**Insect Pest Management for Organic Crops**

**Botanicals for Controlling Insect Pests**

Insecticides that are derived from unmodified (not genetically engineered) plants or plant parts are commonly referred to as **“botanicals.**” Botanicals have been used in agriculture for centuries. Botanical insecticides fall into several classes because of their various modes of action. Some are contact poisons while others inhibit insect development and are therefore called **“Insect Growth Regulators**.” Most botanicals are less toxic to humans, wildlife and the environment, and they degrade more rapidly than synthetic-organic insecticides into harmless components in the field. For these reasons, many botanicals are allowed in organic crop production. Because botanicals generally break down quickly after application, they may also be of use near harvest when insect pest control is needed but other materials should not be applied because of pre-harvest interval (PHI) restrictions. Rapid degradation also means that botanicals are less likely to cause environmental problems.

**Disadvantages:**

However, botanical insecticides are not without concerns. They are usually broad-spectrum poisons that can harm beneficial insects and some botanicals (e.g., rotenone) are acutely and chronically toxic to humans and other mammals. Moreover, the fact that botanicals break down rapidly in the environment also means that they provide very short-term pest control, so that sprays must be timed precisely to coincide with insect pest events, or be applied at lower pest populations, or be applied more frequently.

**Neem**

Neem products are derived from the neem tree, *Azadirachta indica*. Neem products are broad-spectrum insecticides, which work by contact or ingestion. These products may contain neem oil (sometimes formulated as a soap) or the purified active ingredient, azadirachtin.

**Types of Insect Pests Controlled**

Neem extracts have been shown to affect a broad range of insects, but efficacy varies among species. On fruit crops, neem has shown some efficacy against aphids, including rosy apple aphid, woolly apple aphid, tarnished plant bug, some leafhoppers, pear psylla, and spotted tentiform leafminer.

**Application (Next Class)**

Frequent applications are more effective than single sprays because neem does not persist well on plant surfaces. Like most other botanically derived materials, it can be rapidly broken down by sunlight and washed away by rain. Neem may not show signs of efficacy for three to seven days, and it can degrade within three to four days.

**Pyrethrum**

Pyrethrin is a natural insecticide, derived from the crude extract of the Chrysanthemum flower (Pyrethrum) (Gulay dawoody). Pyrethrins are the active chemicals in pyrethrum. “Pyrethrum” and “pyrethrin” are often used interchangeably. Pyrethrum is a fast-acting contact poison that “knocks down” susceptible insects. Pyrethrum induces a toxic effect in insects when it penetrates the cuticle and reaches the nervous system leaving the insects paralyzed. Pyrethrum may also have a repellant effect. Since pyrethrum is a contact poison, the target pest must be present and hit by the spray.

**Types of Insect Pests Controlled**

Used correctly, pyrethrum is moderately to highly effective against aphids, apple maggot, European apple sawfly, caterpillars, leafhoppers, whiteflies, Lepidoptera larvae (including codling moth), mealybugs, pear psylla, plum curculio, many of the true bugs (Hemiptera), and flower thrips. Within these groups, pests may have a greater or lesser susceptibility to pyrethrum products. Some insects may be able to recover after the initial knockdown if the dose is too low. Frequent repeat applications of pyrethrum are required because of its rapid photo-degradation and short residual activity in the field.

**Application**

Pyrethrins (the active chemicals) are rapidly broken-down by sunlight. Therefore, it is recommended that pyrethrum be applied before dawn or in late evening when the target insect pests are active and present in the field, and UV light is minimal. Use of UV-inhibiting adjuvants may allow for a longer period of residual activity.

**Ryania**

Ryania is extracted from the stems of a woody South American plant, *Ryania speciosa* (Salicaceae family). Ryania is a slow-acting stomach poison. Although a slow-acting stomach poison, it causes insects to stop feeding soon after ingestion.

