

Greenhouse Biological Control



**Dr. Vera Krischik, Department of Entomology,
University of Minnesota**

What is greenhouse biological control?

There are several types of biological control. Augmentative biological control involves periodic releases of biological control agents. This is the type of biological control most likely to be used in greenhouses.



When should biological control be used?

Biological control is most effective when enemies are release during low pest densities.

When using biological control agents in the greenhouse, it is important to avoid broad-spectrum pesticides; these may be detrimental to biological control agents. Carefully choose biorational insecticides to conserve specific natural enemies in the greenhouse.



Biological Control Agents by Pest

Aphids	<i>Aphidius matricariae</i> parasitoid	<i>Aphidoletes aphidomyza</i> midge larva	<i>Hippodamia convergens</i> lady beetle	<i>Orius</i> sp. minute pirate bug	<i>Chrysoperla</i> sp. lacewing larva	Predatory thrips
Mealybugs	<i>Anagyrus pseudococci</i> parasitoid	<i>Leptomastix dactylopii</i> parasitoid	<i>Cryptolaemus montrouzieri</i> lady beetle	<i>Chrysoperla</i> sp. lacewing larva		
Soft Scales	<i>Metaphycus helvolus</i> parasitoid	<i>Metaphycus alberti</i> parasitoid	<i>Rhyzobius lophanthae</i> lady beetle	<i>Chilocorus orbis</i> lady beetle	<i>Chilocorus cacti</i> lady beetle	Predatory thrips
Armored Scales	<i>Aphytis melinus</i> parasitoid	<i>Chilocorus kuwanae</i> lady beetle	<i>Chilocorus stigma</i> lady beetle			
Whiteflies	<i>Encarsia formosa</i> parasitoid	<i>Eretmocerus californicus</i> parasitoid	<i>Delphastus pusilus</i> lady beetle	<i>Chrysoperla</i> sp. lacewing larva	Predatory thrips	
Thrips	<i>Thripobius semiluteus</i> parasitoid	<i>Amblyseius cucumeris</i> predatory mite	<i>Hypoaspis miles</i> predatory mite	<i>Orius</i> sp. minute pirate bug	<i>Chrysoperla</i> sp. lacewing larva	Predatory thrips
Fungus gnats	parasitic nematodes	<i>Hypoaspis miles</i> predatory mite				
Spider mites	<i>Phytoseiulus persimilis</i> predatory mite	<i>Neoseiulus californicus</i> predatory mite	<i>Stethorus punctum</i> lady beetle	<i>Orius</i> sp. minute pirate bug	<i>Chrysoperla</i> sp. lacewing larva	Predatory thrips

Aphids

**Order Hemiptera
Family Aphididae**

Aphids reproduce rapidly and feed on many plant species. Aphids discolor and distort foliage. They also produce sticky honeydew, on which sooty mold grows.



Green peach aphid (*Myzus persicae*)

Aphid Parasitoid (*Aphidius matricariae*)

Order Hymenoptera
Family Braconidae

This wasp preys primarily upon green peach aphid. It is not a good parasite of cotton aphid or potato aphid.



Aphidius sp.

Aphid Parasitoid (*Aphidius matricariae*)



***Aphidius* is shipped as parasitized aphid mummies (see left). Up to 300 aphids are attacked by each female. *Aphidius* takes 10 to 14 days to develop from egg to adult. There are usually twice as many females as males.**

Release rates: 500 to 3,000/acre, 2 to 3 times, one week apart.

Aphid Predator (*Aphidoletes aphidomyza*)

Order Diptera

Family Cecidomyiidae

The larval stage of this midge preys on aphids.

Aphidoletes are shipped as pupae. Release in moist shaded areas. Adults hatch in 1 to 12 days. Females lay up to 250 eggs in 10 days.



Larva attacking aphid

Aphid Predator (*Aphidoletes aphidomyza*)

Larvae grow up to 1/8 inch long and can consume 4 to 65 aphids per day. After 3 to 7 days the larvae drop to the ground and burrow 3/4 to 1 1/2 inches into the soil to pupate. They are most effective at 68 to 80 degrees F and high humidity.

Release rates: 1 predator/10 sq. ft. or 4,500/acre; heavier infestations require 2 to 3 predators/10 sq. ft.



Convergent Lady Beetle (*Hippodamia convergens*)

**Order Coleoptera
Family Coccinellidae**

This is a generalist predator that feeds on soft-bodied insects.



