Integrated Pest Management in a Controlled Environment

Rachael Woods

My Background

- Grew up in Minneapolis suburb
- Spent time on grandparents' farm
- Initially interested in music and medicine

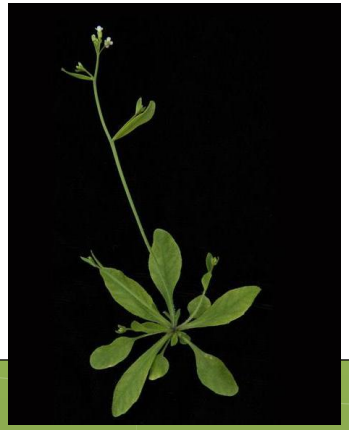
Education

- B.S. in Biology from Drake University in 2008
- Minor in music
- Decided against medical school
- Wanted to stay in Des Moines
- Started Agronomy program in 2010

Drake
UNIVERSITY

Work Experience

- DuPont Pioneer
  - 2008-2009: Lab, field, greenhouse corn NUE research
  - 2010-2012: Greenhouse specific corn NUE research
  - 2012-2014: Lab and greenhouse/growth chamber Arabidopsis NUE



Current Employer

- APC, Inc.
- Isolate functional proteins from plasma
- Nutritional products for livestock
- Would like to get back into agriculture

APC
An LGI Company

My Family

- Husband Chris
- Daughter Adeline Rose born 8/21/14
- Hobbies: traveling, gardening, hiking, music

Topic Selection

- Much of career spent in greenhouses
- Economic threshold different in research
- *Arabidopsis thaliana* extremely finicky
- Became Commercial Pesticide Applicator
- Wanted to know more about non-chemical control

Why A Learning Module?

- Best way to understand is to teach
- Chemical control in a greenhouse is tricky
- Wanted to inspire a more integrated approach
- Make material interactive

Module Contents

- Introduction
- Why is IPM in a Controlled Environment Different Than IPM in a Field?
- Prevention/Cultural Control
- Mechanical Control
- Monitoring
- Common Greenhouse Pests
- Biological Control
- Pesticide Control
- Summary
- Exam

Introduction

A greenhouse is a specialized environment when it comes to Integrated Pest Management (IPM). There are certain concerns in the field that simply are not problems in a controlled environment. One such consideration is weeds. Because sterile soil and containers are used and there is not much space for weeds to germinate, weed control is not something that is usually considered in a greenhouse.

However, there are also things that would not be considerations in the field that must be remembered in a greenhouse. A greenhouse is a unique environment with

- many different crops
- manmade light and temperature cycles
- an inability for natural migration of pests into or away from certain crops.

The inability to migrate makes greenhouses a more favorable environment for biological controls of certain pests.

Greenhouse of tomato seedlings.

Introduction

Prevention is the first step of any Integrated Pest Management program. The easiest way to manage a pest is to prevent it from becoming a problem in the first place. The controlled environment can be carefully monitored and maintained to prevent most pest infestations.

Sanitation of greenhouse space is crucial. Sterilization of growth medium and containers should be performed regularly. The locations of certain crops and how different crops are grown together in the same space must also be carefully managed. Sometimes all that is needed to control a pest is to rotate the location of certain crops in the same way a farmer would rotate crops in the field.

Because the interior climate of a greenhouse is controlled, sometimes a tweak in temperature or humidity can be all that is needed to knock down a pest infestation.

Physically preventing pests from entering the greenhouse is an important step as well. Finally, the people responsible for working in a greenhouse can take certain precautions to help prevent pest issues.

Introduction

When prevention does not work to control a pest population, steps must be taken to control the pest in other ways. Biological and chemical control are valid parts of an Integrated Pest Management plan but should not be heavily relied upon or abused.

Chemical pest control requires a great deal of consideration and planning in order to be implemented safely. Biological control takes time to have an effect on pest population and needs to be planned out in advance.

Objectives:

- Understand the challenges and benefits of controlling a pest in a greenhouse environment
- Be able to name at least five preventive measures that can be taken in a greenhouse
- Identify several common greenhouse insect and pathogen pests
- Understand and provide examples of various types of biological controls used to manage insects in a greenhouses
- Know how to properly and safely use chemical controls
- Understand how to read and follow a chemical label
- Know what a mode of action is and give several examples

Why is IPM in a Controlled Environment Different Than IPM in a Field?

The environment in a greenhouse is warm and humid year-round without the benefit of a winter freeze that traditional crop production provides in many geographic areas. This makes greenhouses incredibly favorable for insects and diseases to exist and multiply.