**Sabadilla**

Sabadilla comes from the ripe seeds of the tropical lily *Schoenocaulon officinal*. Sabadilla is a broad-spectrum contact poison, but has some activity as a stomach poison. The alkaloids in Sabadilla affect insect nerve cells, causing loss of nerve function, paralysis, and insect death.

**Rotenone**

Although the Organic Materials Review Institute (OMRI) Generic Materials List identifies rotenone as “Allowed with Restrictions” on organic farms, the material is only legally allowed under certain conditions. The National Organic Program (NOP) is currently exploring possible changes to the regulations, potentially limiting or prohibiting the use of rotenone. In recent studies, rotenone has been linked to neurotoxic symptoms similar to Parkinson's disease. For these reasons, U.S. organic growers have discontinued use of rotenone.

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## Microbials for Controlling Insect Pests

Microbial insecticides, also called as biological pathogens or biological control agents, contain microbes like bacteria, fungi, viruses, or nematodes that produce toxins that are harmful to insect pests. Most insect pathogens are relatively specific to certain groups of insects and certain life stages. Unlike chemical insecticides, microbial insecticides can take longer to kill or weaken (debilitate) the target pest. This may limit their use to crops that can sustain some insect damage. To be effective, most microbial insecticides must be applied to the correct life stage of the pest, and some understanding of the target pest's life cycle is required. Some microbial insecticides must be eaten by the insect to be effective. Good spray coverage is therefore important. Products containing these organisms are regulated by the Environmental Protection Agency (EPA) and use is governed by the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). While the active ingredients of microbials are generally approved for organic production (Organic Materials Review Institute, OMRI listed) because of their natural origin, certain formulated products are prohibited because the inert ingredients or procedures used in making the product are prohibited.

### Bacteria

Bacterial insecticides are the most common form of microbial biopesticides. They are typically used as insecticides, although they can be used to control unwanted bacteria, fungi or viruses as well. As an insecticide, they are generally specific to individual species of moths and butterflies, as well as species of beetles, flies, and mosquitoes.

#### Bacillus thuringiensis

The most widely used microbial pesticides are subspecies and strains of Bacillus thuringiensis (abbreviated as Bt). Each strain of this bacterium produces a different mix of proteins and specifically kills one or a few related species of insect larvae. When ingested by insect larvae, Bt releases endotoxins (proteins) that bind to the intestinal lining of the insect midgut.

**Types of Insect Pests Controlled.** Insecticidal products comprised of a single Bacillus species may be active against an entire order of insects, or they may be effective against only one or a few species. There are different strains (subspecies) of Bt, each with specific toxicity to particular types of insects. Bacillus thuringiensis var. kurstaki and Bacillus thuringiensis var. aizawai are used against lepidopteran (moths and butterflies) larvae.

**Formulations.** Formulations are available as liquid concentrates, wettable powders, and ready-to-use dusts and granules. Many formulations of Bt are made using natural processes and have been approved by the OMRI for certified organic production.

**Application:** Because Bt must be ingested by the insect it must be applied where and when the insect is feeding. Many insects feed on the undersides of leaves and in hidden parts of the plant, so thorough coverage is required. As with most insecticides, young larvae are generally more susceptible than older larvae, so treatments should be timed accordingly. Early detection and application are crucial for good control. If temperatures are too cool or too hot, insects may stop feeding. Multiple applications are often needed for adequate management of the pest.

**Resistance.** As with any natural or synthetic-organic insecticides, insect populations can develop resistance to Bt; resistance has already occurred with some populations of Colorado potato beetle and diamondback moth. Perhaps the best way to avoid resistance is to avoid continuous Bt applications and to use the product only when necessary. This requires frequent observations or scouting in the field and the use of treatment thresholds whenever possible. Early detection of infestations is especially important when Bt is used as the primary pest control tool.

**Potency:**Manufacturers often provide potency data for their products; these data are usually reported in terms of International Units per milligram (IU/mg) or billions of International Units per kilogram (BIU/kg).

