



# Commercially Available\* Biological Control Agents for Common Greenhouse Insect Pests

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# Commercially Available Biological Control Agents for Aphids

## Parasitoids

## Predators

<i>Aphelinus abdominalis</i>	<i>Aphidius colemani</i>	<i>Aphidius ervi</i>	<i>Aphidius matricariae</i>	<i>Aphidoletes aphidimyza</i>	<i>Adalia bipunctata</i>	<i>Chrysopa carnea</i>	<i>Chrysoperla rhyfilabris</i>	<i>Hippodamia convergens</i>
								
<b>Parasitic Wasp</b>	<b>Parasitic Wasp</b>	<b>Parasitic Wasp</b>	<b>Parasitic Wasp</b>	<b>Predatory Gall Midge</b>	<b>Ladybird Beetle</b>	<b>Green Lacewing</b>	<b>Green Lacewing</b>	<b>Ladybird Beetle</b>
<ul style="list-style-type: none"> <li>◆ Parasitizes a wide-range of aphid species.</li> <li>◆ Can tolerate higher temperatures than most <i>Aphidius</i> species.</li> <li>◆ Slower to establish than <i>Aphidius</i> species.</li> <li>◆ Release 2 to 4 adult wasps per 10 square feet weekly or until 80-90% of the aphids are parasitized.</li> </ul>	<ul style="list-style-type: none"> <li>◆ Parasitizes smaller aphids such as green peach and melon aphid.</li> <li>◆ Can be reared using banker plants (oat or wheat) infested with bird-cherry oat aphid (use a minimum of 4 banker plants per acre).</li> <li>◆ May be sold as a mixture with <i>Aphidius ervi</i>.</li> <li>◆ Release 400 to 2,000 adults per acre.</li> </ul>	<ul style="list-style-type: none"> <li>◆ Parasitizes larger aphids such as foxglove and potato aphid.</li> <li>◆ May be sold as a mixture with <i>Aphidius colemani</i>.</li> <li>◆ Release 400 to 2,000 adults per acre.</li> </ul>	<ul style="list-style-type: none"> <li>◆ Parasitizes green peach aphids.</li> <li>◆ Active at cooler temperatures (50°F to 85°F; optimum 77°F) than <i>Aphidius colemani</i> (Optimum: 86°F).</li> <li>◆ Release 400 to 2,000 adults per acre.</li> </ul>	<ul style="list-style-type: none"> <li>◆ Larval stages prey on all aphid species encountered in greenhouses.</li> <li>◆ Most effective at temperatures between 68 and 80°F and a relative humidity between 70 and 80%.</li> <li>◆ Primarily active at night.</li> <li>◆ Mainly used against high aphid populations.</li> </ul>	<ul style="list-style-type: none"> <li>◆ Both larvae and adult feed on many different aphid species.</li> <li>◆ Used when aphid populations are high.</li> <li>◆ Adults typically attempt to leave the greenhouse after release. Therefore, make releases in the evening.</li> <li>◆ Release adults every 2 to 3 weeks.</li> </ul>	<ul style="list-style-type: none"> <li>◆ Larvae feed primarily on aphids but may also feed on mealybugs.</li> <li>◆ Can consume up to 425 aphids per week.</li> <li>◆ Release 5 to 10 eggs per plant or 1,000 eggs per 200 square feet.</li> </ul>	<ul style="list-style-type: none"> <li>◆ Tolerates a higher relative humidity (&gt;75%) than <i>Chrysopa carnea</i>.</li> <li>◆ Can consume up to 300 aphids per week.</li> <li>◆ Release 5 to 10 eggs per plant or 1,000 eggs per 200 square feet.</li> </ul>	<ul style="list-style-type: none"> <li>◆ Feeds on 2,000 aphids during their lifetime.</li> <li>◆ Multiple releases are usually required.</li> <li>◆ Most effective when aphid numbers are high.</li> <li>◆ Adults typically attempt to leave the greenhouse after release. Therefore, make releases in the evening.</li> <li>◆ Release adults every 2 to 3 weeks.</li> </ul>

\*All release rates are benchmarks – they will vary with crop type and infestation level.

