Integrated Pest Management for Soil & Soil-less Systems

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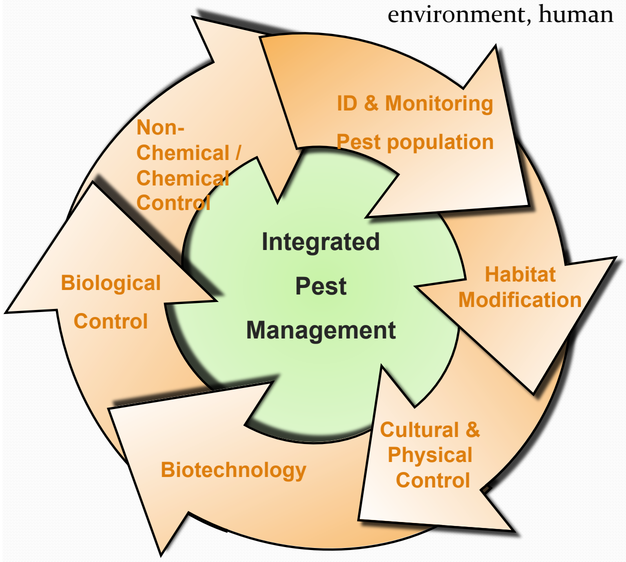
IPM uses **all possible pest control methods** in a well organized and harmonious way in order to achieve long-term pest control. It is important to understand the crop, pests, control strategies, mode of actions, and pest control limitations. The primary goal of IPM is to retain or improve production without negatively impacting the environment, human and aquaculture safety.



BENEFITS

- ✓Effective
- ✓Flexible
- ✓Informed decision makers
- ✓Potential cost savings
- ✓Environmentally responsible
- ✓Enhances worker and workplace safety
- ✓High decision making
    - ✓ Established economic threshold
    - ✓ Selection of the least hazardous control
    - ✓ Chemicals applied on an 'as needed' basis

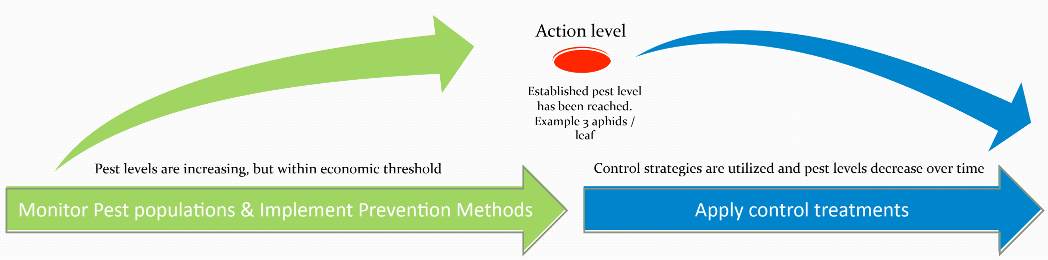
Monitoring

Monitoring allows growers to: assess pest population levels; determine pest activity; track changes over time, create a field history.

Important to monitor: pest population, level of infestation, plant location, natural enemies, time of the year, contributing conditions, environmental conditions, etc.

Action Thresholds

Action thresholds are an established levels that a pest population must reach before pest control action is needed.



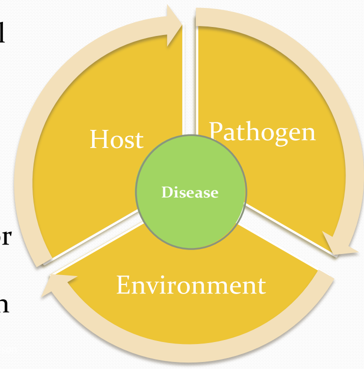
PREVENTATIVE TACTICS:
- Habitat Modification
- Physical Measures
- Cultural Measures
- Biotechnology
- Enhance Natural Enemies

CONTROL STRATEGIES
- Release Bio-control agents
- Implement Non-Chemical Control
- Chemical Control (as last resort)

Integrated Pest Management
Pest Identification: Common Diseases

Plant diseases are the result of a physiological or morphological change in a plant that results in abnormal growth, appearance or development due to a pathogen. Pathogens are parasitic organisms that cause a disease. Pathogens include: fungi, bacteria, viruses, nematodes, phytoplasma.

The diagram to the right illustrates the three factors required for disease development: a host plant, casual pathogen and a favorable environmental conditions. Managing these factors can also help prevent and suppress disease populations.