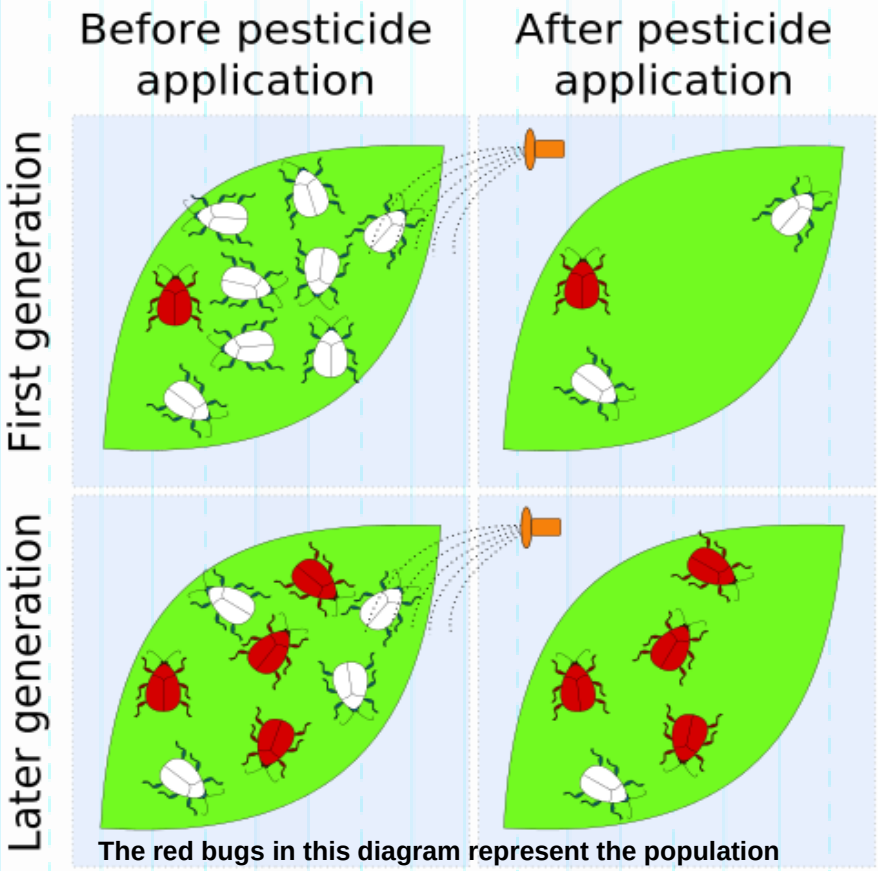
Greenhouses allow plants to grow year-round but also create a welcoming environment for pests. Photo - http://www.lancasterfarming.com/assets/7420264/1210-greenhouse_2.jpg

Why is IPM in a Controlled Environment Different Than IPM in a Field?

Once insects and diseases enter a greenhouse environment, they can multiply freely without predatory pressure. They are also geographically contained and unable to leave.

Management of these pests can be extremely difficult. Because the population is isolated, it is easy for a greenhouse colony to develop resistance.

This is compounded by the fact that certain chemicals that are permitted to be applied in a field environment are not allowed to be used in a greenhouse.



The red bugs in this diagram represent the population resistant to a chemical while the white bugs are susceptible. After a second application of the same chemical, the majority of the remaining population is resistant (red bugs) and continues to reproduce. Image - http://upload.wikimedia.org/wikipedia/commons/6/6e/Pest_resistance_labelled_light.svg

Prevention/Cultural Control

Sanitation

Plant debris should be disposed of efficiently and properly. Greenhouses should be thoroughly cleaned with a disinfecting agent after each crop growth cycle. If at all possible, greenhouses should be left empty for a week in between crop cycles. It is important that greenhouse floors and benches be routinely swept and sanitized.

Any tools that come in contact with plants need to be sanitized regularly. Trash bins should be emptied and cleaned frequently. If possible soil should be autoclaved before use and kept in a sterile environment.

Clothing should remain free of soil and debris.

Poor sanitation practices can lead to pest management problems as well as concerns with safety. Photo - https://www.uvm.edu/~entlab/Greenhouse%20IPM/Scouting.html

Prevention/Cultural Control

Preparation of soil/growth medium

If flats and pots are not discarded after use, they need to be autoclaved or sanitized between uses. If possible soil should be autoclaved (steam pasteurization) before use and kept in a sterile environment.

Chemical fumigation or solarization can also be used to sterilize the soil. The soil should then be removed or allocated using only sterile scoops and containers.

If media disinfection is not feasible, it may help to choose a soil blend that contains composted pine bark or peat as they contain suppressive microbes. Media such as perlite or vermiculite are pre-sterilized and can be considered as well.

Soil steaming is another method of steam pasteurization.
Photo -http://www.soil-steaming-steam-boiler-blog.com/page/2/

Prevention/Cultural Control

Rotation

When at all possible, growing more than one crop type in the same greenhouse should be avoided.

If it is not feasible to leave the greenhouse empty between plant growth cycles, sometimes cycling crop types in the same greenhouse can help reduce pest pressure.

If multiple crops must be grown simultaneously, it is important to scout both crop types for pests even if they are not typically a pest of that crop (i.e. scout corn plants for pests that are antagonists of both corn and wheat).

In this greenhouse it is important to scout for pests of corn and wheat in both crops. Photo - http://kimscountyline.blogspot.com/2013/04/cutting-edge-technology-more-than-bread.html

Prevention/Cultural Control

Greenhouse design

Eliminating UV light in a greenhouse can alter insect behavior and reduce pest pressure. This can be done with UV absorbing plastics or UV reflective mulches.

Insect-proof screening should cover all openings and vents. Using a double entry door can help exclude exterior pests.

Floors and surfaces should be made of concrete so that they can be easily sanitized.