**Recombinant DNA (rDNA) Techniques: (DNA** molecules formed by laboratory methods of genetic **recombination** (such as molecular cloning) to bring together genetic material from multiple sources, creating sequences that would not otherwise be found in the genome.) The newest form of Bt manufacturing is through recombinant DNA (rDNA) techniques, where specific genes linked to the expression (production) of crystalline protein toxins are inserted into bacterial cells.

#### Spinosad: (Spinosad 480 SC (45% w/w (Bayer Product)

Spinosad is a relatively new microbial insecticide that is derived from a soil-dwelling bacterium. It is used for Aphid, Jassid, Shoot and Fruit Borers. It is produced by aerobic fermentation of the soil-dwelling actinomycete species **Saccharopolyspora spinosa**. Spinosad is a fast-acting, somewhat broad-spectrum material that acts on insects primarily through ingestion or by direct contact with a spray droplet or a newly treated surface. Foliar applications of spinosad are not highly systemic in plants, although some movement into leaf tissue has been demonstrated. The addition of a penetrating surfactant increases absorption by tissues.

### Fungi

Fungi are a diverse group of organisms and can be found in almost every environment on Earth. Most have complex lifecycles, and some are parasitic to various insects. Some species have proven useful as microbial biopesticides. The mode of action is varied and depends on both the insecticidal fungus and the target pest. Unlike bacterial spores or virus particles, fungal conidia (spore produced by fungus at tip of hyphae) can germinate on the insect cuticle and produce specialized structures that allow the fungus to penetrate the cuticle and enter the insect’s body.

#### Beauveria bassiana

Beauveria bassiana is a fungus, which causes a disease known as the **white muscadine** disease in insects. B. bassiana is applied to the target pest as a spore, which is the reproductive and dispersal structure of the fungus. Once the spores have contact with the insect exoskeleton, they grow hyphae (long, branching vegetative appendages) that secrete enzymes, which in turn dissolve the cuticle (outermost layer of the skeleton).

#### Trichoderma harzianum

**Trichoderma harzianum** is a fungus that is also used as a fungicide. It is used for foliar application, seed treatment and soil treatment for suppression of various disease causing fungal pathogens.

Trichoderma harzianum provides natural, season-long control of diseases because it grows on the root system in a way that benefits the plant (root colonization). It protects roots from diseases caused by Pythium, Rhizoctonia and Fusarium and permits stronger, healthier root systems.

In recent studies it has been observed treatments with the fungal biocontrol agent *Trichoderma atroviride* strain in tomato plants induce responses that affect pest insects with different feeding habits e.g moth and the aphid. Tomato plant–*Trichoderma* interaction had a negative impact on the development of moth larvae and on aphid longevity. These effects were attributed to a plant response induced by *Trichoderma* that was associated with transcriptional changes (cell regulates the conversion of DNA to RNA ) of a wide array of defense-related genes. The impact on aphids could be related to the up-regulation of genes involved in the oxidative burst reaction, which occur early in the defense reaction, the negative performance of moth larvae was associated with the enhanced expression of genes encoding for plant protective enzymes

### Viruses:

The most common and effective types are the **baculoviruses**, a group that includes two types of insect viruses: **nuclear polyhedrosis** and **granulosis** viruses. Insect viruses are obligate disease-causing organisms that can only reproduce within a host insect. Most are so specific in their action that they infect and kill only one or a few species of Lepidoptera larvae (caterpillars), making the viral insecticides good candidates for management of crop pests with minimal off-target effects.

#### Cydia Pomonella Granulosis

The granulovirus of the codling moth Cydia pomonella, or CpGV, is a good example of a commercially successful viral insecticide. CpGV is highly specific to the codling moth. The codling moth, Cydia pomonella (L.), is a major pest causing severe economic damage in apple and pear orchards throughout most of the temperate world.

