BioNatural Healing College

BioNatural Insect Management
Online Continuing Education (CE) Publication Part I
For CA DPR Licensee/Certificate/or Other

BioNatural Pest Management (Online Continuing Education)

Request for Approval, Online 3-Hours

BioNatural Insect Management

Important Notes to Online Continuing Education Licensee/Certificate

BioNatural Healing College (BNHC) is pleased to offer this CE publication in brief that will enlighten the pesticide licensee, applicators, and operators. This publication is focusing on “Laws and Regulations” based on general pesticide information to DPR licensees, applicators, and other related professionals who are interested. It is important to note that this is not complete information about laws and regulations and is only for the enhancement quality of Continuing Education purposes. Regulations are always adopted for the benefit and safety of the public and the environment. Pesticides are poisonous and always must be taken with care in all aspect’s life. **How does Online Continuing Education work? BNHC welcome!** students are required to register through the website online, by phone, email, or fax, after registration, this publication will provide them with an electronic PDF version. CE licensee is required to study this publication which consists of 4 topics dealing with pesticide safety and management. Assignment Version I and Assignment Version II (Word document) answer the questions with Word document all in order to receive a passing score above 70 percent, then the certificate of accomplishment will be awarded. For those CE online attendees with unsatisfactory results, they are required to retake assignment version II with correct answers, and a certificate of accomplishment will be awarded.

Learn the knowledge, share the knowledge, and implement the knowledge to benefit humanity!!! BNHC

Acknowledgments

The information in this publication regarding Pesticide Laws and Regulations has been searched and gathered from various publications. Therefore, BioNatural Healing College is grateful and acknowledges the following as well as all the organizations, academia, researchers, and colleagues who are involved in the production and protection of crops in this publication:

1. The U.S. Environmental Protection Agency (U.S. EPA).
2. California Department of Pesticide Regulation (CA DPR)
3. United Nations Food and Agriculture Organization (FAO)
4. The U.S. Department of Food and Agriculture
5. https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/456/456-018/ENTO-336D.pdf
6. https://www.ent.iastate.edu/soybeanresearch/files/page/files/FieldCropInsects%20final%202012.pdf
7. https://www.researchgate.net/profile/Nabil_El-Wakeil/publication/337605984_Predacious_Insects_and_Their_Efficiency_in_Suppressing_Insect_Pests/links/5eff5b47458515505087ba30/Predacious-Insects-and-Their-Efficiency-in-Suppressing-Insect-Pests.pdf

BioNatural Pest Management (Online Continuing Education)

BioNatural Insects Management

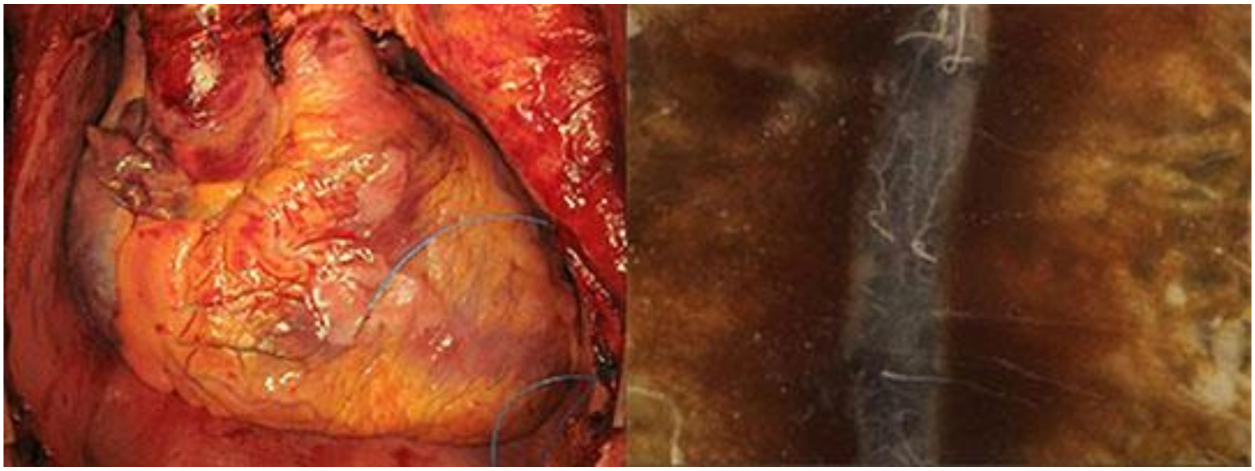
Introduction: The title of this BioNatural Insects Management online course is broad science with meaningful deals with BioNatural systems that emphasize preventing harmful insects' problems from becoming economically, and environmentally damaging to crops. While conserving the beneficial insects in the ecosystem with various techniques and the use of BioNatural products. For instance, relies on maintaining healthy soil ecology, supporting biodiversity, providing habitat for beneficial insects/organisms, and reducing habitat for pests. A pest can be defined as a destructive insect or another animal that attacks crops, food, livestock, etc. It is crucially important to understand when preventative measures are taken in BioNatural Insect Management to consider the physical and cultural controls, biological control, along the option of last resort is the use of appropriate biopesticides. It would be appropriate to understand the differences between insects and humans because this will help us for the rest of this course to absorb and digest the content of information in the context of the BioNatural healing process. According to Arizona State University, as we know that humans and insects have very different bodies size. However, in many ways, both have similarities. Therefore, studying insect physiology is helpful in the medicine, and agriculture industry, particularly in the use of pesticides. For instance, the DNA of fruit flies is 60% of the DNA code of fruit flies and humans are identical. It means that most human genes and insect genes are the same with very similar functions. For instance, humans and insects all require oxygen, water, and food, and they all produce waste. Muscle and nerve cells also work alike in humans and insects. As such, both have brains, hearts, digestive tracks, and reproductive organs. As mentioned, the anatomy and physiology of insects and humans have similarities in many ways. All organs of animals have different jobs within their bodies. For instance, the beetle brain is composed of many thousands of neurons that carry information using chemical and electrical signaling, as they do in the human brain. Let us consider what are the differences besides body size and shape.

Function	**Part In Humans**	**Part In Insects**
Body support	Bones	Exoskeleton
Breathing	Lungs	Tracheal tubes, air sac
Oxygen delivery	Blood proteins (hemoglobin)	Tracheal tubes
Nerve system	Centralized (brain, spinal cord, nerves)	Decentralized (brain, ganglia, nerves)
Pumping fluid	4-chambered heart	Long tube heart
Controlling water levels/filtering waste	Kidneys	Malpighian tubules, hindgut
Toxin removal	Liver	Fat body
Vision	Camera eyes	Compound eyes
Smell	Nose	Antennae
Taste	Tongue	Mouthparts, feet, wings

Source: https://askabiologist.asu.edu/insect-and-human-biology

The above discussion brings our attention to the reality that how important insects, humans, and foods, that connected to our life and guide us for the rest of this course to attempt to learn and achieve in enhancement quality education BioNatural Insects Management.

Chrysochroa fulgidissima, or the "Tamamushi" beetle, has more in common with humans than you might think. Image by Brian Adler.



Some organs are very different between humans and insects, like the heart. On the left is a human 4-chambered heart (just after a heart transplant) and on the right is the enlarged image of a long thin tube heart in a beetle. Human heart image by Vasily I. Kaleda; beetle heart by the Harrison lab.
Source: https://askabiologist.asu.edu/insect-and-human-biology

Having said that insects have a profound impact on the livelihood of humanity. Thus, entomology is the branch of the biological sciences that studies insects. This branch can be divided into Agricultural Entomology, Medical Entomology, Industrial Entomology, and Forensic

Entomology. Agricultural Entomology: This is concerned with the study of harmful and beneficial insects that affect agricultural commodities in fields or storage (e.g., aphids, flour beetles). Medical Entomology: The study of insects that cause vector-borne diseases in humans and animals such as Mosquitoes, Tsetse fly, Sandfly, and lice are a few examples. Industrial Entomology: The science of the use of insects, their activities, or products on industrial scales for human welfare (e.g., honeybees' production, honeybees diversity, beekeeping, diseases, and natural enemies of honey bees, insect pollinators, genetic purposes like the fruit fly Drosophila). Forensic Entomology: Refers to the insects that inhabit decomposing dead bodies to aid the legal investigation.

World of Pesticides in our Farming System: What are Pesticides? Pesticides are a mixture of substances that are intentionally used to control pests. The term pesticide includes insecticides (which may include insect growth regulators, termiticides, etc.), herbicides, fungicides, nematicides, rodenticides, bactericides, insect repellents, antimicrobials, molluscicide, piscicides (a substance used to kill fish), avicide (is a substance to kill birds), and lampricide (any chemical designed to target the larvae of lampreys in river systems before they develop into parasitic adults). As we know, our industrial agricultural system depends on the heavy application of pesticides, which control weeds, insects, and fungi prevention. More than 1.1 billion pounds of pesticides are applied annually to crops in the US. The increasing use of pesticides in recent decades has become a public and environmental concern. Consumers are looking for an alternative way that can minimize the use of pesticides, and more demand for organic food commodities or at least toxic chemicals produce.

The Impact of Pesticides on the Environment

The book Silent Spring 1962, well-documented the detrimental effects of the overuse of pesticides. For instance, DDT (Dichlorodiphenyltrichloroethane), which was banned in the US in 1972, has created an awareness of how pesticides can impact the wider environment. A study performing tests across 38 states found glyphosate in most rivers, streams, ditches, and wastewater treatment plants, as well as in 70 percent of rainfall samples (Battaglin, WA, "Glyphosate and Its Degradation Product AMPA Occur Frequently and Widely in US Soils, Surface Water, Groundwater, and Precipitation." 2014). Even at levels deemed safe, pesticides have been shown to cause a loss of biodiversity, including reduced numbers of beneficial insects, as well as birds and amphibians. (Oosthoek, Sharon "Pesticides spark broad biodiversity loss." *Nature*, June 17, 2013). Another example to know is that Atrazine is a widely used herbicide on corn and other crops. Atrazine is especially prone to running off targeted plants and eventually ending up in rivers, lakes, and groundwater, where it can harm aquatic plants and disrupt the reproduction and growth of amphibians and fish (FoodPrint.org). According to Pesticide Action Network, fish and amphibians are most vulnerable. Numerous studies have shown that atrazine exposure even to trace levels of the herbicide can adversely impact several species. Tyrone Hayes and his colleagues found that 10% of male frogs reared in atrazine-laced water turned into females (https://www.panna.org/resources/atrazine).

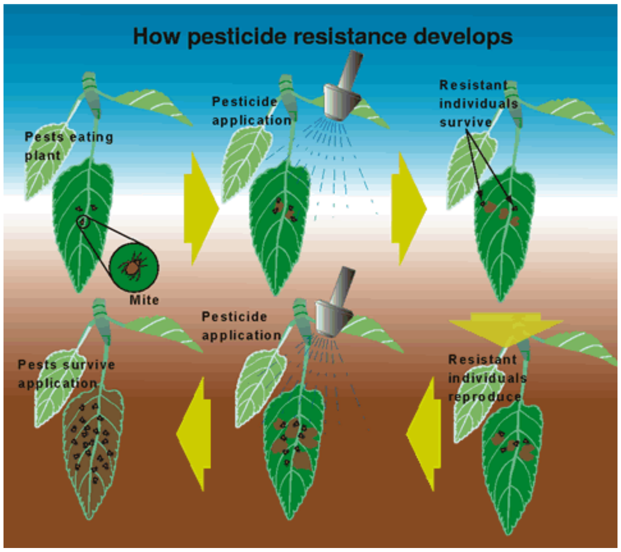
Pollinators and Pesticides: According to Pesticide Action Network, pollinators play an important role in human society's food supply. Negative impacts on bee populations could lead to decreased reliability and diversity in food production. Researchers have shown a total of 161 different pesticide residues have been detected in samples taken from beehives worldwide. A recent review of hive tracking studies from the U.S., France, Spain, and Poland found the highest residue concentrations in wax and pollen. Neonicotinoid (or neonic a popular class of pesticides that attack the nervous system of insects, has grown in popularity since the 1990s, however, wide use of neonic links to the decline of wildlife and pollinators) residues and other pesticides have been detected in several sources. They have been found in plants, nectar, and guttation droplets (like dew), pollen, bee bread (honey or pollen for bee food), dust from treated seeds, and in the bees themselves. Further, researchers have indicated that neonics are not the sole reason honeybee colonies are collapsing, but when combined with other stressors colonies faced in our industrialized food system, like varroa mites, being moved hundreds of miles to pollinate different crops, and huge, monoculture biodiversity deserts, they pose a serious threat. The EPA banned 12 neonic formulations in 2019, many more remain on the market. According to USDA (Plant Protection quarantine) article "Pollinators Benefit Our Health and Environment" stated that invasive pest that directly attacks pollinators indirectly threatens plant health and U.S. agriculture. That's where USDA's Plant Protection and Quarantine (PPQ) program is monitored and regulates direct and indirect pests plant pests according to Plant Protection Act (PPA). That's why critical concern issues with responsibility when it comes to pollinators because bee pollination has a value of more than 15 billion in the added crop, for example, specialty crops almonds, and other nuts, berries, fruits, and vegetables. Indeed, pollinators are the source of delicious foods and important to our overall health and environment. For instance, pollinators support healthy ecosystems that clean the air, stabilize soils, and support other wildlife. As such, they are also vulnerable to pesticides, invasive pests like parasitic mites, viruses, predatory insects, and other related factors. USDA under the Plant Protection Act (PPA) is spending over 2.4 million went to support honeybees and protect them from harmful pests and diseases PPQ will continue to administer the National Survey of Honeybees Pests and Diseases with PPA. Having said that since in January 2022, PPQ attended the annual meeting of the Apiary Inspectors of America. With efforts, an association of non-profit organizations was established with the mission to promote sustainable and healthy honey beekeeping conditions in North America mainly through the detection, mitigation, and suppression of bee pests, parasites, and pathogens. One of the examples of invasive pests here that would be appropriate to mention is the Asian giant hornet (AGH). AGH is a major concern for PPQ and beekeepers nationwide. AGH is a social wasp species. AGH is a native of northern India and extends to East Asia. According to the report, AGH was first discovered in the Vancouver Island area of Canada in August 2019. Subsequently, has been detected in the far northwest corner of Washington State. AGH can attack honeybee hives in the late summer and early fall. As a pest the hornets kill the adult bees, leaving them at the bottom of the hives. The hornets then take the bee larvae and pupae back to their nest to feed their own brood. Another threat is that a large and healthy nest can produce as many as 200 mated queens, which disperse to create new nests in the spring. Researchers consider AGH one of the worst pests of honeybees in the world because a small group of hornets can depopulate an entire honeybee hive in just a few hours. However, since February 2020, PPQ's Science & Technology program published a New Pest Response Guideline (NPRG) for the Asian giant hornet. NPRG in Washington State provided an overview of AGH lifecycle and identified possible trapping options. The good news is that the number of honeybee colonies in the United States has remained relatively stable because of the dedication of our beekeepers, they still lose too many of their hives each year.

However, pesticide resistance is a very concerning issue for every pesticide applicator and grower worldwide.

Pesticide Resistance: According to Michigan State University's "How Pesticide Resistance Develops" It is important to understand the role of population genetics, this concept link an individual organism's genes to determine its physical and behavioral traits. For instance, when individuals reproduce, they pass along unique combinations of genes to their offspring. Different environments favor individuals with different physical and behavioral traits. Those individuals with resistance genes that improve their survival will be more likely to pass along resistance genes compared to the rest of the population. The mix of genes in a population is called the gene pool. The composition of the gene pool continually changes over time through a process called natural selection.