\*Photo credits: <sup>1</sup>Koppert Biological Systems, <sup>2</sup>Bugwood.org or <sup>3</sup>Evergreen Growers Supply.

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# Commercially Available Biological Control Agents for Western Flower Thrips

## Predators

## Beneficial Nematode

*Amblyseius swirskii*



*Neoseiulus (= Amblyseius) cucumeris*



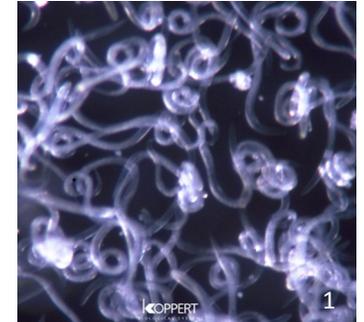
*Orius* spp.



*Stratiolaelaps scimitus*



*Steinernema feltiae*



**Predatory Mite**

**Predatory Mite**

**Minute Pirate Bug**

**Soil-dwelling Predatory Mite**

**Beneficial Nematode**

- ◆ Feeds on both 1<sup>st</sup> and 2<sup>nd</sup> instar larvae.
- ◆ Tolerates higher temperatures than *Neoseiulus cucumeris*.
- ◆ Will also feed on the eggs and nymphs of whiteflies.
- ◆ Feeds on pollen in the absence of prey.
- ◆ More expensive than *Neoseiulus cucumeris*.

- ◆ Most widely used predatory mite for western flower thrips.
- ◆ Feeds on the 1<sup>st</sup> instar larvae.
- ◆ Make releases early in the crop production cycle.
- ◆ Active at temperatures between 70 and 75 ° F; prefers a relative humidity around 65%.

- ◆ Feed on larvae and adults of western flower thrips.
- ◆ May also feed on aphids and whiteflies.
- ◆ Can be used with ornamental pepper plants serving as banker plants (example: 'Purple Flash,' 100 per acre).
- ◆ More expensive than using *Neoseiulus cucumeris*.
- ◆ Most effective when temperatures are >60° F and day length is >12 hours.
- ◆ Release 0.5 to 1 per square foot.

- ◆ Adults may kill up to 30 prey, including western flower thrips pupae or fungus gnat larvae, per day.
- ◆ Release 1,000 to 2,000 per square foot.

- ◆ Apply as either a foliar spray or drench to the growing medium. Drench applications target the pupa stage.
- ◆ Requires soil temperatures of 50 to 80° F to be effective.
- ◆ Apply early in the morning or late in the evening.
- ◆ Water crops both before after application to increase efficacy.
- ◆ For foliar sprays, apply 50 million per 1,000 square feet.
- ◆ Remove screens before making applications.

**\*All release rates are benchmarks – they will vary with crop type and infestation level.**

\*Photo credits: <sup>1</sup>Koppert Biological Systems, <sup>2</sup>Bugwood.org or <sup>3</sup>Evergreen Growers Supply.

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# Commercially Available Biological Control Agents for Twospotted Spider Mites

## Predators

*Amblyseius andersonii*



**Predatory Mite**

- ◆ Feeds on alternative prey if twospotted spider mites are absent.
- ◆ Active at temperatures between 43 and 46° F.
- ◆ Release 10 mites per square foot.

*Amblyseius californicus*



**Predatory Mite**

- ◆ Slower acting than other predatory mites such as *Phytoseiulus persimilis*.
- ◆ More effective at higher temperatures (>80° F) and a lower relative humidity than *Phytoseiulus persimilis*.
- ◆ Used for long-term crops under warm, dry conditions.
- ◆ Release 10 mites per square foot.

*Amblyseius fallacis*



**Predatory Mite**

- ◆ Tolerates cooler temperatures than most predatory mites.
- ◆ Feeds on pollen in the absence of prey.
- ◆ Release 10 mites per square foot.

*Feltiella acarisuga*



**Predatory Gall Midge**

- ◆ Larvae feed on all life stages of the twospotted spider mite.
- ◆ Females lay eggs near colonies of the twospotted spider mite.
- ◆ Adults fly around and can spread among a crop.
- ◆ Most effective when used in combination with other biological control agents.
- ◆ Optimal conditions are 68 to 80° F and a relative humidity >60%.
- ◆ Does not perform well when temperatures are >85° F.
- ◆ Release 10 adults per square foot.

