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SEMINAR
— SERIES —

Biological Control Agents

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What is Biological Control?

- The suppression/control of pests through the use of natural enemies
  - Beneficial action of predators, parasitoids, and pathogens
  - Organic/environmentally sound pest management

Why use biological control?

- Increase in environmental stewardship
  - Sustainable farming practices
  - Increased pesticide regulations
- Pests developing resistance
- Consumers demanding sustainably grown produce

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Types of Implementation

Importation (Classical)

- Importing a pests natural enemy from another region for permanent establishment
- Requires government authorization & time
- Goal: long term establishment

Tamarixia radiata

Types of Implementation

Augmentation

- Periodic release of natural enemies
  - Boost naturally occurring & non-native populations: *N. californicus*
- Released at specific times in production or multiple times throughout the season

Neoseiulus californicus

Types of Implementation

Conservation

- Conserving existing natural enemies through habitat modification
- Increasing species diversity & complexity of plants

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Parasitoids

- Wasps (e.g. braconid wasps), tachinid flies
- Attack pests and spend part or all of their life cycle in/on a single host
  - Ecto-parasitoids
  - Endoparasitoids

Alex Wild

Parasitoids vs Parasite

Spends most of its lifetime developing in its host.

Kills its host

Shorter lifecycle than host & do not usually kill its host

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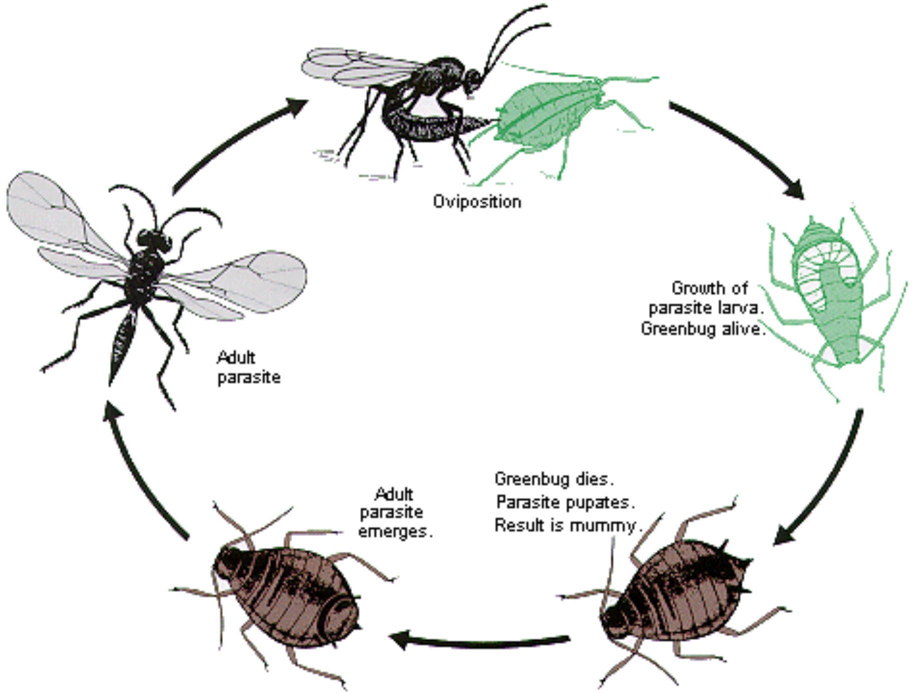
Parasitoids



The life cycle of an aphid parasite. *Lysiphlebus testaceipes*.

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Ecto-parasitoids: eggs laid outside the body, hatch & consume the host.

Egg parasitoid

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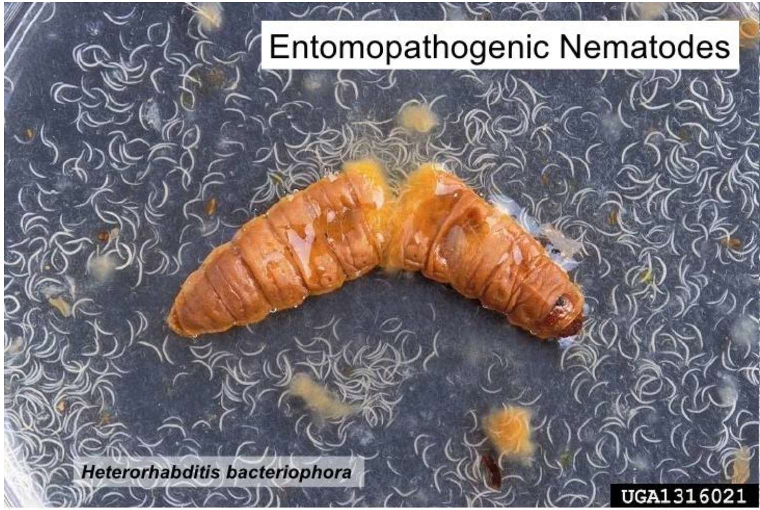
Pathogens

- Bacteria, viruses, nematodes, & fungi that cause disease in pests
- Similar to parasitoids, pathogens also kill their host



What types of pathogens are out there?