Insecticide Resistance: Repeated use of the same class of insecticide to control a targeted insect can cause undesirable changes in the gene pool of targeted insects leading to another form of artificial selection, insecticide resistance. For instance, selection for resistance can occur if a small proportion of the insect population is able to survive treatment with insecticide. These rare resistant individuals can reproduce and pass on their resistance genes to the offspring. If an insecticide with the same mode of action is repeatedly used against this population. As a result, a greater proportion will survive. Ultimately, the once-effective product no longer controls the resistance population.

Resistance management: One of the biggest problems in pesticide usage and pest management worldwide is resistance management. Growers can help delay the development of resistance by applying pesticides only when it is needed, by rotating between different chemical classes, and by using rates of pesticides according to the labeled instruction. BioNatural Pest Management approaches such as pheromone mating disruption and cultural controls (e.g., soil health, crop rotation, cover crops, habitat modification, etc.) can also manage and prevent resistance.



Source: https://www.canr.msu.edu/grapes/integrated_pest_management/how-pesticide-resistance-develops

The Golden State of California is fortunate with fertile soil, diverse growing crops throughout the year, and supply food production within the State, US, and export to the world. As such, the California Department of Pesticide Regulation with its comprehensive Laws and Regulations, with respect to pesticide use for food production as well as aesthetic landscaping value as stated in the DPR mission as follows:

- Protect human health and the environment by regulating pesticide sales and use.
- Fostering reduced-risk pest management.
- Strict oversight begins with pesticide product evaluation and registration and continues through statewide licensing of commercial applicators, dealers, consultants, and other pesticide professionals.
- Evaluation of health impacts of pesticides through illness surveillance and risk assessment.
- Environmental monitoring of air, water, and soil; field enforcement (with the County Agricultural Commissioners).
- For laws regulating pesticide use, residue testing of fresh produce.
- Encouraging the development and adoption of least-toxic pest management practices through incentives and grants.

Therefore, review some of the harmful insects, according to USDA called Hungry Pests are invasive species that threaten to harm our crops and trees. These invasive hungry pests can devastate entire agriculture industries, food shortages, threaten our food supplies, eliminate jobs, and cause billions of dollars to our national economy. Let us consider one of the examples of these top invasive pest threats as follows:

Asian Citrus Psyllid (Diaphorina citri Kuwayama or ACP):
Host crops and Biology: Chinese box-orange, Curry leaf, Finger-lime, Grapefruit, Key lime, Kumquat, Lemon, Lime, Limeberry, Mandarin orange, orange, orange jasmine, Pomelo, Sour orange, Sweet orange, Tangerine, Trifoliate orange. ACP damage causes serious damage to citrus plants and citrus plant relatives as mentioned. Burned tips and twisted leaves result from an infestation of new growth. In addition, the Asian Citrus Psyllids carry the bacterium that causes Huanglongbing (HLB) disease, which is also known as citrus greening disease, one of the reasons that the bacterium spreads the disease to healthy citrus plants. Plants and materials can spread the infection even if there no psyllids are visible. Citrus greening is one of the most serious citrus diseases in the world. Once a tree is infected, there is no cure.
Where can be found? The psyllids have been found in Alabama, American Samoa, Arizona, California, Florida, Georgia, Guam, Hawaii, Louisiana, Mississippi, Northern Islands, Puerto Rico, South Carolina, Texas, and the U.S. Virgin Islands.
Signs and Symptoms: Visible psyllids or waxy psyllid droppings. Lopsided, bitter, hard fruit with small, dark aborted seeds. Fruit that remains green even when ripe. Asymmetrical blotchy mottling of leaves, yellow shoots, twig dieback. Stunted, sparsely foliated trees that may bloom off-season.

Prevention and Management:

- Quarantine is one of the standards options in the prevention and management of Hungry Pests
- Contact local State and Federal websites for specific information and regulations. For instance, the USDA Cooperative Service in your local area for further information.
- Citrus plants must be sold according to a regulated state from a certified vendor along with the USDA certificate.

- Before buying citrus plants ask the vendor if their product is in compliance with the state regulation. All types of commercial citrus businesses, roadside vendors within regulated states, and the internet should be able to prove they are in compliance with federal quarantine officials.
- The movement of branches cut greens, green waste, dead trees, and other regulated items will be regulated and enforced by federal, state, and county quarantine officials.
- Cut flower producers in quarantined areas are not affected unless they utilize Murraya, a host plant closely related to citrus or flowers and branches cut from plants regulated for citrus greening and Asian citrus psyllid.
- Within quarantine areas consume home-grown citrus fruit at home and do not transport home-grown citrus or citrus plants out of the area.

Harmful Insects

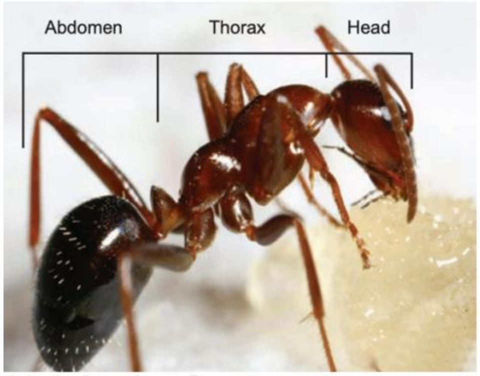
Introduction: Harmful insects are a major problem to agriculture from two frustrating perspectives. First, Not being fully aware that what, and when insecticides should be used on a wide range of different plant genera. Secondly, determining the identity of pests (insects) and the importance of any given pest found feeding on valuable and long-established trees and shrubs. Mankind throughout history has always been in direct competition for food, fiber, and fuel with insects. Historian has the perception that insects as "pest" this battle began about 16,000 years ago with cultivated crops and domesticated animals. Therefore, humans have the responsibility to protect the resources from insect damage (pests). Today the science of Entomology that deals with the study of insects makes it easy to take care of the insects' problems through the linked with other branches of science. For instance, researchers describe that insects are more abundant and diverse than any other animal, with more than one million described species. However, about 600 insect species are considered harmful pests in the United States, which is a relatively amount compared to the total number of species (Iowa State University Extension and Outreach). Crop production has to rise by 7% by 2050 to confront the human population increase (Aune JB 2012). This means that humans have homework to do their homework job successfully in order to accomplish by conserving the environment and limiting the use of insecticides and avoiding undesirable chemicals. Using selective pesticides at optimal concentration and time will protect the population of beneficial insects (Anon 2014). Therefore, natural enemies are components of BioNatural Pest Management (BNPM) which play a very important role in controlling pest insects in agricultural and horticultural crops. For instance, the economic value of these services has been estimated to be more than $400 billion per year globally (Van Lenteren, J., 2006). https://orgprints.org/30032/1/biokontrollsyntes_web.pdf

Despite this, biological control has a significant role in the regulation of pest management, however, neglected in the past five decades and more attention and resources have instead been supported towards synthetic insecticides (Habitat manipulation 2016). Furthermore, the report describes that the negative side-effects of chemical pest control, for instance, pollution of groundwater, human toxicity, decreased biological diversity, and reduced resilience, have increased public concerns. Indeed, created a demand for BioNatural healing and a holistic way of pest control. Researchers have made some progress in this regard and launched a new directive aimed at reducing the use of synthetic pesticides by applying Integrated Pest Management (IPM). IPM is the combination of different methods (cultural practices, biological control, etc.), to utilize it in controlling pest damage and preventive methods are favored over curative approaches such as the application of pesticides (Kogan, M., 1998).

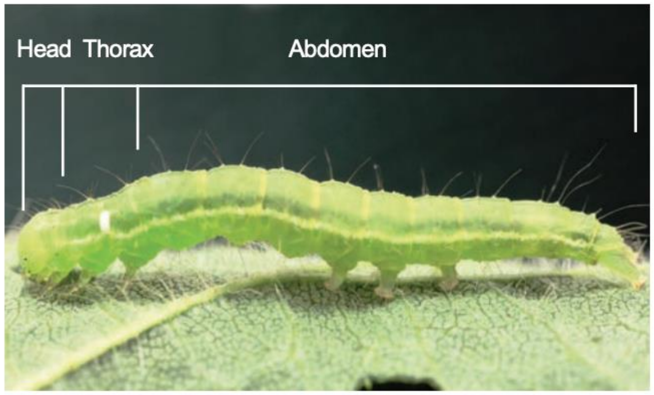
Why do insects cause damage to plants? Insect infestations reduce yields and lower the quality of pre-harvest and post-harvest crops. Many insect pests attack plants (vegetables), during the growing season with three to seven generations. Insects can be injured all plant parts. For instance, some insects bore into roots, seeds, or stems. Many insects suck large quantities of plant sap. Others destroy crops by chewing on succulent foliage, stems, or fruits. Some of the insect species carried the disease. It is crucially important to understand the concept of insect-plant relationships, which will help in crop protection. According to Singh Ranvir and his colleagues (Dynamic of Insect-Plant Relationships and its Application in Crop Production 2017), long-term coexistence had led to the evolution of different kinds of relationships between insects and plants. Insects are known to damage plants in different ways either by feeding on them or transmitting harmful plant pathogens (David B.V. and Ramamurthy 2012). In order to reduce insect attacks, plants have evolved various defense mechanisms. Plants can differentiate physical damage and insect damage by recognizing their feeding pattern; chemicals present in their saliva and oviposition fluids (Doss et al., 2000; Methöfer et al., 2005). After recognition of insect pest attacks, the information is conveyed through various signaling systems (Maffei et al. 2007). In counter-response, insects have also evolved different strategies to overcome plant defense mechanisms by detoxification of toxic plant chemicals or sequestering them and utilizing them for their own defense (Panda et al 1995; Peng et al. 2007). Plants have also developed a mutual relationship with insects, as the majority of flowering plants are pollinated by insects. In return for pollen transfer, plants provide food to their pollinators in the form of nectar and pollen (Faegri et al. 1971.). Carnivores have evolved the mechanism to trap the insects to fulfill their nutrient requirement, as the soil in which they are growing is deficient in nutrients (Temple P. 1993). Therefore, this means that the insects require to obtain their food from the crops by causing damage and yield reeducation as well as damage to the landscape such as esthetic value. Indeed, due to the insect's destructive role, they cause plant injury and reduce the quality or quantity of food crops and ornamental plants. It would be appropriate to review the insect's biological functionality with respect to pest management.

Insect biology: To understanding, the basic biology and ecology of insects will help pesticide applicators to consider how important insects, pesticides, and chemical resistance relationships are playing a significant role in pest management. The basic biology of insects includes taxonomy of insects, for instance, Kingdom (Animalia), Phylum (*Arthropoda*), Class (Insecta), Order (Hemiptera =true bugs), Family (Miridae), Genus (Lygus), Species (hesperus), Common name = lygus bug. Indeed, in terms of pest management, understanding the basic biology and ecology of insects will lead to the control of insects by a "weak phase" (insects pests during laying eggs are stationary and lack an effective defense system), in the life cycle of insects. **Insect eggs** are the weak phase of insect pests for their entire life. These eggs' weak phase is one useful tactic against specific insect pests is look for management and prevention for the upcoming infestation. Especially insect eggs are a weak phase from a biological control standpoint, for instance, eggs offer an easy target for many predators, parasitoids, and parasites in reducing harmful insect populations. **Nymphs** are the immature stages of insect order having an incomplete life cycle, for instance, grasshoppers and true bugs and their immature stages are called nymphs. In most cases, nymphs look like their adult stage (except missing the wings and sexual organs, with different colors). Nymphs have exhibited the same feeding behavior as adults when they are in the same location. This stage is good for pest management because nymphs cannot fly and often lack structural defense (without wings), they are easy to be targeted and control. **Larvae** are the immature stages of insects with their complete life cycle (metamorphosis), for instance, butterflies, flies, and wasps. There are no similarities to look at between larvae and adult counterparts and are adapted for entirely different functions, however, only experts can identify them. One of the useful tactics to apply is if you observe an unknown larva attacking plants it is wise to conserve the larva together with its fruit or vegetable causes damage, in a properly covered container for later identification as an adult. Despite larvae possessing some type of chemical defense or structural (spines), however, their slow-moving behavior makes them a suitable life stage for pest management to be targeted for control. The application of parasitoids is an effective tactic to seek out larvae for egg-laying and one of the effective pest management strategies, especially in organic farming as well as conventional farming. **Pupae** is the third stage of the life cycle insects in the orders undergo complete metamorphosis, it means requires more than a mere shedding of the skin; to do this process require some kind of protected resting stage such as spinning a cocoon (a resting period spent days or weeks). From a pest management point of view, it is smart to control pupae in this resting stage, because they are defenseless from attack by predators and parasitoids as a result of that pupal mortality can be significant in reducing harmful insects' population. Another issue to consider is "diapause" which is the spontaneous interruption of the development of certain animals, marked by a reduction in metabolic activity for instance, in many insects and mites. Diapause is a convenient "weak point" for controlling insect pests, as many insects take advantage of this opportunity and burrow into the ground to undergo diapause. **Adults**' life stage is the least desirable with respect to pest management due to greater mobility (via flight) and improved mature developed structural defenses make adults difficult to manage. One of the best tactics to manage it is through pheromone traps, however, as they target adults seeking out reproductive opportunities (Teaching Organic Farming and Gardening 2016). https://casfs.ucsc.edu/about/publications/Teaching-Organic-Farming/PDF-downloads/TOFG-all.pdf

There are many reasons that make insects very successful animals. For instance, their small size, high reproductive rate, and diverse feeding habits. As such, insects consist of three major body parts: the head, thorax, and abdomen. The head is where the mouthparts, eyes, one pair of antennae, and brain are located. The thorax is between the head and abdomen and is where three pairs of legs and wings are attached. The abdomen is the last major body region of an insect, following the head and thorax. It is where digestion and excretion occur, and where reproductive organs are located. The insect exoskeleton is very rigid and strong, for the purpose to protect against predators, reduce water loss, providing strength for muscle attachment, and protect against disease from entering the body. **Degree days (DD):** Understanding the degree days concept is very important in pest management. This means the appropriate temperature is very important for insects to develop into healthy adults. One of the reasons the insects develop into healthy adults depends upon the accumulation of heat units, like all cold-blooded animals. These heat units are the source of determination for insect species' prediction of growth and development. For instance, when the daily temperature is below the critical base temperature, no development occurs. It is important to note that the necessary base temperature and accumulated degree days required to develop from egg to adult vary from species to species. In addition, DD plays a significant role in the life cycle and may trigger scouting or certain management practices.



ʌlajor body regions of an ant.



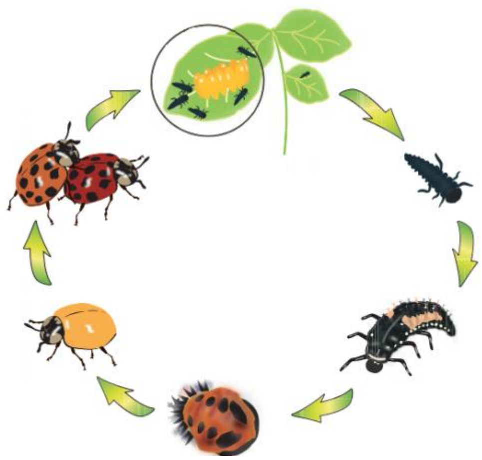
Major body regions of a green cloverworm.