Lady beetles are shipped as adults. Each adult consumes about 5,000 aphids. Within 8 to 10 days of release each female lays 10 to 50 eggs daily on the underside of leaves. Eggs are usually deposited near prey such as aphids.

Convergent Lady Beetle (*Hippodamia convergens*)

Eggs hatch in 2 to 5 days. Larvae grow from about 1 mm to 5 to 6 mm in length and may wander up to 40 feet in search of prey. Larvae eat 50 to 60 aphids per day. After 21 days larvae pupate. Adults emerge in 2 to 8 days.



Convergent Lady Beetle Release Guidelines

- **When beetles arrive put the sack in a cool place until late evening or early morning.**
- **Do not release the beetles during the heat of the day or while the sun is shining.**
- **Lady beetles should be released when the plants are partially covered with aphids.**
- **Try to maintain a balance of a few pests for food and enough lady beetles to keep them in check.**
- **Sprinkle or irrigate the area before releasing beetles.**
- **Release a few at a time; twice a week.**
- **Apply 1 tbsp on each shrub or a handful on each tree.**
- **For heavy infestation, release all of the beetles at once.**
- **Retie the bag and place in the refrigerator until all lady beetles are used.**
- **Beetles may be stored in the refrigerator for 2 weeks.**

Minute Pirate Bug (*Orius* spp.)

**Order Hemiptera
Family Anthocoridae**

These predators are effective against mites, thrips, aphids, and small caterpillars.



Orius insidiosus adult

They are shipped as adults. Release by opening the container or placing them on individual plants with a small paintbrush. Only release if there is a food source (pests or pollen).

Minute Pirate Bug (*Orius* spp.)

Adult bugs live for 3 to 4 weeks and lay eggs in plant tissue. Nymphs emerge in 4 to 5 days and become adults in 7 to 10 days.



Orius insidiosus nymph

Minute Pirate Bug (*Orius* spp.)

Greenhouse release: 1 *Orius* per 1/2 plants or 4 to 5 per plant in hot spots. Repeat release 2 weeks later.

General release: 100 to 2,000/acre. Allow 3 to 4 weeks for thrips control. *Orius* thrive in typical greenhouse conditions.



Orius feeding on thrips

Whitney Cranshaw

Green Lacewing (*Chrysoperla* spp.)

Order Neuroptera

Family Chrysopidae

Larvae are generalists that consume soft-bodied insects and mites. Green lacewing are shipped as eggs, larvae or adults.



Green Lacewing (*Chrysoperla* spp.)

Release rates: In gardens and greenhouses, release eggs at about 1,000 eggs/2,500 sq. ft., 10 to 50 thousand per acre.

Once the larvae emerge, they will feed for 1 to 3 weeks before they become adults. Adults eat only honey, pollen, and nectar, which they need to reproduce.

Repeated releases may be necessary if the infestation has not been arrested 5 to 7 days after the larvae have emerged.

Green Lacewing (*Chrysoperla* spp.)



Clockwise from top left: eggs, larva, cocoons, adult

Predatory Thrips

**Order Thysanoptera
Families Aleoonthripidae
and Phlaeothripidae**

**Predatory thrips attack
pest thrips, aphids,
mites, whiteflies,
and other insects.**



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Franklinothrips vespiformis
(top) and *Leptoanthrips mali*

Mealybugs

Order Hemiptera

Family Pseudococcidae

Mealybugs feed on a variety of plants and can distort foliage. Feeding produces honeydew, on which sooty mold grows. Cottony wax will appear on infested plants.



Citrus mealybug (*Planococcus citri*)

Mealybug Parasitoid **(*Anagyrus pseudococci*)**

Order Hymenoptera
Family Encyrtidae

This parasitic wasp attacks third instar and adult citrus and vine mealybugs. Larvae develop inside parasitized mealybugs. Adults feed on nectar.

Release rate: 4/10 sq. ft. every two weeks.

Mealybug Parasitoid (*Anagyrus pseudococci*)



Adult female

Mealybug Parasitoid (*Leptomastix dactylopii*)

Order Hymenoptera
Family Encyrtidae

This wasp attacks third instar citrus mealybug.

Female on host

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Natural History
Museum,
Cromwell Road,
London, SW7
5BD, UK.