- *B.t. (Bacillus thuringiensis)*
  - Naturally occurring spore forming soil bacterium
  - Produces crystal proteins, which are toxic to many species of insects
  - Subspecies/varieties can be active against an entire order of insects or only a few species

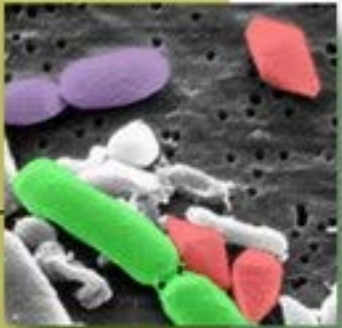
B.t. var *kurstaki:* active against larvae of moths & butterflies only

B. popilliae var popilliae : active against grubs of Japanese beetles, but not masked chafers

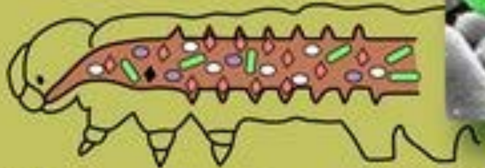
Japanese beetle

Masked chafer

Bt endospores
Bt crystalline toxin
Bt whole bacteria
Normal gut bacteria



Scanning electron microscope image of Bt showing whole bacteria (green), endospores (violet), and crystal protein toxins (red).



Within minutes, the toxin binds to specific receptors in the gut wall, and the caterpiller stops feeding.

Within hours, the gut wall breaks down allowing spores and normal gut bacteria to enter body cavity.

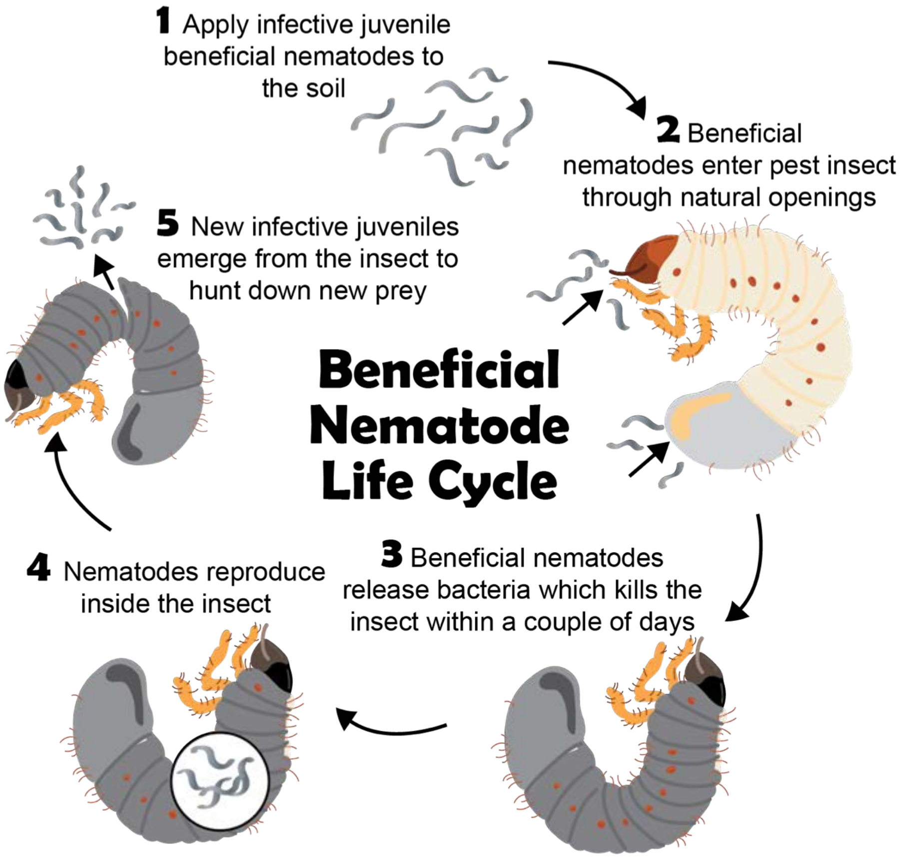
24 to 48 hours later.

Dead cabbage looper. Those killed by BT may turn black and/or become shrivelled.

What types of pathogens are out there?

- Entomopathogenic Nematodes
  - Simple roundworms, colorless, unsegmented
  - Parasitic & predaceous on many soil dwelling pests
  - Mass produced & used as biopesticides
  - High degree of safety on plants & animals
    - Safe for pollinators, groundwater, no chemical residue