TABLE I. Approximate degree days to estimate insect development		
Insect	**Base (°F)** [a]	**Use of Degree Days (DD)**
Seedcorn maggot	39	Adults emerge at about 200, 600 and 1,000 DD.
Stalk borer	41	Start scouting whorls to determine if larvae are present when 1,300-1,400 DD have accumulated in an area.
Western bean cutworm	50	Half of adult emergence and egg laying occurs after 1,422 DD have accumulated after May 1.
Black cutworm	51	Larvae start cutting at 300 DD after eggs are laid.
Corn rootworm	52	About half of eggs hatch between 684-767 DD (soil).
[a] Maximum temperatures are not applied for most field crop insects.		

Source: https://www.ent.iastate.edu/soybeanresearch/files/page/files/FieldCropInsects%20final%202012.pdf

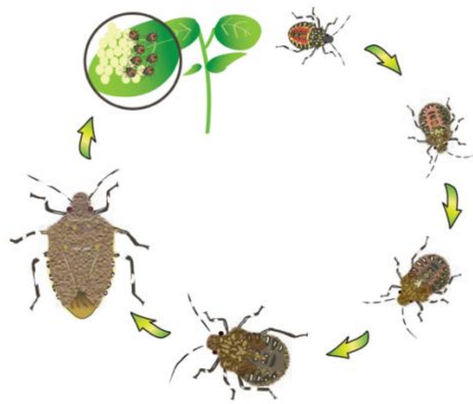
Insect life cycle: Every living organism has its own life cycle which consists of a series of changes. For instance, an insect that goes through many changes to become an adult is called metamorphosis. Understanding metamorphosis helps us to know how insects take advantage of different habitats. As such, metamorphosis can be divided into two phases complete metamorphosis and incomplete metamorphosis. **Complete metamorphosis** belongs to a group of insects that include a four-stage process involving an egg, larva, pupa, and adult. Most insects about 85 percent of all known insects go through complete metamorphosis. For instance, female insects lay single eggs or egg clusters that hatch into larvae. Larvae are looks different from adults and most often in the destructive phase and take advantage of their food from different plants. Larvae have specialized with common names. For instance, immature flies (Diptera) are maggots, immature butterflies and moths (Lepidoptera) are caterpillars and immature scarab beetles (Coleoptera) are often grubs. Larvae molt several times and eventually turn into pupae, which do not feed. After the pupal stage is complete, adult insects emerge. Some more examples of insects with complete metamorphosis are lacewings (Neuroptera) and wasps, bees, and ants (Hymenoptera). **Incomplete metamorphosis** includes a three-stage process involving an egg, nymph, and adult. Also, sometimes this type is known as simple metamorphosis. For instance, female insects lay eggs or masses that will eventually hatch into nymphs. Another characteristic is that the nymphs are a small, wingless version of adults. Small wing pads gradually develop with each molt before becoming functional in the adult stage. Examples of insects with incomplete metamorphosis are grasshoppers (Orthoptera) and stink bugs (Hemiptera). Both nymphs and adults feed and live in similar habitats and knowing all these insects' life cycle stages is highly helpful in pest management for pesticide applicators.

Complete Metamorphosis



Lady beetle life cycle.

Incomplete Metamorphosis



Stink bug life cycle.

Source: https://www.ent.iastate.edu/soybeanresearch/files/page/files/FieldCropInsects%20final%202012.pdf

Learn Terminology from the Entomology

Pest: An organism that interferes with the availability, quality, use, or value of food commodities, or another desirable plant. An organism that creates a nuisance or otherwise is undesirable.
Pest resurgence: The rapid rebound of pest abundance after the numbers were reduced by management action.
Pesticide: Any substance or mixture intended for destroying, killing, preventing, or repelling a pest (including fungi, insects, nematodes, rodents, or weeds) or mitigating problems pests cause. Also includes any substance or mixture intended for use as a defoliant, desiccant, or plant growth regulator.
Pesticide resistance: Resistance can occur due to genetic selection in which a pest population is able to survive or resist the effects of pesticides or a group of pesticides that formerly controlled the pest. However, as a result of that, the pesticide is less effective or no longer effective, and the pest population increases.
Pesticide rotation: The practice of alternating pesticides of a different mode of action in order to prevent the development of pesticide resistance.
Action threshold: The point at which a given pest is numerous enough that a management action (usually a pesticide application) is necessary to prevent economic loss or unacceptable damage. May also be called an aesthetic threshold, economic threshold, or treatment threshold.
Herbivores: Are depend on plants for their survival. These are the "pest" that exist on almost every farm. For instance, spotted cucumber beetles as a pest only if the numbers are above an economic threshold for the farmer, i.e., when the financial loss caused by a pest surpasses the cost of pest control.
Predators: Predatory insects and spiders kill and consume their prey, and tend to be "generalists." It means both pest and beneficial, that they can feed on, therefore, play a fairly wide range of arthropod prey.

Parasitoids: These are insects that lay eggs inside the eggs or bodies of other insects. These eggs hatch and the emerging larvae consume the "host" insect, eventually killing the host and emerging as a free-living adults. To distinguish a "parasite" from a "parasitoid" is that the parasite, for instance, a flea or a tick does not directly kill the host. However, the difference between a predator and a parasitoid is that the predator directly kills and eats the prey, whereas, in the case of the parasitoid, it is the generation or offspring that does kill.

Hyperparasitoids: Hyperparasitoids are parasitoids of parasitoids, for instance, parasitic wasps that attack the larvae and pupae of primary parasitoids.

Scavengers (detritivores): These are insects that consume dead animal or vegetable material as the first phase in the decomposition of organic matter.

Choosing a pesticide from BioNatural Insect Management need to be considered the following factors: When planning for insecticide applications, it is important to consider strategies that minimize risk to the public and the environmental and efficacy problems.

Impact on natural enemies and pollinators: One of the biggest concerns in using pesticides is the damage to natural enemies and pollinators', besides concerns issues with human health and environmental health. As such, a possible solution to reduce harmful insect populations and maintain healthy populations of natural enemies and pollinators is by using integrated pest management (IPM). Natural enemies (predators, parasites, and pathogens) reduce pest pollution and help prevent damage to plants. Natural enemies and pollinators can be harmed by pesticides and their populations are often more affected by pesticides than the targeted pests. Pollinators such as domesticated honey bees, wild bees, as well as other pollinating insects are of significant value for many California crops. For instance, many plant pests are stationary, while natural enemies and pollinators move relatively faster than harmful insects, therefore, this will lead to encountering pesticide residues in more locations. Use pesticides sparingly and spot-treat which can be applied before applying any pesticide, read and follow all the product label directions. It is important to note that targeting the application to the specific area where the pest is a problem reduces the harm to natural enemies and pollinators. Let us review some of the harmful insects and their basic biology and damage.

Harmful soil insects: Soil is a good habitat for many insect pests to live during one or more stages of their life cycle. For instance, these insects are adapted to feeding in or on the planted seeds, roots, or lower stems of plants (You Can Control Garden Insects 2020). The different individual insect has a different length of time depending on the insect type that lives in the soil varies from two to three weeks for some flies and some wireworm species up to three years. Remember, the impact of these insects may be hatched larvae as large new numbers or as partially grown overwintered larvae with full desire for consumption of plants in the farm. As a result, the plants can be severely damaged or even killed in just a few days following planting, if not managed the situation for insects' control in advance such as by inspecting the plant bed soil and cultivating the bed thoroughly.

Seedcorn maggot (Deltia platura (Meigan), Diptera: Anthomiidae: is the larva of a fly with small white maggots without legs or a distinct head, about 1/3-inch-long, that feed externally and internally on roots and seeds. **Damage:** Death of small plants may result from maggots feeding on roots. **Pest management:** One of the BioNatural strategies to apply natural enemies in the prevention of the seed corn maggot include ground beetles, predaceous nematodes, and fungal diseases. https://extension.umn.edu/corn-pest-management/seedcorn-maggot Avoid planting spring turnips and radishes in soil that is high in partially decomposed organic matter and do not plant in wet soil.

Onion maggot (*Delia antiqua*): is the larva of a fly that looks hump-backed gray-brown. About

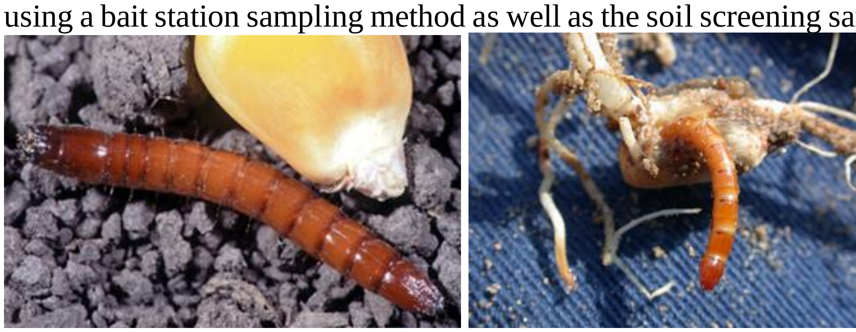
5-7 mm long, it is difficult to distinguish it from seedcorn and cabbage maggot flies with the naked eye, but each will be observed in its appropriate crop family. **Damage:** When eggs hatch, larvae feed on roots and can cause complete destruction of the root system. However, if some of them are not totally destroyed in the field, the damaged bulbs will rot in storage due to encouraging the entry of soft rot pathogens. **Pest management:** Prevention is the key to avoiding damage from onion and seedcorn maggots, insecticides should be applied only when maggot infestation is expected. Avoid planting onions in an area high in partially decomposed organic matter. Remember to remove the culled onions from the field after harvest.

Cabbage maggot (Delia radicum): Host plants include many Cole crops: cabbage, broccoli, cauliflower, Brussels sprouts, turnips, radishes, kale, and other crops of the mustard family. **Damage:** To cabbage and other related host plants during a wet, cold spring with most of the damage limited to the early spring plantings. Injury from the second generation in late June or July is usually not severe because the maggots prefer cool, moist conditions and seedlings, more tender plants. https://www.vegedge.umn.edu/pest-profiles/pests/cabbage-maggot Furthermore, maggots are reported to introduce a fungus causing blackleg and spreading bacterial soft rot.

Pest management: Protect seedlings from egg-laying adults by covering them with a floating row cover or netting to exclude the fly. Avoid planting in cold, damp soil, in the spring, wait until the soil warms up and sufficiently dry. Adding any organic matter to the soil in the fall will help to reduce the soil's attractiveness to egg-laying spring cabbage maggots.

Wireworms (Melanotus spp., Agriotes mancus Say, and Limonius dubitans LeConte): Are slender, hard-bodied, shiny yellow to brown in color, and range in size from 1- ½ inches (13 to 38 mm), long, wire-like larvae and adult wireworms are called click beetles.

Damage: Wireworm larvae may feed on the germ of corn kernels or completely hollow out the seeds, leaving only the seed coat. Damage by the first year is minor, feeding by the larger larvae in subsequent years is normally when economic damage occurs. **Pest management:** Applying insecticides only if necessary, avoid planting potatoes in an area that has been in sod within the last year. Also, using a bait station sampling method as well as the soil screening sampling method.



Wireworm Larva (Courtesy by J. Obermeyer), Feeding wireworm (Courtesy by J. Obermeyer)
Source: https://extension.entm.purdue.edu/fieldcropsipm/insects/corn-wireworms.php

White grub: The larvae of many scarab beetle species are often collectively referred to as white grubs. White or light yellow; hard brown heads; curved; ½ inch to 1 ½ inch long when fully grown. Phyllophaga has several species (spp.); Coleoptera: Sacraaeidae and can be found in soil, decaying wood, and manure. May beetles are also known as June beetles and June bugs.

Damage: Feeding on tuber and root crops. **Pest management:** Knowing the life cycle (requires two years to mature) helps in the prevention and modification of the area unpleasant so that adults cannot lay eggs in grassy areas, avoid alternative host planting, and applied insecticides if white grubs are expected.

A true white grub, Phyllophaga species A May/June beetle
Source: https://extension.umn.edu/corn-pest-management/white-grubs

Potato tuberworm (*Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae): The potato tuberworm *Phthorimaea operculella* (Zeller), also known as potato tuber moth or tobacco splitworm, is an oligophagous pest (an insect feeding on a restricted range of food plants) of crops belonging to the family Solanaceae include potatoes (Solanum tuberosum L.), tomatoes (Solanum lycopersicum L.), peppers (Capsicum spp.,), and other related family members. White caterpillars have a pinkish or greenish tinge and are brown at both ends and are up to ¾ inch long in size white caterpillars. **Damage:** Larvae feed Solanaceae plants leaves, stems, petioles, and the tubers of potatoes in the field and in storage. Also, potatoes are riddled with slender, dirty-looking, silk-lined burrows.

Pest management: Monitoring of potato tuber moth is a critical part of its management. Infested vines should be removed before digging in order to avoid larval movement to tubers. Keep potatoes well cultivated and deeply buried in hills during growth. Insecticides applications upon special consideration for least-toxic ones in necessary situations.

Potato tuberworm damage Larva of the potato tuberworm
Source: http://entnemdept.ufl.edu/creatures/VEG/POTATO/potato_tuberworm.htm

Early-Season Insect Pests: When damage is done to seedling plants in the early growing season by early-season insect pests. The nature of the damage is feeding on the leaves and stems of young seedling plants. **Cutworms:** Normally they are found on or just below the soil surface or on lower parts of plants and are commonly active at night. They have similarities between different species, dull brown caterpillars ranging in length from 1 to 2 inches when fully grown. One of the characteristics is that cutworms curl into a C-shape when disturbed. **Damage:** Cutworms feed and cause damage to the blossoms and leaves of many vegetables and ornamental plants. They clip off seedling stems near or just below the soil level. **Pest management:** Spring is the peak season for cutworm damage. Destroy crop residues; maintain field areas weed-free in winter. Hand-picking at night with a flashlight is a very effective method of management. Climbing cutworms can be kept out of perennial crops such as berries with sticky collars. Baits and insecticidal sprays such as *Bacillus thuringiensis or spinosad* may be applied. Provide proper fertilization and water, protect roots and trunks from damage and avoid planting tomatoes in soil recently in grass or sod.



Cutworm larva. Damage to lettuce leaves Cutworm damage to rhododendron

Source: http://ipm.ucanr.edu/PMG/GARDEN/VEGES/PESTS/cutworm.html

Aphids: These are small sap-sucking insects and exist in almost every plant one or more aphid species that occasionally feed on it, however, depending on the situation, for example, low to moderate numbers of aphids usually aren't damaging to garden or landscape trees. Many species reproduce by parthenogenesis, which means that female aphids do not require to mate to reproduce. **Host plants** Are a wide variety of crops and ornamental plants. **Aphids damage:** Aphids like lush, and new growth, cause damage by sucking plant sap and by transmitting plant diseases. Aphids reproduce rapidly and can occur in extremely high numbers. However, individual aphids consume very little. Feeding is often concentrated on young, expanding leaf and terminal tissue. In addition, the physical damage caused by large numbers of piercing mouthparts can result in distorted plant growth. Aphids excrete large amounts of honeydew or undigested plant sugars. As a result, honeydew will produce the growth of black sooty mold fungi. Furthermore, heavy accumulations of sooty mold interfere with photosynthesis and induce ant accumulation due to honeydew. Many aphid species can complete a generation in as few as 7 days depending on temperature and a favorable environment. **Pest Management:** There are many beneficial insects in the context of BioNatural Pest Management, for instance, lady beetles, and lacewings prey on aphids and are the most common. Parasitic wasps and fungal diseases also have a big impact on aphid populations. BioNatural biological control is a crucially important strategy in controlling aphids as well as other pests. It is important to note that outbreaks of insects are more likely when previous insecticide sprays have disrupted or decline the population's beneficial insects. Another possible solution for heavy concentrations of aphids occurring on the terminal growth of smaller plants, they can be washed off using water spraying from a garden hose. In addition, some of the least-toxic insecticides can be applied such as azadirachtin, insecticidal soap, pyrethrins plus canola oil, acephate, and malathion.

