

Working with Biological Controls of Insects

CFVGA Annual Meeting

February 24, 2020



Whitney Cranshaw
Colorado State University

An example of why natural controls are so important



Cabbage looper is a common insect that chews on many kinds of plants



Adult cabbage looper



Cabbage looper pupa



Cabbage looper egg



Cabbage looper life cycle

Young cabbage looper larva



Full-grown cabbage looper larva



On average one cabbage looper female moth **may lay 100 eggs.** When the egg hatches the insect feeds and grows, ultimately becoming a new adult.....**if everything goes well.**



On average 98 of those 100 eggs will not produce a new adult. Some things get them along the way.

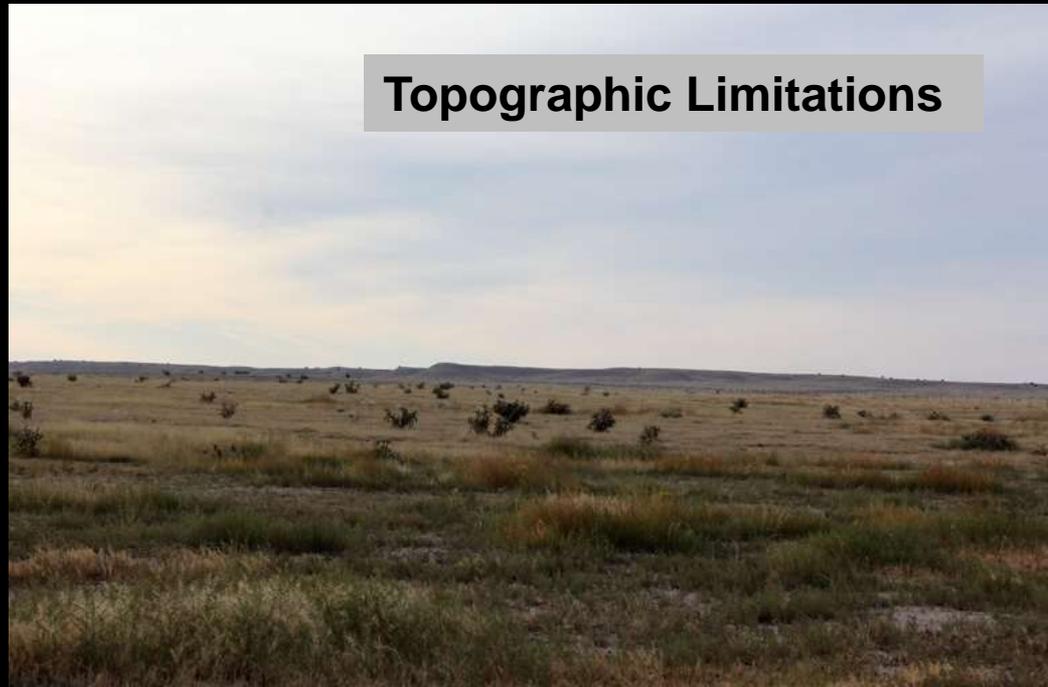
Natural Controls

Natural Enemies



Abiotic (Weather) Controls

Topographic Limitations



Tent caterpillar killed by virus

Natural Enemies

- Predators
- Parasitoids
- Pathogens



Parasitoid wasp laying egg in an aphid



Predatory stink bug feeding on a caterpillar

Branches of Biological Control

- Conserve and enhance the activity of the existing biological control agents
- Augment biological controls with supplemental releases of natural enemies to suppress pests during a crop cycle
- Import into the area new biological control species for permanent establishment/long term suppression

Branches of Biological Control of Insect and Mite Pests

- **Introduction of new species for permanent establishment**
 - Always coordinated by government and regulatory agencies
 - Effects are long-term
- **Augmentation by supplemental releases of natural enemies**
- **Conservation and enhancement of existing natural enemies**

The origin of Classic Biological Control



Cottony
cushion scale
and the
Vedalia beetle

Cottony Cushion Scale – Enters California in 1860s and devastates citrus industry within next two decades





UGA5195051



To the rescue – the *Vedalia beetle*

- **Albert Koebele** visits Australia and searches for natural enemies of cottony cushion scale
- Vedalia beetle (and a predatory fly) are introduced into California – 1888
- **Complete control of cottony cushion scale within two years after introduction**

**Cottony cushion scale
and vedalia**



**Cottony cushion scale
with vedalia eggs**



Larva



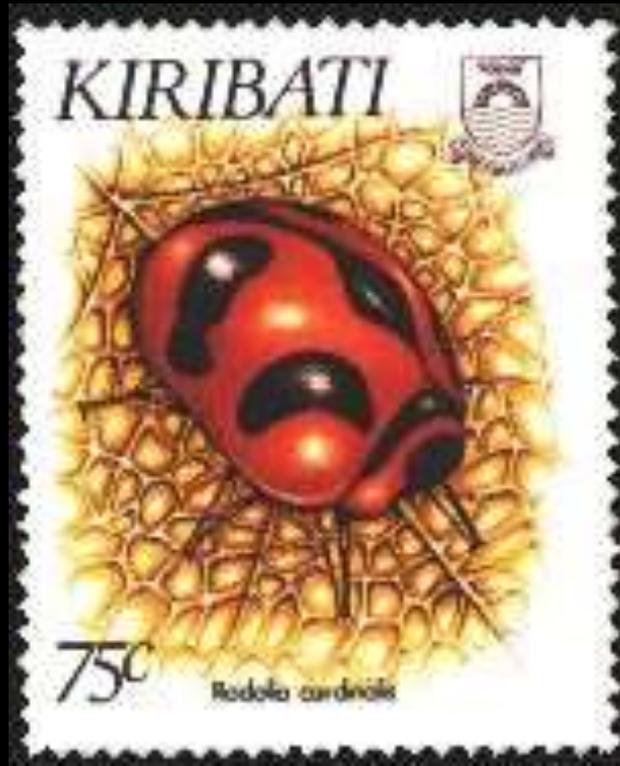
Adult and pupa





UGA5195051

The vedalia beetle was subsequently introduced into dozens of other areas plagued by the cottony cushion scale





Control of Cottony Cushion Scale by the Vedalia Beetle

Birth of the 'Classic' biological control technique for insect pests

COLORADO DEPARTMENT OF AGRICULTURE



Palisade Insectary
Colorado Dept. Agriculture
Conservation Services Division
Biological Control Program
750 37.8 Rd.
Palisade, CO 81526
(970) 464-7916

Presently the CDA Insectary at Palisade is involved with producing and releasing insects that can help reduce invasive weeds



Conservation · Biocontrol

Biocontrol

Biological pest control helps decrease agriculture's reliance on chemical pest control. The Insectary imports, rears, establishes, and colonizes new beneficial organisms for control of specific plant and insect pests. Successful biological pest control reduces production costs, decreases amounts of chemicals entering the environment, and establishes colonies of beneficial insects offering a natural permanent pest control solution.

[Contact](#) the Insectary



Weed and Insect Programs

Approximately 30 weed predators are being cultured, released, and established on weed infestations throughout the State. In addition to the biological weed control programs, this section conducts control programs for the alfalfa weevil, and Oriental fruit moth, with a total of twelve



Weed and Insect Programs

Approximately 30 weed predators are being cultured, released, and established on weed infestations throughout the State. In addition to the biological weed control programs, this section conducts control programs for the alfalfa weevil, and Oriental fruit moth, with a total of twelve beneficial species. The main function of the Biological Pest Control Section is the rearing and releasing of natural enemies for control of specific plant and insect pests. To request biological pest control please contact our office. This section also acts as the State's receiving station for biological control agents. New biological control programs are being developed primarily by agencies of the United States Department of Agriculture. Foreign exploration produces several new species each year that are known to control introduced plant and insect pests. These exotic species are exposed to a strict quarantine procedure before they become available to cooperating states for general release. This ensures that potentially hazardous species are not accidentally introduced with the beneficial insects.

Views Fees & [Request A Bug](#)



[Canada Thistle Biocontrol](#)



[Dalmatian Toadflax Biocontrol](#)



[Diffuse/Spotted Knapweed Biocontrol](#)



[Field Bindweed Biocontrol](#)



[Leafy Spurge Biocontrol](#)



[Musk Thistle Biocontrol](#)



**COLORADO
DEPARTMENT OF
AGRICULTURE**



**The Insectary at Palisade
is celebrating its 75th
Anniversary in August!**

**It is open to tours.
Please call ahead.**



Palisade Insectary

Colorado Dept. Agriculture
Conservation Services Division
Biological Control Program
750 37.8 Rd.
Palisade, CO 81526
(970) 464-7916

**Natural Enemy
Introductions to Control
Japanese Beetle in
Eastern Colorado**

- ***Istocheta aldrichi***
 - Tachinid fly
- ***Tiphia* species**
 - Parasitic wasps
- ***Ovavesicula popilliae***
 - Microsporidium (fungus)



Natural Enemies of Japanese Beetle for Introduction into Colorado

Tiphia vernalis (Spring
Tiphia) – parasitoid was of late
stage Japanese beetle grubs



Photograph by David Shetlar, The Ohio State University

David Shetlar photo



Female wasps dig into the soil to locate Japanese beetle grubs that are nearly full-grown.

They then lay an egg on the grub.

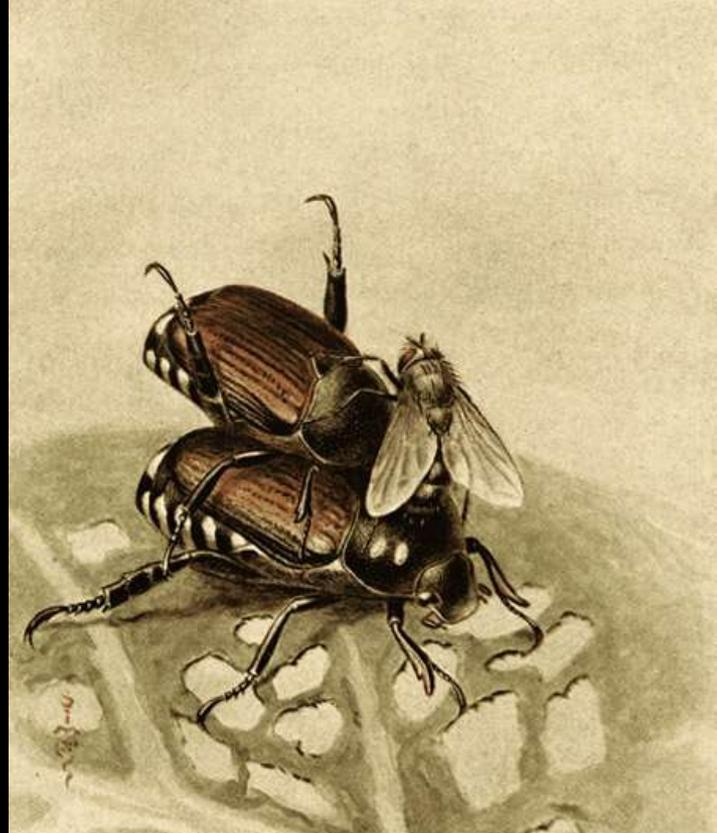
The developing larva of the wasp feeds on and kills the grub.

It then pupates. The adult emerges next spring.



Natural Enemies of Japanese Beetle for
Introduction into Colorado

Istocheta aldrichi – tachinid
fly parasitoid of Japanese beetle
adults



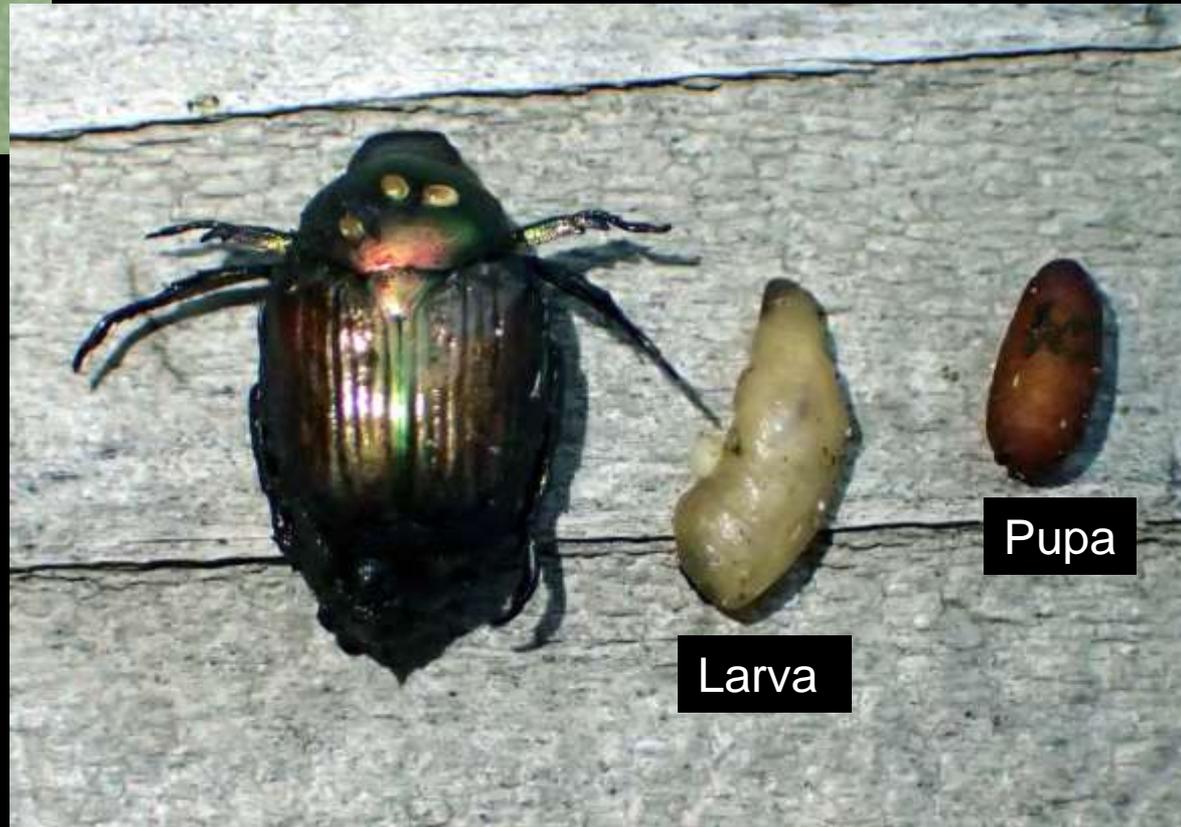


The egg(s) hatches and the larva of the fly enters the beetle.