Mealybug Parasitoid **(*Leptomastix dactylopii*)**

Under favorable conditions (78 degrees F, 60 to 65% humidity) females lay 60 to 100 eggs within 10 to 14 days inside mealybugs. Each larvae completely consumes its host. The pupa swells and hardens into a yellow-brown mummy. The adult wasp emerges through a round hole at the rear of the mummy. The life cycle is approximately 25 days.

Release rates: 1 to 2/sq. meter or 5/heavily infested plant.

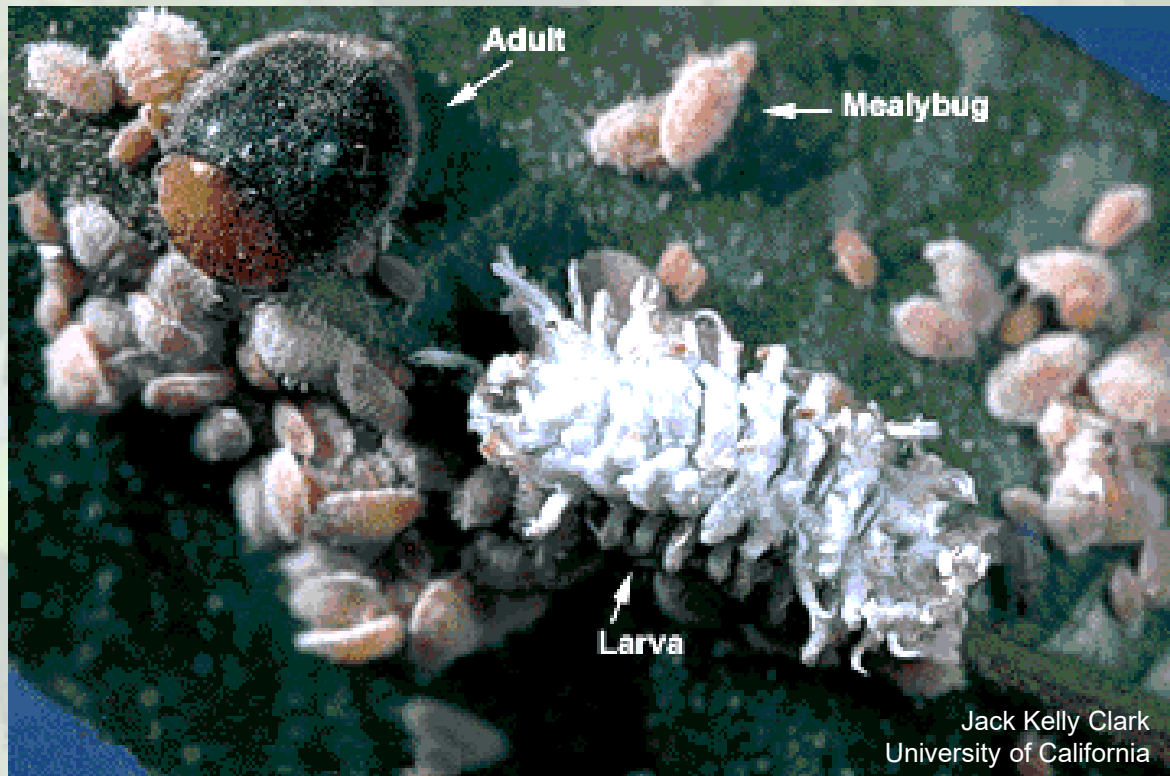
Mealybug Destroyer **(*Cryptolaemus montrouzieri*)**

Order Coleoptera
Family Coccinellidae

This beetle was imported into the United States in 1891 from Australia by Albert Koebele to control citrus mealybug in California. Although *C. montrouzieri* initially devastated the citrus mealybug populations in citrus groves, it was unable to survive the winter except in coastal areas. It also feeds on longtailed mealybug, but only reproduces on citrus mealybug because it oviposits in citrus mealybug egg masses.

Mealybug Destroyer (*Cryptolaemus montrouzieri*)

Larval stage lasts 13 to 17 days; pupal stage, 7 to 10 days; adult stage, 15 to 25 days. Larvae and adults feed on all stages of mealybugs.



Mealybug Destroyer (*Cryptolaemus montrouzieri*)

***Cryptolaemus* are shipped as adults and are most effective in high infestations. Optimal conditions are 61 to 91 degrees F, relative humidity between 70 to 80%.**

Release rates: 5 adults/infested plant; 500 to 5,000/acre. Store at room temperature.

Adults feeding on mealybug egg mass



Green Lacewing (*Chrysoperla* spp.)