Source: https://extension.msstate.edu/sites/default/files/publications/publications/p2369.pdf

Thrips Are tiny, slender insects less than 1/20-inch-long and their color varies depending on the species and life stage. Thrips hatch from eggs and develop through two feedings larval (nymphal) stages and two nonfeeding stages (prepupa and pupa) before developing into adults. **Damage:** When thrips feed, they distort or scar leaves, flowers, or fruit. Herbaceous ornamentals and developing fruits and vegetables can suffer more serious injuries. Western flower thrips also vector Impatiens necrotic spot virus and Tomato spotted wilt virus, which can severely or kill certain vegetable crops and herbaceous ornamentals. **Pest management:** Thrips management is a difficult task, use an integrated approach that combines the use of good cultural practices, BioNatural enemies, and apply the most selective or least-toxic insecticides that are effective and holistic way.

Adult western flower thrips. Greenhous thrips adults (black) and nymphs (yellow). Leaf bleaching and black speckling caused by thrips.

Source: http://ipm.ucanr.edu/QT/thripscard.html

Flea beetle: These are small with numerous flea beetle species, shiny beetles with black legs enlarged for jumping when disturbed, this quality makes it easy to identify. For instance, the tobacco flea beetle (*Epitrix hirtipennis*), which is brown with black markings across its back, and the western potato flea beetle (*Epitrix subcrinita*), which is shiny bronze or black, are widespread in the western U.S. **Damage:** Flea beetle adults feed and cause damage mostly on leaves, making tiny pits or small holes at their feeding sites. The early seedling stage is the most serious damage stage. For instance, on carrots, larvae may cause sunken spots on roots. On eggplants and potato tubers, larvae feed on roots and stems and create straight narrow tunnels in tubers, that will lead to the opportunity for entry of fungi. **Pest management:** Sanitation is the most important key in the prevention of pests, removing debris in the fall to remove any overwintering beetles. For instance, seedlings can be protected with protective coverings especially reflective mulches until the plant becomes enough strong with the sixth leaf stage; older plants are less likely to suffer damage. Insecticides spray should be considered the least-toxic insecticide are apply before serious damage take place.



Adult potato flea beetle. Tobacco flea beetle Flea beetle damage to leaf (Courtesy Jack Kelly Clark).
Source: http://ipm.ucanr.edu/PMG/GARDEN/VEGES/PESTS/fleabeetles.html

Lygus bugs (Western Tarnished Plant Bug) (Lygus hesperus): Commonly known as lygus bug, adults are about 0.25 inches (6 mm) long, and oval, in shape. They are a serious pest in Central Coast and Oxnard strawberry growing areas where strawberries are grown. Lygus bugs are more active as a pest in May through the summer months. However, rarely becomes a pest in Southern California and the Central Valley where fresh market berry harvest is generally complete by the end of June, but occasionally a problem. **Damage:** Adults and nymphs pierce and suck juices from the berry, stems, blossoms, and fruit. **Pest management:** Monitor and weed control as an alternative host in winter. Anaphes iole is a parasitic wasp, which is a beneficial biological agent. It can be found in strawberry fields and surrounding lygus bug habitats. BioNatural occurring predators that feed on the nymphal stages of the lygus bug include bigeyed bugs (*Geocoris spp*.), damsel bugs (*Nabis spp*.), minute pirate bugs (*Orius tristicolor*), as well as other species of spiders. Insecticide sprays to control is time-critical, the spray should apply before lygus bug nymphs cause significant damage, but it should consider the least-toxic insecticides and must follow the label directions.

Insect pests infest plant foliage and fruits throughout the season.

Whiteflies: Whiteflies are Hemipterans and about one-sixteenth inch long. Adult whiteflies are small, moth-like insects covered with a white, waxy powder. Many white butterfly species carry their white powdery wings folded tent-like over their bodies. Whiteflies are commonly observed on the undersides of leaves, also when plants are disturbed, many adults will fly around infested plants. Whiteflies in an immature state are immobile, scale-like insects that feed on the undersides of leaves. Required a hand lens to see the whitefly's immature flattened and oval-shaped, depending on the species, may have a waxy filament protruding from their bodies.

Damage: Whiteflies damage plants similar to aphids, due to sucking plant sap through piercing-sucking mouthparts. Whiteflies like aphids in their tendency to build high populations. Whiteflies also with their ability to produce honeydew, as a result of that sooty mold formation. Examples of common species are citrus whiteflies, bandedwinged whiteflies can be identified by the two gray bands across each wing and occur primarily on hibiscus and other malvaceous plants. The Silverleaf whitefly is an important pest of many vegetables and nursery crops and occasionally occurs on landscape plants as well. This species is difficult to control. **Pest Management:** Avoid unnecessary insecticide applications that can disrupt BioNatural beneficial insects and other organisms. Some of the least toxic insecticides such as azadirachtin, Neem oil, insecticidal soap, and horticultural oil. For controlling whiteflies dinotefuran and imidacloprid are applied as soil drenches. Acetamiprid is one of the more effective foliar sprays for whiteflies. It is important to note that the following label directions must be followed as always, remember with foliar sprays, apply at least two successive treatments 5 to 7 days apart.

Silverleaf whiteflies. Note the numerous eggs and flattened, scale-like immatures, as well as the white-winged adults.

Source: https://extension.msstate.edu/sites/default/files/publications/publications/p2369.pdf

Mexican bean beetle (*Epilachna varivestis* Mulsant): Mexican bean beetle is belonging to the order Coleoptera same as the ladybird beetle beneficial belongs. Mexican bean beetle (*Epilachna varivestis* Mulsant) and the squash lady beetle (*Epilachna borealis* Fabricius), are two serious pests. The adult Mexican bean beetle is oval in outline, and about 6 to 7 mm in length.
Damage: Both larval and adult stages of the Mexican bean beetle will feed upon the leaves, flowers, and pods of the bean plant, but the greatest amount of injury is done to the leaves. The larvae cause more damage than adult beetles. **Pest management:** Prior application of insecticides, it is crucially important to consider cultural control, and biological control (including at least 17 species of predators that feed on bean beetle eggs, larvae, and pupae). Resistant varieties and the application of systemic insecticides at planting have a standard practices for controlling when becoming an economic pest.

Adult Mexican been beetle (Courtesy James Castner, University of Florida) Larva Source USDA.
Sources: https://extension.tennessee.edu/publications/documents/PB595.pdf
http://entnemdept.ufl.edu/creatures/veg/bean/mexican_bean_beetle.htm

Stink Bugs (*Halyomorpha halys, Bagrade hilaris, Euschistus conspersus, Murgantia histrionica, Chlorochroa sayi, Nezara viridula)*: Stink bugs belong to the family *Pentatomidae*, due to fluid excrete when disturbed they release an unpleasant odor that is why as called stink bugs. However, over 50 stink bug species occur in California, adult is shield-shaped, flat, bright green or brown, 5/8-inch-long with wings and a narrow head; bad-smelling when crushed. Adults reside overwinter in weeds. Both nymph and adult resemble in shape but are somewhat more rounded than shield-shaped, wingless, and green, black, and orange.
Damage: Damage can be caused by adults and nymphs on various tree fruits and fruiting vegetables suck juices. Also, cause plant pods to fall and cause distortion of seeds. The result is the formation of brown spots on plant pods from the feeding. **Pest management:** Cultural practices such as handpicking the bugs and their eggs from small plants. Eliminate weeds in early spring

before stink bugs become residents there and then move to alternative hosts. BioNatural management such as parasites and general predators can contribute to the management of certain species. Insecticides' least toxic option may need to be considered in some situations when there is a need for it.

Common stink bugs: (clockwise from left) southern green stink bug, *Acrosternumhilare;* redshoulderedstinkbug, *Thyanta pallidovirens;* and consperse stink bug, *Euschistus conspersus* (Photo Courtesy Jack Kelly Clark)

Eggs and nymphs of stink bug. Nymph of Say stink bug.

Sources: http://ipm.ucanr.edu/PMG/GARDEN/VEGES/PESTS/stinkbug.html
https://extension.tennessee.edu/publications/documents/PB595.pdf

Hornworms (Manduca ***spp.*****):** The name hornworm is a suitable name due to the distinctive horn at the rear end. Mature green caterpillars are reaches in size up to 4 inches. Host plants are tomatoes, eggplants, bell pepper, potatoes, and tobacco. **Damage:** Hornworm larvae are usually the most common in midsummer that causes damage to the entire leaves, and small stems, and may be consumed in large pieces from green tomatoes fruit. It may extend the damage until the late summer. **Pest management:** One of the best cultural practices is handpicking and destruction is often easily accomplished because of size. However, if a large plant population is infested with hornworms then use ecological least-toxic of recommended insecticide.

Mature tobacco hornworm larva Hornworm damage to tomato fruit Adult tomato hornworm (Courtesy of Jack Kelly Clark) Sources: http://ipm.ucanr.edu/PMG/GARDEN/VEGES/PESTS/hornworm.html
https://extension.tennessee.edu/publications/documents/PB595.pdf

Squash Vine Borer (*Melittia cucurbitae*): The squash vine is a diurnal (active during the day) species of sesiid moth. It is a serious pest of vine crops such as summer squash, winter squash, pumpkins, and other related plants. It is about ½ inch long with an orange abdomen with black dots, the larvae are white or cream-colored with brown heads. **Damage:** infested host plants are often completely girdled and late in the season, making tunneling into fruit and eventually becoming rotten and dying. **Pest management:** One of the challenges is that once the larvae invade the stem, it is difficult to treat squash vine bores. Plant as early as the weather will allow. One of the best strategies with a few infested plants is, stems can be split, and larvae can be destroyed. A spade full of moist soil should be over-damaged stems to encourage new root growth. After all cultural practices, if still there is a need for applying a recommended insecticide weekly or as instructed by the label during the fruiting period must be followed.



Adults squash vine borer   Squash vine borer larva with frass on the stem   wilting plants

Sources: https://extension.umn.edu/yard-and-garden-insects/squash-vine-borers
https://extension.tennessee.edu/publications/documents/PB595.pdf

Leafminers: A wide range of leafminer species of insects especially the larval stage lives cause damage to the wide host of vegetables, fruits, and ornamental plants. **Damage:** Winding white trails or broad white spots that appear on leaves may be weakened, and the mines or tunnels may serve as points where pathogens can enter, and decay may start. **Pest management:** It is important to remove weeds, like lambsquarter, to reduce the alternative host as a food source, for leafminers. Using a physical barrier such as installing fine-meshed netting row covers to protect plants from insects. Select a least-toxic insecticide that does not target natural enemies (e.g., parasitic wasps) and pollinators (e.g., bees).


Vegetable leafminer fly   feeding damage on an onion leaf   Row cover

Sources: https://extension.umn.edu/yard-and-garden-insects/leafminers
https://extension.tennessee.edu/publications/documents/PB595.pdf

Mealybugs: These are one-third-inch long insects somewhat flattened and oval-shaped (depending on the species) with soft-bodied, wingless that are related to aphids and whiteflies. One of the key characteristics of mealybugs is that their bodies are covered with a whitish or yellowish powdery wax material. Some of them may be elongated, waxy filaments extending from the margins of the body. Mealybugs are slow-moving insects; eggs are deposited in cottony egg sacs attached to the plants in most species. It is important to note that some larvae species of lady beetles superficially resemble mealybugs. These lady beetle larvae are often found in association with an infestation of aphids or mealybugs and are most often mistaken for mealybugs. Lady beetle larvae are faster than mealybugs with a distinct head and are predators that actively eat aphids and mealybugs. **Mealybugs damage:** Mealybugs damage is more commonly seen on indoor plants and greenhouses, but also, occurs on certain landscape plants and outdoor potted plants. Mealybugs often feeding cause damage to young tissue in the terminals of plants, and as a result of that distort leaves and stems due to heavy infestation. Mealybugs have piercing-sucking mouthparts like aphids and whiteflies and also produce honeydew that induces the growth of sooty mold and makes it unsightly. **Pest Management:** BioNatural management plays an important role, especially with the occurring predators and parasites a key role in maintaining mealybugs pollution in check. Washing with forceful water spray on infested plants also can temporarily reduce the mealybugs populations. Insecticidal soap, Neem oil, horticultural oil, pyrethrins, and canola oil are among the list of least-toxic insecticides, such as acetamiprid, acephate, imidacloprid, and dinotefuran, it is always good to check with local state agencies and followed the label instructions.

Maderia mealybugs. Note the small, yellow crawlers and the cottony egg sacs.

Source: https://extension.msstate.edu/sites/default/files/publications/publications/p2369.pdf

Scale insects: Are occur on a wide range variety of plants, such as camellias, hollies, magnolias, euonymus, and many other plants.

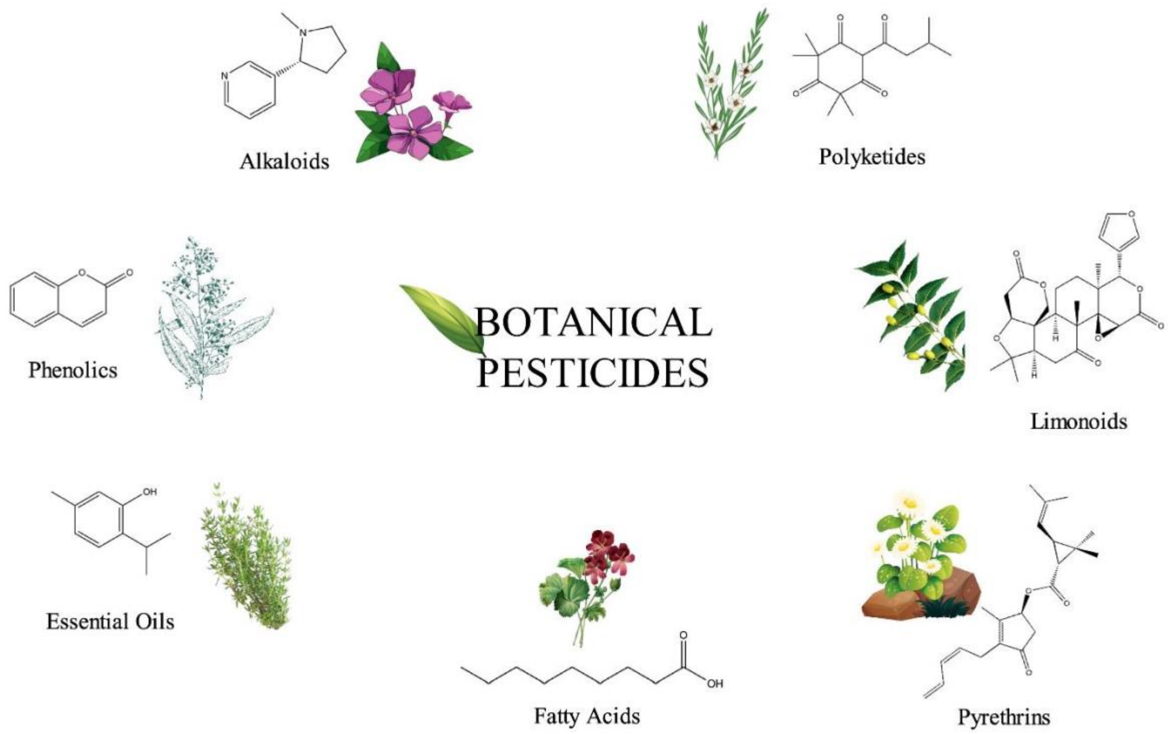
BioNatural Insect Management

World of BioNatural Healing

Introduction: BioNatural Insect Management comprises many aspects of insect management techniques from a BioNatural point of view which exist naturally from living organisms including the application of beneficial insects, microorganisms (bacteria, fungi, viruses, nematodes, etc.), plants, animals, as well as minerals. These ecological-based tools can control serious plant-damaging insect pests by their nontoxic BioNatural mode of action, which makes them increasing attention worldwide. BioNatural beautifully creates a holistic environment as such the author David Goulson, Ph.D. explains in his book, A Sting in the Tale, "We need worms to create soil; flies and beetles and fungi to break down dung; ladybirds and hoverflies to eat greenfly[ies]; bees and butterflies to pollinate plants to provide food, oxygen, fuel, and medicines, and hold the soil together; and bacteria to help plants fix nitrogen and … cows to digest grass… [yet] we often choose to squander the irreplaceable, to discord those things that both keep us alive and make life worth living".