Ultimately the beetle is killed.

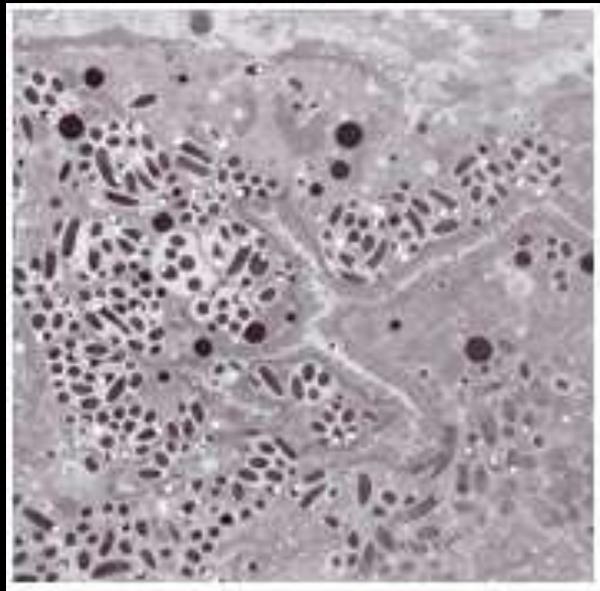
The larva then migrates out of the beetle and moves into the soil where it pupates.

The adult emerges the following year.



Natural Enemies of Japanese Beetle for Introduction into Colorado

Ovavesicula popilliae – a microsporidian (fungal) disease of Japanese beetle larvae



Ovavesicula infection of Malpighian tubules of Japanese beetle larva



Main observed effects from infection – reduced fecundity, reduced winter survival

If the Japanese Beetle Biological Control Project works, what would be considered success?



In 10-15 years
there would only
be three
Japanese beetles
on your rose,
instead of ten

Branches of Biological Control

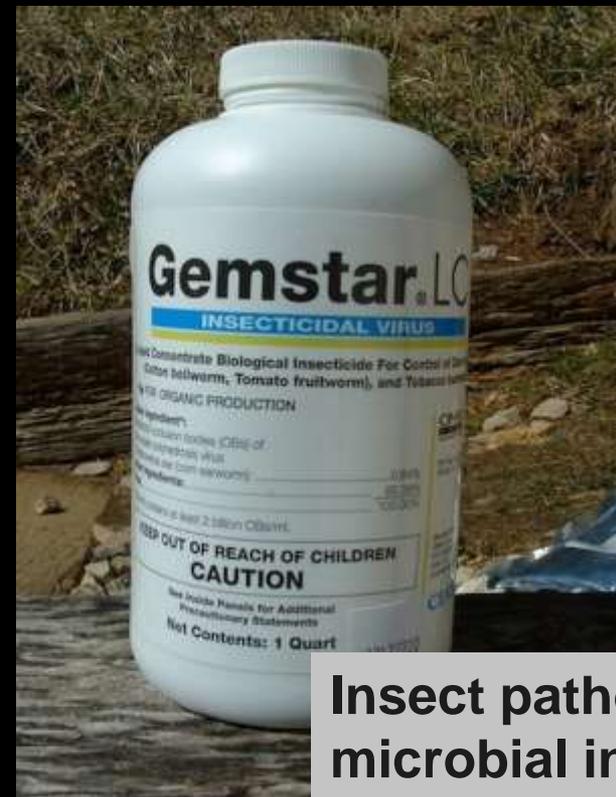
- Conserve and enhance the activity of the existing biological control agents
- **Augment biological controls with supplemental releases of natural enemies to suppress pests during a crop cycle**
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Predators of insects/mites



Insect parasitoids



**Insect pathogens/
microbial insecticides**

**Commercially
available biological
control organisms
to manage
insects/mites**



**Insecticides derived
from microbes**

BIOLOGICAL CONTROL ORGANISMS FOR INSECTS AND MITES: Sources and Uses for Pest Management Situations in Colorado

A list of commercially available biological controls. It includes 36 insect predators, 21 parasitoids of insects, and 17 insect pathogens. There are 36 suppliers.

Whitney Cranshaw and Andrew Miller
Colorado State University
January 1, 2020 Version

Organisms are offered for sale by several suppliers to assist in management of pests. This is a listing of most of the US suppliers and it is organized into three sections: a listing of organisms with potential applications followed by reference to sources. This is followed by a brief summary listing of pest groups and the organisms used for their control. At the end is a listing of addresses of many suppliers/producers.

Predators of Insects/Mites

Convergent Lady Beetle/Lady Beetles. When sold as “lady beetles” or “ladybugs” the species involved is the convergent lady beetle, *Hippodamia convergens*, a native lady beetle found throughout North America. Purchased lady beetles are all field collected insects, captured in high elevation areas of California where they periodically migrate to and mass aggregate, allowing easy collection. Ability of the collected lady beetles to reproduce is suspended (they are in "reproductive diapause") so eggs are not produced for several weeks after release. (Pre-feeding lady beetles prior to release can allow some egg maturation to start and a few companies provide such "pre-conditioned" lady beetles). Lady beetles tend to readily disperse from the area of release. Since they store well, lady beetles are available most of the year, although supplies often are limited by midsummer.

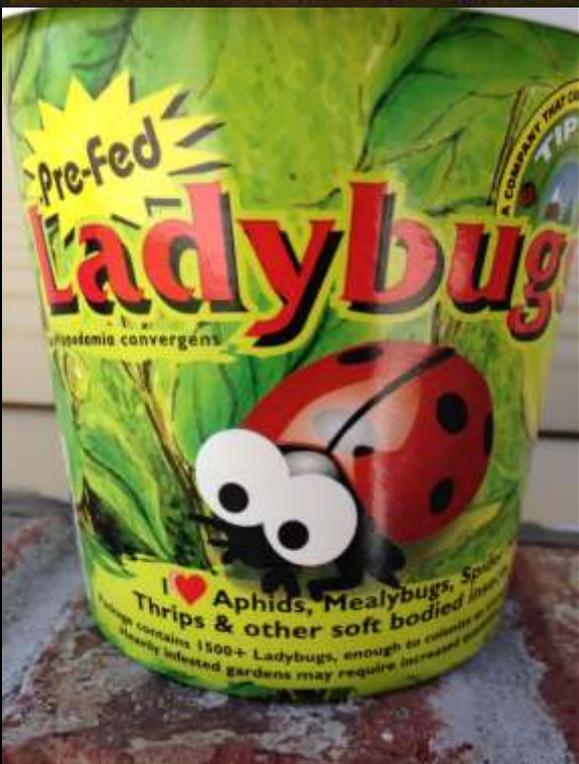
Sources: 1, 2, 4, 5, 10, 11, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25, 27, 29, 30, 31

LADYBIRDS DO THE WORK...

No More Poison Sprays

Use the safe biological method used by government and large growers to destroy aphids, inchworms, Japanese beetles, fruit scales, leafhoppers, boll worms, corn ear worms, mites, etc. Ladybugs (ladybird beetles) live on larvae, eggs and insect pests. About 9000 Ladybugs to the pint. Instructions.

A000455E ... Ladybugs (3/2 pint) \$9.95
A000463E ... Ladybugs (1 pint) \$15.95



Bulk purchase
of field
collected
*Hippodamia
convergens*

Adults



Eggs

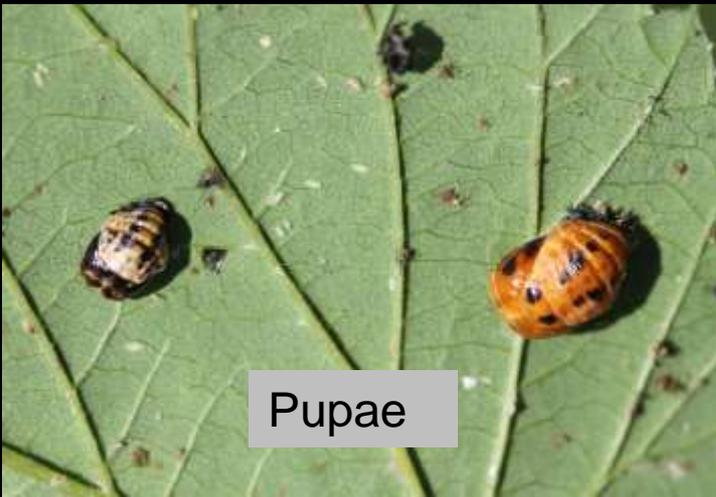


Larvae



Lady Beetle Life Stages

Pupae



Lady beetle larvae



Predators of small soft-bodied arthropods (aphids etc...)



Convergent lady beetle
(*Hippodamia convergens*)
– the lady beetle of
commerce

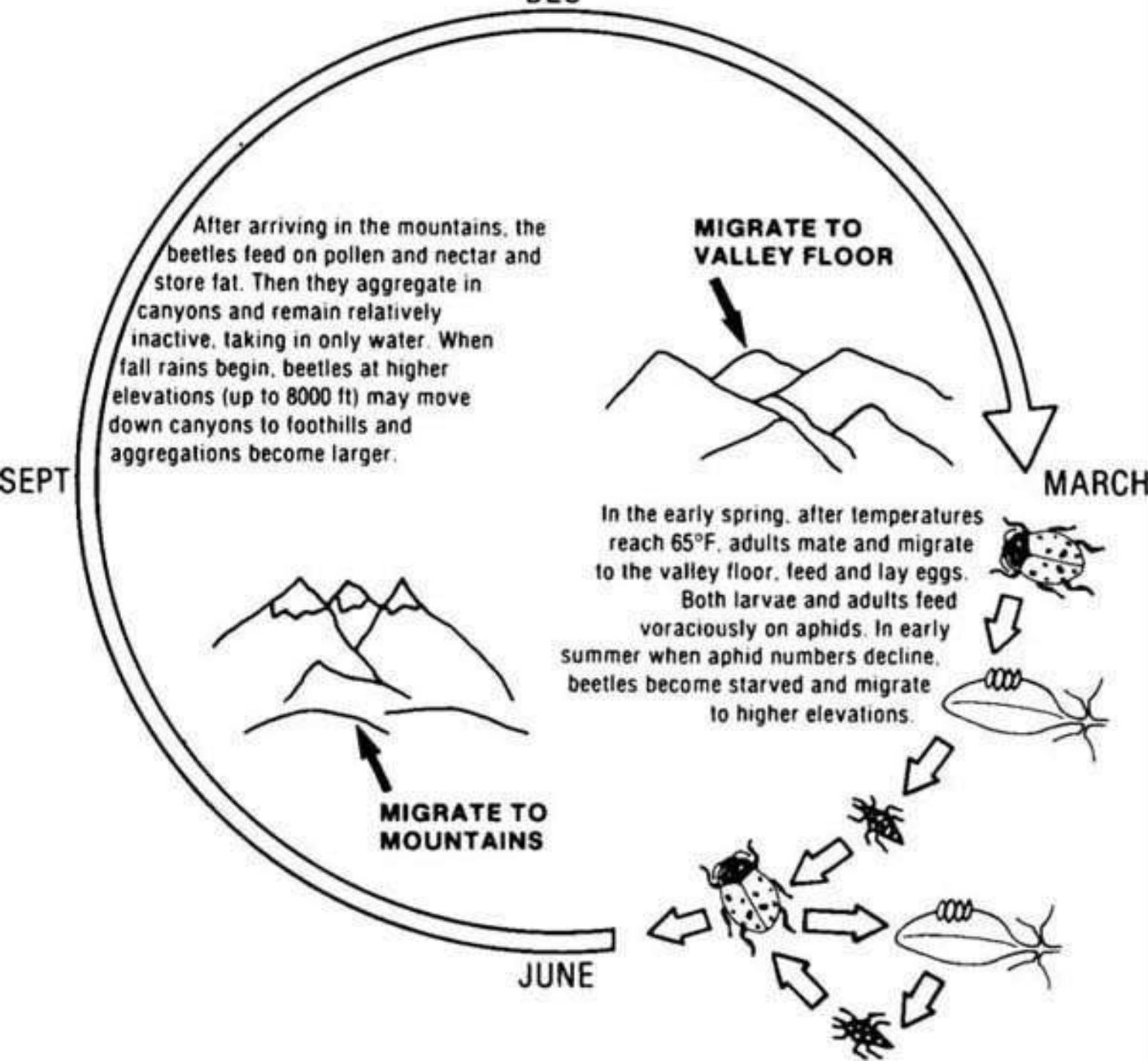
Garden Insects OF NORTH AMERICA





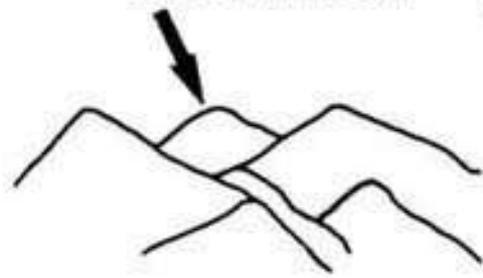
Unlike most lady beetles, the convergent lady beetle often masses during the dormant period





After arriving in the mountains, the beetles feed on pollen and nectar and store fat. Then they aggregate in canyons and remain relatively inactive, taking in only water. When fall rains begin, beetles at higher elevations (up to 8000 ft) may move down canyons to foothills and aggregations become larger.