Order Neuroptera

Family Chrysopidae

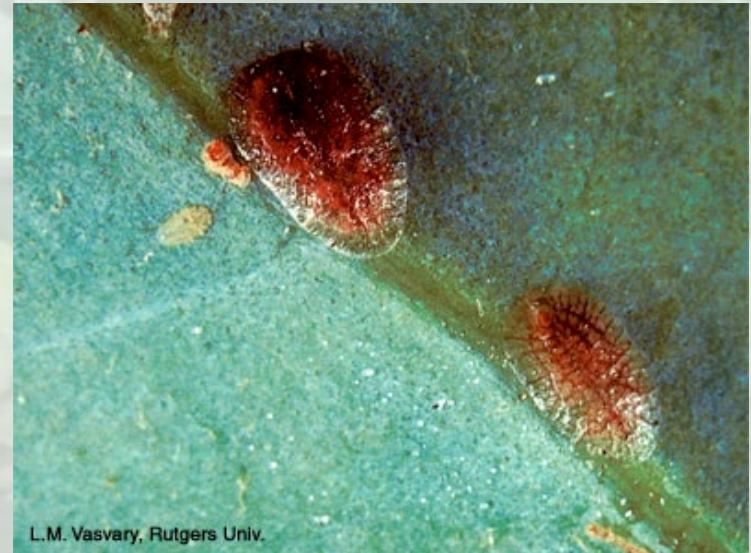
Larvae are generalists that consume soft-bodied insects and mites. Green lacewings are shipped as eggs, larvae or adults.



Soft Scales

**Order Hemiptera
Family Coccidae**

Soft scales can be found on many plants. Waxy covers make plants unsightly. Feeding causes wilting and honeydew, on which sooty mold grows.



Brown soft scale (top) and hemispherical scale

Scale Parasitoid (*Metaphycus* spp.)

Order Hymenoptera

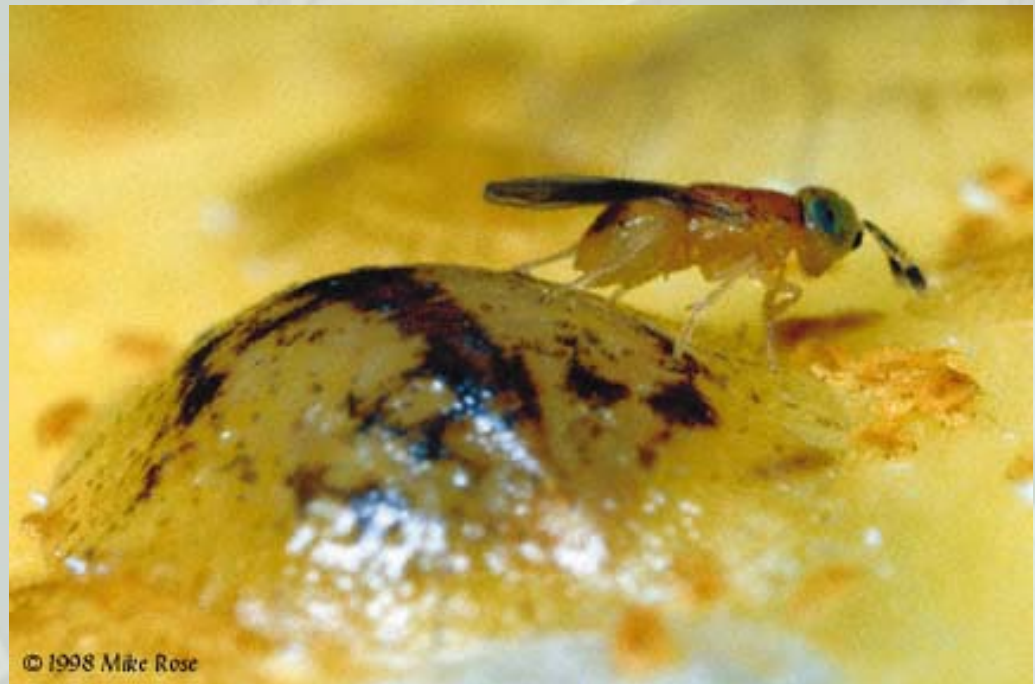
Family Encyrtidae

Metaphycus alberti (Howard) was originally brought to California from Australia in 1898 by Albert Koebele, whose earlier entomological investigations of that continent led to the successful biological control of the cottony cushion scale (DeBach and Rosen, 1991). The new parasite was subsequently named for Koebele by L.O. Howard (Howard, 1898).