A double entry door can greatly reduce the number of pests brought in to a greenhouse. Photo - http://www.growingcapsicums.com.au/pdf/3_greenhouse_pest_disease/greenhouse_pest_disease.pdf

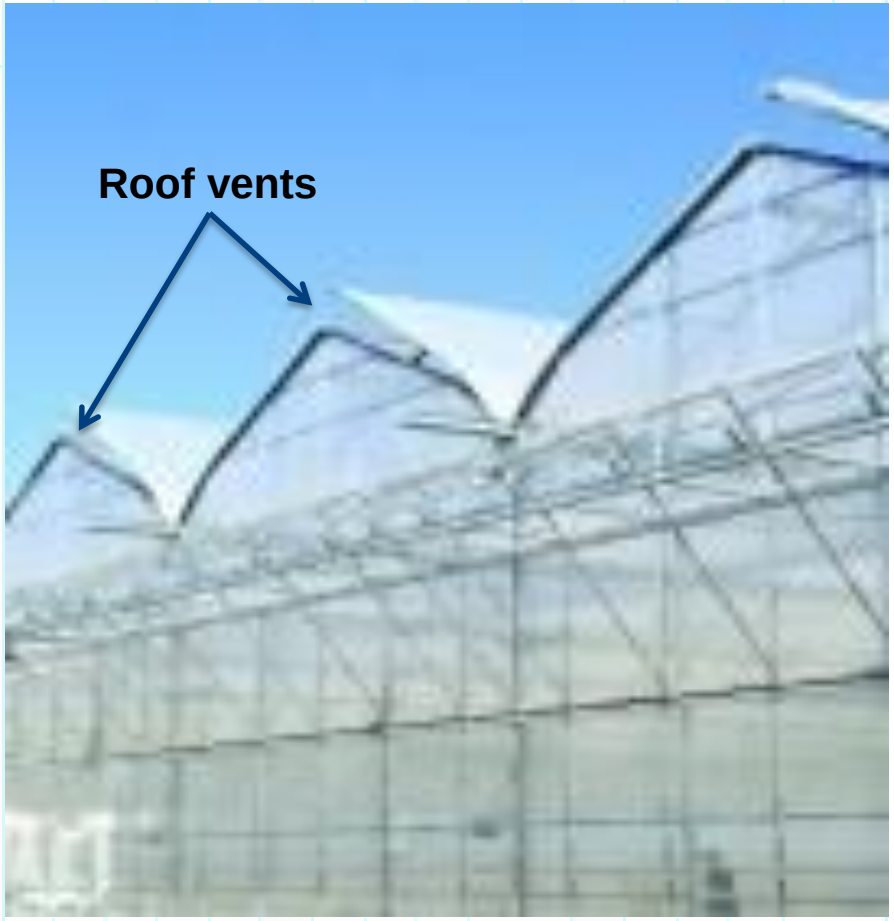
Prevention/Cultural Control

Environmental control

In the greenhouse, the physical environment can be altered slightly to make the environment less favorable to certain pests.

Some pests do not tolerate high or low humidity or air temperature. By changing these conditions the rate of growth of a pest population can be drastically reduced.

Condensation in greenhouses also leads to pest problems as standing water on plant surfaces can harbor diseases and increase humidity. Decreasing condensation on greenhouse surfaces, increasing air circulation with fans or altering the solar radiation inside of the greenhouse can be effective in reducing pest pressure.



Roof vents can also be used to alter ventilation within a greenhouse.
Photo - http://www.greenhousegrower.com/structures-equipment/greenhouses/ggs-open-roof-greenhouse-design-helps-hendriks-greenhouses-with-drip-control-problem/

Prevention/Cultural Control

Worker practices

Foot bath and hand sanitizer stations can be used to prevent pests from entering the greenhouse on employees.

After working in a greenhouse with a known infestation or condition, workers should change clothing before entering another greenhouse.

Foot mats soaked in disinfectant should also be placed outside of each greenhouse entrance to prevent pest transmission between greenhouses.

Disposable gloves and shoe covers can also be used.

Disposable protective gear can be used by employees and visitors when entering sensitive areas of the greenhouse. Photo - http://msue.anr.msu.edu/news/greenhouse_sanitation_is_the_first_step_in_managing_pests_and_pathogens

Prevention/Cultural Control

Quarantine/inspection

When introducing plants arriving from other greenhouses, it is helpful to have a separate section of the greenhouse dedicated to quarantine.

These plants should be visually examined with a hand lens before leaving quarantine. Infested plants can also be quarantined to a treatment area in order to prevent the spread of pests or disease.

When working in the greenhouses, employees should try to do the tasks in the quarantined greenhouse last to avoid going into other greenhouses after potential exposure to pests or pathogens in the quarantined material.

Plants should be visually inspected with a hand lends before being released from quarantine. Photo - http://hdoa.hawaii.gov/pi/files/2013/01/IMG_0026.jpg

Mechanical Control

Sticky traps

Sticky cards are an important tool for greenhouses to monitor pests. They trap adult stages of many flying insects and can help track population trends over time. Sticky sheets should be monitored and replaced regularly.

Sticky cards are generally yellow or blue as these colors attract insects. When being used as a monitoring tool they should be placed just above the plant canopy. At a minimum, there should be one card for every 1000 square feet.

Sometimes sticky traps can be used as insect control as well. This is especially effective in small confined spaces, such as growth chambers.

Yellow or blue sticky cards should be placed just above the plant canopy. Photo - https://www.hummert.com/newsletter/volume-5/a-sticky-situation

Mechanical Control

Vent barriers/screening

Excluding pests from the greenhouse is one of the first steps to an IPM program. All vents and doorways should be screened to prevent pest entry.

Choosing the proper mesh size depends on the targeted insect. Mesh with holes less than 200 micrometers is necessary to exclude some kinds of thrips, but mesh with holes as large as 640 micrometers will exclude leaf miners.

The smaller the holes in the mesh, the more reduced airflow will be. This can be counteracted by increasing the surface area through which the air flows.

This doorway is lined with mesh to prevent the entry of insects. Photo - http://www.linxgreenhouse.com/EquipmentSubCatDetail.asp?eId=10&escId=26

Monitoring

Proposed monitoring guidelines

Greenhouse scouting should be performed at least 1-2 times a week. Monitors should establish a pattern that covers all areas of the greenhouse and cover the same pattern every time.