MIGRATE TO VALLEY FLOOR



MARCH

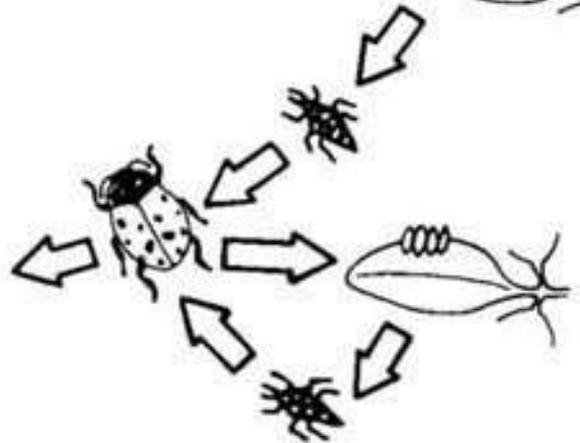
In the early spring, after temperatures reach 65°F, adults mate and migrate to the valley floor, feed and lay eggs. Both larvae and adults feed voraciously on aphids. In early summer when aphid numbers decline, beetles become starved and migrate to higher elevations.



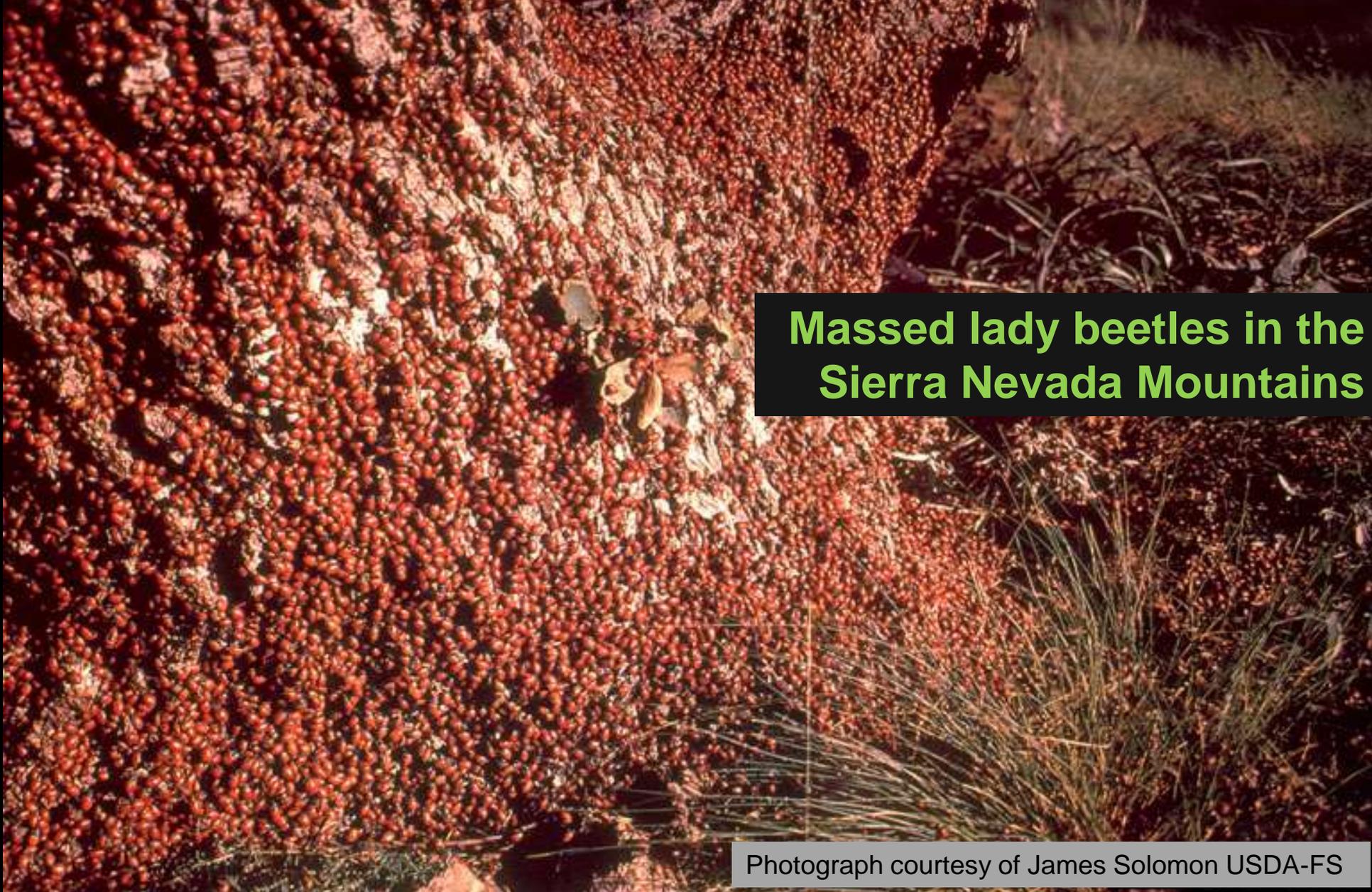
MIGRATE TO MOUNTAINS



JUNE



SEPT



Massed lady beetles in the Sierra Nevada Mountains

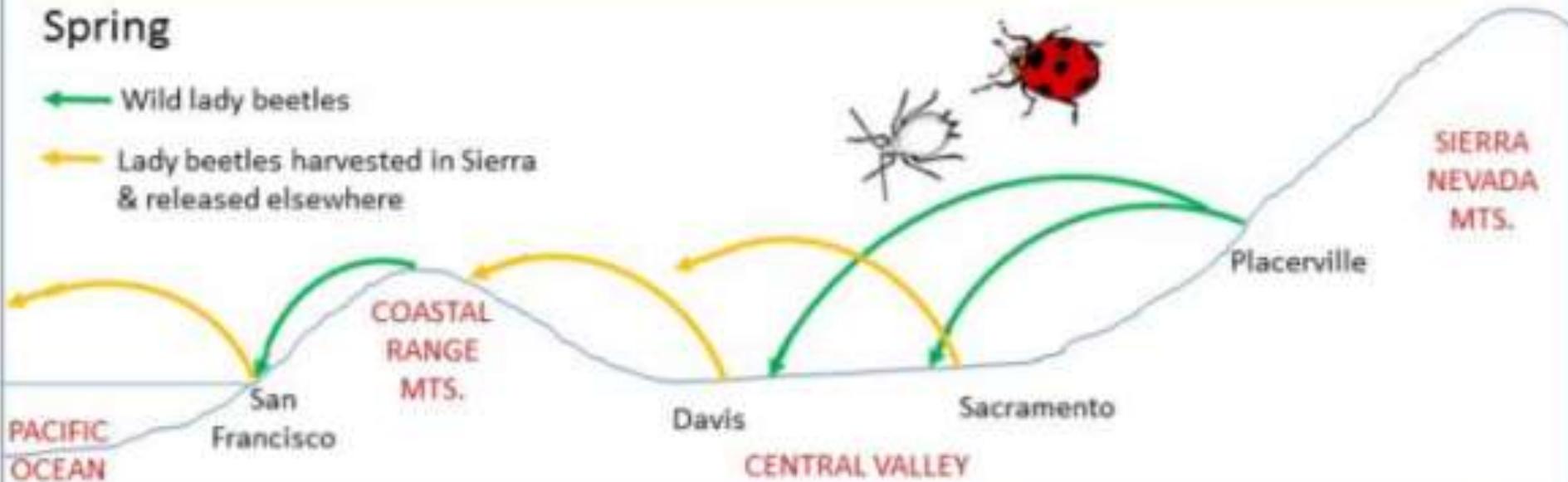
Photograph courtesy of James Solomon USDA-FS

Lady beetles are the only biological control of insects that are field collected

Spring

← Wild lady beetles

→ Lady beetles harvested in Sierra & released elsewhere



Summer/Fall

→ May-June migration

← September-October migration to overwintering sites

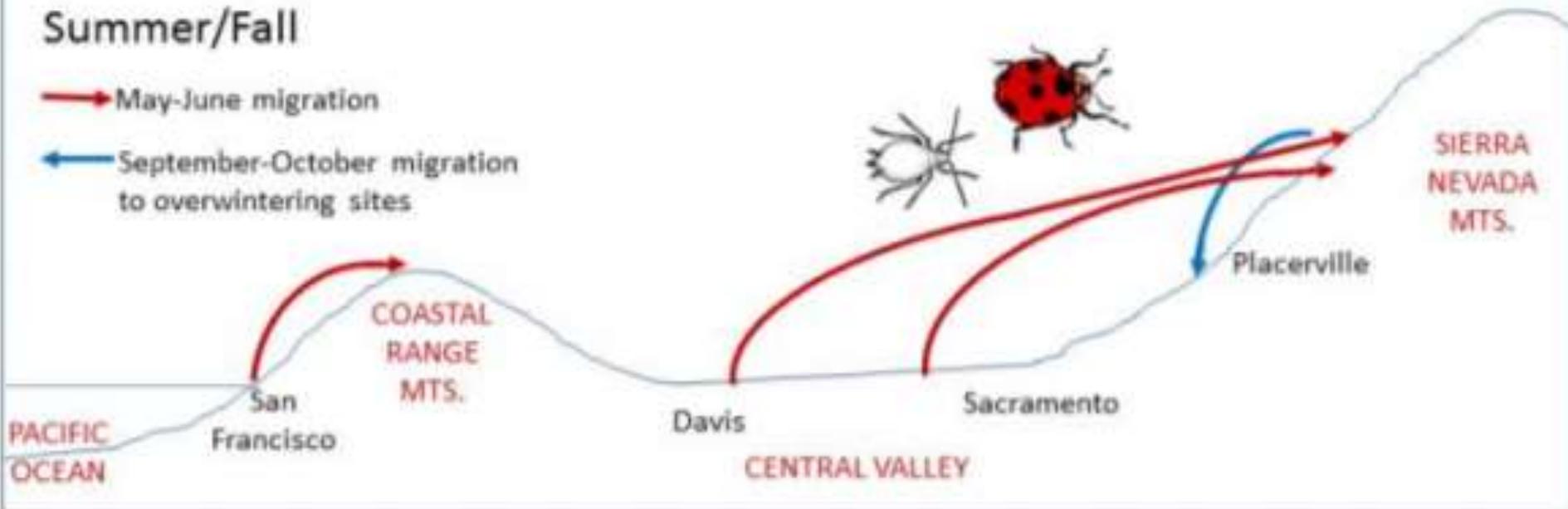


Diagram of the seasonal migrations of lady beetles and aphids in central California.



Effectiveness of releasing field-collected convergent lady beetles

- Most can be *expected to very soon disperse from area*
- Usually the beetles are in a semi-dormant condition (**diapause**) and *will not lay eggs for several weeks*

Lady Beetle Releases for Aphid Control: How to Help Them Work

Many retail stores sell lady beetles (commonly called ladybugs) for controlling aphids in gardens and landscapes. Your customers might wonder: Does releasing lady beetles really work? University of California research has demonstrated lady beetle releases can effectively control aphids in a limited area if properly handled and applied in sufficient numbers. However, because of inadequate release rates or poor handling at the store, in shipping, or after purchase, it is likely most lady beetles purchased at stores fail to provide satisfactory control. Here are some things to consider if you sell lady beetles:

Keep lady beetles refrigerated.

Live lady beetles on display are attractive to customers, but beetles left out at room temperature will rapidly deteriorate. Perhaps leave out one container with an attractive display advising customers to take a container of fresh beetles from the cooler and refrigerate them at home until they release them.

Lady beetles need water.

When you receive a shipment of lady beetles, mist them with a little water

(beetles directly from collectors) and avoid suppliers who regularly ship dead beetles. Generally, retailers shouldn't store beetles for more than two months.

Suggest adequate release rates.

University research shows high numbers of lady beetles are required to control aphids. One large, heavily infested rose bush in the landscape required two applications of about 1,500 lady beetles each, spaced a week apart. Most packages sold in stores contain only enough lady beetles to treat one aphid-infested shrub or a few small plants.

Release lady beetles at dusk or early evening.

Lady beetles will fly away almost immediately if released during the heat of the day or when the sun is shining. Spray a fine mist of water on the plants, as giving beetles a drink can keep them around longer. Place beetles at the base of plants or in the crotches of low branches. Lady beetles will crawl higher into the plant in search of aphids. Don't release lady beetles on plants that have been sprayed with insecticides.



J. K. Clark, UC IPM

The convergent lady beetle, Hippodamia convergens, named for the converging white marks on its thorax, is the species sold in stores for aphid control. Suppliers collect beetles from large overwintering aggregations in California's foothills and mountains. Many other species of lady beetles occur naturally in California landscapes but aren't sold.

in research studies flew away within 48 hours. Lady beetles are unlikely to lay eggs on the plants they are released on. If aphids return a week or two later, customers will need to release more lady beetles, hose aphids off with water, use insecticidal soap sprays, or wait for other native beneficial insects to fly in. Instead of releasing lady beetles, some customers might get better results by hosing aphids off with water or using insecticidal soap or horticultural oil sprays. However, these beneficial insects can be fun and educational!



Green Lacewings

These are insects that are able to be economically reared in **insectaries**.

Most often these are **sold as eggs**.



**Green lacewing eggs
are distinctive – laid
on a stalk**



Green lacewing
larvae are
generalist
predators of many
kinds of insects



Photograph courtesy of Brian Valentine



Photograph courtesy of David Shetlar



Left: Green lacewing larva eating aphid

Right: Green lacewing larva eating leaf beetle larva





Photograph courtesy of Ken Gray/Oregon State University



Green lacewing
eggs are available
from many
suppliers that rear/
distribute insects



Handling green lacewings supplied as eggs



- Best released *shortly after eggs hatch*
- Keep eggs warm, but out of direct sunlight when stored
 - Do not refrigerate
- Moderate humidity (ca. 30-50%) helps with egg survival

Green lacewings are provided in different life stages



Bulk eggs – usually less than \$0.005 apiece

Newly hatched larvae – usually around \$0.02 apiece



Later stage larvae in individual cells – usually around \$0.05-\$0.06 apiece





Minute pirate bugs (*Orius* spp.) – generalist predators of little insects and spider mites

Two other insect predators used in greenhouse production

Note: Both go dormant (diapause) with short day length

Aphid predator midge
– predator of aphids



Predatory Mites

Several species are reared and sold to control **spider mites and thrips**



Spider Mite Predators/Predatory Mites. Several species of commercially available predatory mites (Phytoseiidae family) appear to have some particular applications particularly for greenhouse and interiorscape use where humidity is adequate. Each predatory mite species has a range of temperature and humidity under which they are most efficient, and some require humidity conditions rarely reached in arid areas of the country. The more experienced suppliers/producers can provide consultation as to appropriate species to consider.