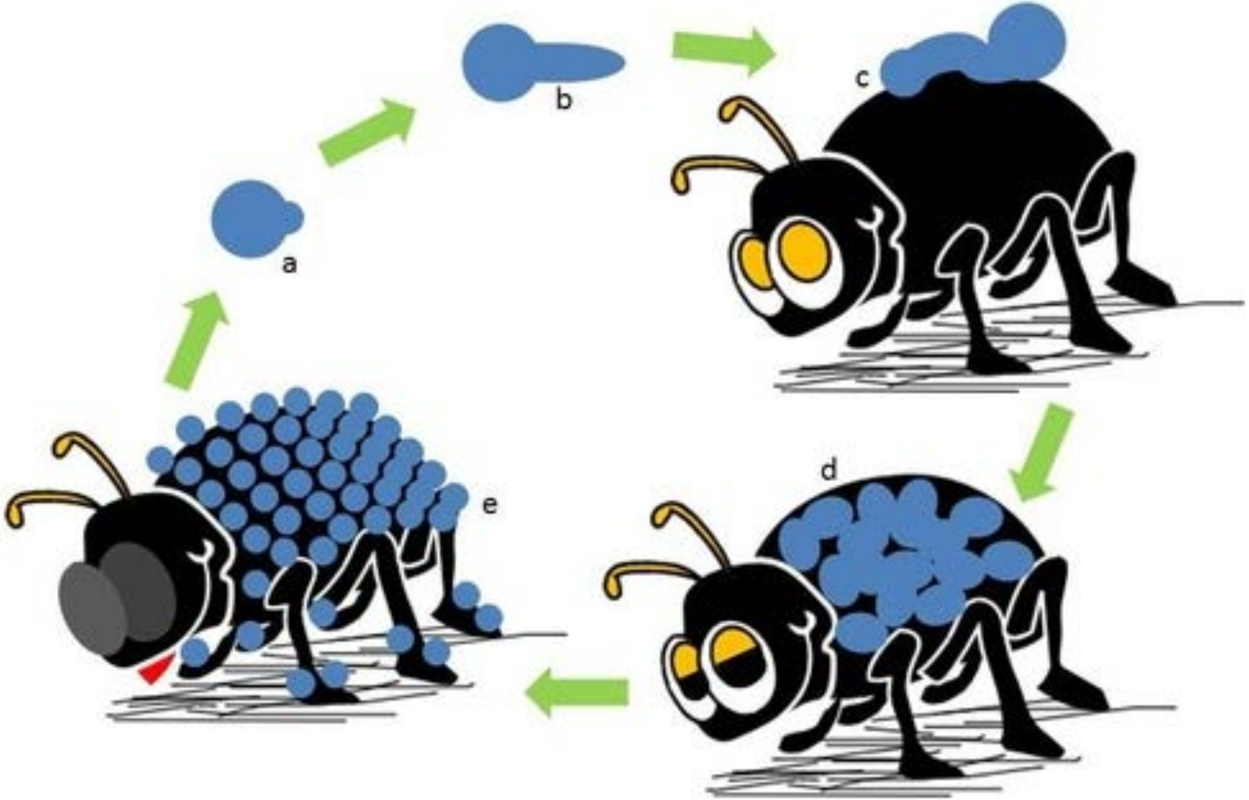
Steinernematidae
Heterorhabditidae



What types of pathogens are out there?

- Entomopathogenic fungi
  - Act as a parasite on arthropods & kill or disable its host
  - Invade their host directly through the cuticle
  - Do not need to be ingested. Can infect eggs & pupae of pests
  - Low cost & safe for beneficials

Beauveria bassiana



Mode of infection of entomopathogenic fungi. Conidial spore (a) in the formulation or discharged from an infected cadaver germinates and produces a germ tube (b). It produces an appressorium (c) on insect cuticle when it finds an ideal penetration site. Upon successful entry into the host body, it divides and produces hyphal bodies and invades the host tissues (d). Fungus emerges from the dead host and produces more conidial spores (e).

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What types of pathogens are out there?

- Baculoviruses
  - Large group of double-stranded DNA viruses
  - Species-specific, narrow host range
  - Safe on plants, other animals, & non-target insects
  - Has to be ingested by target pest
  - Downside: no commercial production yet