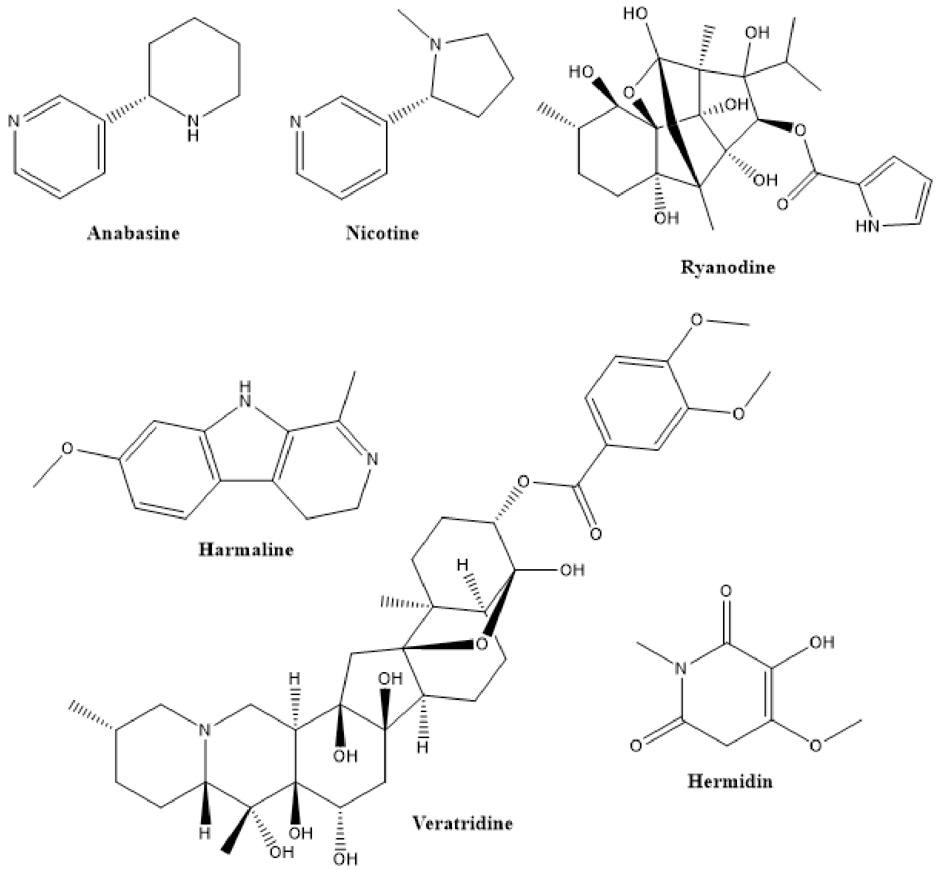
Annual crop losses caused by insects, weeds, and diseases are estimated between 20 to 40 %, similar to those of 50 years ago (UN FOA 2017). Phytochemicals have low or no toxicity to animals and useful insects, possess an array of activity with variable and various sites of action and have a relatively high degradation rate (Regnault et al., 2004; Kaliyadasa and Jayasinghe, 2018). The extensive use of pesticides causes several serious problems, including the non-target effect on humans and beneficial organisms, including insects pollinator (Gajger, I.T et al., 2017), natural enemies, pest resurgence, the emergence of secondary pests, biotypes, high costs associated with both active ingredients and the application and development of resistance to pesticides by target pests (Ekström, G. ad Ekbom, B. 2011). Insect herbivores traditionally can be divided into generalists (polyphagous) that feed on several hosts from different plant families or specialists (monophagous and oligophagous), which feed on one or a few plant types from the same family (Tibebu Belete 2018). Plants possess the ability to some extent to defend themselves from herbivores by constitutive resistance and induce resistance. Constitutive defense is usually plants produce a certain quantity of a chemical defense a sort of background amount. Induced defense after a plant is attacked, however, the amount of these chemicals usually increases. In other cases, entirely new compounds are produced after the attack (Ecology Center). It would be appropriate, to begin with, Botanical insecticide is a part of BioNatural Pest Management to understand better how Botanical insecticide is important.

What are Botanical Insecticides? Botanical insecticides are naturally occurring insecticides that are derived from plants. It has been used for many centuries in the past for pest control. When stored grains from Oriental (3000-30 B.C.), Greek (2000-200 B.C.), and Roman antiquity (500 B.C.-76 A.D.) were analyzed, they showed that many plants, for example, Cymbopogon spp (lemongrass, barbed wire grass, silky heads, Cochin grass, Malabar grass, oily heads, citronella grass or fever grass)., were commonly used to protect stored food against insect damage in ancient times. Indeed, the same plant species are still used today in traditional farming systems. The most widely used botanical insecticide in the world is pyrethrum, extracted from the chrysanthemum flower (*Tanacelm cineraefolium*) with production has become increasing worldwide (Handbook on pesticidal plants 2015). Botanical insecticides are characterized by bioactive mixtures/extracts/compounds from plant materials that serve as insecticides and repellents but also as herbicides, bactericides, fungicides, and nematicides (Isman, M.B. 2006). Botanical pesticides particularly insecticides because of their unique secondary metabolites, for example, alkaloids, essential oils including terpenes, flavonoids, phenolics, phytosterols, polyketides, and resins are all botanical pesticides that can be used in BioNatural Pest Management.



Source: General structural diversity of phytochemicals plant-based pesticides. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8869379/pdf/biomolecules-12-00311.pdf

Alkaloids: These are a very broad group of more than 12,000 structures with diverse complex chemical shapes and forms. Alkaloids are found in considerable quantiles in several plant species belonging to families including Annonaceae, Apocynaceae, Fabaceae, Fumariaceae, Lauraceae, Papaveraceae, Rubiaceae, Rutaceae, and Solanaceae (Bruneton J., 1999). Most are accumulated in the aerial part of these plants (Taiz, L.; Zeiger, E., 2006). Here are two examples: 1. The low or medium molecular mass and the presence of one or more heterocyclic nitrogen-containing rings derived from amino acids in their molecule, 2., the ability to provide an alkaline reaction in aqueous solution (Schläger, S.; Dräger, B., 2016). Due to the diverse chemical nature of alkaloids, therefore, most alkaloids are exhibit insecticidal activities at low concentrations. Insecticidal Examples of alkaloids are anabasine (from *Anabasis aphylla*), nicotine (from *Nicotiana species*), ryanodine (Rayania; from *Ryania speciosa*) and veratridine (from *Schoenocaulon officinale*) (Rattan, R.S. 2010). **Below are the structures of some pesticidal alkaloids.**



Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8869379/pdf/biomolecules-12-00311.pdf

Alkaloids and their mode of action: Alkaloids are very large nitrogenous compounds; more than 12,000 alkaloids have been described. These compounds are synthesized by plants that contain one or more heterocyclic nitrogen atoms; they are derived from amino acids, and a few of them terpene or purine and pyrimidine bases (pseudo-alkaloids). Some of examples well-known alkaloids such as strychnine, cocaine, caffeine, nicotine, α-solanine, and α-tomatine (Wink, M.A., 1998). Many alkaloids interfere with nerve acetylcholine receptors, for example, nicotine or membrane sodium channels, for instance, veratridine (is a steroidal alkaloid found in plants of the lily family, specifically the genera Veratrum and Schoenocaulon) of insects. Studies have shown that alkaloids exert a feeding deterrent action against numerous insects, such as *Choritoneruria fumiferana* and *Spodoptera littoralis* (Bentley et al., 1984; Brem et al., 2002). Other alkaloids such as harmaline (contain various plants e.g., *Peganum harmala* (Syrian rue seeds)), and hermidine can affect the growth and development of insects, including *Tribolium castaneum* (Red Flour Beetle), but their modes of action are not fully understood (Rharrabe et al., 2020). Ryanodine, an alkaloid compound from the plant species Ryania speciosa, exerts a strong insecticidal activity, acting at the sarcoplasmic reticulum, with ryanodine receptors influencing the secretion of Ca^{2+}channels. Additionally, sabadilla alkaloids are agonists of Na^{+} channels in a similar manner to pyrethrins, causing neurotoxic effects on insect pests (Dhaliwal and Arora 2001; Silver et al., 2014).

Phenolics: These are more than 50,000 distinct structures, a highly heterogenous group of plant secondary metabolites. Phenolics can be divided into flavonoids (anthocyanidins, flavones, flavonols, flavanones, isoflavones, coumarins, and rotenoids) and non-flavonoids (phenolic alcohols, phenolic acids, stilbenes, and lignans) (Bruneton, J., 1999., Rattan, R.S., 2010., Manach, C., 2004). Phenolic compounds play an important role in plants' protection from ultraviolet (UV) radiation, microbial and herbivore invasion as well as the attraction of pollinator species (Cutrim, C.S.; Cortez, M.A.S 2018, Sharma et al., 2019). Furthermore, phenolic compounds with antifungal properties including anthraquinones with a different mode of action, such as coumarin and its derivatives, flavanols, flavonoids, simple-structured phenols, and tannins (Furiga et al., 2009). Phenolics pesticidal examples of structures are either simple (phenol: MW 94, identified in some plant EOs) or complex (polyphenols, anthocyanins (MW up to 2000) and tannins (MW up to 20.000), identified in plant extracts).

Phenolics and their mode of action: Phenolics (O-heterocyclic compounds), studies have shown that plant phenolics and related compounds, for example, coumarins or anthraquinones are considered an important defensive line against insects. They reduce insect activities through deterrent or antifeeding effects. A large range of insects belonging to various orders, including aphids, Coleoptera, Diptera, Lepidoptera, and Orthoptera, appear to be sensitive (Regnault-Roger et al., 2004).

Essential Oils (EOs): More than 17,500 known aromatic plants are involved to be derived essential oils belonging to angiosperm, families including Asteraceae, Lamiaceae, Myrtaceae, Rutaceae, and Zingiberceae (Regnault-Roger et al., 2012). Essential oils can be obtained from the flowers, leaves, roots, or seeds of these plants through hydrodistillation. Mainly perfume and food industries get benefit from the usage of these distillates due to the sensory properties of the volatile compounds. However, many compounds in these mixtures also exhibit pesticidal activities mainly due to their insecticidal and repellent properties. Examples are orange oil, *Lavandula angustifolia, Origanum majorana, Rosmarinus officinalis, Salvia officinalis, Cannabis sativa, Tanacetum vulgare,* and *Thymus vulgaris* (Isman, M.B., 2006., Ikbal, C.; Pavela, R 2019., Isman, M.B., 2020). EOs are attractive due to the easiness of preparation and chromatographic analysis, and due to the broad number of plant species synthesizing this cocktail of volatile phytochemicals of potential pesticidal usage (Isman, M.B., 2011).

Essential oils (EOs) and their mode of action: According to studies the modes of action insecticidal effects of EOs against Curculionidae have not been fully described. In general terms, it has been described that EOs inhibit some physiological functions of gamma-aminobutryic acid (GABA) receptors, which is the primary inhibitory neurotransmitter of the central nervous system of insects (Tampe et al., 2015). It has also been determined that plant metabolites can inhibit the actions of acetylcholinesterase (AChE an enzyme that causes rapid hydrolysis of acetylcholine with action to stop excitation of nerve after transmission of an impulse), which hydrolyzes acetylcholine a neurotransmitter responsible for signal transmission in the central nervous system (Lopez and Pascual-Villalobos, 2010; Bhavya et al., 2018) analyzed the effect of eugenol and *Ocimum tenuiflorum* essential oil on AChE activity in rice weevil (*Sitophilus oryzae*) (in vivo), and reported that eugenol reaches a higher percentage of AChE inhibition after two hours, while both EOs inhibit approximately 40% of AChE only after 4 hours of contact. These values are related to the high insecticidal activity of eugenol and Ocimum tenuiflorum since inhibiting AChE produces neurotoxic effects against S. oryzae, which finally results in the death of the pest (Bhavya et al., 2018). https://www.frontiersin.org/articles/10.3389/fagro.2022.876687/full

Limonoids: These are phytochemicals of the triterpenoid class which is abundant in sweet or sour-scented citrus fruit and other plants of the families Cucurbitaceae, Rutaceae, and Meliaceae. Certain limonoids are antifeedants such as the neem tree (*Azadirachta indica*), belonging to the family Meliaceae and are native to India and Burma but today is a part of the landscape worldwide. A. indica, Juss, is the most species of this group considered with several benefits including medicinal and agricultural products. For example, all parts of the tree (leaf, flower, seed kernel, wood, bark, and twig), are a source of biologically active ingredients, and the maximum activity is associated with the seed kernel (Kumar et al., 2016). For example, azadirachtin can be isolated from all parts of *Azadirachta indica* (Neem tree), especially from the seeds, with reported concentrations of 4-6 mg/g seed (Mordue, A.J 2004.).

Limonoids and their mode of action: Here we address the mode of action with the example of Azadirachtin which is structurally like the insect hormones known as "ecdysones" which are responsible for metamorphosis in insects. The feeding behavior in insects is dependent on the neural inputs received from the chemical sensors of the insects. For example, the taste receptors in the mouthparts, tarsi, and oral cavity. These sensors integrate a "sensory code" that is delivered to the central nervous system. Furthermore, a manifestation of antifeeding by azadirachtin occurs through the stimulation of deterrent cells in these chemoreceptors and by blocking the feeding stimulation in insects by firing the "sugar" receptor cells (Jennifer Mordue Luntz et al., 1998). In addition, to antifeedant, azadirachtin injection also leads to physiological effects in the insect's midgut, which causes a reduction in the post-ingestive digestive efficiency. Azadirachitin interferes with the growth and molting process of insects its ingestion leads to abnormal molts, growth reduction, and increased mortalities. Azadirachtin interferes with the synthesis of an "ecdysteroid" hormone responsible for insect molting (Chaudhary et al., 2017). It is important to read the label and must follow the label instruction.