One species, Amblyseius swirskii, has more generalized habits and has been used to control both spider mites and thrips.

Sources (Neoseiulus (= Amblyseius) californicus): 4, 6, 7, 9, 10, 11, 12, 17, 19, 20, 22, 24, 26, 27, 30, 31, 32, 33, 34, 35

Sources (Neoseiulus (= Amblyseius) fallacis): 4, 6, 9, 10, 12, 18, 19, 21, 24, 27, 30, 31, 32, 33, 34

Sources (Amblyseius andersoni): 4, 6, 7, 12, 19, 32, 33, 34, 35

Sources (Galendromus (= Mesoseiulus, = Metaseiulus) occidentalis): 4, 9, 10, 12, 19, 22, 24, 27, 31, 34

Sources (Mesoseiulus (= Phytoseiulus) longipes): 4, 9, 10, 12, 17, 19, 21, 24, 27, 31, 34

Sources (Phytoseiulus persimilis): 4, 6, 7, 9, 10, 11, 12, 16, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 30, 31, 32, 33, 34, 35

Sources (Amblyseius (= Typhlodromips) swirskii): 4, 6, 7, 10, 11, 12, 18, 19, 20, 21, 25, 26, 30, 32, 33, 34, 35



Amblyseius cucumeris is also used to help manage thrips

Amblyseius swirskii
A predatory mite that is used for control of thrips on plants



Predatory Mite: *Galendromus occidentalis*

Optimal environmental conditions

80-100 degrees F

> 50% RH



Predatory Mite: *Mesoseiulus longipes*

Can only tolerate the very low humidity of 40% when the temperature is 70°F.

Requires increasing humidity as temperature rises.



A generalist predator of arthropods in soil

Soil predator mite (*Stratiolaelaps scimitus*)

Target pests:

Thrips stages in
soil, fungus gnat
larvae





Four species of parasitoid wasps are sold to control aphids



Aphid parasitoids



Host evaluation



Oviposition



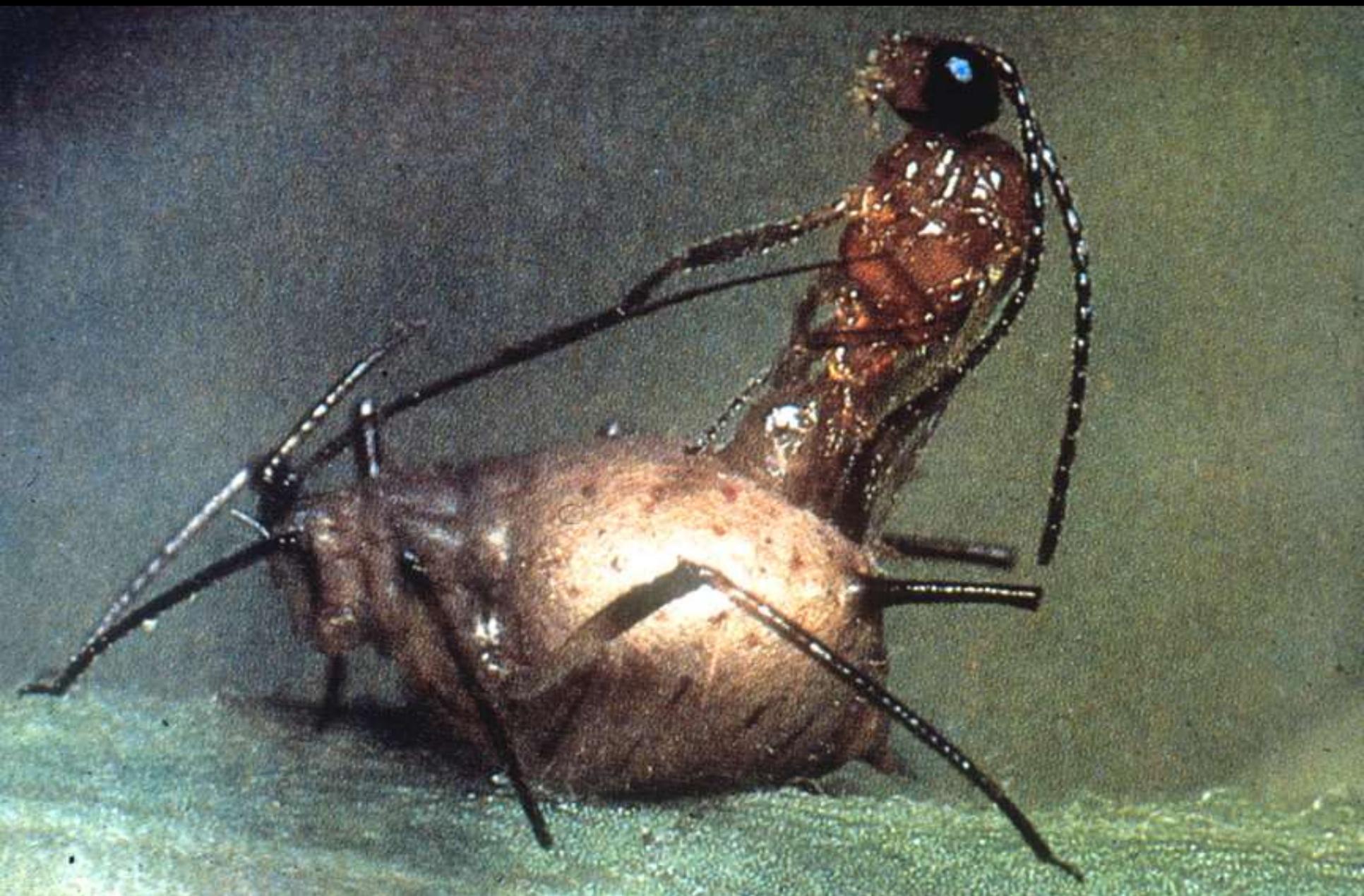
**Photographs courtesy of
Brian Valentine**

Aphid Mummies











Commercially available aphid parasitoids

- *Aphidius colemani*
- *Aphidius ervi*
- *Aphidius matricariae*
- *Aphelinus abdominalis*

Note: Each species has a range of aphids which are most effectively parasitized



Whitefly parasitoids

- *Encarsia formosa*
- *Eretmocerus californicus*



Whiteflies have simple metamorphosis – but have considerable differences in appearance and habit in adult and nymphal stages.



Encarsia formosa

- Used to control greenhouse whitefly for almost 100 years
- Inserts eggs into whitefly nymphs
- Can work at relatively low temperatures/optimal 75F
- Adequate light, humidity improve performance



Adult



Emerging female



Parasitized whitefly pupa



Emergence hole (left)



Encarsia formosa and greenhouse whitefly

Photographs courtesy of University of California IPM Program

Eretmocerus *eremicus*

- Native to SW United States
- Lays eggs underneath whitefly nymphs
- Adults kill many whiteflies while taking a blood meal
- Most effective at warm temperatures/optimal 77F to 84F

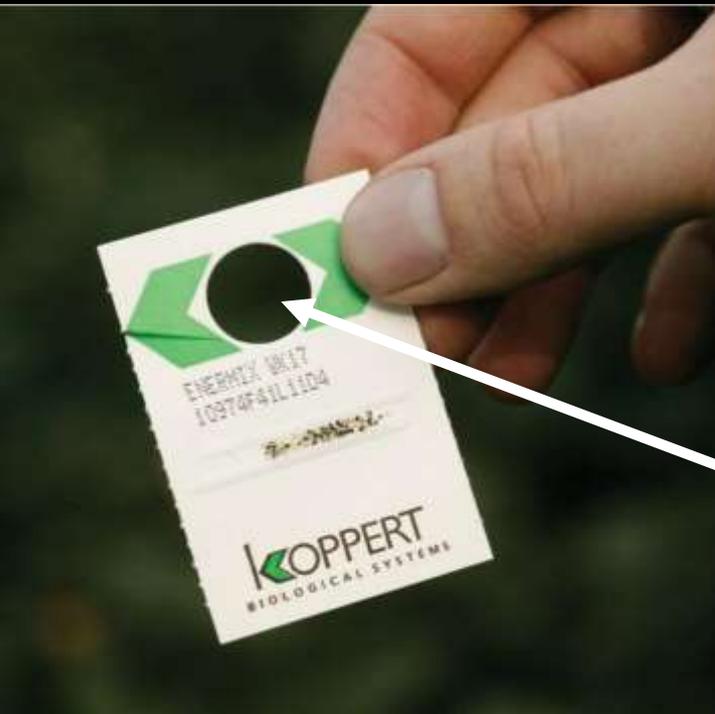


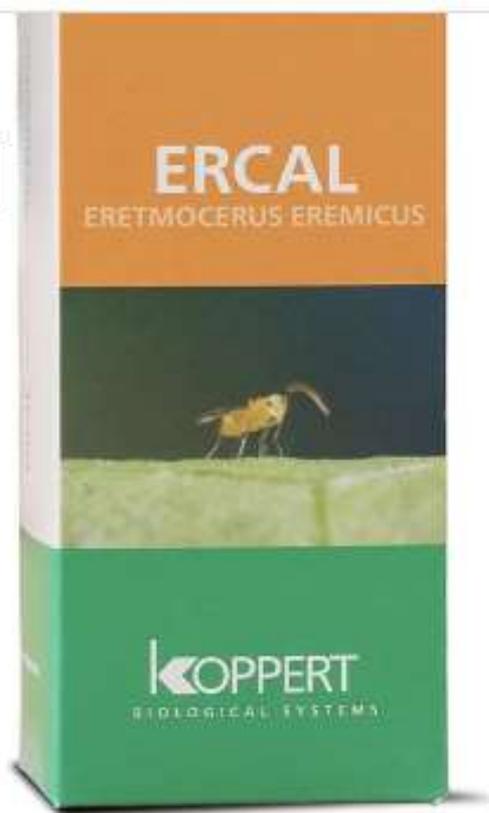


**Whitefly parasites –
Parasitic wasps
that selectively
attack whiteflies**



Whitefly parasitoids are supplied as parasitized whitefly nymphs with the developing wasp within





Packaging:

Each box contains cardboard strips with 5 cards each, wrapped in plastic, with parasitized whitefly pupae

10 cardboard strips, hatching 3,000 parasitic wasps

50 cardboard strips, hatching 15,000 parasitic wasps

Trichogramma wasps, a parasitoid of eggs of various caterpillars (Order: Lepidoptera)



"WONDER WASPS"

(*Trichogramma*)

The Wonder Wasp seeks and destroys the eggs of over 200 pest insects—bollworms, gypsy moths, tomato hornworms, to name a few. She drills into and lays her eggs within the eggs of destructive pest insects, then the newly hatched wasp larvae feed on and destroy the host eggs. These wasps *will not sting* people or pets or harm plants, and they coexist with praying mantis and other beneficial insects. Each container provides enough wasps to protect one-half acre of garden or field crop.

A009795E ...	WONDER WASPS—1 vial	.....	\$ 3.95
A009803E ...	WONDER WASPS—3 vials	.....	\$ 9.95
A009811E ...	WONDER WASPS—6 vials	.....	\$17.95
A009829E ...	WONDER WASPS—9 vials	.....	\$24.00
A009837E ...	WONDER WASPS—12 vials	.....	\$27.95

(Delivery March thru June)

Trichogramma species for sale

- ***Trichogramma pretiosum***
 - Field, row crops, vineyards
- ***Trichogramma platneri***
 - Orchards
- ***Trichogramma brassicae***
 - Row crops
- ***Trichogramma minutum***
 - Forests, orchards (eastern NA)



UC Statewide IPM Project
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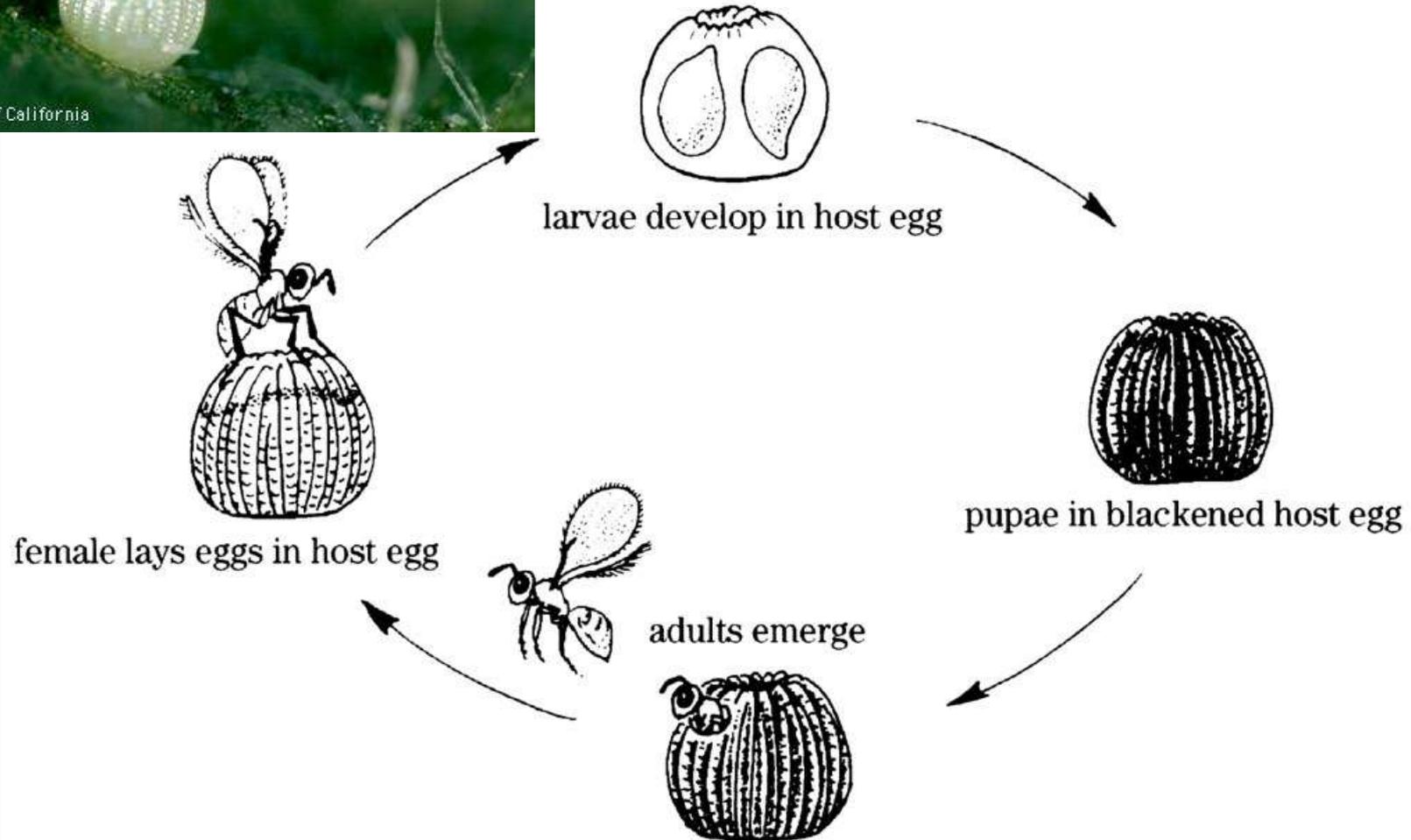