Fungal Pathogens

Common plant disease composted of threadlike structures called hyphae. Reproduce and disperse by spores. Common fungal pathogen include: powdery mildew, downy mildew, *Alternaria*, *Cercospora*, *Phythophthora*, etc.

Nematode Pathogens

Roundworms that attack the root system of plants and impair water and nutrient uptake. Symptoms: stunting, poor plant growth, narrow and weak stems, foliar chlorosis, root rotting and galling, plant toppling and poor root development.

Viral Pathogens

Viruses have a nucleic acid surround by a protein coat. They can only survive on living plant tissue. Once infected there is no cure. They are mainly transmitted by insect vectors. Common plant viruses include: Banana Bunch Top Virus, Tomato Spotted Wilt Virus, etc.

Bacterial Pathogens

Bacterial pathogens reproduce quickly and form masses called colonies. They are spread primarily via rain, or splashing water. They often enter plant tissue through natural openings or injury sites. Examples include: *Xanthamonous*, *Pseudomonas*, *Erwinia*, etc.

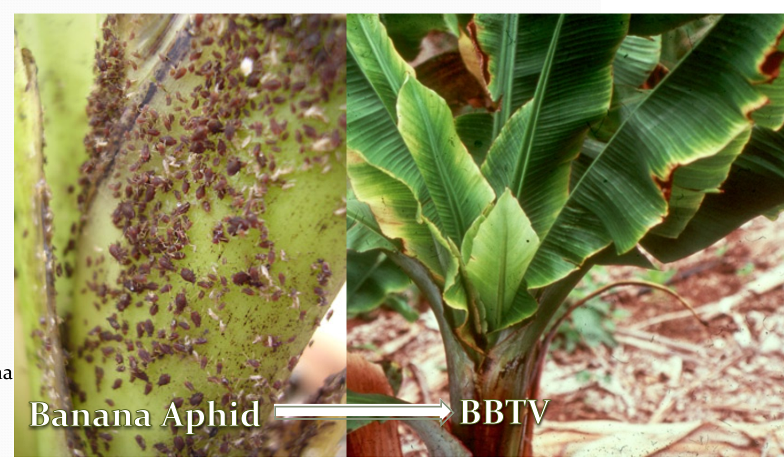
Phytoplasma

Phytoplasma is a bacteria which parasitizes on the phloem of plant tissue via an insect vector. Symptoms range from yellowing of plant tissue, cupping of leaves and even death of infected plants. Leafhoppers are often associated with vectoring of phytoplasmas like the Watercress Aster Yellow (WAY)

Example of a Plant Vector

Plant vectors are organisms that can transmit a pathogen such as a bacterium, virus, or phytoplasma into a plant.

EXAMPLES:
Banana aphid → Banana Bunchy Top Virus (BBTV)
Western flower thrips → Tomato Spotted Wilt Virus (TSWV)
Aster Yellow Leaf Hopper → Watercress Aster Yellow Phytoplasma
Onion thrips → Iris Yellow Spot Virus (IYSV)



Integrated Pest Management
Pest Identification: Common Pests

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Proper identification and understanding the nature of the pest are the key steps in selecting the best pest management strategy.

Chewing Pests

Chewing pest feed on the foliage, stems, fruit or roots. Pests within this group include beetles, caterpillars, earwigs, leaf miners, etc.

Ants

Ants are honeydew consumers and protect pests from natural enemies. Honey dew secretions promote sooty mold development. There are: sugar vs. fat loving ants.

Sucking Pests

These pest pierce plant's vascular tissue and withdraw plant sap. They cause plants to discolor, twist and distort. Pests within this group include aphids, whiteflies, mealy bugs, scales and leaf hoppers.

Fruit Flies


Photo credit: USDA ARS

There are 4 fruit flies in Hawaii: Oriental fruit fly, Melon fly, Mediterranean fruit fly, Malaysian fruit fly. Adult females sting fruits and vegetables resulting in blemishes. Larvae tunnel within fruit.

Mites


Photo credit: T. Radovich

Mites have rasping and sucking mouthparts. Damage results in a brown to russet discoloration of leaves, stems, fruit and flowers.

Thrips


Photo credit: www.ent.uga.edu

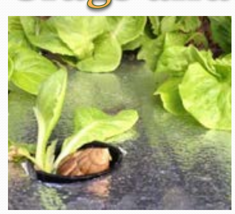
Thrips have rasping and sucking mouthparts. Damage results in discoloration and scaring of leaves, stems, fruit and flowers.