Plants near doorways or openings in the greenhouse should be checked carefully as that is where new pests would be introduced.

For every 1000 square feet of greenhouse, at least 10 minutes should be spent monitoring at least 20 plants.

At least 3 plants on every bench should be inspected. These plants should be chosen at random.

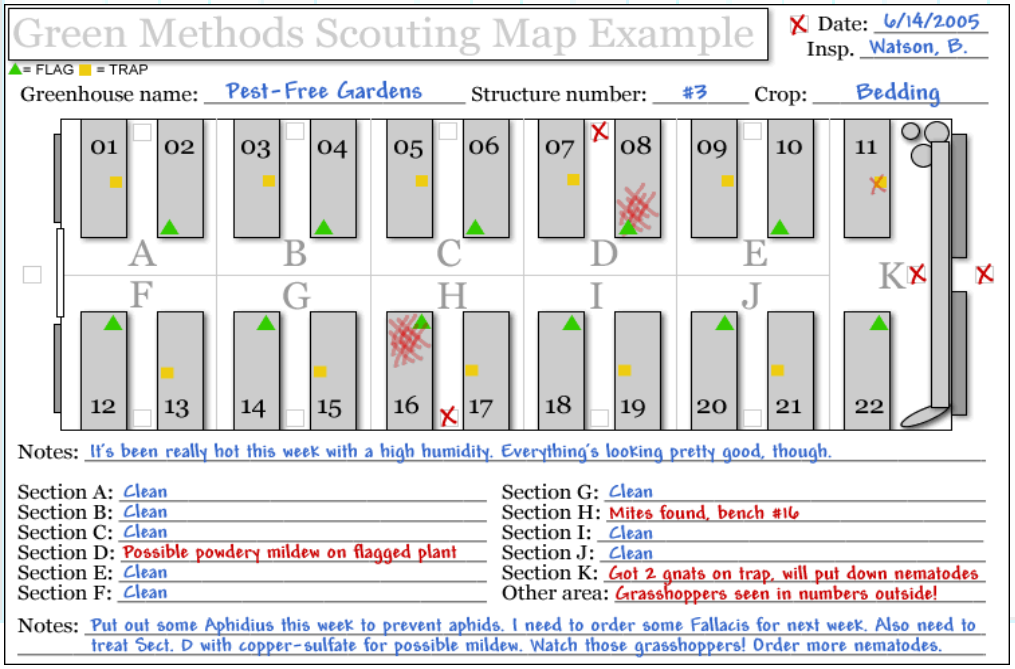
Scouting should be performed meticulously and regularly. Photo: http://longwoodgardens.org/education/college-and-university-programs/internships-for-us-students/internship-areas

Monitoring

If a plant is found to be harboring a pest or disease, it should be marked with a stake and labeled as an indicator plant.

Indicator plants should be checked daily to follow the development of the pest problem and note the rate at which the pest is progressing.

A map of the greenhouses should be kept detailing where sticky traps and indicator plants are located. Scouting dates and crop treatments should be carefully documented as well.



An example of a scouting map noting flags, traps, and problem areas. Photo: https://greenmethods.com/necessary/scouting-plan/

Common Greenhouse Pests

Thrips

There are many species of thrips known to injure greenhouse crops. Visual identification through inspection of plants and sticky traps is the best way to monitor thrips activity.

Sanitation, screening, and a fallow period (soil temperature maintained at 60° F) are all non-chemical control methods. Air temperatures of 104° F with relative humidity of 10% have also been effective at thrips control.

Greenhouse thrips (*Heliothrips haemorrhoidalis*) are a common pest in greenhouses. Photo: http://169.237.77.3/news/thripsworkshop.html

Common Greenhouse Pests

Thrips

Thrips can be scouted by tapping or shaking crop flower over a white sheet of paper. Lightly blowing into flowers or whorl will lure them out as well.

Signs of thrips damage include leaf spots, brown or oozing patches, necrotic leaves, and concentric rings or striations on leaves.

With more severe damage deformed leaves, buds, and flowers may be observed.

Thrips also transmit over 20 viruses including tomato spotted wilt virus and capsicum chlorosis virus.

Spots that appear bleached from thrips damage are visible on a corn leaf.
Photo: http://extension.entm.purdue.edu/fieldcropsipm/insects/corn-occasionals.php

Common Thrips Species of North American Greenhouses

Greenhouse Thrips
Heliothrips haemorrhoidalis

Western Flower Thrips
Frankliniella occidentalis

Pop-up Information on each species

Eastern Flower Thrips
Frankliniella tritici

Onion Thrips
Thrips tabaci

Photos: https://firstdetector.org/pdf/chili_thrips_deck.pdf

Common Greenhouse Pests
Pop-up information

Greenhouse thrips
(*Heliothrips haemorrhoidalis*)
- Fairly distinctive species
- Primarily feeds on foliage
- Adults: 1 mm in size
- Eggs may be visible with hand lens

Western flower thrips
(*Frankliniella occidentalis*)
- Adult females: 1.5 mm in size
- Adult males: 1.1 mm in size
- Prefers feeding on flowers
  Feeds on spider mites

Eastern flower thrips
(*Frankliniella tritici*)
- Adult females: 1 mm in size
- Males slightly smaller
- Prefer to feed on flowers, fruits, stems
- Well developed setae visible on anterior of thorax

Onion thrips
(*Thrips tabaci*)
- Adults: 1.3 mm in size
- Primarily feed on new plant growth
- Known vector for TSWV
- Distinguished by gray eyes and 7-segmented antennae

Common Greenhouse Pests

Mites

Spider mites are web-forming mites that pierce plant cells and remove their contents, resulting in a pale green mottling on leaves. Mites can be scouted by identification of the insects with a hand lens or by looking for signs of mite damage or webs.