UC Statewide IPM Project
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Adult Trichogramma wasp inserting egg into the egg of a corn earworm



UC Statewide IPM Project
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Corn earworm egg parasitized (left) and successfully hatched (right)

Corn earworm larva in sweet corn (top) and egg on corn silk (bottom)



Corn earworm in tomato fruit (tomato fruitworm)



UC Statewide IPM Project
© 2000 Regents, University of California

Codling moth eggs parasitized by Trichogramma wasps



Trichogramma wasps are usually sold on cards, containing eggs of a moth that have developing wasps within



A typical price might be around \$30.00/100,000 parasitized eggs

Trichogramma wasps

- Attack egg stages of moths/butterflies
- Used in repeated mass releases, timed for when eggs of target pest are being laid
- Several species are commercially available, each with different crop niche



Entomopathogenic Nematodes (EPNs)

(“Insect Parasitic Nematodes”, “Beneficial Nematodes”, “Predator Nematodes”)



Photograph courtesy of Peggy Greb

Nematodes enter insects through natural openings

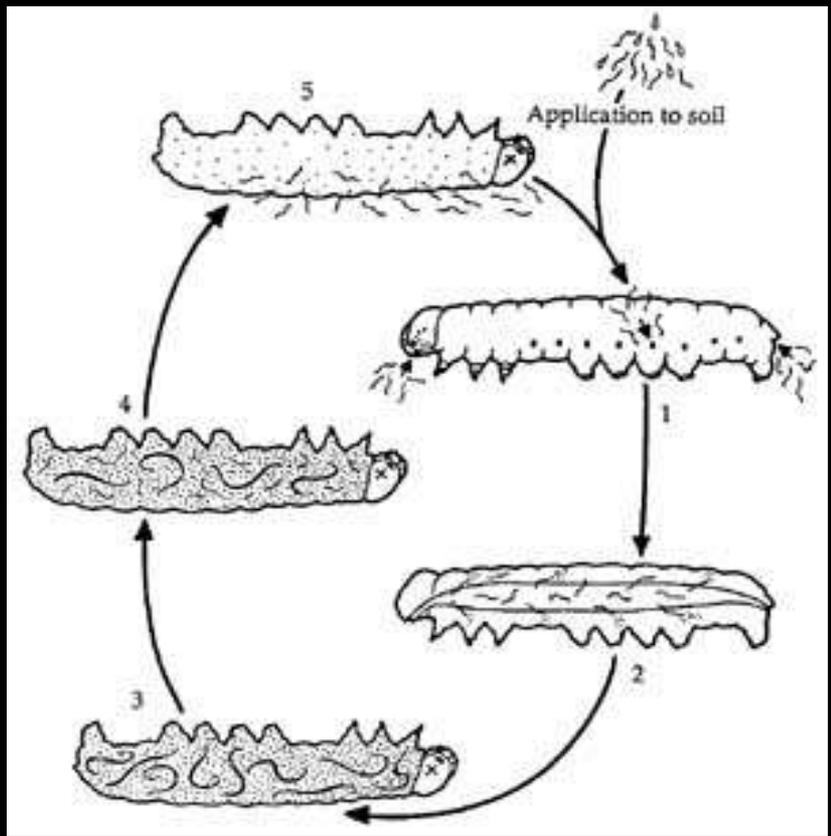
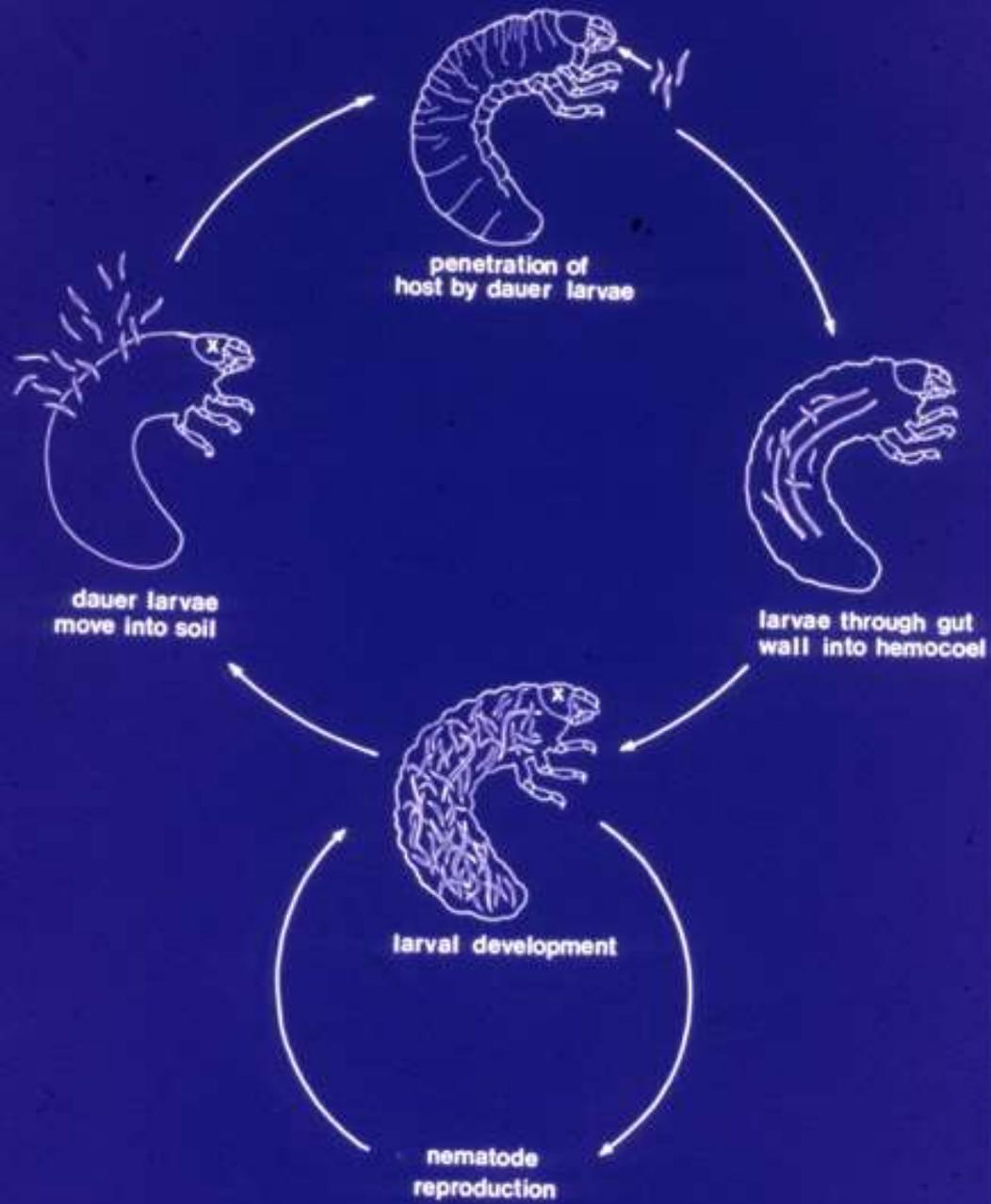
***Heterorhabditis* spp.**
nematodes can penetrate directly through the body wall



Heterorhabditis spp.

Steinernema spp.

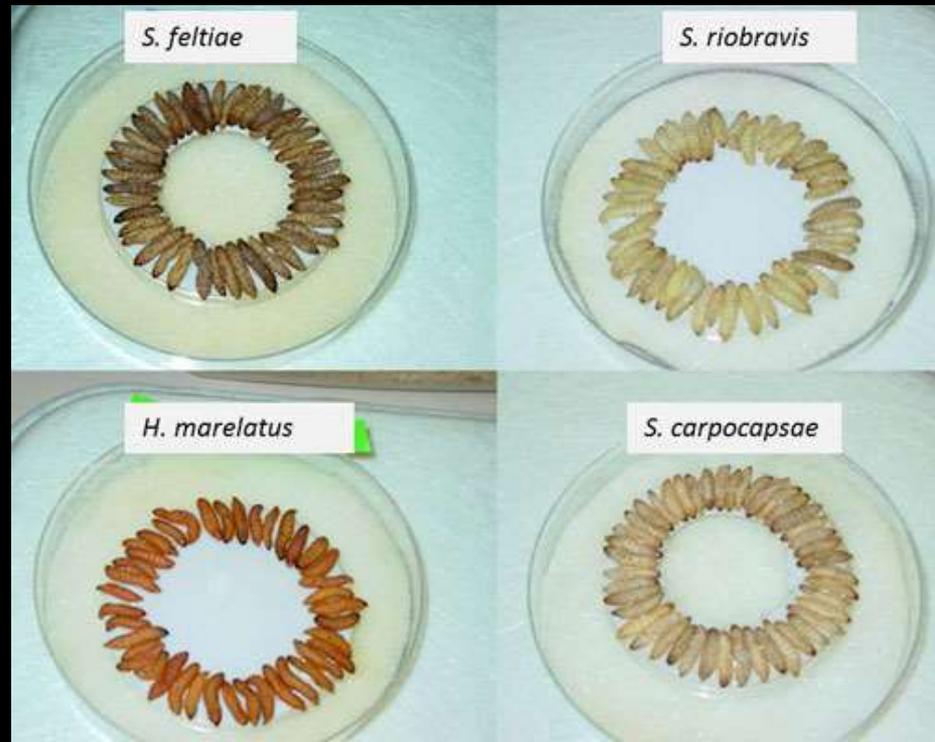
The nematodes introduce bacteria into the host insect. The bacteria kill the insect.





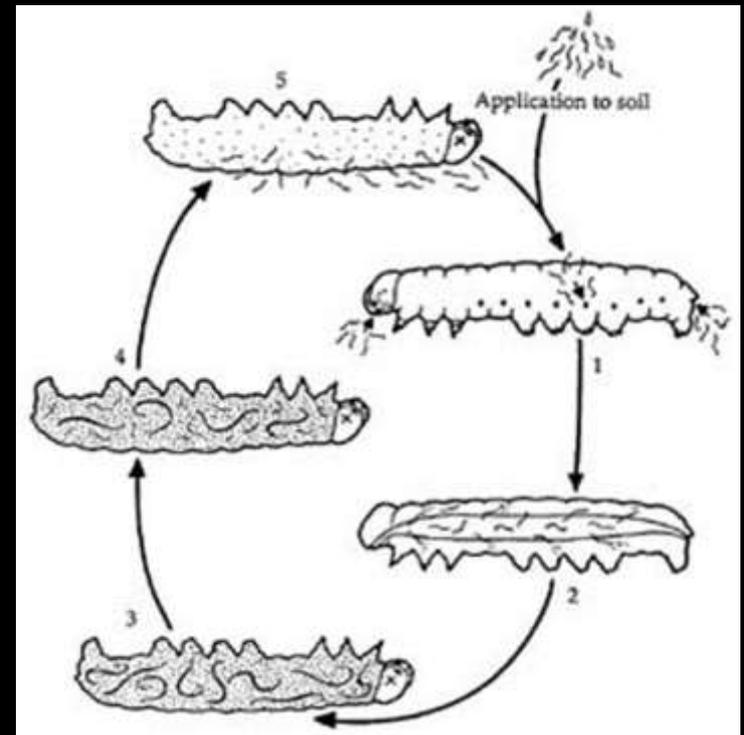
Each kind of EPN has its own bacterium associated with it

The color of the bacteria affect the color of the infected host insect



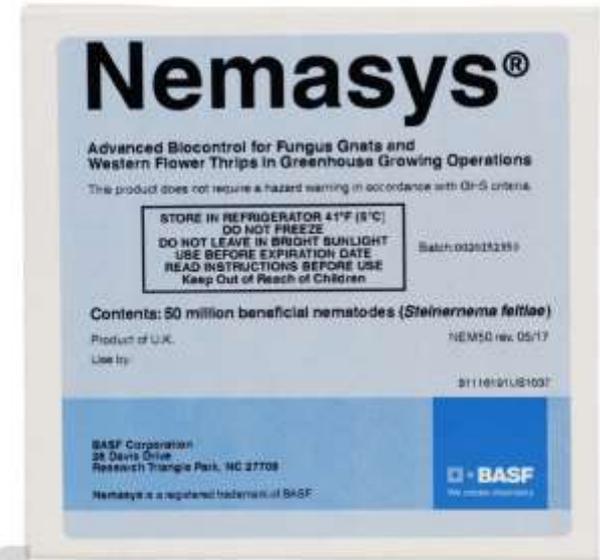
The nematodes feed on the host tissues degraded by the bacteria

Reproduction occurs and new infective juveniles emerge and may attach other insects



Several species of entomopathogenic nematodes are sold

- ***Steinernema carpocapsae***
 - Mostly caterpillars in soil
- ***Steinernema feltiae***
 - Thrips in soil, fungus gnats
- ***Heterorhabditis bacteriophora*, others**
 - White grubs, other beetle larvae in soil



Entomopathogenic nematodes are usually sold in a slightly moist matrix that is then put into water to release the nematodes



Entomopathogenic nematodes are usually applied to the soil in a large volume of water



EPNs can be applied through most spray equipment



Entomopathogenic Nematodes

- **Almost entirely used for soil insects**
- Exposure to UV, drying or high heat is detrimental
- Soil type, soil moisture, temperature affect performance
- Several species are commercially available, each with pest niche



The list of commercially available biological control organism is available at the [Insect Information Website](#)

BIOLOGICAL CONTROL ORGANISMS FOR INSECTS AND MITES: Sources and Uses for Pest Management Situations in Colorado

Whitney Cranshaw and Andrew Miller
Colorado State University
January 1, 2020 Version

A wide variety of beneficial organisms are offered for sale by several suppliers to assist in management of insects and mites. The following is a listing of most of the US suppliers and it is organized into three sections. First is a brief description of organisms with potential applications followed by reference to sources where they may be purchased. This is followed by a brief summary listing of pest groups and the associated potential biological controls. At the end is a listing of addresses of many suppliers/producers.