Scale Parasitoid (*Metaphycus* spp.)

M. alberti attacks brown soft scale and a related species, *M. helvolus*, also attacks soft scales. Indoors, in locations where it has become established, it may be found in the vicinity of plants attacked by its host.

M. alberti stinging
brown soft scale
(*Coccus hesperidum*)



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Scale Parasitoid (*Metaphycus* spp.)

Release rate: 5/10 sq. ft., 5 to 10/plant, or 1K to 5K/acre.



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Brown soft scale and scale cover with parasitoid exit hole

Purple Scale Predator (*Rhyzobius lophanthae*)

Order Coleoptera
Family Coccinellidae



Purple Scale Predator **(*Rhyzobius lophanthae*)**

Also known as *Rhyzobius lophanthae*, this predator thrives in temperatures of 59 to 77 degrees F and a relative humidity of 20 to 90%.

The primary prey of both the larvae and adults are soft scales, including black, brown, and red, although they may eat mealybugs and smaller insects.

Release rates: 3 to 5 beetles/sq. yd. for light infestations or 4 to 6/sq. yd for heavy infestations.

Twice-Stubbed Lady Beetle (*Chilocorus* spp.)

Order Coleoptera
Family Coccinellidae

Adults and larvae feed on scales. *Chilocorus* species are known for armored scale control, but a few species, such as *C. orbis* and *C. cacti*, feed on soft scales.



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Chilocorus orbis adult

Predatory Thrips

**Order Thysanoptera
Families Aleoonthripidae
and Phlaeothripidae**

**Predatory thrips attack
pest thrips, aphids,
mites, whiteflies,
and other insects.**



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Franklinothrips vespiformis
(top) and *Leptoanthrips mali*

Armored Scales

Order Hemiptera
Family Diaspididae

Armored scales attack a variety of plants. Waxy covers make plants unsightly. Feeding causes discoloration and leaf death.



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California red scale (*Aonidiella aurantii*)

Red Scale Parasitoid (*Aphytis melinus*)

Order Hymenoptera
Family Aphelinidae

This wasp attacks
California red
scale, citrus red
scale, oleander
scale, San Jose
scale, ivy scale,
and citrus yellow
scale.



Female ovipositing into *Aonidiella aurantii*

Red Scale Parasitoid (*Aphytis melinus*)

***Aphytis* are shipped as adults, and the adult females lay their eggs in scales. Offspring from each female kill more than 30 scales. Adults live about 26 days and feed on honeydew.**

Ideal conditions are 76 to 85 degrees F, relative humidity 40 to 50%.

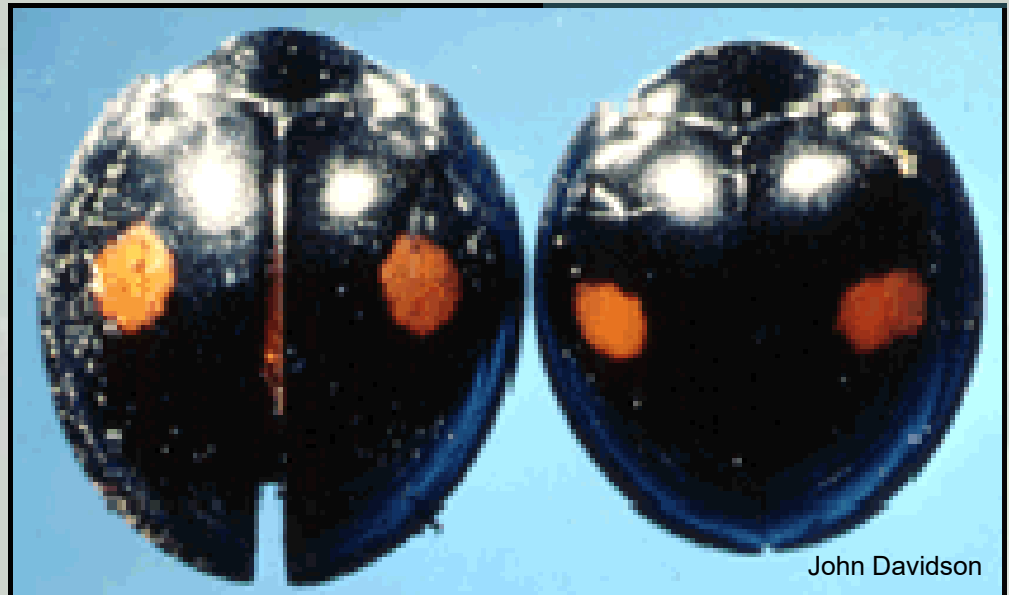
Release rates: 1 to 2 wasps per sq. ft, weekly; three applications usually required.