Nematodes


Photo credit: Dr. Scot Nelson

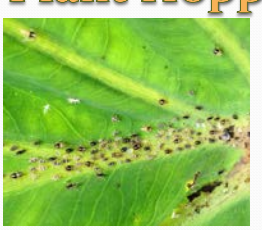
Roundworms that attack the root system of plants and impair water and nutrient uptake. Symptoms: stunting, poor plant growth, narrow and weak stems, foliar chlorosis, root rotting and galling, plant toppling and poor root development.

Slugs and Snails



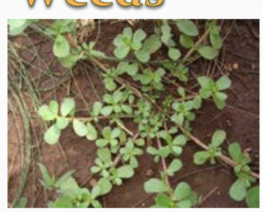
Slugs and snail are problem for low-growing vegetables. They are active in the evenings and are commonly associated with seedlings magically disappearing overnight.

Plant Hoppers



Plant hoppers damage leaves, stems, fruits, and flowers. They also serve as vectors for plant diseases, especially phytoplasmas.

Weeds



Weeds (annuals, biennials, perennials, etc.) often outcompete plants for food, sunlight, etc. They are fast growing, prolific seed producers, etc. Some weeds may be alternative hosts for crop pests (insects and diseases).

Sustainable and Organic Agriculture Program
Sustainable Pest Management Lab, University of Hawai'i at Mānoa, College of Tropical Agriculture and Human Resources
HYDROCULTURE, College of Tropical Agriculture and Human Resources, University of Hawai'i at Mānoa
LIFE Local & Immigrant Farmer Education, University of Hawai'i at Mānoa, College of Tropical Agriculture & Human Resources
WESTERN SARE Sustainable Agriculture Research & Education

Integrated Pest Management Control Strategies

* Control strategies are often utilized after action thresholds are surpassed. IPM aims to utilize all possible pest control methods in a well organized and harmonious way in order to achieve long-term pest control. Chemicals are not prohibited but often used as a last resort.

Biological Releases

The use of natural predators, parasites, parasitoids, etc. to manage pests. Examples include ladybugs, hoverflies, spiders, etc.




Other Non- Chemical Measures i.e., Mulch, Hot Water Treatments

Out of the box, non-chemical control strategy are also utilized in IPM. Pesticide are not encouraged in aquaculture systems. However, it is allowed if label language does not prohibit it and the crop is listed on the label.


Chemical Measures

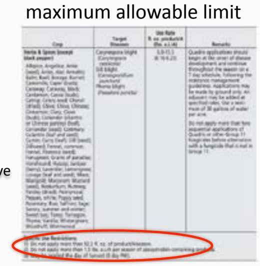
Use of a chemical to prevent, destroy, or repel pests. Typically considered after other control methods. Low toxicity chemicals are considered first. If available, use selective vs. broad spectrum chemicals. Chemicals should always be rotated with other chemicals to minimize resistance issues. Application and timing intervals are important.



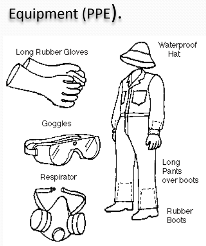
Pesticide Safety Reminders:

A pesticide is defined as a chemical used to prevent, destroy, or repel pests in all types of systems and farming operations.

- Read and follow the label
- Calculate the treatment area
- Calibrate your equipment
- Do not apply more than the maximum allowable limit



Wear REQUIRED Personal Protective Equipment (PPE).



Follow Re-entry Intervals (REI), Pre-harvest Intervals (PHI), and post appropriate signage according to crop labels.

EXAMPLE ONLY: Crop sprayed

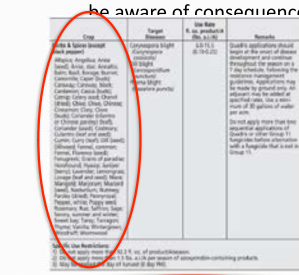
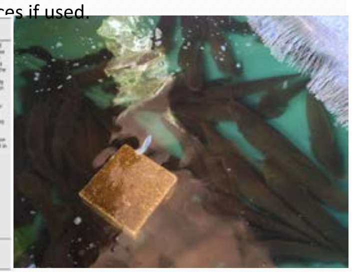
REI: 24 hours | OK to enter field

DO NOT HARVEST: PHI: 4 days | Ok to harvest / sell

Crop Season

Pesticide Use in Aquaponics are allowed IF:

- Label language does not prohibit it
- If there is a reference that the pesticide is harmful to fish, then be aware of consequences if used.

ENVIRONMENTAL HAZARDS
This product is hazardous to fish and aquatic invertebrates.
For Terrestrial Uses: Do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark. Do not contaminate water when disposing of equipment washwater or rinsate.