Pyrethrins: These are a class of organic compounds normally derived from Chrysanthemum cinerariifolium that have potent insecticidal activity on the targeting nervous system of insects. Pyrethrin is a natural mixture comprising at least six compounds categorized into two groups, namely "Pyrethrins I" (pyrethrin I, cinerin I, jasmolin I; esters of chrysanthemic acid) and "Pyrethrins II" (pyrethrin II, cinerin II, jasmolin II; esters of pyrethric acid). (Casida, J.E., 1980; Grdiša, M et al., 2013). Another example is Dalmatian pyrethrum (*Tyrethrum cinerariifolium*), also called pyrethrum daisy, which produces a potent insecticide. Pyrethrins I and Pyrethrins II are plentiful in *Tanacetum*, especially in the flower heads (10-30 mg/g dry weight) (Ambrožicˇ et al., 2007).

Pyrethrins and their mode of action: Pyrethrins exhibit a neurotoxic mode of action by interfering with ion channels of the insects, which are kept open and thus cause nerve impulses to fail (Isman, M.B., 2006). In particular, pyrethrins interfere with the Na^+, and K^+ exchange pump in the nerve cells of the target pests, leading to rapid nerve impulses and causing paralysis (Soderlund et al., 1989). As a result, in a rapid knock-down effect on the insects and leads to death. Studies have shown if applied at low doses, pyrethrins also act as repellents for flying insects. Researchers have proven the great efficacy of pyrethrins against various insect pests belonging to different orders, while their albeit moderate toxicity against mammals and non-target insect species provides some constraints for their broad usages (Jeran et al 2021).

Polyketides: These are a class of natural products that can be derived from bacteria, fungi, plants, and certain marine organisms (Lane Al; Moore BS, 2011). One example of a plant polyketide is the β-triketone leptospermone, which is produced by Myrtaceae spp., such as *Leptospermum scoparium* (manuka), β-Triketones can act as herbicides by inhibition of 4-hydroxyphenylpyruvate dioxygenase (HPPD), an enzyme that is relevant in the metabolism of tyrosine and the production of its downstream products (Acheuk., et al., 2022).

Polyketides and their mode of action: Spinosad is a hydrophobic compound belonging to a lipid class known as polyketide macrolactams. Spinosad is an 85%:15% mixture of spinosyns A and D, natural fermentation products of the soil bacterium *Saccharopolyspora spinosa*. https://elifesciences.org/articles/73812.pdf the genus Saccharopolyspora was discovered in 1985 in isolates from crushed sugarcane. The spinosyns and spinosoids have a novel mode of action, primarily targeting binding sites on nicotinic acetylcholine receptors (nAChRs) of the insect nervous system that are distinct from those at which other insecticides have their activity (Wikipedia). Spinosad binding leads to the disruption of acetycholine neurotransmission (Qiao et al., 2007).

Fatty Acids: In general, fats are a blend of particular fatty acid chain lengths. Soap is a general term for the salts of fatty acids. Commercially available insecticidal soaps contain the active ingredient, potassium salts of fatty acids (Cloyd, Kansas State University). These are a major component of lipids and typically serve as a solvent in conjunction with emulgators to stabilize the active principles (such as azadirachtin or pyrethrins) in commercial biopesticides. For example, conjugated unsaturated fatty acids such as rumenic acid, which can be described as a conjugated linoleic acid (CLA) have been shown to directly act on insect pests, such as the Colorado potato beetle. Another example is the foliar application of a mixture of CLAs demonstrated its insecticidal properties, inducing larval mortality, antifeedant effects, and reduced survival rates of the eggs (Clements, J., et al., 2019).

Fatty Acids and their mode of action: The mode of action of soap require more research, however, soaps may kill insects and mite pests in one of the three ways. (1) soaps may work when fatty acids penetrate through the insect's cuticle (outer covering) and dissolve or disrupt cell membranes. This interferes with cell integrity causing cells to leak and collapse, destroys respiratory functions, and results in dehydration and death of an insect or mite. (2) soaps may act as insect growth regulators interfering with cellular metabolism and the production of growth hormones during metamorphosis. (3) soaps may block the spiracles (breathing pores), which disrupts normal respiration as reported by Dr. Raymond Cloyed.

Insectary plants and their benefits: According to the University of California Insectary plants are those plants to attract, feed, and shelter insect parasites (parasitoids) and predators to enhance BioNatural Insect Management. For example, insectary plants provide nectar and pollen, which the adults of many natural enemy species need to consume. Therefore, conservational BioNatural Insect Management is one of the most important tactics to manage insect pests in several crops. An intentionally specific flowering plant species are planted as secondary plants in fields for the purpose to attract beneficial insects and manage harmful insect pollution. It is important to

understand the biology of these insectary plants. For example, the time of flowering of these plants begins, which will help qualified applicators to determine the most susceptible period of the main crop to insect pests. Studies have shown the effects of insectary plants in different crop systems around the world (Chaney, 2004). Here is one of the research projects contacted in Salinas, California indicated that sweet alyssum, chervil, cilantro, layia, and hemophilia attracted the highest number of predatory hoverflies (Diptera: Syrphidae) across 19 different insectary plant species tested (Chaney 1998). As reported by Del-Pozo et al UC IPM., insectary plants could be taken as an area-wide effort to enhance the presence of beneficial insects, not only in organic fields but also, in conventional fields. https://capca.com/wp-content/uploads/2019/04/201904-CAPCA_Apr2019_UCIPM.pdf
It would be appropriate to define some of the related terms because BioNatural Insect Management is the concept that deals with the whole system of the internal and external related issues of insect pests of the farm. According to the publication Hedgerows and Farmscaping for California Agriculture:

Hedgerows: Are defined as lines or groups of trees, perennial and/or annual forbs, and grasses that are planted along roadways, fences, field edges, or other non-cropped areas. The word "hedge," from the Old English word "hegg," referred to an enclosure or boundary formed by closely growing bushes or by dead plant material.

Source: https://hedgerowsunlimited.com/wp-content/uploads/2018/03/CAFF-2018-Hedgerows-and-Farmscaping-for-California-Agriculture-A-Resource-Guide-for-Farmers.pdf

Windbreaks: These are barriers usually consisting of trees or shrubs that are used to reduce and redirect wind, resulting in microclimate changes in the sheltered zone.

Source: https://hedgerowsunlimited.com/wp-content/uploads/2018/03/CAFF-2018-Hedgerows-and-Farmscaping-for-California-Agriculture-A-Resource-Guide-for-Farmers.pdf

Filter Strips: Are planted areas that use vegetation to control soil erosion, slow water runoff from agricultural lands, and capture and prevent sediment and nutrients from entering waterways.

Source: https://hedgerowsunlimited.com/wp-content/uploads/2018/03/CAFF-2018-Hedgerows-and-Farmscaping-for-California-Agriculture-A-Resource-Guide-for-Farmers.pdf

Grassed Waterways: These are plantings of native or non-native annual or perennial grasses or other suitable vegetation in water drainages, to hold the soil in place and to reduce scouting, channeling, and gully erosion.

Source: https://hedgerowsunlimited.com/wp-content/uploads/2018/03/CAFF-2018-Hedgerows-and-Farmscaping-for-California-Agriculture-A-Resource-Guide-for-Farmers.pdf

Beetle Banks: These are plantings of the native or non-native perennial bunchgrasses within fields or on field edges that provide shelter and alternate prey for general crop pest predators.

Therefore, all the above strategies have habitat value for beneficial insects. For example, among the natural enemies attracted in the case of hedgerow plants are bigeyed bugs, syrphid flies, lady beetles, minute pirate bugs, green and brown lacewings, parasitic and predatory wasps, tachinid flies and spiders, by providing nectar and pollen, alternate hosts and prey, shelter during the winter cold and summer, heat, wind protection, and nesting. Some of the many insect pests that are under prey to the above-listed natural enemies are aphids, mealy bugs, leaf hoppers, scales, mites, white flies, Lygus bugs, thrips, squash bugs, stink bugs, codling moths, corn earworms, leafrollers and other caterpillars as reported in the above publication.

Source: https://hedgerowsunlimited.com/wp-content/uploads/2018/03/CAFF-2018-Hedgerows-and-Farmscaping-for-California-Agriculture-A-Resource-Guide-for-Farmers.pdf

Riparian Areas: these are plant habitats and communities along river margins, creeks, and banks, characterized by water-loving plants.

Source: https://hedgerowsunlimited.com/wp-content/uploads/2018/03/CAFF-2018-Hedgerows-and-Farmscaping-for-California-Agriculture-A-Resource-Guide-for-Farmers.pdf

Farmscaping: is the management of vegetation on and around the farm, field margins, waterways, natural areas, and within cropped or in non-cropped areas. The term "farmscaping" can cover a wide range of practices, such as grassed waterways, buffers, filter strips, insectary strips, riparian plantings, and cover crops, as well as hedgerows and windbreaks.

Plants that attract beneficial insects: the thoughtful and beautiful view of BioNatural Healing bring our prompt attention to crawling and flying creatures of the Creator (Almighty God) whose diet include pests that ravage farm and keep balance and harmony in the ecosystem. Below is the list of beneficial insects and plants that they like to visit for sources of food especially sugar from flowers, and shelter. To keep the beneficial insects on the job, which belong to three main categories such as predators, parasitoids, and pollinators, and eliminate harsh insecticide use and protect the public and the environment. **Predators:** These are organisms that capture and consume other organisms such as insects or mites. Predators include ladybird beetles, ground beetles, lacewings, syrphid (hover) flies, aphid midges (Aphidoletes), and yellowjacket wasps.

Parasitoids: These are insects that parasitize other insects. The immature stages of parasitoids develop on or within their host, eventually killing it. Parasitoids may attack all stages of their host. For example, eggs, larvae, nymphs, pupae, and adults. **Pollinators**: Pollinators transfer pollen in and between flowers of the same plant species (pollination) which is essential to seed and fruit production for plants. These organisms are a wonderful part of feeding, fueling, and healing including honeybees, leafcutter bees, other wild bees, butterflies, moths, and other insects that visit flowers to feed on nectar and pollen.

Ladybugs (Coccinellidae):

Identification: There are many species of ladybugs beetles, that vary in size, color, and pattern. Most species have colored spots or marking on their backs. Depending on the species, colors are red, orange-red, black to almost yellow.
Body size: Mature larva-1.0-7.5 mm, adult- 1.0-5.0 mm.
Life cycle: Overwinter as adults. Eggs (orange, elongated) are laid in clusters on the underside of leaves and branches. Both the larvae and adults feed on pests. Depending on environmental conditions, usually one generation per year.
Insect pests attacked: Aphids, whiteflies, scales, mites, mealybugs, and other soft-bodied insects.
Monitoring: Require routine inspect colonies of aphids for adults and/or larvae.



Twospotted ladybug beetle adult. Multicolored Asian ladybug beetle adult Ladybug beetle eggs
Feeding on aphid


Ladybug beetle larvae Ladybug beetle pupa

Lacewings (Chrysopidae):

Identification: There are two common species of green lacewings such as two green lacewing species, *Chrysoperia carnea* and *Chrysopa oculate,* and brown lacewing species (*Hemerobius pacifus*). The green and brown lacewing larvae are very similar except for minor differences in their body shape. The brown lacewing's habit of moving its head from side to side while walking. Lacewing eggs are white and laid singly or in groups on long stalks on the underside of leaves or branches.
Body size: Mature larva-6.0-10.0mm; Adult-10.0-20.0 mm.

Life cycle: Both green lacewings and brown lacewings are overwintering as adults; *Chrysopa oculate* as pupae. Up to four generations per year depending on temperature.
Insect pests attacked: green lacewings are commercially available. Attack on aphids, spider mites, whiteflies, thrips, leafhoppers, scales, mealybugs, psyllids, small caterpillars, and insect eggs. Green lacewing larvae feed on insect pests. Brown lacewings both larvae and adults feed on pests.
Monitoring: Routine monitoring of aphid-or psylla-infested leaves and shoots for feeding larvae or use limb taps.


Green lacewing adult Brown lacewing adult Photo courtesy E.S. Cropconsult Ltd.


Lacewing eggs Lacewing larva

Syrphid fly or Hoverfly (Syrphidae):
Identification: They are name-matching with their activities because often hover for nectar at flowers. Hoverfly larvae are flattened, legless maggots with no distinct head and a tapered body. With various colors including yellow, green to brown. Adults hover flies frequently visit flowers over which hover before landing to feed on nectar and pollen, as a food source. Hoverfly eggs are white, elongated, with fine sculpturing, and visible in aphid colonies. It is important to note they are often mistaken for bees or wasps which they mimic in coloration.
Body size: Mature larva-10.0-15.0 mm- Adult- 8.0-15.0 mm
Life cycle: Many generations per year depending on the temperature and location. Eggs laid on aphid-infested plant parts. Overwinter as larvae, pupae, or adults depending on the species.
Monitoring: Examine aphid-infested leaves and shoots for maggot-like larvae. Adults frequent flower visitors.


Syrphid fly pupa


Syrphid fly larva feeding on aphid


Syrphid fly adult


Syrphid fly adult

Praying mantids

Identification: All members of the Mantodea have the characteristic raptorial front legs. Mantids have an elongated thorax and grasping forelegs, which they use to hold their prey while they eat.
Body size: Adults are 5-10 cm long and green, brown, or yellow in color.
Life cycle: The eggs overwinter within egg cases, which are connected to wood, bark, or other plant material, and hatch in the spring into very small versions of the adult. One generation per year.
Insect pests attacked: Wide range such as aphids, flies, and beetles. Feeds on pests as well as beneficial insects. Mantids grasp their prey with spined front legs and hold them while they eat.
Monitoring: Examine many plant parts, some resemble leaves or other plant parts.


Mantids eating (L-R) a leafhopper, caterpillar, grasshopper and horse fly.
Source: https://hort.extension.wisc.edu/articles/praying-mantids/

Minute pirate bug (*Anthocoris spp., Orius spp.*)

Identification: Adult anthocorids have a narrow, pointed head, and flattened, smooth body with a distinctive clear mark on their back.
Body size: Mature nymph-1.8-3.7 mm- Adult- 2.0-4.0 mm
Life cycle: 3 to 4 generations depending on temperature and local conditions. Overwinter as adults and active during the early season.
Monitoring: Examining limb taps in orchards will detect adults and nymphs.
Insect pests attacked: Aphids, spider mites, thrips, psyllids, whiteflies, and small caterpillars.

Adult minute pirate bug   Three nymphal instars of the anthocorid, A. melanecerus

Aphid midge (*Aphidoletes spp.*)

Identification: The adults of the predaceous delicate midge Aphidoletes aphidimyza are tiny (3mm long), delicate, long-legged brown flies that hide beneath the leaves during the day, and are active at night.
Body size: Mature nymph-3.0mm- Adult-3.0mm
Life cycle: Eggs are laid in colonies of aphids. Overwinter as pupae in the soil and many generations per year when the right temperature and conditions are available.
Monitoring: Examine aphid colonies for the presence of tiny orange maggot-like larvae or tiny paprika-like eggs. It is important to note to inspect under aphids to find them.