Twice-Stubbed Lady Beetle (*Chilocorus* spp.)

Order Coleoptera
Family Coccinellidae

Adults and larvae of *Chilocorus stigma* and *C. kuwanae* feed on armored scales.

C. stigma (left)
and *C. kuwanae*



John Davidson

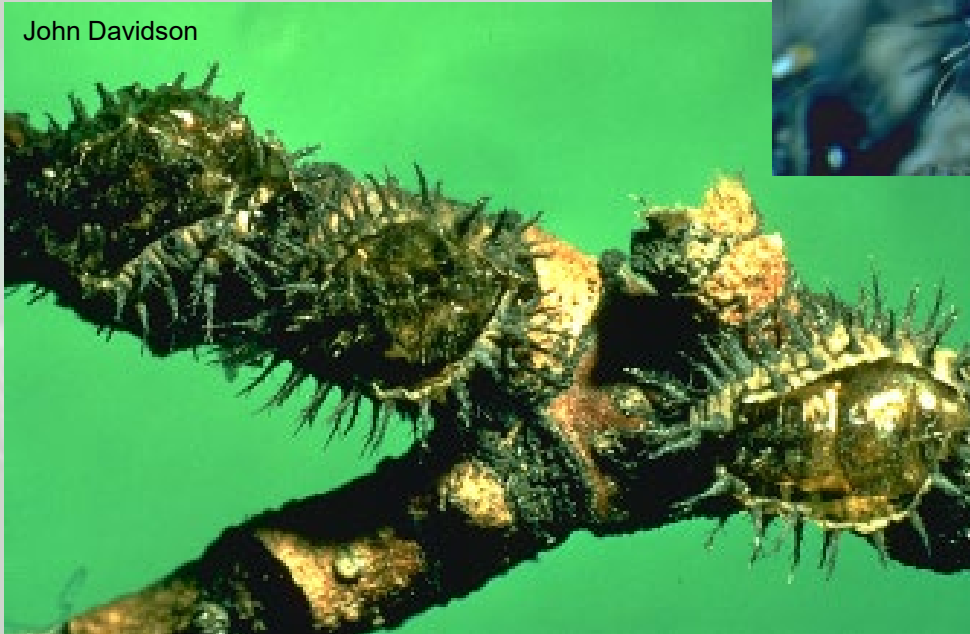
Twice-Stubbed Lady Beetle (*Chilocorus* spp.)

Chilocorus larva feeding
on euonymus scale

Cliff Sadof



John Davidson



Chilocorus pupae

Whiteflies

Order Hemiptera
Family Aleyrodidae

Whiteflies feed on many plants. Feeding causes discoloration and honeydew, on which sooty mold grows. They may also transmit viruses.

Silverleaf whitefly
(*Bemisia argentifolii*)



Scott Bauer
USDA ARS
www.insectimages.org

UGA1316008

Whitefly Parasitoid (*Encarsia formosa*)

Order Hymenoptera

Family Aphelinidae

***Encarsia formosa* is used worldwide for control of whiteflies in the greenhouse. Hosts include greenhouse, sweet potato, and silverleaf whiteflies. Commercial use began in Europe in the 1920's, but by 1945 interest waned due to development of pesticides. After 1970, use was reinitiated and has expanded from 100 to 4,800 hectares of greenhouse crops in 1993 (van Lenteren and Woets, 1988; Hoddle et al., 1998). Most usage occurs in Europe and Russia.**

Whitefly Parasitoid (*Encarsia formosa*)

***Encarsia formosa* was originally described from specimens reared from an unidentified aleyrodid on geranium (*Pelargonium* sp.) in 1924 in a greenhouse in Idaho (USA) (Gahan 1924). *E. formosa* has a cosmopolitan distribution and its native range is uncertain.**

Adults lay 100 to 200 eggs. Wasps develop inside the whitefly nymphs and emerge after 20 days.



