Control Index

Michigan State University's Landscape Ecology and Biological Control Lab

North Central Regional Committee on Arthropod Biological Control

Texas A&M, Department of Entomology

The Ohio State University's Insect Parasitic Nematodes

Oregon State University's Research on Entomopathogenic Nematodes at OSU

Purdue University's Biological Control Laboratory

University of Florida's Beneficial Insects

University of Nebraska - Lincoln's Nematodes as Biological Control Agents of Insects

University of Wyoming's Cooperative Agricultural Pest Survey Databases on Biocontrol of Noxious Weeds and Insects

**Government Agencies**

USDA-ARS Beneficial Insects Introduction Research
Summary

Worldwide and in the U.S. an estimated 12% of crop plants are lost to disease. Not only are crop plants lost, but also marsh plants, forests and other plant systems. Although biological control has been in use for over 100 years, the general public is not all that familiar with it. The USDA, APHIS provides funding to educate the public. Educational publications are available to all interested individuals and groups from the APHIS.
In any ecosystem there are natural control factors that limit the growth of an organism and prevent it from becoming a pest. However, when natural enemies are killed by man or non-native plants are introduced without their natural enemies, natural control is compromised resulting in pest outbreaks. At such times, man needs to intervene with the use of natural enemies or biological control. The difference between the two is that biological control requires intervention from man, whereas natural control depends solely upon the ecosystem for balance.

Biocontrol does not completely eliminate pests; rather the goal is to keep the pests at low levels. Not a simple task. Education and continued research are essential. Before using commercially available products or natural pests, it is important to understand and research the biology of the pest, their natural enemies and their environment. The lady beetle is a good example of the importance of research. The lady beetle has been highly praised as a predator of aphids, mites, insects and small caterpillars. But as one community found, the lady beetle will not control mosquitoes.

Other communities jumped on the benefits of the lady beetle and purchased large amounts of lady beetles and involved school children in a publicized release program. Come fall, home owners were battling an infestation of ladybugs. The cute ladybugs that once were a welcome site in the garden were now a nuisance, finding their way inside homes through window screens and cracks. The community officials should have identified what pest they were actually doing battle with and researched the natural enemies. In so doing, they would have found that dragonflies and basil are both reputed to repel mosquitoes and marigolds have long had a reputation has the workhorse for repelling garden pests. Knowledge through research is critical for any biological control program.

Glossary
Aibotic – means factors that include climate, soil, air, space and light

APHIS - Animal and Plant Inspection Service

Arthropod – means any invertebrate of the phylum Arthropoda, having a segmented body, jointed limbs, and usually a chitinious shell that undergoes moltings, including the insects, spiders and other arachnids, crustaceans, and myriapods

Augmentation – means the increase of native agents for control of native or exotic pests.

Biological Control – means the use of natural enemies by man to control pests

Environmental Resistance – means the sum total of all mortality factors including: physical such as temperature and biotic such as natural enemies. The amount of mortality factors in the environment influences the organism in reaching its full capacity to reproduce.

Classical Biological Control – means the use of exotic biological control agents imported from its native home into the target area against exotic pests that have arrived without their natural enemies.

Ecology - means the study of an organism's interrelationship with its environment.

Epizootic - means a disease outbreak within an insect population.

Host Selection – means the process in which an organism selects its hosts. The four phases include: locating the host habitat, finding the host in the habitat, selecting a suitable host for laying the eggs, the successful development of the parasite in the host resulting in producing fertile offspring.
Larva, Larvae (pl.) - means the immature stage between the egg and pupa of insects having complete metamorphosis where the immature differs radically from the adult (e.g., caterpillars, grubs).

Life Cycle - means the sequence of events that occurs during the lifetime of an individual organism.

Maggot - means the immature form (larva) of a fly or wasp, lacking legs and a well-developed head.

Microbial - means a microscopic organism; a germ.

Mite - means any of several minute invertebrates belonging to the phylum Arthropoda, class Arachnida.

Natural Control – means the sum effect of natural control factors that limit the increase of an organism in the ecosystem.

Nematode - means an elongated, cylindrical worm parasitic in animals, insects, or plants, or free-living in soil or water.

Neoclassical biological control – means the use of exotic biological control agents against a native pest.

New association – means natural enemies that have not evolved with the target pest.

Old association - means natural enemies that have evolved with the target pest in its place of origin.

Parasite – means an organism that lives and feeds in or on a host.
**Pest** - means an organism that interferes with human activities, property, or health, or is objectionable.

**Parasitoid** – means an insect parasite that destroys its host.

**Pathogen** – means a microorganism that causes disease in its host.

**Protozoan** - means a microscopic, single-celled organism that is largely aquatic and includes many parasitic forms.

**Predator** – means a living organism that feeds upon other organisms that are smaller and weaker than itself.

**Races or strains** – means members of the same race or strain look similar and have the same characteristics, but differ from other races in function and activity.

**Stage** (life stage) - means a distinct period in the development of an organism (e.g., for some insects, egg, larval, pupal, and adult stages).

**Tolerance** (host-plant resistance) – means the ability of a plant to withstand injury by pests.

**Virus** - means any of various submicroscopic pathogens which can only replicate inside a living cell.