Predators of Insects/Mites

Convergent Lady Beetle/Lady Beetles. When sold as “lady beetles” or “ladybugs” the species involved is the convergent lady beetle, *Hippodamia convergens*, a native lady beetle found throughout North America. Purchased lady beetles are all field collected insects, captured in high elevation areas of California where they periodically migrate to and mass aggregate, allowing easy collection. Ability of the collected lady beetles to reproduce is suspended (they are in "reproductive diapause") so eggs are not produced for several weeks after release. (Pre-feeding lady beetles prior to release can allow some egg maturation to start and a few companies provide such "pre-conditioned" lady beetles). Lady beetles tend to readily disperse from the area of release. Since they store well, lady beetles are available most of the year, although supplies often are limited by midsummer.

Sources: 1, 2, 4, 5, 10, 11, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25, 27, 29, 30, 31



Fungi

Viruses

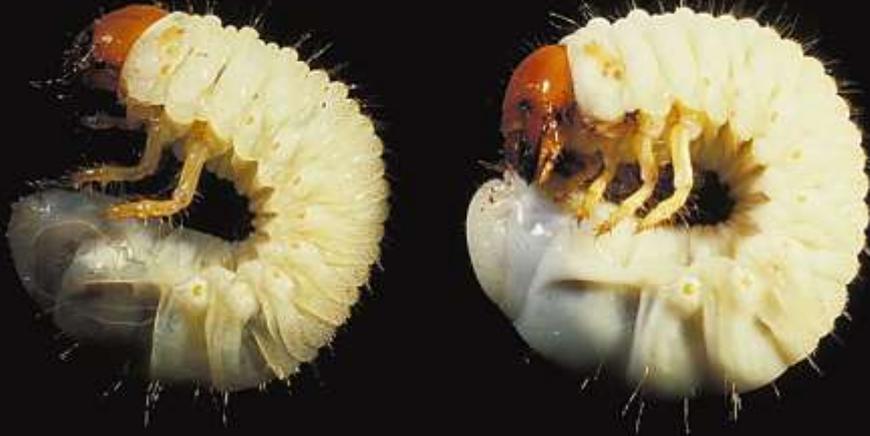
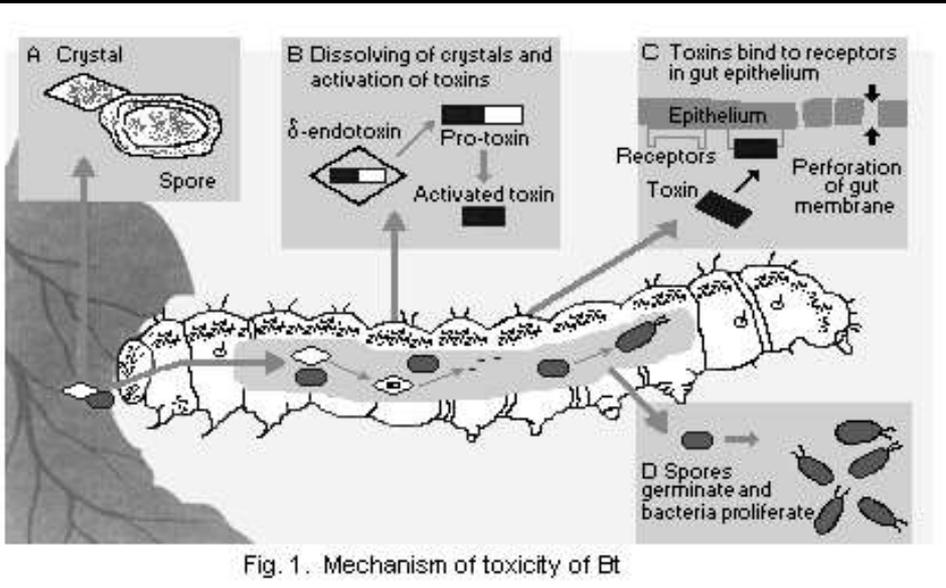


Insect Pathogens

Bacteria



Bacteria as Pathogens of Insects



Bacillus thuringiensis (BT)

- Derived from a widely distributed soil bacterium
- Active ingredient a toxic protein crystal that destroys cells of the midgut
- Used as a stomach poison



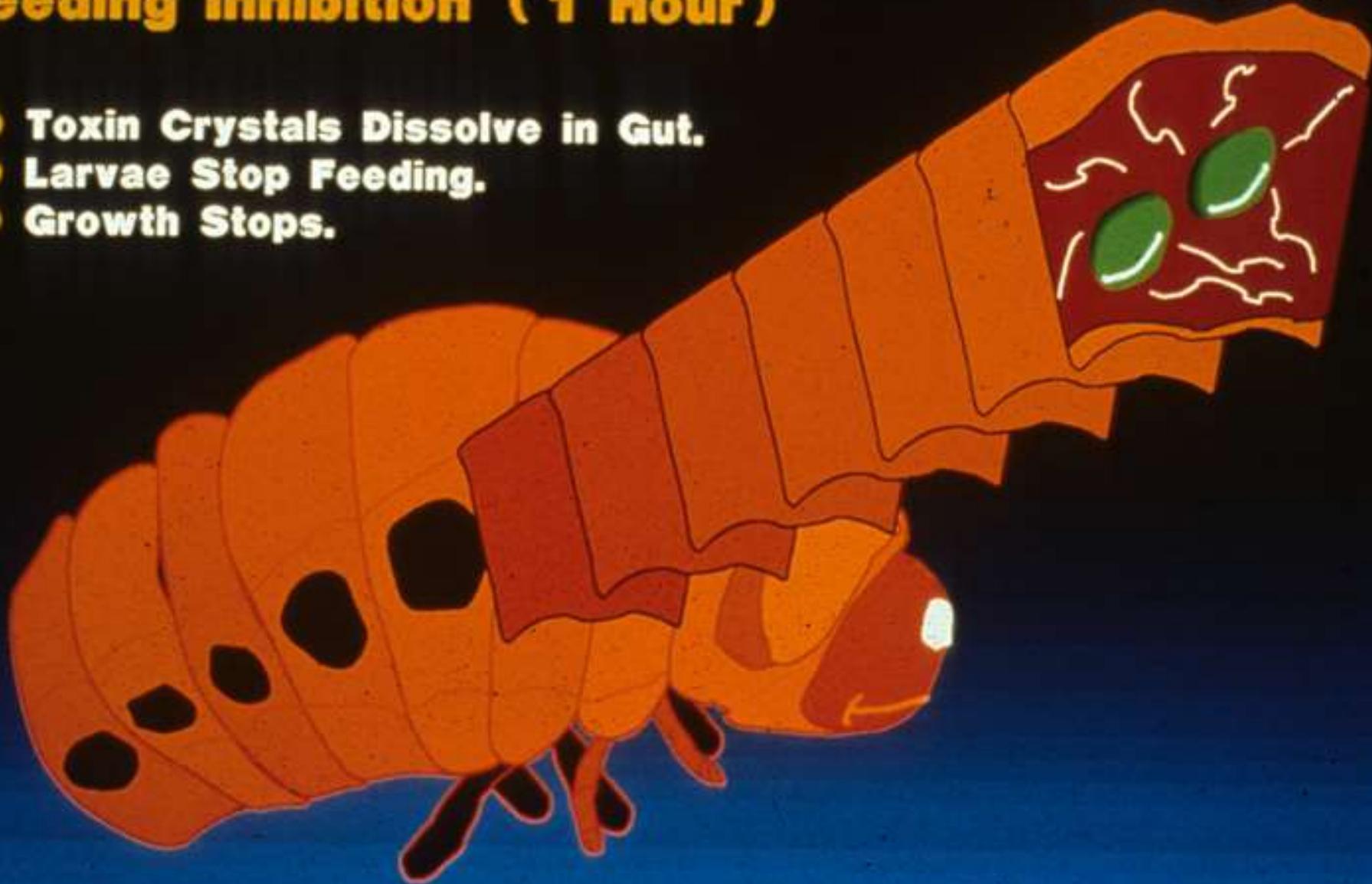
Treated Foliage Consumed



Feeding Inhibition (1 Hour)

- **Toxin Crystals Dissolve in Gut.**
- **Larvae Stop Feeding.**
- **Growth Stops.**

Insect Gut



Death (2-5 Days)



- Starvation
- Gut Disruption



Several strains are present, each with specific activity

- *kurstaki* strains (leaf feeding Lepidoptera larvae)
- *tenebrionis* strain (leaf beetles)
- *israelensis* strain (mosquito, gnat, black fly larvae)



Bacillus thuringiensis var. **kurstaki**

- Originally developed strain of Bt
- Target pests: Leaf-feeding caterpillars
 - Cabbageworms, hornworms, loopers



Bacillus thuringiensis var. **aizawai**

- **Target pests:** “Cutworm family” caterpillars
 - Cutworms, armyworms, corn earworm, etc. loopers



Bacillus thuringiensis var. **israelensis**

- **Target pests:** Larvae of certain kinds of flies
 - Fungus gnats (in soil), mosquito larvae (in water)



BTI

Bacillus thuringiensis var. *israelensis*



Used to control mosquitoes in water, black flies in water – and fungus gnats in soil

Bacillus thuringiensis var. ***galleriae***

- Newest strain developed
- Target pests: Larvae/adults of scarab beetles
 - White grubs, Japanese beetle



grubGONE! G

Biological Insecticide Granule Controls Annual White Grubs in Turf and Ornamentals

ACTIVE INGREDIENT: *Bacillus thuringiensis* strain galleriae, strain 001-002 (Bovine strain), spores, and formulated bait* 20% w/w
OTHER INGREDIENTS: 80% w/w
TOTAL: 100% w/w

KEEP OUT OF REACH OF CHILDREN

CAUTION: See enclosed panel for additional precautionary statements.

EPA Reg. No.: 000011
EPA Est. No.: 5000118000

FIRST AID	
For a full listing of first aid instructions, see the enclosed panel for additional precautionary statements.	
For a full listing of first aid instructions, see the enclosed panel for additional precautionary statements.	
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NOT FOR USE ON: See enclosed panel for additional precautionary statements.

Manufactured for: Phylom BioProducts



Two new bacterial-derived insecticides

Chromobacterium subtsugae
strain PRAA4-1 and spent
fermentation media

Heat-killed *Burkholderia*
spp. strain A396 cells and
spent fermentation media



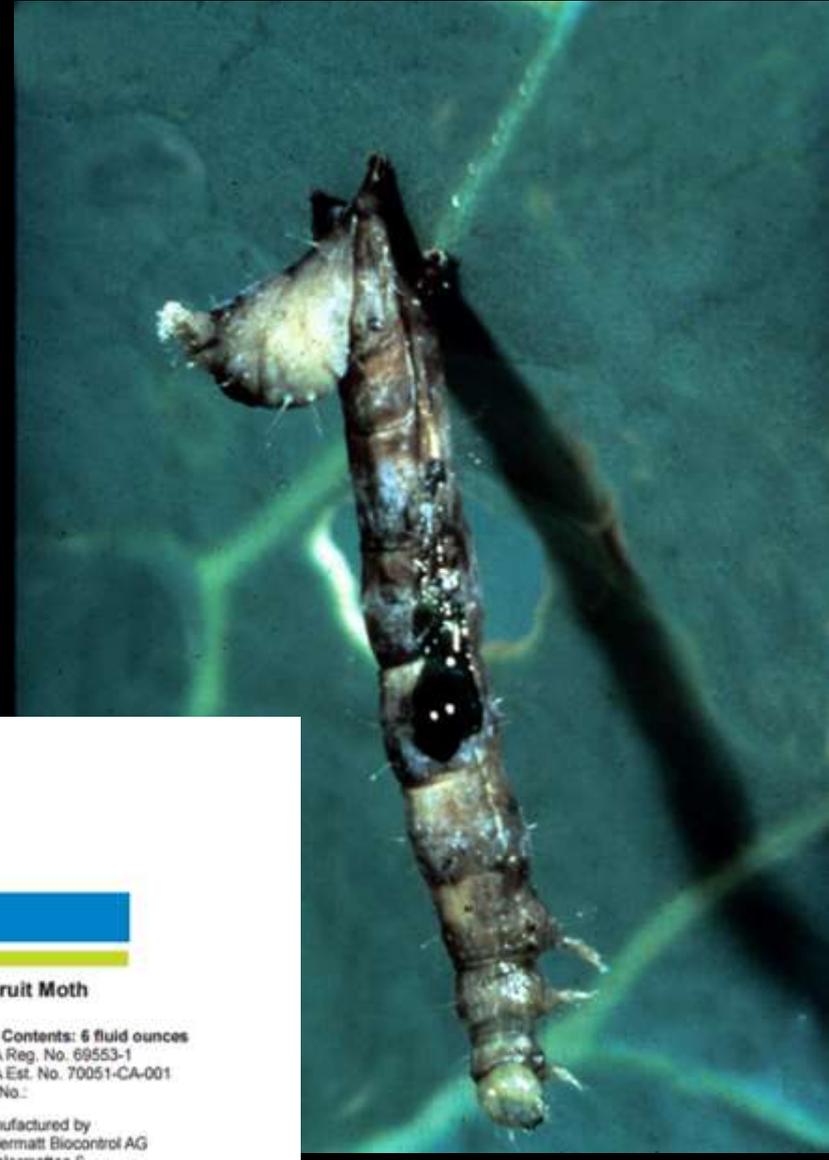
Venerate/ Grandevo

- Used as a foliar spray
- Host range unclear
 - Mostly caterpillars, spotted-winged drosophila
 - Other CO pests - TBD
- OMRI allowable