** NOTE: Workers who enter fields within the specific REI MUST wear appropriate PPE.

Integrated Pest Management
Prevention Strategies

* Prevention is an important strategy in avoiding and keeping a pest populations below economic threshold levels. Prevention strategies include practices such as but not limited to: field and equipment sanitation, utilizing pest free or resistant planting materials, managing alternative host materials, installation of physical barriers, reflective mulches, crop rotation, modifying crop spacing, trap crops, encouraging beneficial insects, timely crop destruction, etc.

Habitat Modification

Eliminate pests breeding sites. Eliminate favorable conditions such as pest / disease build up, removal of food or habitat sources, sanitation of fields and adjacent areas, etc.

Physical Measures

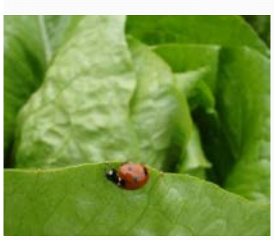
Installation of physical barriers or devices to discourage the pests such as: screens, barriers, sprinkler systems, wires, etc.

Cultural Measures

Manipulation of cultural practices to disadvantage the pest such as: crop rotation, fallow periods, crop spacing, companion planting, crop selection, aeration, worms-waste converter, reflective mulches, etc.

Biotechnology

Application of scientific techniques to modify and improve plants, insects and pathogens such as selective breeding (hybridization), variety screening, genetically modified crops, etc.



Encouraging Beneficial Insects

The use of natural predators, parasites, parasitoids, etc. to manage pests. Examples include ladybugs, hoverflies, spiders, etc.

EXAMPLES

Integrated Pest Management
Chemical Control Strategies

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Reduced Risk Products (1 of 2)

Bacillus *subtilis/ pumilus*
Derived from a soil bacterium that is antagonistic to fungal and disease pathogens by means of nutrient competition, site exclusion, colonization, attachment of the bacteria to the fungal pathogen, etc.
Example: Serenade Max (o), Sonata (o)

***Bacillus thuringiensis* (Bt)**
Derived from a bacterium which is selectively toxic to many moth and larvae. When ingested, Bt produces an endotoxin in the insects gut which is toxic to the insect
Examples: Dipel (o), Crymax, XenTari (o)

Beauveria bassiana
Spores of the Beauveria bassiana come into contact with the body of an insect host, germinate, enter the body, and grow inside, eventually killing the insect. The fungus multiplies and destroys the internal structures of the host under high humidity environments
Examples: BotaniGard, Mycotrol (o)

Copper products
Controls blights, mildew, anthracnose, but commonly associated with bacteria control
Example: Basic Copper 53 (o), Nucop 50DF (o), Champ WG (o)

Diatomaceous earth:
Naturally occurring substance comprised of the fossilized remains of diatoms. Insects such as roaches, ants, silverfish, fleas, etc. come in contact with this powder and die from desiccation.

EM, Compost Teas:
Fungicidal and nutritional supplement
Examples: Bokashi, Agripower

Horticultural Oils:
Cover, wet, and suffocate, over wintering eggs, nymphs and adults. Effective on scale insects.
Examples: Volck oil, JMS Stylet-oil (o), Biocover

Hydrogen Dioxide
Oxidizes rapidly on contact.
Examples: Oxidate (o)

Insecticidal Soaps:
Potassium Salts of Fatty Acids typically disrupt membranes of soft body pests leading to rapid death by evaporation.
Example: Mpede (o)

Kaolin Clay:
Common food additive approved by the FDA. It primarily serves as a protective barrier, distracts pest from the host plant and deters pest movement and damaging behavior.
Examples: Surround WP (o)

Neem Oil/ Azadirachtin: (IGR) ** many labels say it is toxic to fish
Disrupts insects' hormonal balance so they die before they molt, suppresses some insects' desire to feed, and it also repels. It has fungicidal properties as well.
Examples: Trilogy (o), Neemix (o), Debug Turbo (o), Molt-X (o)

NOTE: (o) Refers to products approved for organic production by the Organic Material Review Institute (OMRI).