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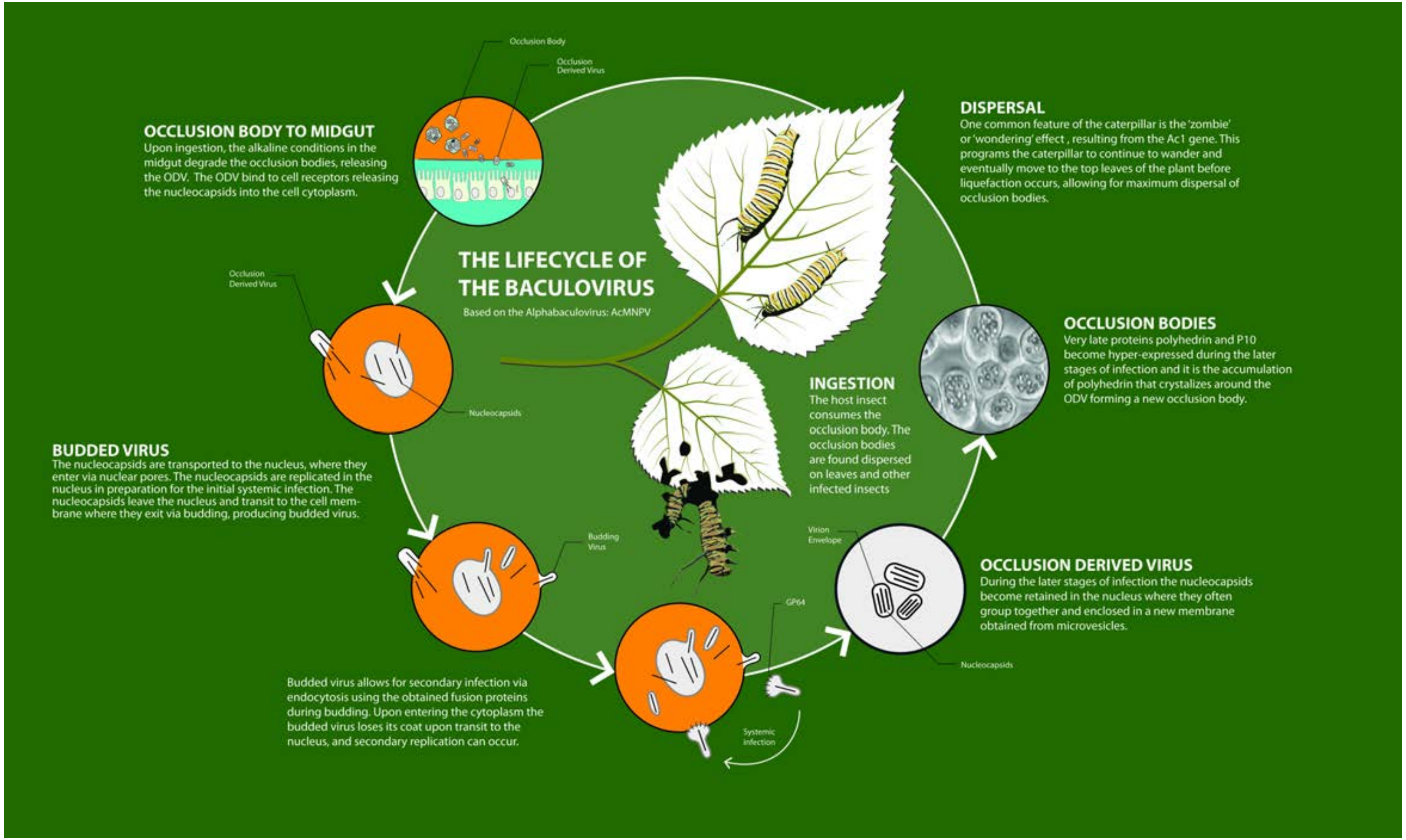

THE LIFECYCLE OF THE BACULOVIRUS
Based on the Alphabaculovirus: AcMNPV
Occlusion Body
Occlusion Derived Virus
OCCLUSION BODY TO MIDGUT
Upon ingestion, the alkaline conditions in the midgut degrade the occlusion bodies, releasing the ODV. The ODV bind to cell receptors releasing the nucleocapsids into the cell cytoplasm.
DISPERSAL
One common feature of the caterpillar is the 'zombie' or 'wondering' effect, resulting from the Ac1 gene. This programs the caterpillar to continue to wander and eventually move to the top leaves of the plant before liquefaction occurs, allowing for maximum dispersal of occlusion bodies.
Occlusion Derived Virus
Nucleocapsids
OCCLUSION BODIES
Very late proteins polyhedrin and P10 become hyper-expressed during the later stages of infection and it is the accumulation of polyhedrin that crystalizes around the ODV forming a new occlusion body.
INGESTION
The host insect consumes the occlusion body. The occlusion bodies are found dispersed on leaves and other infected insects
BUDDED VIRUS
The nucleocapsids are transported to the nucleus, where they enter via nuclear pores. The nucleocapsids are replicated in the nucleus in preparation for the initial systemic infection. The nucleocapsids leave the nucleus and transit to the cell membrane where they exit via budding, producing budded virus.
Budding Virus
Virion Envelope
OCCLUSION DERIVED VIRUS
During the later stages of infection the nucleocapsids become retained in the nucleus where they often group together and enclosed in a new membrane obtained from microvesicles.
GP64
Nucleocapsids
Budded virus allows for secondary infection via endocytosis using the obtained fusion proteins during budding. Upon entering the cytoplasm the budded virus loses its coat upon transit to the nucleus, and secondary replication can occur.
Systemic infection

Biological Control Agents

Predators

- Generalist & specialist
- Kill & feed on many individuals in their lifetime
- Excellent searching & dispersal abilities



Some Commercially available predators

- Lacewings
- Ladybird beetles
- Predatory mites
- Predatory true bugs
- Predacious snails






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- Release rates depend on species of predator, pest species, pest pressure, crop (artchitecture, growth state, etc).
- Each predator has their own behavior that must be taken into account
  - Can be different even for a group of predators
  - Example: predatory mites…


Associates Insectary

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Type I (Specialist)	Type II (Selective of Tetranychids)	Type III (Generalist)	Type IV (Pollen feeders/generalist)
P. persimilis	*N. californicus*	*A. andersoni*	*Euseius spp.*
	N. fallacis	*A. swirskii*	
	Galendromus occidentalis	*N (A). cucumeris*	
		Ambylromalus limonicus	

Now that I know what BCA's are, how can I incorporate them into my IPM program?

Incorporation requires knowledge & understanding of interactions with crop management practices

- They are living organisms
- Safeguarding can conserve populations
- Environment can affect control efficacy
  - Temperature, humidity, prey & other food sources, crop type, pesticides

Scouting is your best friend!