Viruses as Pathogens of Insects

- Nuclear polyhedrosis (NPV) viruses
- Granulosis viruses



MADEX HP INSECTICIDAL VIRUS

Biological Insecticide for Control of the Codling Moth and Oriental Fruit Moth

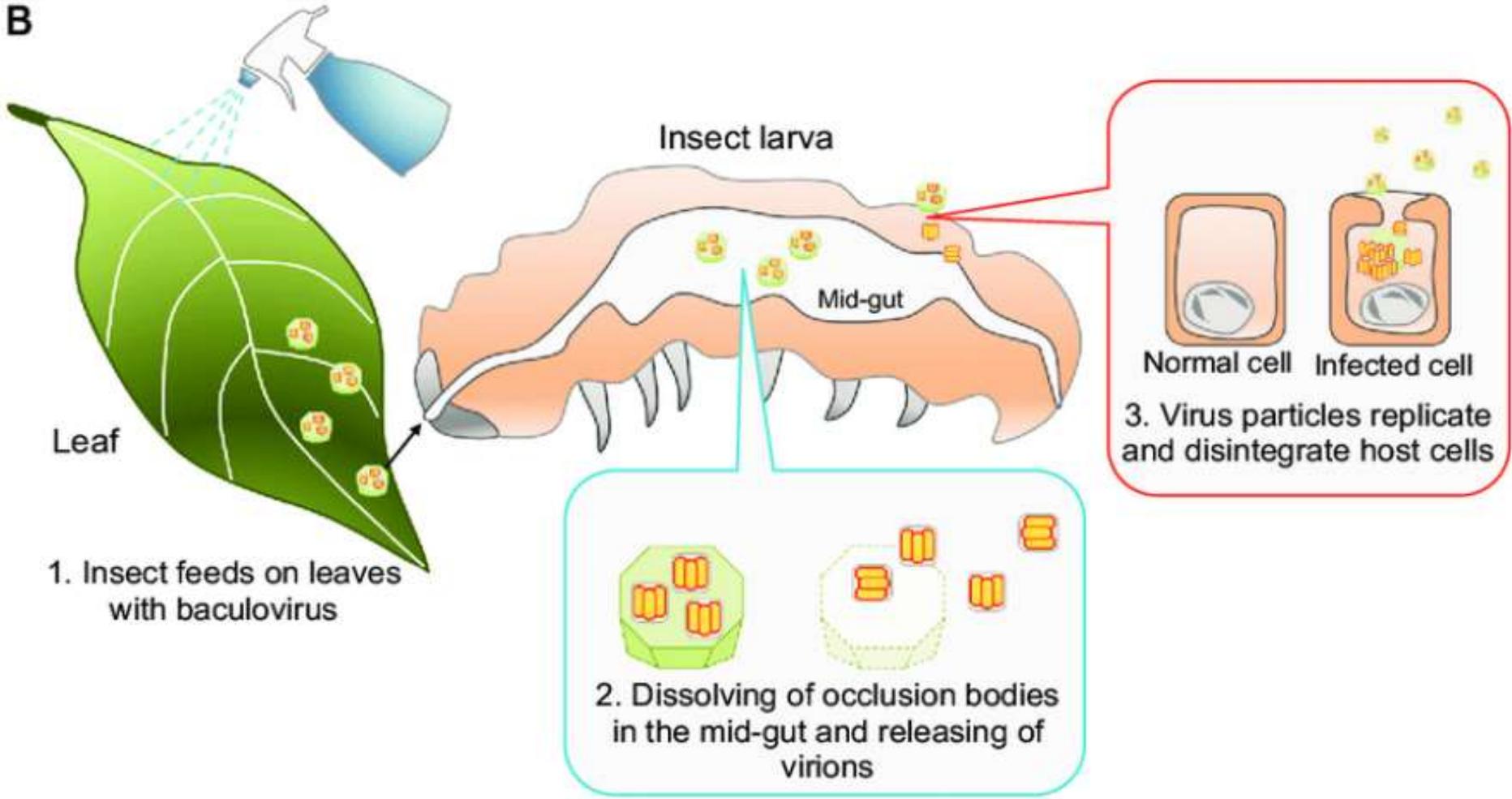
Active ingredient*:		
Cydia pomonella granulovirus isolate V22	0.06%	
Other ingredients:	99.94%	
Total	100.00%	

*Contains a minimum of 3×10^{13} viral occlusion bodies per liter.

Net Contents: 6 fluid ounces
EPA Reg. No. 69553-1
EPA Est. No. 70051-CA-001
Lot No.:

Manufactured by
Andermatt Biocontrol AG
Frankfurt, Germany

B



Insect larva

Mid-gut

Leaf

Normal cell Infected cell

1. Insect feeds on leaves with baculovirus

2. Dissolving of occlusion bodies in the mid-gut and releasing of virions

3. Virus particles replicate and disintegrate host cells

Douglas-fir tussock moth NPV



Photographs by Dan west

Tent caterpillar NPV



NPV infection of caterpillars and sawfly larvae cause the dead larvae to hang by their prolegs – “hangers”

Cabbage looper NPV



Sawfly NPV





There are three products containing strains of NPV to kill corn earworm and closely related caterpillars (e.g., tobacco budworm)



Corn earworm killed by Gemstar in hemp. Photo by Helene Doughty.

**Other NPV products
have been developed
for other caterpillars**

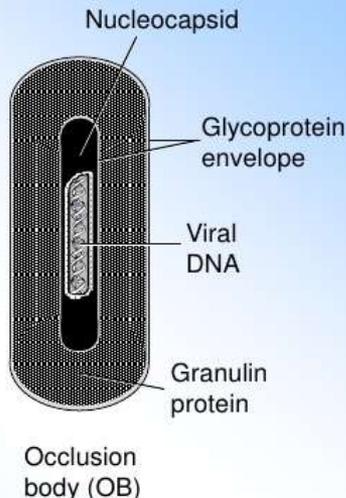


***Spodoptera* species, such
as beet armyworm**

**Loopers, such as
cabbage looper**



Active ingredient:
Codling moth granulosis virus



- *Cydia pomonella* granulovirus (CpGV)
- Natural pathogen of codling moth



The primary granulosis virus developed is for control of codling moth

A couple of different strains of the virus are marketed

MADEX HP INSECTICIDAL VIRUS

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EPA Est. No. 70051-CA-001
Lot No.:

Manufactured by
Andermatt Biocontrol AG

Fungi as Pathogens of Insects



NOLO BAIT
FOR ORGANIC PRODUCTION

NOLO BAIT
BIOLOGICAL INSECTICIDE

Nolo bait is a natural, non-toxic, and effective biological insecticide for organic production. It is a natural, non-toxic, and effective biological insecticide for organic production.

Manufactured in the USA by
MSA Domestic, Inc.
1800 Hwy. 177, Springdale, CO 81137
Tel. 970-356-9526

KEEP OUT OF REACH OF CHILDREN

SEE FIRST AID AND PRECAUTIONARY STATEMENTS ON LABEL PANEL.

EPA Registration 448128-2
EPA Establishment 46140-02-000

For use in organic production, see the following label: Nolo Bait, 100% Natural, 100% Effective, 100% Safe. For use in organic production, see the following label: Nolo Bait, 100% Natural, 100% Effective, 100% Safe.



**Fly fungus – a disease of
seedcorn maggot flies
common following cool, wet
springs**



Pathogen: *Entomophthora muscae*

Fungus-killed Grasshoppers

Pathogen: *Entomophthora grylli*



Photograph courtesy of Bill Leithhead



Beauveria bassiana
“White muscardine” fungus”



Some *Beauveria bassiana*-containing products

Beauveria bassiana

- Used as a foliar spray
- Potentially broad host range
 - Aphids, beetles, caterpillars
- Humidity/moisture after application important in infection
- Some (not all) OMRI allowable



Isaria fumosorosea

- Used as a foliar spray
 - Aphids, whiteflies, thrips
- Used as a soil drench
 - Caterpillars, beetle larva
- Broadly labeled on food crops, indoors and outdoors
- Very high humidity (ca. 80% recommended)

Greenhouse only





Metarrhizium anisopliae
“Green muscardine” fungus



A *Metarrhizium anisopliae*-containing product



Metarrhizium anisopliae

- Used as a foliar spray or as soil drench
- Limited labeling on food crops
 - Onions, peppers/tomatoes, lettuce, spinach small fruits
- Labelled hosts:
 - Thrips, spider mites, whiteflies, root weevils
- Not OMRI allowed





NOLO BAIT™

FOR ORGANIC PRODUCTION

**NOLO BAIT
BIOLOGICAL INSECTICIDE**

Nosema locustae
Biological Insecticide

For use in suppressing grasshoppers and Mormon Crickets
Active Ingredient: *Nosema locustae* Connaing™..... 0.05%
Inert Ingredients:..... 99.95%
Total..... 100.00%

*Contains at least one billion viable spores
per 454 grams (1.0 pound)
Net contents: _____ Date Formulated: _____
Lot# _____

Manufactured in the USA by:
M&R Durango, Inc.
6565 Hwy. 172, Ignacio, CO 81137
Tel: 970-259-3521



KEEP OUT OF REACH OF CHILDREN

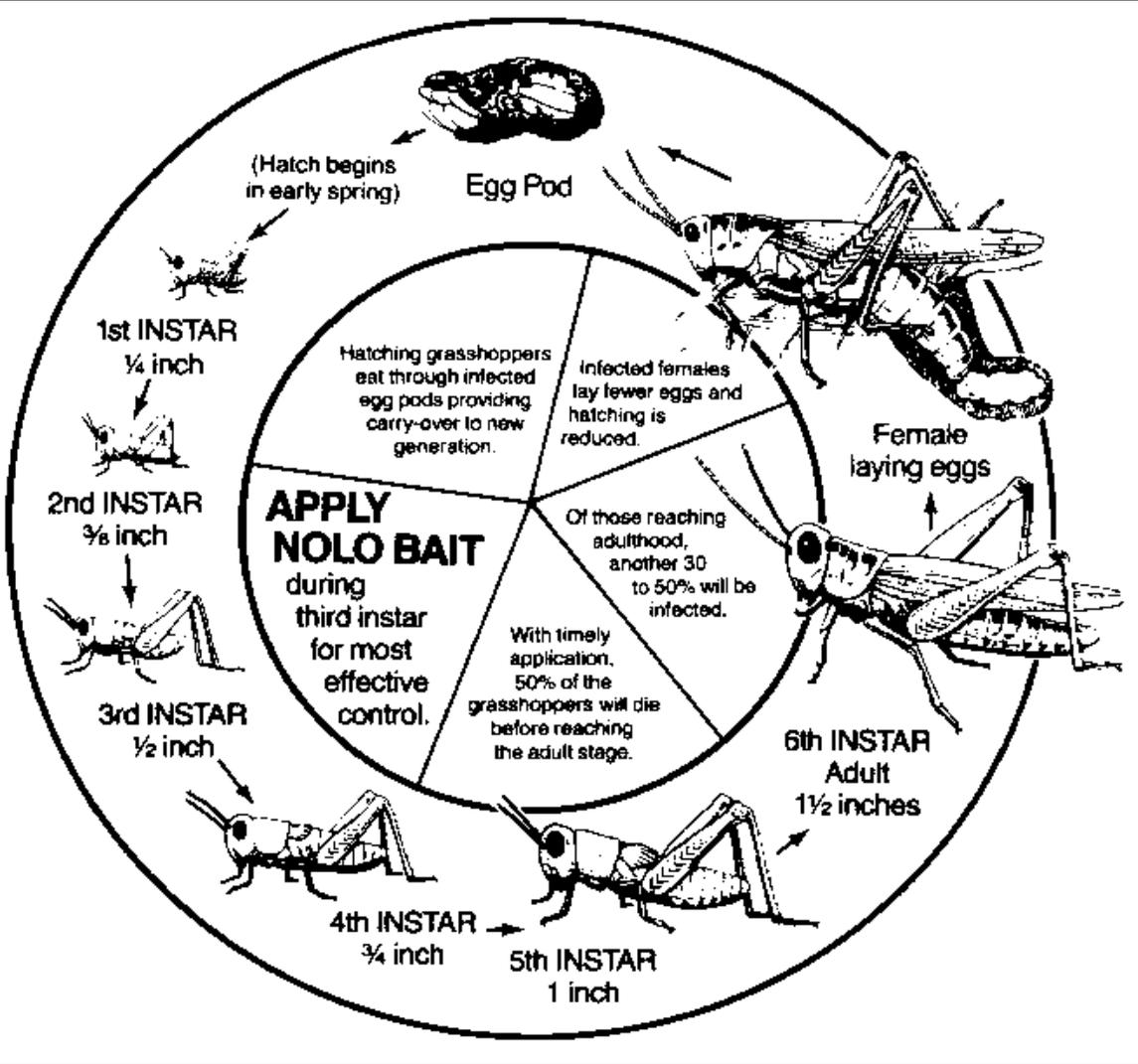
SEE FIRST AID AND PRECAUTIONARY
STATEMENTS ON BACK PANEL

EPA Registration #46149-2
EPA Establishment #46149-CO-001

Nosema locustae

*A microsporidian
(fungus) disease of
grasshoppers*



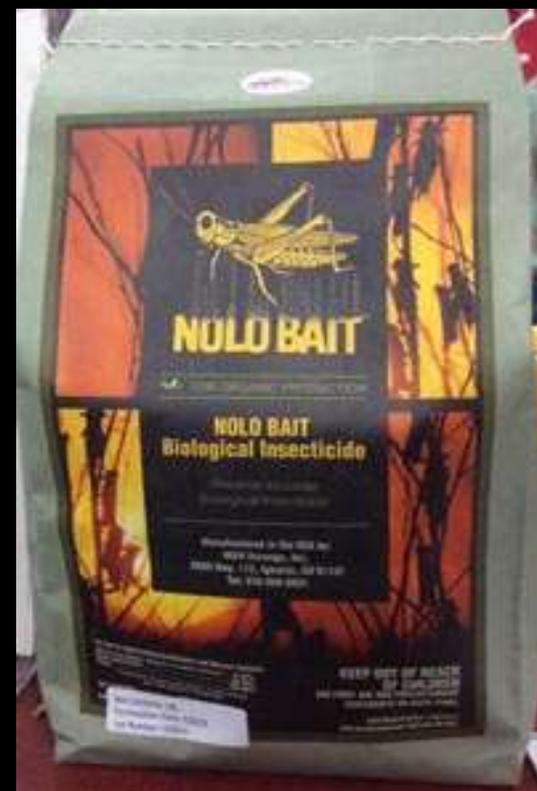


If you use *Nosema locustae*, make sure the material is fresh

Apply it when the young grasshoppers are present

Nosema locustae

- Applied as a bait to **off-field areas**
 - Not labeled for in-field use
- **Target pests:** Young stages of grasshoppers
 - Produces chronic infection that kills insects when stressed
- Perishable with limited storage life (particularly if not refrigerated)