### Nematodes

Nematodes are microscopic roundworms that lack segments or appendages and may be parasitic (lives on other organism called host), free living, or predaceous (kill other animal for food). Entomopathogenic (microorganisms that are pathogenic to arthropods such as insects, mites, and ticks) nematodes have a symbiotic association with a bacterium (Xenorhabdus spp.) that is lethal to many soil-dwelling insects but does not affect animals and plants. Because they are highly mobile and can locate and destroy new victims in just a few days, entomopathogenic nematodes make outstanding candidates for all kinds of biological control.



#### Nematode Species

Species of nematodes vary in their host range and host-finding behavior. Most failures in efficacy of field applications are related to a poor match between the nematode species and target insect pest. Species of nematodes vary in their host range and host-finding behavior. Some nematodes (e.g., Heterorhabditis bacteriophora) are very active in the soil and search a relatively large area for a host insect, whereas the widely available nematode Steinernema carpocapsae is relatively sedentary (inactive) and tends to sit and wait for a host insect to pass by in close proximity.

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**Biological Control of Insect Pests (With the use of** Beneficial insects)

Biological control uses natural enemies—usually called “beneficial insects” or “beneficials”—to manage pests. Natural enemies include insect **predators** (insects that consume part or all of pest insects), **parasitoids** (insects that use other insects to produce their offspring, thereby killing the pest insect in the process), and **pathogens**, including viruses, bacteria, protozoa, fungi, and nematodes (diseases that kill or decrease the growth rate of insect pests). The goal of biological control is to hold a target pest below economically damaging levels—not to eliminate it completely—since destroying the population also removes a critical food resource for the natural enemies that depend on it. Biological control is often most effective when coupled with other pest control tactics in an integrated pest management (IPM) program. Practices that are often compatible with biological control include **cultural controls, crop rotation, insectary plantings** (plants that attract natural enemies of harmful insects e.g mustard plants such as Brassica juncea, buckwheat, marigold, coriander, fennel, mint, blackberry, Convolvulus, Chrysanthemum)**, trap crops, planting pest-resistant varieties,** using approved insecticides with selective modes of action, or spot treatments that leave untreated areas to serve as refuges for natural enemies.

Types of Natural Enemies for Biological Control

Predators, parasites, and pathogens are the primary groups used in biological control of insects and mites. Most parasites and pathogens, and many predators, are highly specialized and attack a limited number of closely related pest species.

**Predators**

Predators include birds, fish, amphibians, reptiles, small mammals, and arthropods. Arthropods (insects, mites and spiders) are the most important predators in pest management and include lady beetles, ground beetles, syrphid flies, green lacewings, assassin bugs, predaceous bugs, minute pirate bugs, predatory mites, and spiders. Predators are usually larger than the prey, which they capture and kill.

**Parasites**

Parasites of insects (wasps, flies, beetles and worms also called parasitoids) are insects that lay their eggs in or on a host insect e.g Trichogramma wasp lays its eggs inside the eggs of moths (sugar cane borers) preventing the moth egg from hatching into a caterpillar.

This prevents the damage caused by the feeding caterpillars, and also breaks the life cycle of the pest, effectively preventing the pest from reproducing. In some species of moth up to 5 parasite eggs may be laid in each moth egg. As the parasite develops within the egg, it turns black, and after about 10 days, an adult Trichogramma emerges. Adult Trichogramma can live up to 14 days after emergence. **Some of the common pests Trichogramma combat are:** Cabbageworm, Tomato Hornworm, Corn Earworm, Codling Moth, Cutworm, Armyworm, Webworm, Cabbage Looper, Corn Borer, Fruitworms, and Cane Borers.

When the parasite egg hatches, the young parasite larva feeds on the host (the pest) and kills it. After feeding on host body fluids and organs, most parasites leave their hosts to pupate or emerge as adults.

**Nematodes**

Insect-parasitic nematodes (also called entomopathogenic nematodes) are small, almost microscopic worms that attack and kill insects that live in moist habitats, especially water and damp soil.