- What pests are out?
  - Narrow your BCA's
- What's the weather like?
  - Narrow your BCA's based on temperature

Species	Temperature	Egg	Egg to Adult
P. persimilis	59	8.6	19.6
T. urticae	59	14.3	32.9
N. californicus	55	8	22.4
P. persimilis	86	1.7	3.9
T. urticae	95	2.4	5.7
N. californicus	91	1.6	3.7

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Know how pesticides affect BCAs

- BCAs are exposed to pesticides:
  - Directly: Spray contact/interception
  - Indirectly: Exposure to residues, eating contaminated food

- Understanding how pesticides affects BCAs can aid in timing releases
  - BCA's need to re-invade sprayed areas to provide control of pest resurgence

Know how pesticides affect BCAs

- Understanding how pesticides can affect BCAs will increase their success
  - Don't swim against the current!

- This can also help you decide which BCA you should release

Know how pesticides affect BCAs

- Differences in toxicity of products to diff. phytoseiids
  - E.g. Spinosad highly toxic to *A. swirskii,* harmless to *T. montdorensis*
- Important for choosing toxicity indicator species
  - You may see 1 spp. and wonder why others are absent.

Persistence of pesticides

Active	Category	*Phytoseiulus persimilis* Athias-Henriot	*Neoseiulus californicus* (McGregor)	*Neoseiulus cucumeris* (Oudemans)	*Amblyseius degenerans* (Berlese)	*Amblyseius swirskii* (Athias-Henriot)	*Amblydromalus limonicus* (Garman and McGregor)
abamectin	I,A	1-2 w	5 d 4 w	2 w	1-2 w	1-2 w	2 w
acetamiprid	I	1-3 w	5 d- 1 w	5 d	1 w	1-3 w	?
Bacillus thuringiensis var. *kurstaki*	I	0	0	0-1 d	0	0-1 w	?
bifenazate	I	1->1 w	0	0	?	0	0
chlorpyrifos	I	0-3 d	2 w	6-8 w	6-8 w	?	?
citric oil	I	?	?	?	?	?	0
clofentezine	A	0	0	0	0	?	?
diflubenzuron	I	0	0	0	0	?	?
indoxacarb	I	0	0	0	0	?	?
lambda-cyhalothrin	I	8-12 w	?	8-12 w	8-12 w	?	?
maltodextrin	I	?	?	?	?	?	0
methoxyfenozide	I	0	0	?	?	0	?
pirimicarb	I	3 d	0	0-3 d	0-3 d	0	?
pymetrozine	I	0	0	0	0	0	0
pyrethrin + piperonyl butoxide	I	0-1 w	1 w	1 w	1 w	?	?
pyrethrin + resmethrin	I	0.5 w	?	2 w	2 w	?	?
spinosad	I	1 w	0	1-2 w	0	1-2 w	?
spirodiclofen	A,I	2-3 w	?	?	?	2-3 w	?
spirotetramat	I	3-6 w	?3d	?	?	? 1w	?
tebufenpyrad	A	1-2 w	0	?	?	?	?
thiacloprid	I,A	2 w	?	0	?	0	?
thiamethoxam	I	>2 w	?	?	?	1 w	?
Lecanicillium lecanii-m	I	0	0	0	0	0	?

I = Insecticide
A = Acaricide

Fountain & Medd 2015

From Koppert, IPM impact & Biobest database

Effects on Foraging

- Residues on prey may repel some species, but not others
  - This may make outcome of control less predictable
- Residues on other food sources (pollen) can also negatively affect populations

UC IPM has information on toxicity of selected pesticides used on avocado on BCAs…

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UC IPM

Statewide Integrated Pest Management Program

- HOME
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ON THIS SITE

- What is IPM?
- Home & landscape pests
- Agricultural pests
- Natural environment pests
- Exotic & invasive pests
- Weed gallery
- Natural enemies gallery
- Weather, models & degree-days
- Pesticide information
- Research
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MAKE A GIFT

How to Manage Pests

Avocado

All crops

Year-Round IPM Program

Tells you what you should be doing throughout the year in an overall IPM program. Includes Year-Round IPM Program Annual Checklist.

Using a year-round IPM program | Forms and supplemental pages

Year-Round IPM Program for Avocado (9/16)

- Bloom
- Early fruit development
- Late fruit Development
- Harvest

UC IPM Pest Management Guidelines

University of California's official guidelines for pest monitoring techniques, pesticides, and nonpesticide alternatives for managing pests in agriculture, floriculture, and commercial turf. More

Authors & credits | All crops | Download PDF | Recent updates

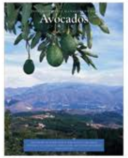
General Information

- Manipulating Cultural Practices and Growing Conditions (9/16)
- Timings for Key Cultural/Monitoring Practices (9/16)
- When to Monitor Pests, Damage, and Natural Enemies (9/16)
- Monitoring Caterpillars and their Natural Enemies (9/16)
- Monitoring Persea and Sixspotted Mites (9/16)
- Monitoring Diseases and Disease-Promoting Conditions (9/16)
- Rootstock Tolerance to Disorders and Pathogens (9/16)
- Relative Toxicities of Insecticides, Miticides, and Molluscicides Used in Avocados to Natural Enemies and Honey Bees (9/16)