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Whitefly Parasitoid (*Encarsia formosa*)

***Encarsia formosa* are shipped on strips (below right) that contain parasitized whitefly pupae and more than 1,000 *Encarsia*. Release at the first signs of whiteflies.**



Whitefly Parasitoid (*Encarsia formosa*)

Release rates: for greenhouse tomatoes and peppers, 1 *Encarsia*/4 plants weekly for 8 to 10 weeks; cucumbers, 1 *Encarsia*/2 plants weekly for 8 to 10 weeks; poinsettias, 2 *Encarsia*/plant weekly for 8 to 12 weeks.

For others crops, 10,000 *Encarsia*/acre

Release upon receipt.

Empty pupal cases and black parasitized pupae containing *Encarsia formosa*



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Whitefly Parasitoid (*Eretmocerus californicus*)

Order Hymenoptera
Family Aphelinidae

These wasps control sweet potato, silverleaf,
and greenhouse whiteflies.



Male



Female

Whitefly Parasitoid (*Eretmocerus californicus*)

***Eretmocerus* are shipped as eggs packed in bran. Sprinkle the mixture into leaf axils or around the base of plants.**

Wasps hatch within 1 to 2 days. *Eretmocerus* can be stored at 40 degrees F for 2 to 3 days if you do not release them immediately upon arrival.

Application rates are the same as for *Encarsia formosa*.

Whitefly Predator (*Delphastus pusillus*)

Order Coleoptera

Family Coccinellidae

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Whitefly Predator (*Delphastus pusillus*)

This beetle is effective against greenhouse, sweet potato, and tobacco whiteflies. Larvae and adults feed on all stages of whiteflies and eat spider mites when whiteflies are scarce.

***Delphastus* are shipped as adults and can eat hundreds of whitefly eggs and nymphs daily. Adult females live for 1 month and lay 3 to 4 eggs/day. Use with *Encarsia* and green lacewing.**

Release rate: 1,000/1,500 sq. ft.

Green Lacewing (*Chrysoperla* spp.)

Order Neuroptera

Family Chrysopidae

Larvae are generalists that consume soft-bodied insects and mites. Green lacewings are shipped as eggs, larvae or adults.



Predatory Thrips

**Order Thysanoptera
Families Aleoonthripidae
and Phlaeothripidae**

**Predatory thrips attack
pest thrips, aphids,
mites, whiteflies,
and other insects.**



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Franklinothrips vespiformis
(top) and *Leptoanthrips mali*

Thrips

**Order Thysanoptera
Family Thripidae**

These small insects feed on hundreds of hosts. They cause leaf drop, yellowing, stippling, streaking, and distortion of leaves. Some species transmit viruses.



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**Greenhouse thrips (above) and
western flower thrips**

Thrips Parasitoid (*Thripobius semiluteus*)

Order Hymenoptera
Family Eulophidae

This parasitic wasps attacks greenhouse thrips.

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*Thripobius
semiluteus*
stalking
immature
thrips prey

Thrips Predator (*Amblyseius cucumeris*)

Class Arachnida

Order Acari

Family Phytoseiidae



This mite feeds primarily on immature thrips, as the adults are too large for them to kill. Release when thrips populations are low.

Ideal conditions are 66 to 80 degrees F and a relative humidity of 65 to 72 percent.

***A. cucumeris* are shipped as adults in bran.**

Thrips Predator (*Amblyseius cucumeris*)

At 75° F, *Amblyseius cucumeris* eggs mature to adult in 6 to 9 days. First and second stage nymphs and adults are predacious. Adults live approximately 20 days.

Release rates:

Greenhouse crops: 50 to 100 predators per cucumber plant; 10 to 100 per pepper plant

Bedding and potted plants: 1,000 per 1,000 square feet

Tropical plants: 1,000 per 150-200 square feet

Predatory Mite (*Hypoaspis miles*)

Class Arachnida
Order Acari
Family Phytoseiidae



This mite attacks fungus gnats and thrips pupae.

Females lay eggs in soil. Eggs hatch in 1 to 2 days. Each mite consumes 5 to 20 prey per day and algae or plant debris when prey is scarce. The entire life cycle is 7 to 11 days.

Release rates: 5,000 mites treats 500 to 1,000 plants; 10,000 to 25,000/per acre.

Minute Pirate Bug (*Orius* spp.)

**Order Hemiptera
Family Anthocoridae**

These predators are effective against mites, thrips, aphids, and small caterpillars.



Orius insidiosus adult

They are shipped as adults. Release by opening the container or placing them on individual plants with a small paintbrush. Only release if there is a food source (pests or pollen).

Green Lacewing (*Chrysoperla* spp.)