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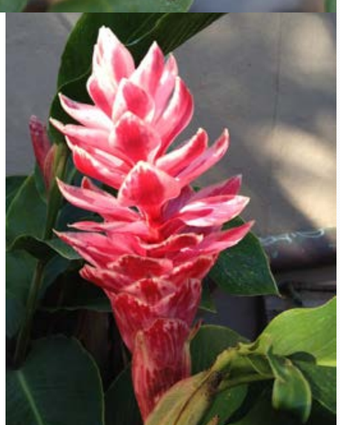

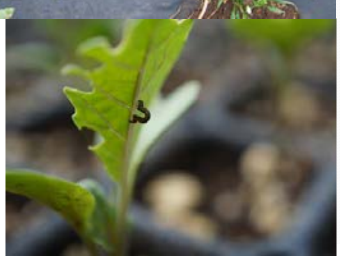

Reduced Risk Products (2 of 2)

Natural / Essential Oils:
Pepper, citrus, clove, mint, oils. Caution as oils can burn. Herbicide properties.
Examples: Ecotec (o)

Phosphorous Acid
Different from P fertilizers, phosphorus acid has fungicide properties that are especially effective against
Oomycete pathogens, such as *Phytophthora*, *Phythium*, and Downy mildews. Systemic properties.
Examples: Aliette, Fungi-Phite, Fosphite

Potassium Bicarbonate
Used as a contact fungicide mainly for powdery mildew in organic farming systems.
Examples: Armicarb (o), Kaligreen (o), Milstop (o)

Pyrethrin:
Derived from the blossoms of the pyrethrum flower, a chrysanthemum (contact). Breaks down in the environment quickly.
Example: Pyganic (o)

Reynoutria sachalinensis
Bio fungicide used to enhance plant health and trigger the plant's natural defenses to control fungal and bacterial diseases. Delays onset of disease through multiple modes of actions. Plant based extract with systemic properties.
Example: Regalia (o)

Spinosad
Derived from a bacteria in the soil. Kills by contact and ingestion. (Nerve and stomach poison)
Examples: Entrust (o), Radiant, GF-120 NF (o)

Spirotetramat
A new insecticide with a novel mode of action which interferes with lipid biosynthesis. It prevents molting and causes death of immature pest stages.
Example: Movento

Steinernema carpocapsae
Entomopathogenic nematodes are used as a biological control of insect pests. Entomopathogenic nematodes only infect insects. Entomopathogenic nematodes live inside the body of their host and are most effective on soil dwelling insect pest.
Example: Nematac

Streptomyces lydicus WYEC 108
Beneficial bacterium that colonizes on the surface of the roots and leaves. It attacks many soil borne and foliar diseases via different modes of action.
Example: Actinovate (o)

Sulfur
Inhibits the attack of healthy plants by fungus disease by creating an environment that is not conducive to disease growth. Also effective on selected mites.
Examples: Sulfur DF (o), Kumulus DF (o)

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Integrated Pest Management
Beneficial Insects & Insectary Plants

Sustainable Pest Management Lab
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Insectary plants are plants that produce pollen or nectar, or provide baits to attract arthropod predators including lady beetles, hoverflies, lacewing, spiders, parasitoid wasps etc.

Lady Beetle (Coccinellidae)

The lady beetle, both the larvae and adult, eat aphids, scales, and mealybugs.

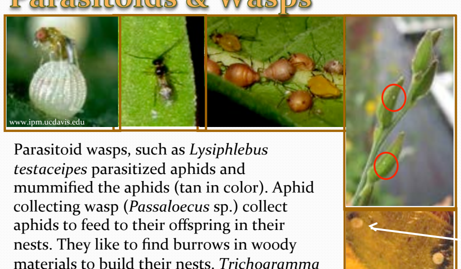
Insectary plants for lady beetles:
- Cilantro, Buckwheat, dill, fennel
- Cowpea
- Marigolds, cosmos
- Oleander (globe lady beetle)
- Morning Glory (*Convolvulus minor*)

Green Lacewing (Chrysopidae)

The lacewings, the adult will eat pollen, nectar, and honeydew, and the larvae eat aphids, various larvae and the eggs of other insects.

Insectary plants for lacewings:
- Cowpea
- Bay Leaf
- Carrot (*Daucus* sp.)
- Oleander (*Nerium oleander)*
- Red Cosmos
- Wild Lettuce (*Lactuca* sp.)

Parasitoids & Wasps



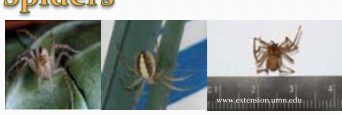
Eggs of Lycaenidae being parasitized by Trichogramma inside sunn hemp flower.

Sunn hemp and cowpea act indirectly as an insectary plants for Trichogramma wasps because the wasp like to come to parasitize Lycaenidae eggs commonly found on sunn hemp flowers. Sunn hemp can be planted as border crop or intercrop.