Diseases

- Anthracnose (9/16)
- Armillaria Root Rot (Oak Root Fungus) (9/16)
- Avocado Black Streak (9/16)
- Bacterial Canker (9/16)
- Branch Canker and Dieback (formerly Dothiorella Canker) (9/16)
- Fruit and Stem-end Rots (9/16)
- Fusarium Dieback (9/16)
- Phytophthora Trunk Canker and Crown Rot (formerly Citricola Canker) (9/16)
- Phytophthora Fruit Rot (9/16)
- Phytophthora Root Rot (9/16)
- Rosellinia Root Rot (9/16)
- Sooty Mold (9/16)
- Sunblotch (9/16)
- Sunburn (9/16)
- Verticillium Wilt (9/16)

Invertebrates



Pests of Primary Concern

- Amorbia (Western Avocado Leafroller) (9/16)
- Avocado Brown Mite (9/16)
- Avocado Thrips (9/16)
- Greenhouse Thrips (9/16)
- Omnivorous Looper (9/16)
- Persea Mite (9/16)
- Polyphagous Shot Hole Borer - Kuroshio Shot Hole Borer (12/17)
- Sixspotted Mite (9/16)

Young Tree Pests

- Branch and Twig Borer (9/16)
- Brown Garden Snail (9/16)
- European Earwig (9/16)
- False Chinch Bug (9/16)
- Fuller Rose Beetle (9/16)
- Grasshoppers (9/16)
- June Beetles (9/16)

Uncommon or Rarely Managed Pests

- Ants (9/16)
- Armored Scales (9/16)
- Avocado Lace Bug (9/16)
- Glassy-Winged Sharpshooter (9/16)
- Longtailed Mealybug (9/16)
- Neohydatothrips (9/16)
- Orange Tortrix (9/16)
- Soft Scales (9/16)
- Whiteflies (9/16)

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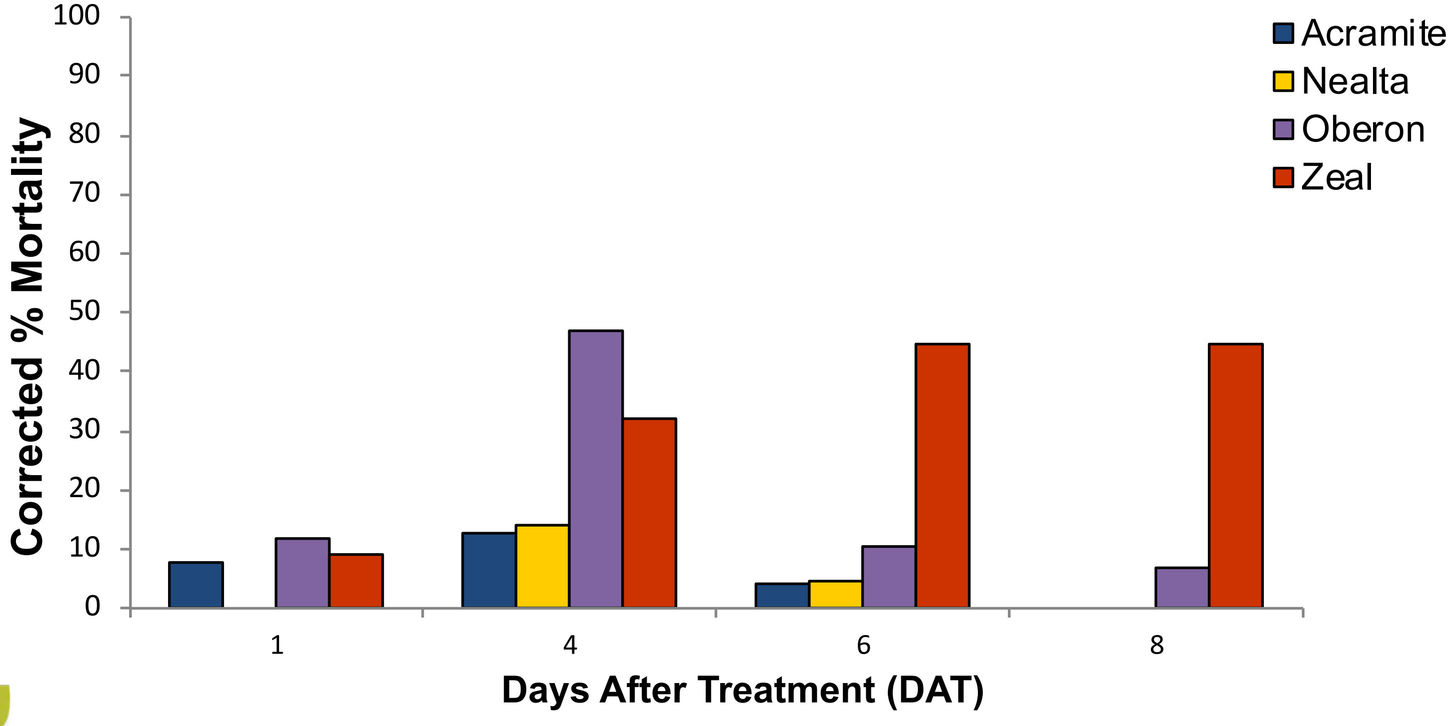
Common name (Example trade name)	Mode of action[1]	Selectivity[2] (affected groups)	Predatory mites[3]	General predators[4]	Parasites[4]	Honey bees[5]	Duration of impact to natural enemies[6]
abamectin (Agri-Mek)	6	moderate (mites, thrips)	M	M[7]	M/H	I	moderate to predatory mites and long to affected insects
Bacillus thuringiensis ssp. *aizawai*	11A	narrow (caterpillars)	L	L	L	II	none
Bacillus thuringiensis ssp. *kurstaki*	11A	narrow (caterpillars)	L	L	L	III	none
boric acid bait (Gourmet)	8D	narrow (ants)	L	L	L	III	none
copper sulfate (Bordeaux mixture) trunk spray	—	narrow (snails)	L	L[7]	L	III	long as a barrier
etoxazole (Zeal)	10B	narrow (mites)	H[11]	L	—	II	short
fenpropathrin (Danitol)	3A	broad (insects, mites)	H	H	H	I	—
imidacloprid (Admire)	4A	narrow (sucking insects)	—	L	L	I	long
iron phosphate (Sluggo)	—	narrow (snails and slugs)	L	H[7]	L	III	short
malathion	1B	broad (insects, mites)	H	H	H	I	moderate
oil, narrow-range	—	broad (exposed insects, mites)	L	L	L	II	short
pyrethrin (PyGanic)	3A	moderate (insects)	—	M	M	I	short
pyrethrin/piperonyl butoxide (Pyrenone)	3A/—	moderate (insects)	—	M	M	I	short
pyriproxyfen (Esteem)	7C	broad (aphids, caterpillars, flies, leafminers, scale, whiteflies)	L	H[10]	L	II	long
sabadilla (Veratran-D)	—	narrow (feeding thrips)	L	L	L	II	short
spinetoram (Delegate)	5	narrow (caterpillars, aphids, thrips)	M	M[8]	L/M	II	moderate[9]
spinosad (Success, Entrust)	5	narrow (caterpillars, aphids, thrips)	M	M[8]	L/M	II	moderate[8]
spirodiclofen (Envidor)	23	narrow (mites)	L	—	—	II	—
spirotetramat (Movento)	23	narrow (aphids, scale, psyllids, whiteflies)	L	L	L	II	short
sulfur	un	narrow (mites)	L/H	L	H	III	moderate
thiamethoxam (Actara - foliar)	4A	narrow (sucking insects)	—[12]	M/H	M/H	I	moderate