Midge larva (Aphidoletes spp.) feeding on a winged aphid A. aphidimyza larva among aphid

Bigeyed bug (Geocoris spp)

Identification: Adults and nymphs (immatures) are oval and generally black, brownish, gray, or reddish. Feed harmlessly on pollen, seeds, and plant juice.
Body size: Adults range from about 1/8 to ¼ inch (3-6) long. Nymphs commonly resemble adults in coloration and shape but are wingless.
Life cycle: Develop through three life stages and have several generations per year. Eggs hatch into nymphs, which develop through 5 increasingly larger instars.
Monitoring: Examine planting flowering species that provide blossoms throughout the growing season. **Insect pest attacked:** Feed on bug nymphs, all stages of aphids, flea beetles, insect eggs, small caterpillars, mites, and whiteflies.   **Bigeyed**

Source: https://www2.ipm.ucanr.edu/natural-enemies/bigeyed-bugs/

Predatory mites

Identification: Adults are pear-shaped, and nymphs and adults are translucent to white or the color of their prey, commonly pale brownish or reddish.
Body size: Mature larvae are about 1/100 inch (0.3 mm). Adults are about 1/70 inch (0.36 mm) long.
Life cycle: Overwinter as adults. Eggs are laid on the underside of leaves in crevices of buds and on flowers and hatch in about 1 to 4 days depending on the temperature of the location.
Monitoring: required visual microscopic inspection of leaves or leaf brushing.
Insect pests attacked: spider mites, thrips, fungus gnat larvae.

Predatory mite and 2-spotted spider Z. Mali feeding on European red mite mite

Source: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/animal-and-crops/plant-health/beneficial_insects.pdf

Why parasitic wasps are important? These parasitic wasps belong to the order Hymenoptera which are tiny with many species. Due to their tiny size and efficiency as thousands of parasitic species in over 40 families. For example, Ichneumons, Brachnoids, Chalcids, Trichogramma. Therefore, put on a list of the most important BioNatural control for pesticide applicators. These tiny parasitic wasps with their mode of action as ectoparasitoids or endoparasitoids without sting to people.

Source: https://extension.umd.edu/resource/parasitoid-wasps

Body size: Mature larva about 1.0-26.0mm- Adult about 1.0-24.0mm
Life cycle: Depending on types of species and local temperature, several generations per year.
Monitoring: It's wise to routinely examine aphid colonies for the presence of "mummies" However, there is no standard method to develop.
Some of the well-known parasitic wasps: *Trichogramma* (is an egg parasitoid and works well on many caterpillars), *Encarsia formosa* (for control of whiteflies in greenhouses) *and Aphidius parasitoids* (to control aphids) such as *Aphidius ervi*, *A.colemani*, *A. matricariae* are commercially available.



Parasitic Wasp (Meteorus trachynotus), a common leafroller parasitoid. Photo: Agriculture & Agri-Food Canada

Aphid mummy shows. Exit hole of parasitic wasp

Braconid wasp parasite cocoons on tomato hornworm



Encarsia formosa, whitefly parasitoid *Parasitized scale insects* *Aphelinus mali,whoolly apple aphid*

Source: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/animal-and-crops/plant-health/beneficial_insects.pdf

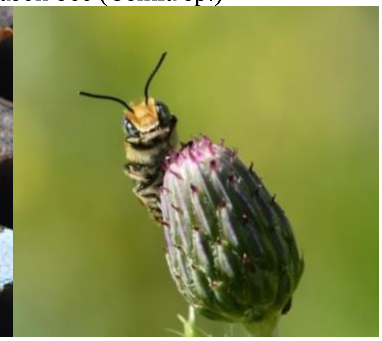
Pollinators healing world



Honey bee Honey bee Bumble bee



Mason bee (Osmia sp.). Mason bee (Osmia sp.). Mason bee (Osmia sp.)



Leafcutter bee on alfalfa (Megachile rotundata). Photo. Courtesy Dr. Shelly Hoover Alberta Agriculture & Forestry

Leafcutter bee (M. rotundata) Photo courtesy Dr. Shelley Hoover, Alberta Agriculture & Forestry.

Leafcutter bee (M.rotundata) Photo courtesy Dr. Shelly Hoover Alberta Agriculture & Forestry.

Butterfly

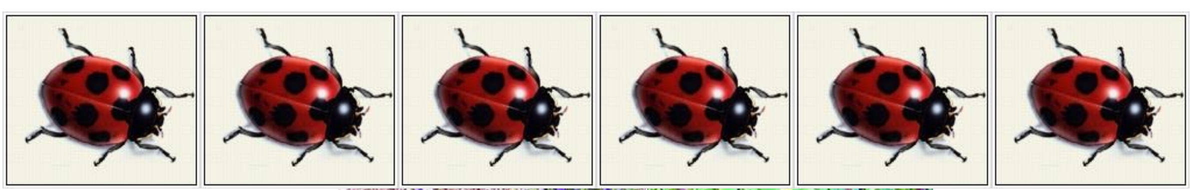
Digger bee

Halictid (Sweat) bee

Source: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/animal-and-crops/plant-health/beneficial_insects.pdf

Plants that attract beneficial insects: The following is the partial list of plants that attract beneficial insects:

Plants that attract ladybugs:



Carpet bugleweed

Spike Speedwell

Hairy vetch

Marigold “lemon gem”

Fern-leaf yarrow (*Achillea filipendulina*), Common yarrow (Achillea millefolium), Carpet bugleweed (Ajuga reptanas), Basket of Gold (Alyssum saxatilis), Dill (*Anethum graveolens*), Golden marguerite (*Anthemis tinctoria*), Butterfly weed (Asclepias tuberosa), Four-wing saltbush (*Atriplex canescens*), Coriander (*Coriandrum sativum*), Queen Anne's lace (*Daucus carota*), CA Buckwheat (Eriogonum fasciculatum), Fennel (*Foeniculum vulgare*), Prairie sunflower (Helianthus maximilianii), Rocky Mt. penstemon (*Penstemon strictus*), Sulfur cinquefoil (*Potentilla recta 'warrenii'*), Alpine cinquefoil (*Potentilla villosa*), Mariglod "lemon gem" (*Tagetes tenuifolia*), Tansy (*Tanacetum vulgare*), Dandelion (*Taraxacum officinale*), Spike speedwell (*Veronica spicata*), Hair vetch (*Vicia villosa*).

Plants that attract Lacewings

Queen Anne's Lace Golden marguerite Fern-leaf yarrow Cosmos white sensation. Angelica
Source: https://www.nrcm.org/wp-content/uploads/2016/05/Plants-that-attract-beneficial-insects.pdf

Dill (*Anethum graveolens*), Angelica (*Angelica gigas*), Golden marguerite (*Anthemis tinctoria*), Four-wing saltbush (*Atriplex canescens*), Purple poppy mallow (*Callirhoe involucrate*), Caraway (*Carum carvi*), Coriander (*Coriandrum sativum*), Cosmos white sensation (*Cosmos bipinnatus*), Queen Anne's lace (*Daucus carota*), Fennel (*Foeniculum vulgare*), Prairie sunflower (*Helianthus maximilianii*), Tansy (*Tanacetum vulgare*), Dandelion (*Taraxacum officinale*).

Plants that attract parasitic mini wasps: As Michigan State University Extension describes that there are over 40 families of parasitic wasps including Aphidiid wasps, Braconid wasps, and Parasitic flies.

Fern-leaf yarrow (*Achillea filipendulina*), Common yarrow (*Achillea millefolium*), Lavender globe lily (*Allium tanguticum*), Dill (*Anethum graveolens*), Golden marguerite (*Anthemis tinctoria*), Masterwort (*Astrantia major*), Purple poppy mallow (*Callirhoe involucrate*), Caraway (*Carum carvi*), Coriander (*Coriandrum sativum*), Cosmos white sensation (*Cosmos bipinnatus*), Queen Anne's lace (*Daucus carota*), Fennel (*Foeniculum vulgare*), Statice (*Limonium latifolium*), Butter and eggs (*Linaria vulgaris*), Edging lobelia (*Lobelia erinus*), Sweet alyssum-white (*Lobularia maritima*), Lemon balm (*Melissa officinalis*), Pennyroyal (*Mentha pulegium*), Parsley (*Petroselinum crispum*), Sulfur cinquefoil (*Potentilla recta 'warrenii'*), Alpine cinquefoil (*Potentilla villosa*), Orange stonecrop (*Sedum kamtschaticum*), Marigold - lemon gem (*Tagetes tenuifolia*), Tansy (*Tanacetum vulgare*), Crimson thyme (*Thymus serpylum coccineus*), Zinnia – lilliput (*Zinnia elegans*).

Braconid wasps Ichneumonid wasps Trichogramma wasps

Sweet alyssum shite. Parsley Dill Dill

Source: https://www.nrcm.org/wp-content/uploads/2016/05/Plants-that-attract-beneficial-insects.pdf

Tachinid flies: One of the largest and most important groups of insect parasitic flies especially larvae of all species are parasitic to major insect pests. For example, caterpillars, sawfly larvae, beetle larvae, and adults are the usual hosts. Tachinid flies usually gray, black, or striped also, resemble house flies, but with bristles at the tips of their abdomens. Eggs may be laid in or on the body of the host and the larvae develop internally in the host and eventually kill the host.

Plants that attract tachinid flies

CA Buckwheat Crimson thryme Golden marguerite. Lemon balm

Golden marguerite (*Anthemis tinctoria*), CA Buckwheat (*Eriogonum fasciculatum*), Lemon balm (*Melissa officinalis*), Pennyroyal (*Mentha pulegium*), Parsley (*Petroselinum crispum*), Phacelia (*Phacelia tanacetifolia*), Tansy (*Tanacetum vulgare*), Crimson thyme (*Thymus serpyllum coccineus*).

Some tolerate minor pest infestation plants: these will provide a food source for the beneficial insects that keep them on the farm.

Prairie sunflower Purple poppy mallow. Fennel



Dandelion Four-wing saltbush Basket of Gold Alyssum



Butterfly weed. Coriander Rocky Mt. penstemon Orange stonecrop

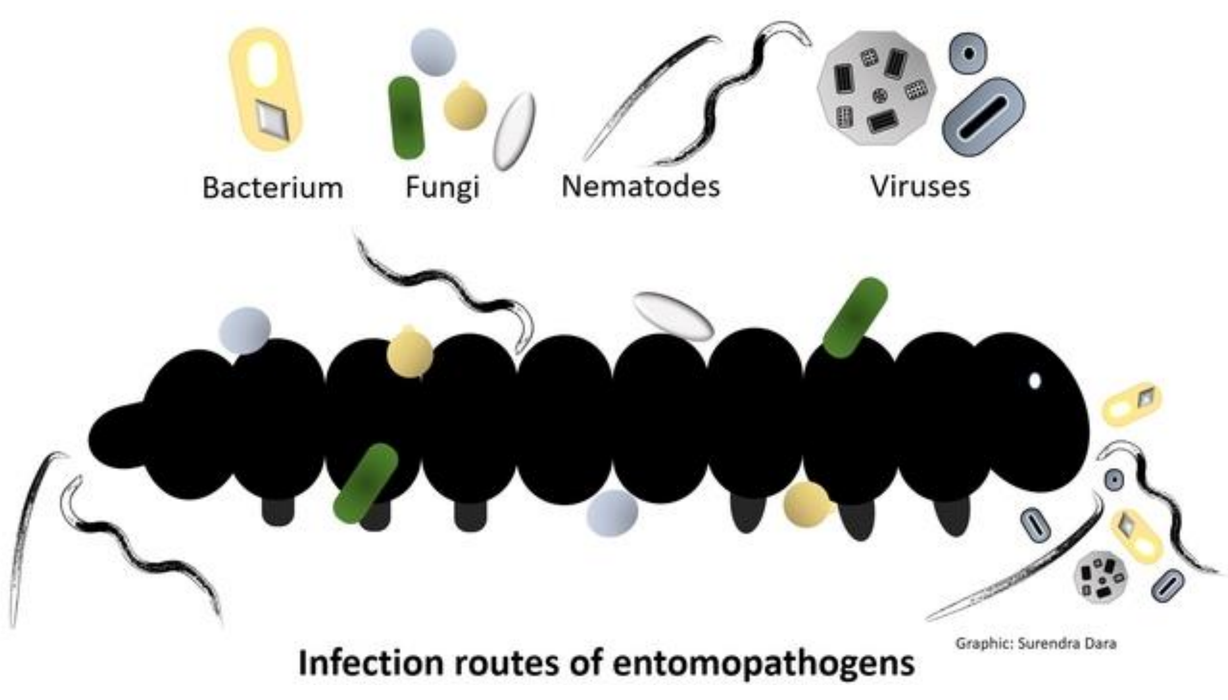



Conservation of BioNatural Control: Beneficial insect populations are nurturing and thriving if we create a balanced environment and maintain the populations of natural enemies (e.g., predators and parasitoids) within plant diversity based on the presence of flowering plants (floral resources), and the monitoring of insect pests' populations. Studies have shown that manipulating or preserving a harmonious habitat, especially the availability of flowering plants fosters the establishment of a beneficial insect population. Indeed, the use of pesticides would destroy the beneficial insect population this can be observed in the conventional farming system, because of pesticide application, which harms the soil, water, air, and ecosystems. Researchers describe nectar and pollen and their important vitality as a carbohydrate source that is essential for the survival and reproduction of parasitoids (beneficial insects).

BioNatural microbial-based insect pest management: The threat of invasive pests to agriculture commodities and climate changes is the biggest concern to the agriculture and pest management professional community. According to the Entomological Society of America (ESA) recent position statement, invasive insects incur control costs of over $2.5 billion and cause economic damages to crops, lawns, forests, and pastures totaling $18 billion per year (The Not-So-Hidden

Dangers of Invasive Species., 2018). Indeed, insecticides play an important role in insect pest control. However, a high public health concern increasing demand for the alternative holistic approach due to the public and environmental health from the adverse impact of pesticides. One of the important issues to discuss is Entomopathogenic microorganisms and their modes of action in the management of insect pests as reported by Dr. Surendra Dara.

Why Entomopathogenic is important in insect pest management? It's a wonderful connection between one part of nature to another part of nature which is equal to BioNatural panacea. As such, there are pathogenic microorganisms that play an important role in the management of insects, mites, and ticks. For example, several species of naturally occurring bacteria, fungi, nematodes, and viruses infect a wide range of insect pests. There are two types of entomopathogenic mass production for commercial entomopathogenic as well as for non-commercial local use. For example, mass-produced in vitro include bacteria, fungi, and nematodes or in vivo nematodes and viruses, these are sold commercially. These antipathogenic microbial insect pest control can be useful for BioNatural Pest Management. Researchers have demonstrated the classical microbial control approach to import exotic microorganisms and release them to manage invasive pests for long-term control. It is important to note that releasing of exotic microorganisms is under strict regulations of government agencies after extensive tests and evaluations. However, commercially available enteropathogenic release through inundative application methods is commonly used by researchers, pesticide applicators, government agencies, farmers, and homeowners. It is important to understand the entomopathogenic-insect pest interactions from ecological perspectives their mode of action, host range, and plant biology. This will guide us for better pest management in various sectors of agriculture including, agronomic crops, horticulture and landscaping turf grass, and possibly organic farming.



Source: https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=24119

Entomopathogenic group and their mode of action:

Bacteria: Among the entomopathogenic bacteria groups good examples are *Bacillus spp., Paenibacillus spp.,* and *Clostridium spp*. In contrast, non-spore-forming belong to the genera *Pseudomonas, Photorhabdus, Serratia,* and *Xenorhabdus*.