Parasitoid wasps, such as *Lysiphlebus testaceipes* parasitized aphids and mummified the aphids (tan in color). Aphid collecting wasp (*Passaloecus* sp.) collect aphids to feed to their offspring in their nests. They like to find burrows in woody materials to build their nests. *Trichogramma* wasps lay eggs in many Lepidopteron eggs that are pests of many crops.

Insectary plants for parasitoid wasps:
- Cilantro
- Buckwheat
- Milkweed
- Almost all insectary plants

Spiders



Spiders are generalist that can attack many insect pests especially when no harmful broad-spectrum insecticides are used. They are frequently found wondering on the cinder grow beds, or building webs to catch their preys.

Hoverflies (Syrphidae)

Hoverflies: larva eat aphids and other soft bodied insects, and adults eat nectar and pollen.

Insectary plants for hoverflies:
- Cilantro
- Buckwheat
- Marigold, cosmos
- Basil
- Carrot

Pirate or Assassin Bug

The pirate bug, adults feed on small arthropods like thrips ,aphids and insect eggs. The assassin bug, adults will eat beetles, caterpillars and flies.

Insectary plants for pirate or assassin bugs:
- Macaranga (*Macaranga tanarius*)
- Carrot (*Daucus carota*)
- Oleander (*Nerium oleander*)
- Sunn hemp (*Crotalaria juncea*)
- Cowpea (*Vigna unguiculata*)
- Marigold, cosmos

Function of Insectary Plants

- Increase pollen and nectar resources required by the natural enemies of insect pests such as hoverflies and parasitoids (Cowgill et al., 1993; Lavandero et al., 2005; Hogg et al., 2011).
- Attract pollinators.
- Supply food source for spiders (Taylor and Pfannenstiel, 2008).
- Act as trap crops for insect pests.

Attracting Beneficials to Aquaponic System

- Devoting a grow bed of diverse insectary plants around your aquaponic system will draw a variety of beneficial insects and natural enemies of insect pests to your crops. Examples: fennels, marigolds, milkweeds, buckwheat, and cilantro.
- Plant an attractant crop like buckwheat around the border of hydroponic benches to serve as insectary plants that attract hoverflies and wasps. Sunn hemp can be planted on the borders to attract Trichogramma wasps.
- Wasp's nesting box can be constructed and placed around production areas to attract solitary wasps. Most solitary wasps are predators of beetle larva and caterpillars. Photos on the right (below) show how the predatory wasp use the nesting boxes to collect insect pest. Holes that are plugged with soil indicate mud wasps are present and they have laid their eggs (and insect catches) in the nesting boxes.

Grow bed devoted to insectary plants

Hydroponic bench with buckwheat in first row, sunn hemp as boarder, and a wasp nesting block

Close up of the wasp nesting box

Reference and Photo Credit:
http://www.organicgardeninfo.com/beneficial-insectary-plants.html
Concept and photo by Koon-Hui Wang and Jane Tavares, unless specified otherwise in the photo.

Sustainable Pest Management

Examine Insectary Settings against Insect Pests on Pak Choi in a Hydroponic System

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Imported cabbage worm larvae


Diamond back moth (DBM) larvae

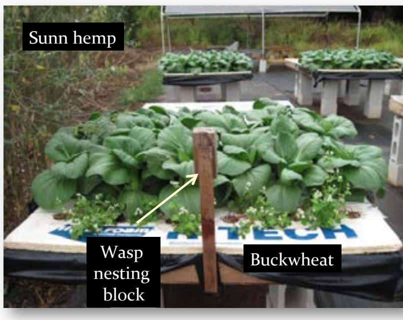

Aphids


Hoverfly


Hoverfly larvae eating an aphid


A parasitized DBM

Treatments



Insectary Settings

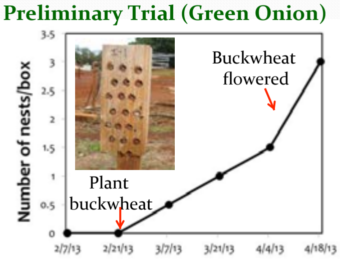

Reflective (Metalic) Board

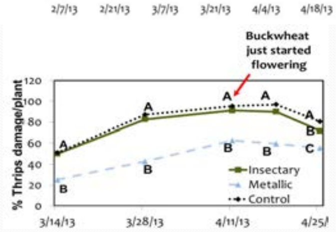

Control

Objectives were to examine if:

1. wasp nesting block attracts beneficial wasps,
2. insectary plants attract predatory insects,
3. reflective board repels insect pests.