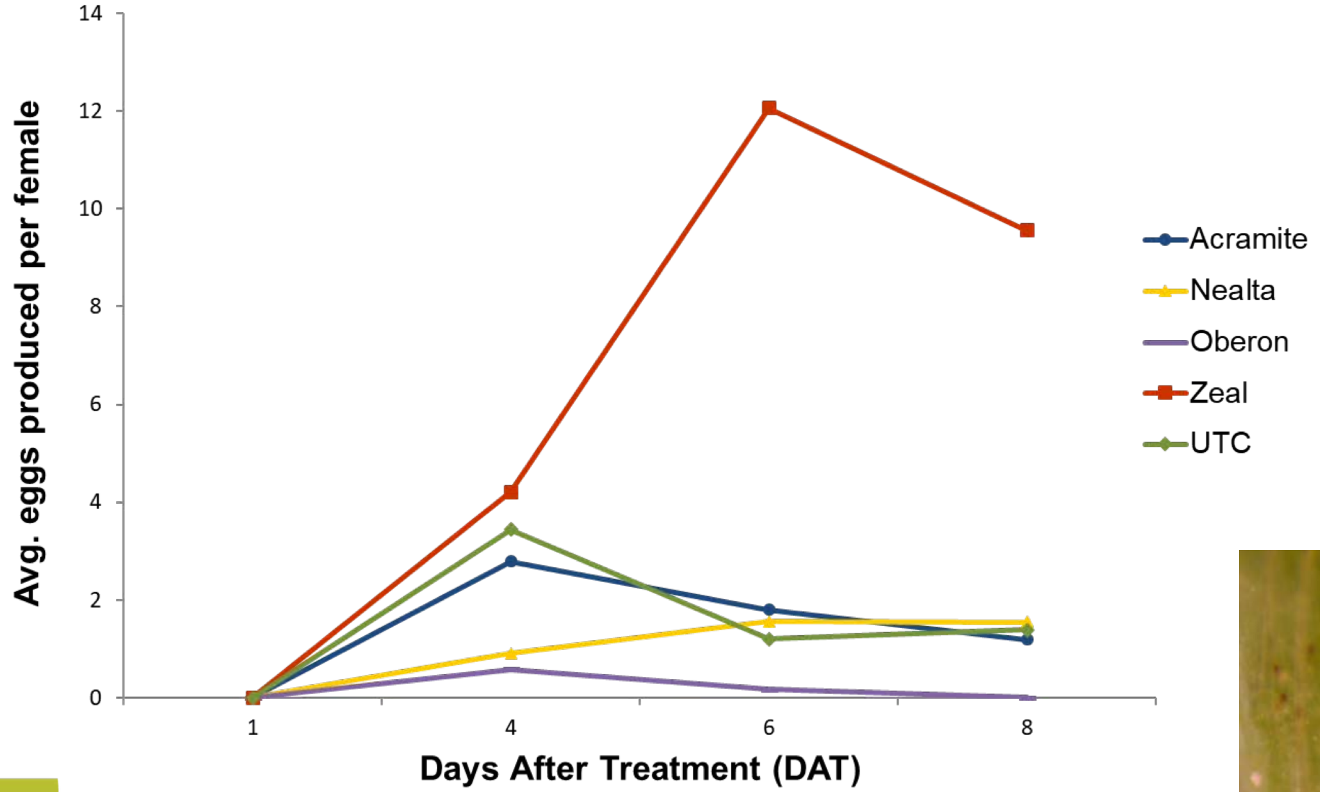
Example of how pesticides can affect control…