Production areas should be kept free of weeds that can host mites. Mites are more prevalent in drip-irrigated greenhouses and can be reduced by washing off the surfaces of the plants.

Over-fertilization of plants can also promote succulent new growth that is favored by mites and will enhance reproduction.

In severe infestations, twospotted spider mite (*Tetranychus urticue*) webbing will overtake entire plants. Photo: http://badger.uvm.edu/xmlui/bitstream/handle/2051/4383/spidermites%20%281%29.JPG?sequence=1

Common Greenhouse Pests

Mites

Scanning electron micrograph of a two-spotted spider mite feeding on a rose leaf. Photo by Eric Erbe, USDA, ARS.

Pop-up Information

Adult female false spider mites or flat mite . Photo – USDA - http://entnemdept.ufl.edu/creatures/orn/mites/Brevipalpus_phoenicis.htm

Pop-up Information

Bud, gall, rust or eriophyid mites. Photo - http://www.sel.barc.usda.gov/acari/content/eriophyoidea.html

Pop-up Information

Pop-up Information

Broad and cyclamen mites can only be viewed by a microscope. Microscope close-up of broad mites on impatiens. Photo - http://www.missouribotanicalgarden.org/Portals/0/Gardening/Gardening%20Help/images/Pests/Cyclamen_and_Broad_Mites438.jpg

Common Greenhouse Pests

Mites – Pop-up Information

Two-spotted spider mite
(*Tetranychus urticae* Koch)

- Mite produces a fine silk webbing where its eggs are attached
- Eggs hatch in approximately 3 days
- Life cycle is completed in 5 – 20 days
- Many overlapping generations per year
- Prefers hot, dry weather conditions of summer
- Found primarily on the underside of leaf
- Mite feeding causes graying or yellowing of leaf tissue

Bud, gall, rust or eriophyid mites
(*Phyllocoptes fructiphilus* Keifer)

- Associated with most rose species and cultivars
- Carries rose rosette virus disease
- Multiple generations per year; mite produces 1 egg per day for 30 days
- Eggs appear like jewels under microscope
- Damage appears on underside of young leaves
- Damage results in leaf scalloping or deformed buds

False spider mites or flat mite
(*Brevipalpus phoenicis*)

- These mites do not spin a web.
- Hosts: as many as 1000 plants
- Longer life cycle than two-spotted spider mite
- Lay eggs on surface and underside of leaf
- Feeding of mite causes collapse of mesophyll cells in the plant.
- Known to transmit citrus leprosis virus
- Also feed on stems of plant

Broad and cyclamen mites
[*Phytonemus pallidus* (Banks)]

- Mites often found in corms of cyclamens in storage
- Overwinters in an adult stage
- Life cycle is 1 to 3 weeks per generation
- Pest of many ornamental flowers and shrubs
- Damage consists of streaked and/or blotched appearance, distorted leaves with small distorted flowers, galls

Common Greenhouse Pests

Fungus gnats

Fungus gnats are a pest unique to greenhouses and enclosed growing environments. They are not usually considered a pest of outdoor crops.

Fungal gnats spend the most time in the larva and pupa stages so these are the easiest to control. Because they thrive in moist conditions, it is important to avoid overwatering and to provide good drainage.

Fungus gnats feed on organic and decaying matter so incompletely composted planting media can harbor them. Organic fertilizers, such as manure, or blood meal also cause them to thrive.

An adult fungus gnat (*Bradysia* spp.) is seen caught in a yellow sticky trap. Photo: https://mrec.ifas.ufl.edu/lso/fungusgnats.htm

Common Greenhouse Pests

Fungus gnats

As with most other pests, exclusion through the netting of entrances is an effective prevention method.

Fungus gnat population can be reduced through the use of yellow sticky traps. Raw potato is also very attractive to fungus gnat larvae. Chunks of raw potato can be placed on the soil to check pots for larvae as well as to trap them.

Fungus gnats serve as a vector for many fungal diseases and the root feeding of larvae allows the entry of soil-borne pathogens into the plant.

Fungus gnat larva.
Photo: http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn7448.html

Biological Control

Biological control uses natural enemies that are predators, pathogens, and/or parasitoids to manage pest populations.

Predators feed on target pests but do not reproduce in them. They eat more than one pest throughout their life cycle. Predators are not as host-specific as parasitoids. Often predators will lay their eggs near a target pest so that when the eggs hatch, there is a source of food nearby.

Parasitoids are insects that deposit eggs on or in a pest. The parasite develops in the pest and kills it. Parasites are more host-specific and each individual parasite only results in the death of one host organism.

Pathogens are organisms that cause fatal disease to the insect pest. They can be fungi, bacteria or viruses.

Biological control can be difficult and expensive to implement but is a viable option for integrated pest management in a greenhouse and can be more successful long-term than continuous chemical application.

Predators

Predators are a viable option in a greenhouse environment because they can be contained and are not able to physically leave the infested area. This forces them to prey on the target organism.

It is best to have a predator that thrives in the same conditions as the pest. Make sure that the predator is suited for the affected crop.

Predatory biological control can fail:

- ✓ if too few individuals are released
- ✓ if the predator adapts poorly to the environmental conditions
- ✓ if there is a lack of synchrony between the natural enemy and target pest.