Note to the attendees of the CFVGA Conference

From this point on is material prepared, but which I did not present, because I ran on too long.....

Branches of Biological Control

- **Conserve and enhance the activity of the existing biological control agents**
 - Augment biological controls with supplemental releases of natural enemies to suppress pests during a crop cycle
 - Import into the area new biological control species for permanent establishment/long term suppression

Working with Natural Enemies of Insect Pests

- Learn to recognize them – and don't kill them
- Provide for food needs of adults
- Provide for food needs of immature stages





LADY BEETLE

Most lady beetle adults are brightly colored



Adults



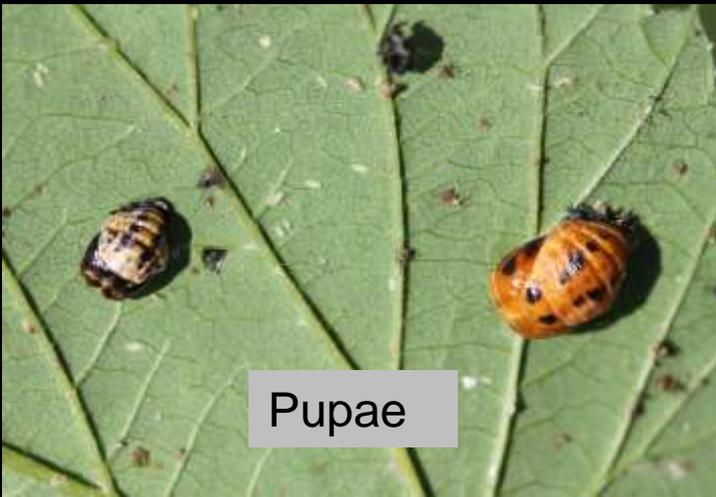
Eggs



Larvae



Pupae



Lady Beetle Life Stages

Lady beetle egg masses



Eggs of lady beetles are usually laid where prey are nearby that can feed their young, such as aphids



**Lady
Beetle
Larvae**



Principles of Gardening for Natural Enemies of Insect Pests

- Learn to recognize them – and don't kill them
- **Provide for food needs of adults**
- Provide for food needs of immature stages



Lady beetles

(“Lady bugs”, “Lady birds”....)





Lady beetle adults feed on nectar and pollen



Green Lacewings

Neuroptera:
Chrysopidae



Most adult green lacewings maintain themselves on nectar and pollen





Flower (Syrphid) Flies



**Flower fly larvae
are efficient
predators of
aphids**



Brian Valentine



Brian Valentine



Ken Gray



Adult flower flies sustain themselves on nectar





Adults of many natural enemies use flowers (nectar, pollen) for sustenance



Parasitoid wasps maintain themselves on nectar and pollen





Tachinid fly adults
sustain themselves on
nectar and pollen



Larvae develop within and
kill other insects



UGA5303086

Small, accessible flowers are most commonly used by natural enemies of garden pest insects



Some plants useful for providing food for adult stages of insect natural enemies



- Most Apiaceae - (dill, fennel, coriander, Ammi, Queen Anne's lace, etc.)
- Yarrow (some)
- Many sedums
- Spurges
- Sweet alyssum
- Basket-of-gold
- Thyme, several herbs





Farm Planning for Conservation Biocontrol

Xerces habitat planting, California almond orchard

Principles of Gardening for Insect Natural Enemies

- Learn to recognize them – and don't kill them
- Provide for food needs of adults
- **Provide for food needs of
immature stages**



**Natural enemies
develop on other
insects**

**Some insects –
insects that are not
damaging to the crop,
are needed for these
insects to function
well**



Bridal wreath spirea



Rubber rabbitbrush



Perennial plants that consistently provide predator food sources in my garden

Early season thrips on potato



=



Minute pirate bugs that eat thrips



Good numbers of minute pirate bugs

~~=~~



Suppression of potato psyllids coming in later



Cabbage loopers, potato and imidacloprid use

Outbreaks of cabbage looper
have only been seen on
imidacloprid-treated plants

Imidacloprid is weak on caterpillars and does not kill
loopers

Imidacloprid, a systemic insecticide, will kill predatory bugs
that occasionally drink from the plant



Damsel bugs



Minute pirate bugs

Pest Resurgence following application of pesticide

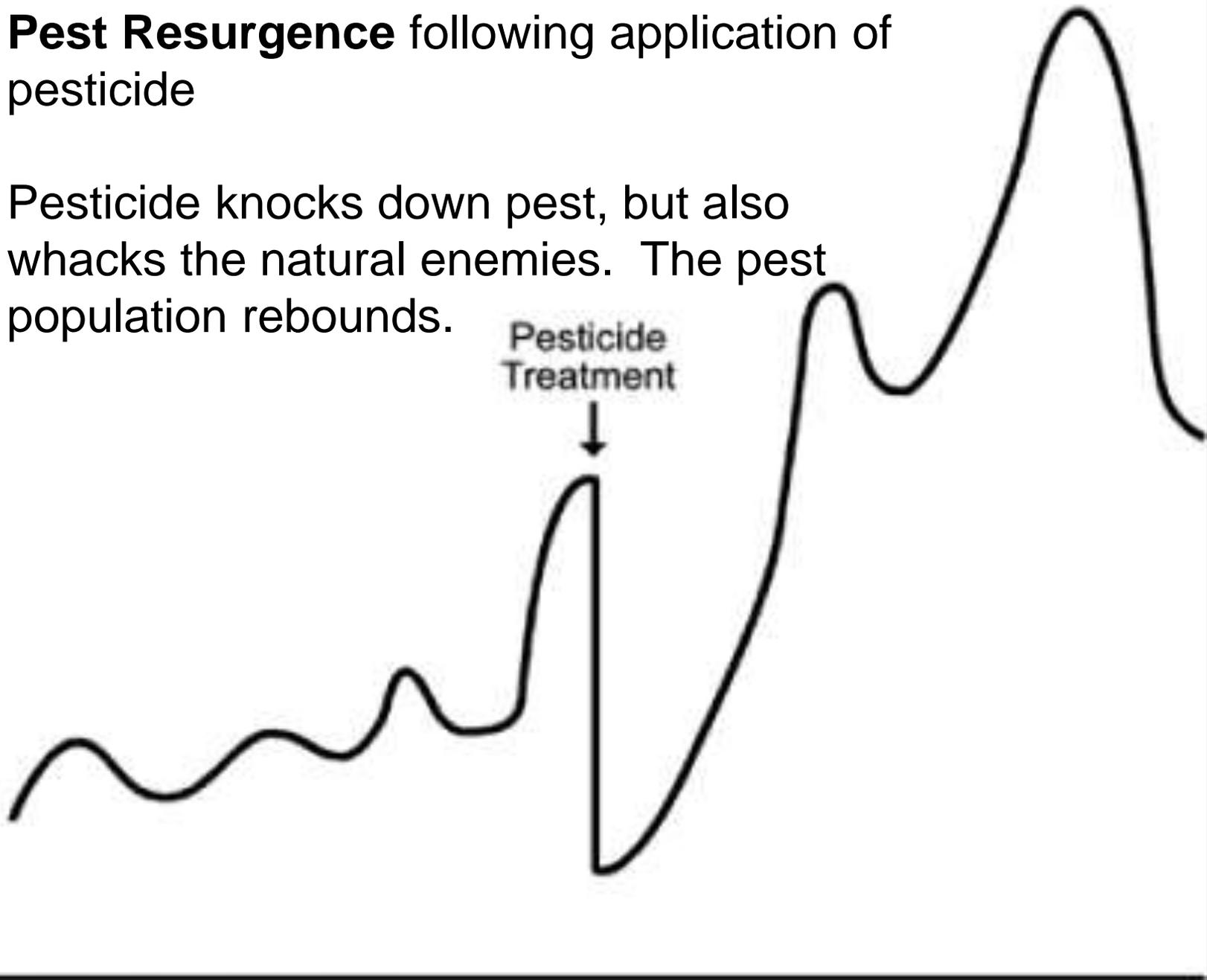
Pesticide knocks down pest, but also whacks the natural enemies. The pest population rebounds.

Pest Population

Pesticide Treatment



Time



Promote habitat diversity to optimize natural enemies





Intercropping

- Increases diversity of site
- May impact ability of insects to locate crop
- Can provide habitat for natural enemies, including more consistent sources of prey/hosts



Branches of Biological Control of Insect and Mite Pests

- Introduction of new species for permanent establishment
- Rearing/Distribution of natural enemies
- Conservation and enhancement of existing natural enemies
 - Involves on-site manipulations
 - Continuation of favorable practices can provide long-term effects

Farming *with* Native BENEFICIAL INSECTS

Ecological Pest Control Solutions



Identify the beneficial insects
controlling pests on your farm



Improve crop yields by
reducing pest damage



Provide habitat for beneficial insects
with hedgerows and buffer strips

An excellent
publication by
the **Xerces
Society** on
improving
habitat for
natural enemies
of insect pests

Want more? Search
**Conservation
Biological Control**

This presentation will be posted at the Colorado Insect Information Website

- **Housed at Department of Agricultural Biology (formerly Bioagricultural Sciences and Pest Management)**
- **Within Entomology**
 - Insect Information
- **Extension presentations for 2020 posted at bottom of page**

Click on Entomology

Then click on Insect information in the pop-up



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The Department of Agricultural Biology

*Improving ecosystem sustainability through teaching, research,
and extension in entomology, plant ecophysiology, plant
pathology, and weed science.*

Insect Information

Top of the Page

All materials needed in another accessible format can be made available upon request.

Arthropods of Colorado Fact Sheets

This is a listing of about 200 downloadable fact sheets related to insects and other "bugs" found in in Colorado. It contains fact sheets that are written for the Colorado Arthropods of Interest series and the Extension fact sheets that are related to insects.



Some Entomology Hot Links:

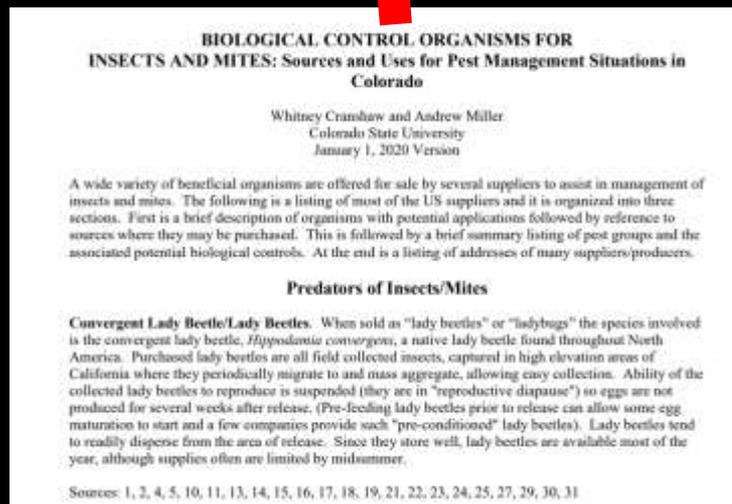
- [Colorado Hemp Insect Website](#)
- [Western Colorado Entomology Website](#)
- [IPM Images/Bugwood \(Cranshaw\)](#)
- [IPM Images/Bugwood \(Peairs\)](#)
- [Entomology Resources List](#)
- [Honey Bee Swarm Hotlines](#)
- [High Plains Integrated Pest Management Guide](#)

Miscellaneous Insect Information

This contains a variety of downloadable fact sheets and pamphlets on diverse miscellaneous subjects from "Bug Mugs" and "Life in a Colorado Water Garden" to "Mystery Bites and Itches" and "Commercially Available Sources of Biological Control Organisms: Sources and Uses in Colorado."



Over 200 Fact Sheets on Colorado insect are here



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Click on this (Powerpoint Presentations/Webinars).
The most recent ones are posted at the very end.

Recent Extension Presentations

This is a listing that provides the PowerPoint presentations (as PDF) of most Extension entomology programs conducted during the past 12 months.

PowerPoint Presentations/Webinars



Bottom of the Page

Questions?



whitney.cranshaw@colostate.edu