Preliminary Trial (Green Onion)





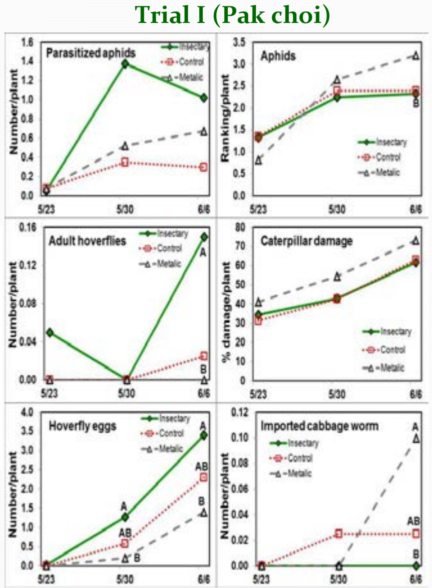
Results from Green Onion Trial:

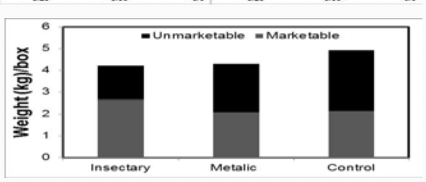
- Buckwheat flowered about 3 weeks after seeding.
- Reflective board was effective in reducing thrips damage but not the insectary setting.

Summary

- Wasp nesting block + 3-wk old buckwheat + sunn hemp border increased beneficial insects and suppressed aphids and caterpillar pests on well established pak choi seedlings in a hydroponic system.

Trial I (Pak choi)



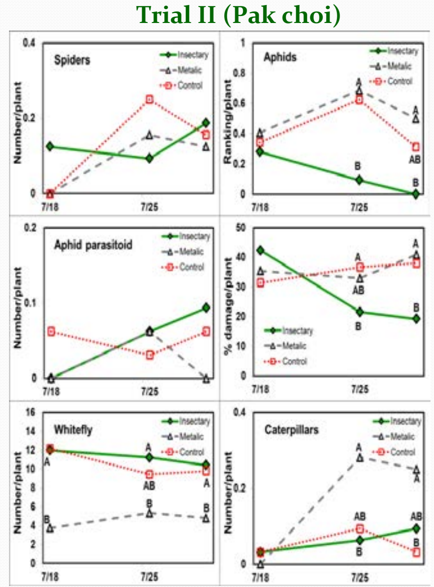


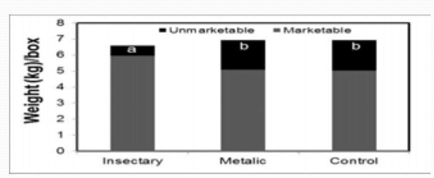
Results from Pak Choi Trial I:

- Buckwheat planted 3 wks after seeding, thus increased hoverflies and parasitized aphids soon after pak choi planting.
- Reflective board was not effective in reducing aphids and caterpillar pests.
- Pak chois were transplanted at 2-wk old, seedlings struggled to establish.

- Reflective board was more effective in repelling thrips and whiteflies but might also repel hoverflies and parasitoids.

Trial II (Pak choi)





Results from Pak Choi Trial II:

- Pak choi was transplanted at 3-wk old, seedlings were sprayed with Bt once before transplanting. Pak choi established well thereafter.
- Insectary setting increased aphid parasitoids and reduced caterpillar pests, and significantly reduced unmarketable pak choi.
- Metalic board only reduced white flies numbers.

Sustainable Pest Management

Evaluating Efficacy of Organic Insecticides on Key Insect Pests of Leafy Greens in Hydroponic and Aquaponic Systems

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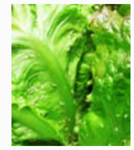
Cabbage looper on lettuce

Imported cabbage worm larvae



Aphids in between lettuce leaves

Aphids on a pak choi leaf

Insecticide	a.i.	Rate		a.i.	Rate
Pyganic	Pyrethrin	64 oz/acre	Sucrashield	Sucrose Octanoate Esters	1% v/v
Entrust	Spinosad	2 oz/acre			
Crymax	Bacillus thuringiensis	2 lb/acre	Adjuvant:		
Dipel	Bacillus thuringiensis	1 lb/acre	Latron	Modified phthalic glycerol alkyd resin	2 oz/acre
Debug Turbo	Azadirachtin	32 oz/acre	Oroboost	Alcohol ethoxylate	20 fl oz/acre

Several organic insecticides were tested for their efficacy in suppressing damage caused by cabbage looper and imported cabbage worm on Manoa lettuce grown in 15×21 sq in hydroponic boxes at the Poamoho Experiment Station , Oahu, HI. Two trials were conducted. Insecticides were sprayed weekly. Latron and Oroboost were used as surfactants in Trial I and Trial II, respectively. The key insect pests in these trials were cabbage looper, imported cabbage worm and diamond back moth. Damage caused by these insects on the lettuce was monitored at weekly interval.