A lady beetle is seen preying on an aphid. Photo: http://www.utcrops.com/cotton/cotton_insects/biocontrol/biological_control.htm

Predators

Examples of some common predators used in greenhouses and their respective pest target are presented in the table below.

Target Pest	Common Name	Genus species Name
Spider mites, some beetles	Western predatory mite	*Galendromus occidentalis*
Spider mites	Predatory mite	*Phytoseiulus persimilis*
Spider mites	Sixspotted thrips	*Scolothrips sexmaculatus*
European corn borer, spider mites	Spider mite destroyer lady beetle	*Stethorus picipes*
European corn borer, thrips, spider mites, aphids	Minute pirate bug	*Orius* spp.
European corn borer, aphids, spider mites	Bigeyed bug	*Geocoris* spp.
European corn borer, fungus gnats, thrips	Green lacewing	*Chrysopa* spp., *Chrysoperla* spp.
Aphids	Western flower thrips	*Frankliniella occidentalis*
Aphids, thrips	Predatory mirid bug	*Macrolophus caliginosus* Wagner
Aphids, thrips	Predatory mirid bug	*Dicyphus tamaninii* Wagner
Beetles, thrips	Predatory mite	*Amblyseius* spp.
Beetles, thrips	Predatory thrips	*Aeolothrips* spp., *Haplothrips* spp.
Beetles, aphids	Ladybird beetles	Many species
Fungus gnats, aphids	Predacious midge	*Aphidoletes aphidimyza*
Fungus gnats	Predatory mites	*Hypoaspis* spp.
Fungus gnats	Hunter flies	*Coenosia* spp.
Fungus gnats	Rove beetle	*Atheta coriaria*

Predators

Western predatory mite
(*Galendromus occidentalis*)

- Size of a twospotted spider mite, but lack spots
- Color vary cream to amber red – depending on what they recently consumed
- Life cycle consist of egg stage, a six-legged larval stage, 2 eight-legged immature nymphal stage, and adult stage
- Both the nymphal stage and adult stage can feed on all stages of spider mites (egg to adults)
- Tolerates hot climates as long as relative humidity is above 50 percent

Western predatory mite feeding on spider mite eggs. Photo **–** E. Beers, WSU-TFREC

Predatory mite
(*Phytoseiulus persimilis*)

- Adults are bright reddish-orange in color
- Long legs and pear-shaped body
- Immature predators are salmon colored
- Adults are 0.5 mm long, eggs are 0.3 mm long (twice the size of spider mite eggs)
- Consume egg, nymph, and adult stages of pest mites
- Thrive in humid environments as opposed to pest mites which prefer dry
- Over-winters and sustains on pollen
- Consume 5-30 prey daily

A predatory mite (red mite on right) feeds on a pest mite. Photo **-** http://www.arbico-organics.com/product/mite-predator-phytoseiulus-persimilis-spidermite-killer-greenhouse/pest-solver-guide-mites

Parasitoids

Insect parasitoids have an immature life stage that develops on or within a single insect host and result in death of the insect host. Adult parasitoids are free-living and may also prey on insects.

Most parasitoids only attack a particular life stage of one or several closely related species. The life cycle of the pest and parasitoid may coincide or the life cycle of the pest may be altered by the parasitoid to accommodate its development.

Parasitoids kill more slowly than predators but are more efficient in completing their life cycle. Some parasitoids can be parasitized by other parasitoids, which decreases their effectiveness.

A parasitoid wasp is seen attacking a soybean aphid. Photo - http://fyi.uwex.edu/fieldcroppathology/soybean_pests_diseases/aphid_parasitoids/

Parasitoids

Examples of some common parasitoids used in greenhouses and their respective pest target are presented in the table below.

Target Pest	Common Name	Genus species Name
Thrips	Greenhouse thrips parasite	*Thripobius semiluteus* Boucek
Thrips, beetles	Nematodes	*Steinernematidae* spp.
Thrips	Nematodes	*Heterorhabditidae* spp.
Thrips	Sphaerulariid	*Thripinema nicklewoodi*
European corn borer	Tachinid fly	*Lydella thompsoni*
European corn borer	Wasps	*Eriborus terebrans, Macrocentrus grandii*
Thrips, aphids, European corn borer	Parasitic wasps	*Hymenoptera* spp.
Beetles	Winsome fly	*Isocheta aldrichii*
Beetles	Tiphiid wasps	*Tiphia vernalis, Tiphia popilliavora*
Fungus gnats	Sciarid parasitoid	*Synacra paupera*

Parasitoids

Greenhouse thrips parasite
(*Thripobius semiluteus* Boucek)

- Only attacks *Heliothrips haemorrhoidalis*
- Uniparental (all individuals are female)
- Adult female inserts an egg inside the body cavity of a thrips larva
- Parasitized thrips is eventually killed by the parasite
- Entire body cavity of thrips is filled by wasp larva
- Parasite transforms into black pupa

A distorted parasitized thrips appears on the right with a black parasitoid pupa in the center and a normal thrips pupa on the left. Photo - http://ucce.ucdavis.edu/files/repository/calag/img4506p31b.jpg

Nematodes
(*Steinernematidae* spp., *Heterorhabditidae* spp.)