Mode of action: When bacteria are ingested by the susceptible insect hosts, then, the infection can occur. When Bt is ingested, alkaline conditions in the insect gut (pH 8-11) activate the toxic protein (delta-endotoxin) that attaches to the receptor sites in the midgut and creates pores in midgut cells. As a result of the loss of osmoregulation (the maintenance of constant osmotic pressure in the fluids of an organism by the control of water and salt concentration), midgut paralysis, cell disintegration, and cell rapture and eventually death of the host insect. However, insects show different kinds of responses to Bt toxins depending on the crystal proteins (delta-endotoxin), receptor sites, production of other toxins (exotoxins), and requirement of spore.

Fungi: Entomopathogenic fungi have a broad host range and are especially suitable for controlling insect pests with piercing and sucking mouthparts because spores do not have to be ingested.

Mode of action: When entomopathogenic fungi spores come in contact with the arthropod (insect pests) host. Fungal spores germinate under ideal conditions of moderate temperatures and high relative humidity. Thus, breaching the insect cuticle through enzymatic degradation and mechanical pressure to gain entry into the insect body cause infection. Once inside the insect body, the fungi multiply, invade the insect tissues, emerge from the dead insect, and produce more spores. These fungal pathogens have a broad host range with a mode of action for controlling piercing and sucking mouthparts because spores do not have to be ingested. Here, are some of the BioNatural control that occur not available commercially examples Pandora neoaphidis in controlling aphids, Entomophaga maimaiga in controlling gypsy moths, Entomophthora muscae in controlling flies, Neozygites fresenii in controlling aphids. N. floridana in controlling mites. Some of the commercially available in multiple formulations worldwide. For example, *Beauveria bassiana, Isaria fumosorosea*, *Metarhizium anisopliae, M. acridum, M. brunneum, Lecanicillium lecanii,* and *Hirsutella thompsonii,* Additionally, entomopathogenic fungi are effective against wireworm, and borers that have chewing mouthparts.

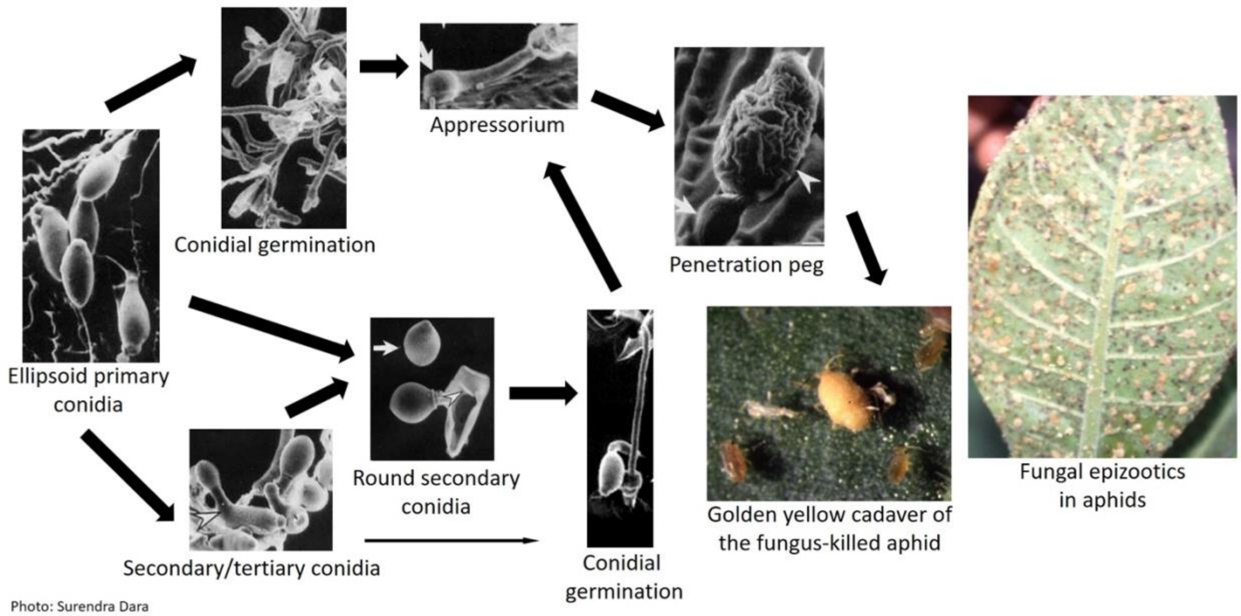
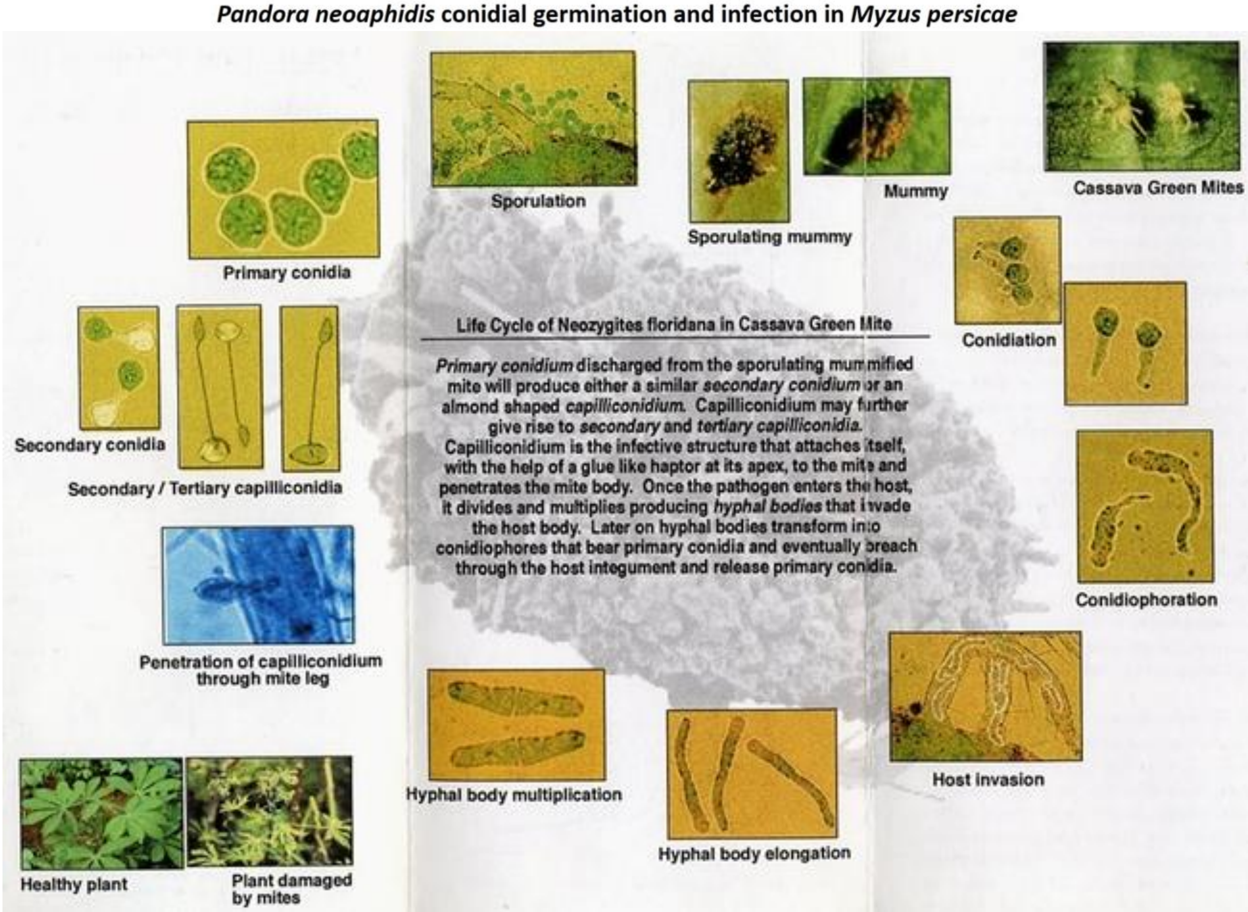
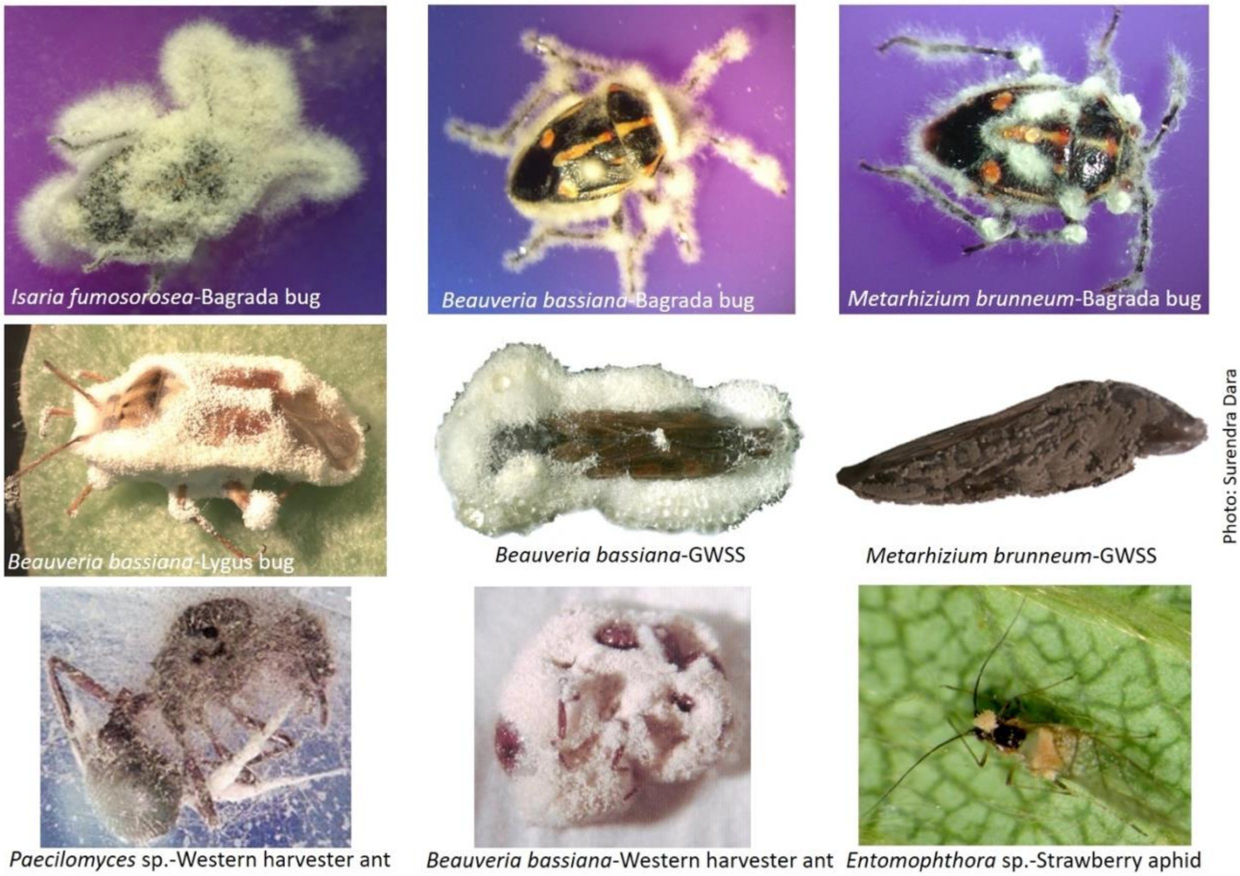


Photo: Surendra Dara

Pandora neoaphidis* conidial germination and infection in *Myzus persicae





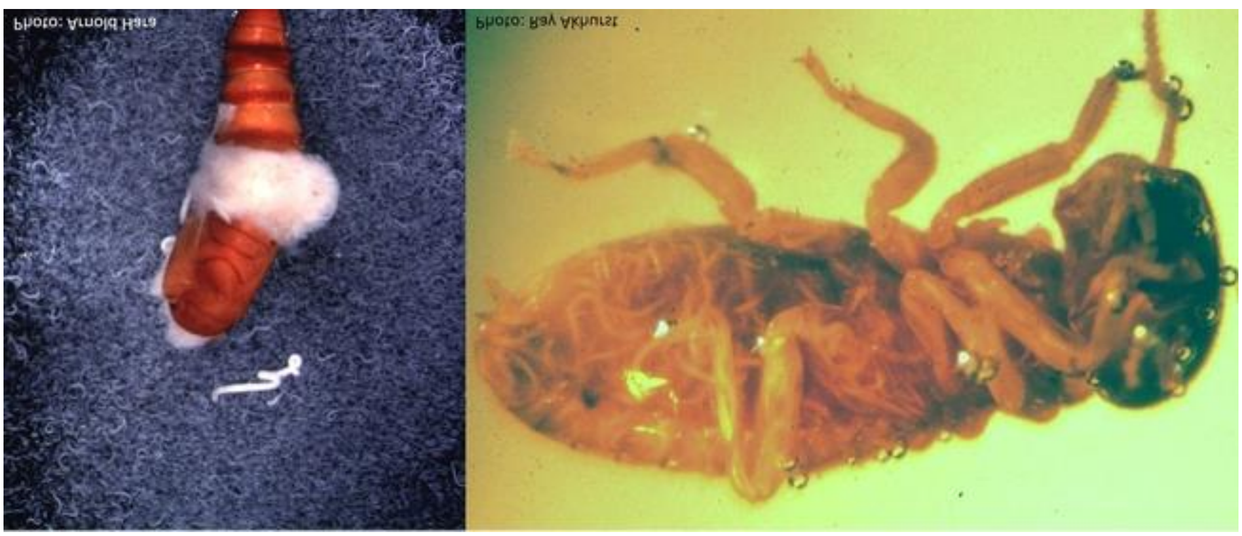
Various insects killed by different species of entomopathogenic fungi

Source: https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=24119

Nematodes: Entomopathogenic nematodes are microscopic, soil-dwelling worms that are parasitic to insects. Two popular commercial species such as *Heterohabditis* and *Steinernema* are available in various formulations for managing soil insect pests.

Mode of action: infective juveniles of entomopathogenic nematodes actively seek out their hosts and enter through natural openings such as the mouth, spiracles, and anus or the intersegmental membrane. Once inside the host body, the nematodes release symbiotic bacteria that kill the host through bacterial septicemia. *Heterorhabditis* spp, carry *Photorhabdus spp*, bacteria, and *Steinernema spp*, carry *Xenorhabdus spp*, bacteria.

Infective juvenile of *Steinernema carpocapsae* entering the first instar larva of a leafminer through its anus.



Nematodes in beet armyworm pupa (left) and termite worker (right).

Source: https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=24119

Viruses: Entomopathogenic viruses are playing an important role in killing insects, particularly chewing mouthparts. Lepidopteran insect pests are major important hosts of baculoviruses including nucleopolyhedroviruses (NPV) and granuloviruses (GV). A nucleic acid is wrapped in a protein coat known as capsid in virus partials, which plays a vital role in the host cell infection process. These entomopathogenic viruses are made up of double-stranded or single-stranded DNA (dsDNA) and RNA (dsRNA and ssRNA). Examples of some commercially available viruses include *Helicoverpa zea single-enveloped zea* single-enveloped, nucleopolyhedrovirus (HzSNVP), Spodoptera exigua multi-enveloped nucleopolyhedrovirus (SeMNPV), and Cydia pomonella granulovirus (CpGV).

Mode of action: When viruses need to be ingested by the insect host, virus particles invade the nucleus of the midgut tissue cells, compromising the integrity of the tissues and liquefying the cadavers. Before death, infected larvae climb higher in the plant canopy, which aids in the dissemination of virus particles from the cadavers to the lower part of the canopy.