Summary

- Entrust followed by Dipel were most effective in suppressing common caterpillar pests such as cabbage looper, imported cabbage worm or diamond back moth on Manoa lettuce

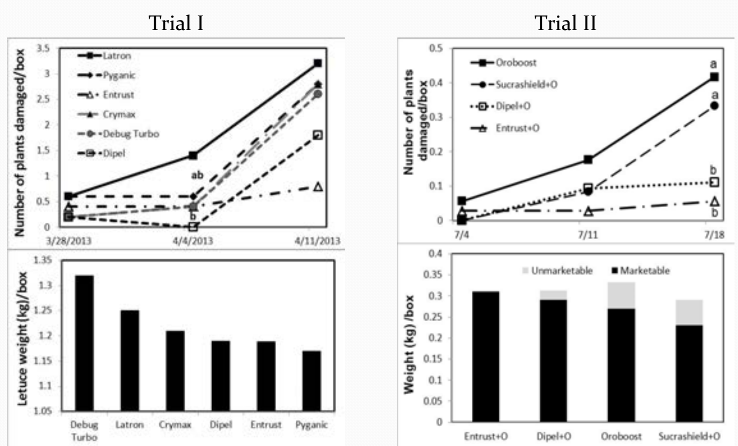


Fig. 1. Number of leaves with chewing damage caused by cabbage looper, imported cabbage worm or diamond back moth, and lettuce yield affected by organic insecticides in Manoa lettuce Trial I and Trial II of hydroponic experiment.

Laboratory Assay

Laboratory assays were conducted to examine effects of organic insecticides on aphids. A leaf disk of 1.5-cm diameter infested with lettuce aphids collected from an aquaponic farm was sprayed with the designated insecticide and incubated for 1 and 5 days in Trial I and Trial II, respectively.

Insecticide	a.i.	Rate		a.i.	Rate
TriTek	Mineral oil	1 gal/100 gal	Mycotrol	*Beauveria bassiana*	0.5 quart/acre
M-pede	Potasium salt of fatty acids	2% v/v	Grandevo	*Chromobacterium subsugae*	3 lb/acre
Molt-X	Azadirachtin	10 oz/acre			

Summary

Efficacy of most of these insecticides increased with mixing of Oroboost as an adjuvant except for Debug Turbo.

Among the insecticides tested, Debug Turbo was most efficient in killing aphids on lettuce leaves.

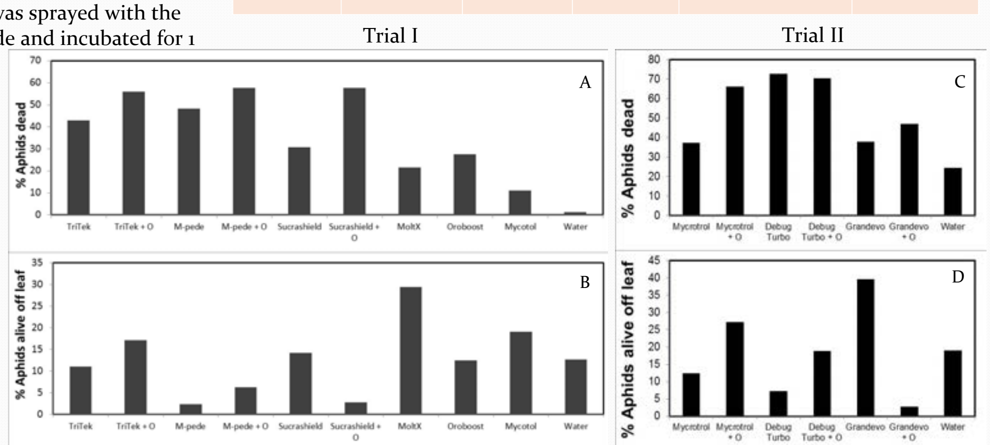


Fig 2. Percentage of aphids dead or alive but wonder off the leaf disk at 1 day (A, B) and 5 days (C, D) after insecticide spray on a lettuce leaf disk in the petri dish. Each spray treatment was composed of 5 replications.