- *Heterorhabditidae* only effects thrips in soil and causes 36-49% mortality
- *Steinernematidae* causes anywhere from 4-77% mortality
- Non-feeding, developmentally arrested juvenile seeks out insect hosts and initiates infections
- Penetrate body cavity via natural body openings or in areas of thin cuticle
- Symbiotic bacterium *Xenorhabdus* (*Steinernematidae*) or *Photorhabdus* (*Heterorhabditidae*) is released from the nematode gut which multiplies and causes insect death
- Nematodes feed on bacteria and liquefying host and mature into adults
- *Steinernematidae* may become males or females, while *Heterorhabditidae* develop into self-fertilizing hermaphrodites (although subsequent generations within a host produce males and females)
- *Steinernema scarabaei* can parasitize beetle larvae

Infective juvenile stage of *Steinernema carpocapsae*. Photo - http://entnemdept.ufl.edu/creatures/nematode/entomopathogenic_nematode.htm

Pathogens

Pathogens can be fungal, viral, protozoan or bacterial. They can be highly lethal or simply slow insect development, shorten an insect's life or prevent reproduction.

Pathogens are usually highly selective and only work on a certain species. Specific conditions are required depending on the type of pathogen used.

Fungal pathogens require high humidity to be effective. Viral pathogens work best when the host population is high because this facilitates the spread of the disease within the population.

Bacterial pathogens must be ingested to be effective and do not work on sucking insects, such as aphids.

***Verticillium lecanii* is seen infecting a thrips larva.**
Photo - http://learningstore.uwex.edu/assets/pdfs/ncr581.pdf

Pathogens

Examples of some common pathogens used in greenhouses and their respective pest target are presented in the table below.

Target Pest	Common Name	Genus species Name
Thrips, aphids	Fungal pathogen	*Verticillium lecanii*
Thrips, aphids, beetles, spider mites	Fungal pathogen	*Beauveria bassiana*
Thrips, European corn borer, aphids	Microsporidian	*Nosema pyrausta*
Thrips, fungus gnats, European corn borer	Bacterium	*Bacillus thuringiensis*

Pathogen

Verticillium lecanii

- Fungal mycelium produces a toxin which infect insect pests resulting in their death
- Fungal spores come in contact with the cuticle of the insect, the spores germinate, and grow through the insect cuticle to inside of the insect
- Fungus grows throughout the insect consuming nutrients within the insect which results in insect death in 48-72 hours
- Fungi are unaffected by day length and environment
- Are slow-acting and of low effectiveness

Aphid covered with fungal mycelium. Photo - https://www.flickr.com/photos/koppert/2775536659/

Beauveria bassiana

- Grows as a white mold and produces dry, powdery **conidia** in distinctive white spore balls.
- Causes a disease called white muscardine disease
- Spores enter directly through insect's skin
- Conidium adhering to host cuticle will germinate
- Fungus secretes enzymes which attack and dissolve cuticle, allowing fungus to enter insect body and grow
- Produces toxin called Beauvericin that weakens the host's immune system

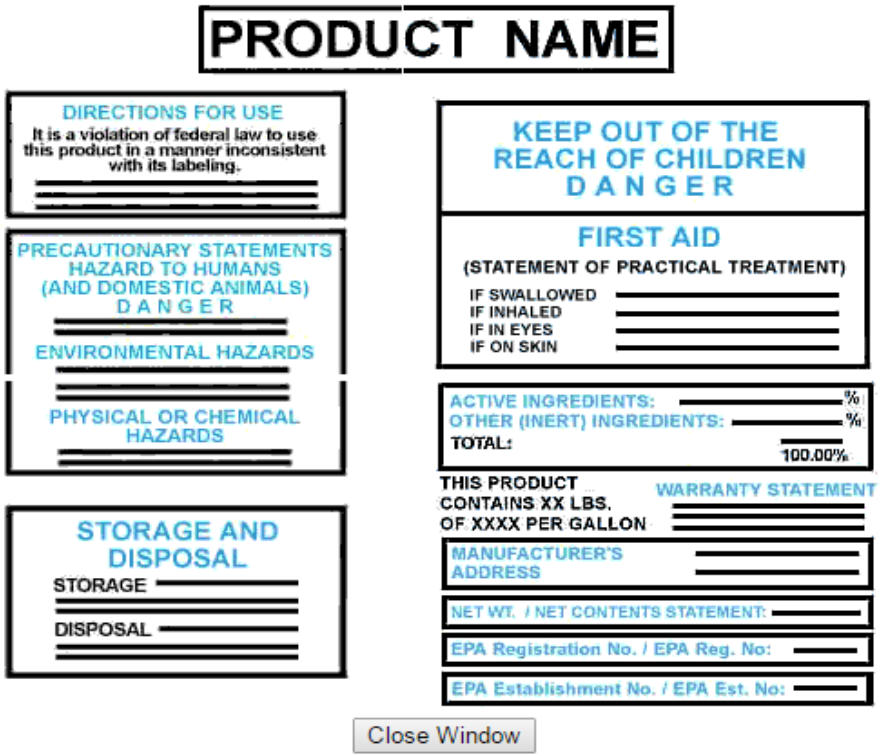
An early stage corn borer died on a leaf covered in *Beauveria bassiana*. Relative humidity must be greater than 92% for fungal spores to grow outside of the host. Photo - http://www.ent.iastate.edu/pest/cornborer/larva-leaf-killed-fungus

Pesticide Control

Good pesticide practices

There are a few things that need to be done to ensure the maximum efficacy of a pesticide application.

- Make sure the pesticide is not expired.
- Check the pesticide label for usage instructions and safety considerations.
- Mix the pesticide at the concentration directed by the label.
- Use proper equipment to apply the pesticide.
- Adjust the droplet size as needed.
- Cover all areas of the plant, even the undersides of leaves if needed.
- Ensure that particle distribution is even.