Bioassays of pestiside effects on *N. californicus*

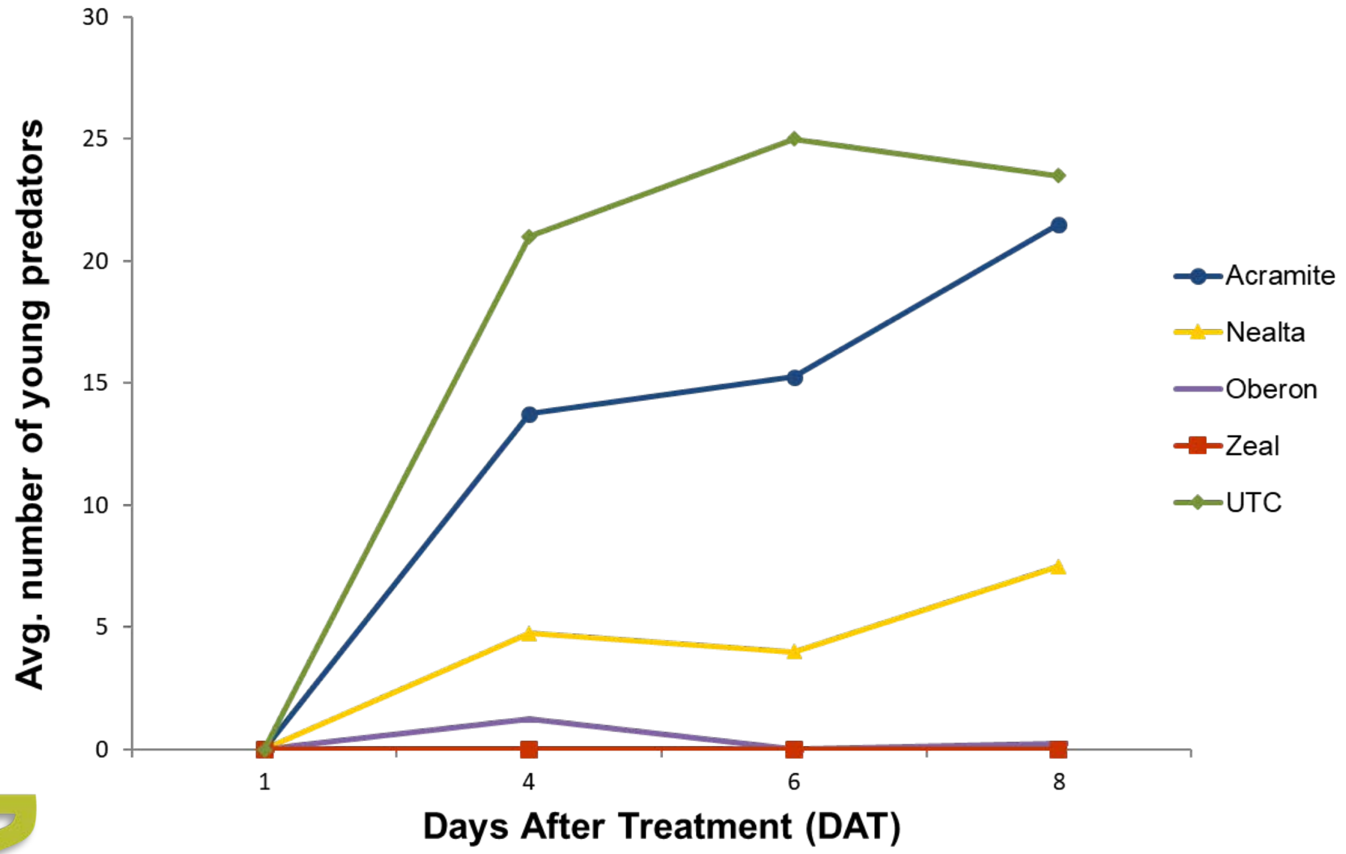
Corrected percent mortality



of eggs produces per female



Young Produced



Zeal applied

No Zeal applied

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Summary

- BCAs are increasing in popularity due to an increase in environmental stewardship
- BCAs can be incorporated into your IPM program
  - Knowledge of biology and crop management practices needed for success
  - Data on effects of pesticides on BCAs is increasing
- Effects of pesticides on BCAs must be considered when incorporating them

Summary

- If BCAs are not "working" it is more likely an environmental cause
  - More work must be done to better incorporate BCAs for higher success
- BCAs are not sprays. They will not give you a quick knockdown!!

THANK YOU!!

Questions?