**Pathogens**

Natural enemy pathogens are microorganisms including certain bacteria, fungi, viruses, and nematodes that can infect and kill the host. Populations of some aphids, caterpillars, mites, and other invertebrates are sometimes drastically reduced by naturally occurring pathogens, usually under conditions such as prolonged high humidity or dense pest populations. Some pathogens have been mass produced and are available in commercial formulations for use in standard spray equipment.

General Approaches to Biological Control

Effective biological control often requires a good understanding of the biology of the pest and its natural enemies, as well as the ability to identify various life stages of relevant insects in the field. There are three broad approaches to the biological control of insects: (1) augmentation of existing natural enemies by releasing predators or parasites; (2) conservation of natural enemies by changing aspects of the environment that threaten their survival or effectiveness; and (3) importation of natural enemies.

Augmentation of Natural Enemies

Augmentation is an attempt to reduce a pest’s population to noneconomic levels by temporarily increasing natural enemy numbers in an area through periodic releases. The natural enemies then seek out and attack the insect pest. Increasing the natural enemy population improves the chance of gaining economic control over the pests. Natural enemy augmentation is based on the assumption that, in some situations, there are not adequate numbers of natural enemies to provide sufficient biological control (even though some may be present), or that their immigration is not timely enough to suppress the pest before it reaches economic levels. Today, commercial natural enemies are available for controlling aphids, mites, scale insects, mealybugs, leafminers, thrips, caterpillars, and other insect pests.

Conservation of Natural Enemies

The second approach, conservation, involves boost populations of existing or naturally occurring beneficial organisms such as predators, parasitoids, and pathogens by supplying them with appropriate habitat and alternative food sources. “Farmscaping” is a term sometimes used to describe the creation of habitat to enhance the chances for survival and reproduction of beneficial organisms. It involves identifying the factor(s), which may limit the effectiveness of a particular natural enemy and modifying them to increase the effectiveness of the beneficial species.

Importation of Natural Enemies

Classical biological control differs from the other two general methods (augmentation and conservation) because it is not directly conducted by the grower. International agencies, federal agencies (especially U.S. Department of Agriculture, USDA), and state agencies (state departments of agriculture and land-grant universities) are responsible for identifying potential target pests, locating their natural distributions, searching these areas for candidate natural enemies, and introducing selected natural enemies into the necessary areas. Indeed, specific quarantine laws prohibit private individuals or agencies from introducing non-native organisms (including natural enemies) without proper authorization from USDA.

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**Insecticidal Soaps for Controlling Insect Pests**

Insecticidal soaps are sprayable liquid formulations of potassium salts of fatty acids that are specifically intended for insect control. Insecticidal soap products work by disrupting the cuticle (skin) layer and suffocating soft-bodied insects. To be effective, the spray solution must contact and thoroughly cover the targeted pest. Soaps work best against soft-bodied pests such as aphids, scales, whitefly, mealybugs, thrips, spider mites, and the immature stages of other pests; predatory mites and the soft-bodied larval stages of beneficial insects such as ladybird beetles (“ladybugs”) and hoverflies are also likely to be affected. Soaps are ineffective against insect eggs and harder-bodied adult insects, such as beetles. Some soap-based products are formulated with neem oil, and these tend to have a broader range of action.

Application

Target pests must be directly contacted by the spray; once the residue dries on the plant, it is no longer effective. For this reason, it is more effective to spray in the early morning when the insects are becoming active but temperatures are still relatively cool so that drying is less rapid. Application must be thorough and completely wet the pest. This usually means spraying undersides of leaves and other protected sites. Insects that cannot be completely wetted, such as aphids within curled leaves, will not be controlled. Repeat applications may be necessary to achieve control. Once an insecticidal soap spray has dried, there is no residual activity because soaps work only on contact. Results from the application of soap are usually seen in one to three days. Insecticidal soaps are usually diluted with water before applying.