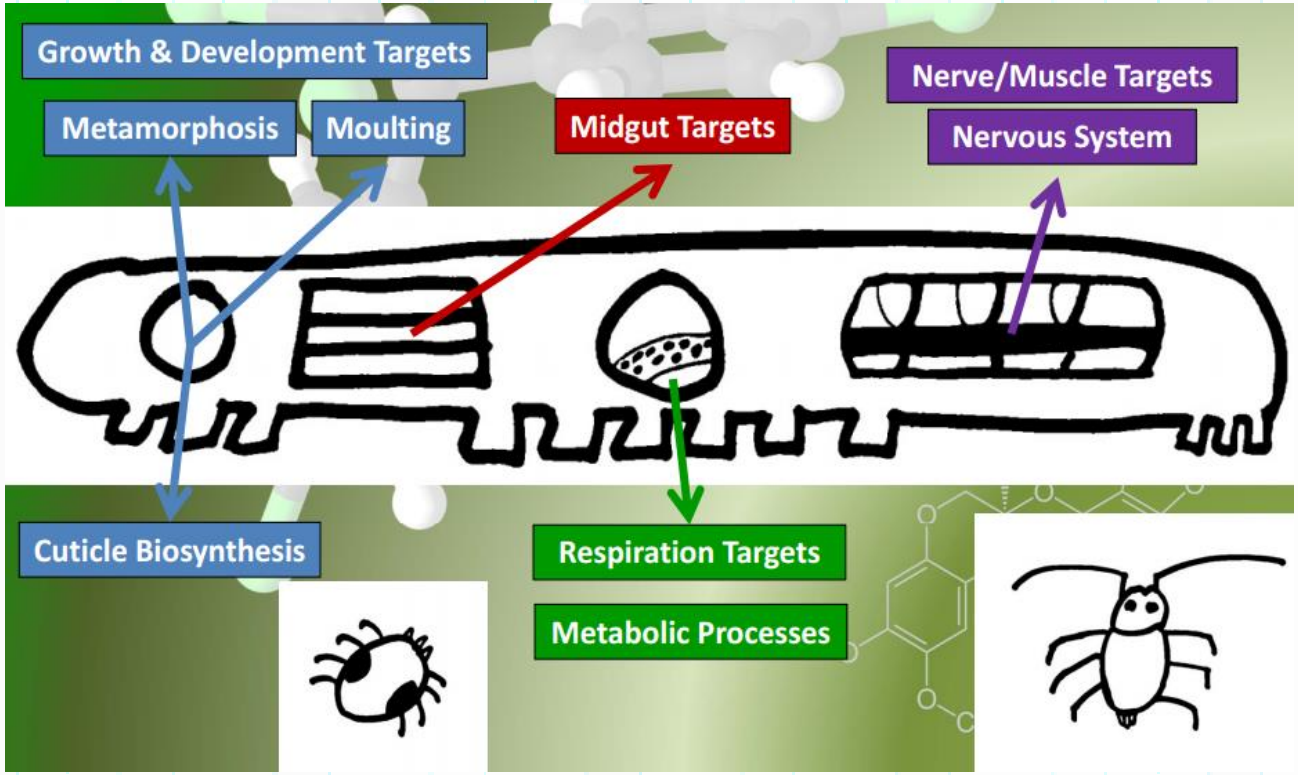
An example of the information contained on a pesticide label is shown above. Photo - http://www.epa.gov/pesticides/kids/hometour/label/read.htm

Always Read and Follow Product Label Instructions

Pesticide Control

Insecticides

Insecticides may affect a number of various functions within the insect. Which functions that are affected will depend on the respective insecticide.



Different modes of action are shown in the diagram above. Slide - http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/crop15019/$FILE/greenhouse-pesticide-options-rob-spencer.pdf

Pesticide Control

Insecticides

Growth & Development Targets

- Prevents insect development from one stage to another stage during metamorphosis and molting
- Inhibits exoskeleton formation by inhibiting cuticle biosynthesis
- Can cause premature molting

Respiration Targets

- Disrupts the insect's metabolic processes
- ATP synthesis may be inhibited
- Energy production within the insect is reduced
- There can be a number of metabolic targets affected which all affect the energy production and utilization within the insect

Midgut Targets

- Specific for butterfly and moth larvae
- Insecticide is ingested resulting in pore formation in the gut lining of the insect
- Results in a stop in insect feeding followed by starvation

Nerve/Muscle Targets

- A large number of insecticides affect these targets
- A number of different actions can occur
- Nervous system can be hyper-excited resulting in the insect to have spasms, be disoriented, be jumpy with finally paralysis
- Fine motor control responsible for feeding can be blocked
- These insecticides are also toxic to humans affecting the human nervous system

Sample Quiz Questions

1. What is the first step of an Integrated Pest Management program?
   - **a. Prevention**
   - b. Monitoring
   - c. Biological Control
   - d. Chemical Control

2. Which option below does NOT describe a greenhouse condition favorable to pests?
   - a. Humid environment
   - b. Hot temperature
   - **c. Winter freeze**
   - d. Sunny year round

3. Why do insects thrive in greenhouses?
   - a. Impossible for insects to develop resistance
   - b. Can freely leave geographical area
   - c. Wider variety of chemicals available than in the field
   - **d. Lack of predators**

Module includes 36 multiple choice quiz questions

Conclusion

- Module aids in insect and disease identification and management
- Shares ideas for prevention and cultural control
- Introduces concept of biological control
- Hope to prevent misuse of chemical control

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Questions