Order Neuroptera

Family Chrysopidae

Larvae are generalists that consume soft-bodied insects and mites. Green lacewing are shipped as eggs, larvae or adults.



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Franklinothrips vespiformis
(top) and *Leptothrips mali*

Darkwinged Fungus Gnats (*Lycoriella* spp. and *Bradysia* spp.)

Order Diptera
Family Sciaridae

Larvae of these small flies feed on roots and organic matter. They cause wilting and may transmit pathogens.

Larvae (top) and adult darkwinged fungus gnats



Parasitic Nematodes (*Steinernema feltiae*)

Phylum Nematoda
Family Steinernematidae

Nematodes prey on many kinds of insects. They enter their prey through body openings. Nematodes inject hosts with lethal bacteria and feed on the resultant “goo.” The hosts die in 48 hours.

Nematodes reproduce and offspring feed on cadavers before emerging to find new hosts.



Parasitic Nematodes (*Steinernema feltiae*)

Nematodes are shipped on a sponge or in a powdery clay formulation that is mixed with water. The solution can be applied using a watering can, hose, backpack, pump sprayer, or irrigation system. Release in early morning or late afternoon away from direct sunlight. Moisten area before and after application.

Release 1 million/50 sq. ft. every 3 to 6 weeks or until infestation subsides.

Nematodes can be stored in a refrigerator for up to 2 weeks.

Predatory Mite (*Hypoaspis miles*)

Class Arachnida

Order Acari

Family Phytoseiidae

This mite attacks fungus gnats and thrips pupae.

Females lay eggs in soil. Eggs hatch in 1 to 2 days. Each mite consumes 5 to 20 prey per day and algae or plant debris when prey is scarce. The entire life cycle is 7 to 11 days.

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Spider Mites

Class Arachnida
Order Acari
Family Tetranychidae

These common pests attack many different plant species. Feeding causes stippling, yellowing, and leaf drop. In addition, spider mites web profusely on plants.



Two-spotted spider mite (*Tetranychus urticae*)

Spider Mite Predator (*Phytoseiulus persimilis*)

Class Arachnida
Order Acari
Family Phytoseiidae

This mite was accidentally introduced into Germany from Chili in 1958 and then shipped to other parts of the world. Individuals consume 5 to 10 adult spider mites or up to 20 eggs per day. It



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Phytoseiulus persimilis
eating a two-spotted
spider mite egg.

Spider Mite Predator **(*Phytoseiulus persimilis*)**

***P. persimilis* need a relative humidity greater than 60%. This mite dies when food runs out, so if reinfestation occurs, release every 3 to 5 weeks. Spider mites are controlled in 2 to 3 weeks during low infestations.**

Release rates: tomatoes and cucumbers, 1 predator/plant plus 1 to 2/infested leaf; for other greenhouse crops and tropical plants, 2,000/3,000 sq. ft; for bedding plants, 1,000/10,000 sq. ft.; for large agri-business, 5,000 to 20,000/acre depending on infestation.

Spider Mite Predator (*Neoseiulus californicus*)

Class Arachnida
Order Acari
Family Phytoseiidae



This mite attacks spider mites and tarsonemid mites. Individuals consume one adult or a few eggs per day and can survive longer under starvation conditions.

***N. californicus* prefer a minimum of 60% humidity and temperatures 60 to 85 degrees F.**

Spider Mite Predator (*Neoseiulus californicus*)

Release rates: 4 mites/sq. ft, bi-weekly, 2 to 3 times; 5,000 to 20,000/acre, bi-weekly, 2 to 3 times. Works well in gardens and greenhouses.



***N. californicus* attacking mite egg**

Spider Mite Destroyer (*Stethorus* spp.)

Order Coleoptera
Family Coccinellidae

Adults and larvae of this lady beetle feed on spider mites. Adults are shipped. Works best in low pest densities.

Release rate: 200 to 500/acre



John Davidson



L. Hull

Stethorus punctum adult (top) and larva

Spider Mite Destroyer (*Stethorus* spp.)

John Davidson



Above: left to right: spider mite and three life stages of *Stethorus*: larva, pupa, adult

Right: *Stethorus* eggs in mite colony



Minute Pirate Bug (*Orius* spp.)

**Order Hemiptera
Family Anthocoridae**

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Orius insidiosus adult

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Green Lacewing (*Chrysoperla* spp.)

Order Neuroptera

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Franklinothrips vespiformis
(top) and *Leptohiprips mali*