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## Pheromones for Controlling Insect Pests

The National Materials List allows the use of synthetic pheromones for mating disruption of insect pests. Pheromones target the reproductive life stage (the adult), thus preventing the development of the damaging life stage. Pheromones used in mating disruption are species-specific and are thus highly selective. Typically, only the primary target species responds to the pheromone, and non-target effects on biological control agents within a field or outside of a cropping system are not observed. They are generally non-toxic and will not control other pests. Additional benefits include reduced worker re-entry or pre-harvest intervals and limited impacts on other management practices, such as irrigation scheduling. Pheromone-based mating disruption has also been identified as a strong tool for managing insecticide resistance. The use of pheromones against key pests does not result in outbreaks of secondary pests or pest resurgence.

### Advantages and Disadvantages of Insect Pheromones

Some of the advantages in using insect pheromones include their high species specificity and relatively low toxicity. Sex pheromones tend to be specific to a particular insect species or even strain of insect, making them one of the most targeted pest management strategies. This specificity thus maintains an ecological balance by leaving undisturbed populations of other insect species and non-target organisms.

### Pheromones Used to Control Insect Pests

Pheromone-based devices have achieved the successful control of insect pests in almost all types of agriculture, including perennial orchards, vineyards, annual vegetables, and fiber crops. The following five insect pests have enjoyed historical and recent successes with pheromone-based management systems.

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**Insect Growth Regulators**

Insect growth regulators (IGRs) have proven extremely effective as components in IPM programs for control of insects which have become resistant to standard insecticides. Typically, IGRs are less harmful to the environment and more compatible with pest management systems that include biological controls. They generally don’t affect nontarget species—such as humans, birds, fish, or other vertebrates. Insect growth regulators are compounds that mimic (intimate) the action of hormones to disrupt the molting process and modify growth of insect or mite pests. They do not kill insects directly, but interfere with normal development so insects die before they mature. Some cause insects to stop feeding. Others affect egg, larval, nymphal (immature form of insect), or pupal development. They inhibit metamorphosis (change in the animal's body structure through cell growth and differentiation) and may negatively affect reproduction and egg viability. Insect growth regulators are primarily used to kill immature stages of plant-feeding insects, including caterpillars, fungus **gnats** (a tiny flying insect), leafminers, mealybugs, scales, shoreflies, thrips, and whiteflies.

How Insect Growth Regulators Work

Insect growth regulators (IGRs) use a different and more selective mode of action; they disrupt the growth process of insects, preventing them from the reaching reproductive stage. IGRs have a complex mode of action that prevents insects from rapidly developing resistance.

**Insect growth regulators (**IGRs) are pesticides that don't usually kill insects outright but instead affect the ability of insects to grow and mature normally. IGRs either block the insect's ability to turn into an adult or cause it to change into an adult before it is physically able to reproduce. These are hormones that can be produced artificially.

**Juvenile Hormone Analogs and Mimics**

When applied to an insect, these abnormal sources of juvenilizing agent (stop the development) can have striking consequences. For example, if the normal course of events calls for a molt to the pupal stage, an abnormally high level of juvenilizing agent will produce another larval stage or produce larval-pupal intermediates.

**Chitin Synthesis Inhibitors**

These prevent the formation of chitin, a carbohydrate that is an important structural component of the insect's exoskeleton. When treated with one of these compounds, the insect grows normally until the time to molt.

**Anti-juvenile Hormone Agents**

Anti-juvenile hormone agents cancel the effect of juvenile hormone by blocking juvenile hormone production. For example, an early instar treated with an anti-juvenile hormone agent molts prematurely into a nonfunctional adult. A disadvantage of these chemicals is that they are so selective that they may not be economic for a manufacturer to develop.

**Application of Insect Growth Regulators**

Application timing is important with insect growth regulators. Products have a brief period of residual activity, and exposure to ultraviolet light can affect longevity, so repeat applications usually are warranted. Insect growth regulators are most active on the early life stages of insects that undergo complete metamorphosis (egg, larva, pupa, and adult). They should be applied as soon as possible.