*Galendromus occidentalis*



**Predatory Mite**

- ◆ Smaller than *Phytoseiulus persimilis*.
- ◆ Most effective at higher temperatures and a relative humidity between 40 and 80%.
- ◆ Survives well when twospotted spider mite populations are low.
- ◆ Feeds on twospotted spider mite, broad mite and cyclamen mite.
- ◆ Release 10 mites per square foot.

*Phytoseiulus persimilis*



**Predatory Mite**

- ◆ Main predatory mite used against the twospotted spider mite.
- ◆ Most effective at temperatures between 70 and 80° F and a relative humidity >60%.
- ◆ Does not perform well when temperatures are >85° F.
- ◆ At optimal temperatures, develops twice as fast as twospotted spider mite.
- ◆ Release 10 mites per square foot.

*Stethorus punctillum*



**Predatory Beetle**

- ◆ Both larvae and adults feed on all life stages of twospotted spider mites.
- ◆ Release 10 adults per square foot.

**\*All release rates are benchmarks – they will vary with crop type and infestation level.**

**\*Photo credits: <sup>1</sup>Koppert Biological Systems, <sup>2</sup>Evergreen Growers Supply, <sup>3</sup>Wikimedia Commons or <sup>4</sup>Biobest.**

# Commercially Available Biological Control Agents for Fungus Gnats

## Beneficial

### Predators

*Dalotia coriaria*



3

**Predatory Rove Beetle**

- ◆ Apply directly onto the surface of the growing medium.
- ◆ Larvae and adults are predators and highly mobile.
- ◆ Both adults and larvae are very sensitive to light.
- ◆ Adults can fly and spread within a greenhouse.
- ◆ Release 1 adult per 10 square feet.

*Stratiolaelaps scimitus*

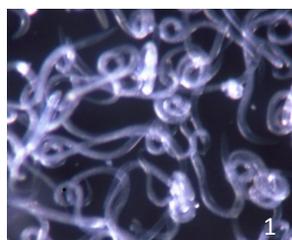


3

**Predatory Mite**

- ◆ Adults may kill 15 to 30 fungus gnat larvae per day.
- ◆ Feeds on eggs, larvae and pupae of fungus gnats.
- ◆ Apply directly to the growing medium.
- ◆ Previously known as *Hypoaspis miles*.
- ◆ May be used in combination with *Steinernema feltiae*.
- ◆ Release 1,000 to 2,000 mites per square foot.

*Steinernema feltiae*



1

**Beneficial Nematode**

- ◆ May be effective up to 4 weeks.
- ◆ Attacks the larval stages of fungus gnats.
- ◆ Requires a moist growing medium and growing medium temperature between 50 and 86° F.
- ◆ Apply early in the morning or late in the evening.
- ◆ Irrigate before and after application.
- ◆ Apply 50 million per 1,000 square feet as a drench.

**\*All release rates are benchmarks — they will vary with crop type and infestation level.**

\*Photo credits: <sup>1</sup>Koppert Biological Systems, <sup>2</sup>Bugwood.org, <sup>3</sup>Evergreen Growers Supply, or used with permission from <sup>4</sup>Kent M. Daane, University of California.

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# Commercially Available Biological Control Agents for Mealybugs

### Parasitoids

### Predators

*Leptomastix dactylopii*



1

**Parasitic Wasp**

- ◆ Females attack only the 3<sup>rd</sup> and 4<sup>th</sup> instars of the citrus mealybug.
- ◆ Effective at low mealybug populations.
- ◆ Release 5 parasitoid adults per 10 square feet.

*Anagyrus pseudococci*



4

**Parasitic Wasp**

- ◆ Attacks both vine and citrus mealybugs.
- ◆ Females attack 2<sup>nd</sup> through 4<sup>th</sup> instars.
- ◆ Optimal temperature is around 86° F.

*Cryptolaemus montrouzieri*



2

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**Predatory Beetle**

- ◆ Both larvae and adults feed on all mealybug life stages.
- ◆ Not effective at temperatures <50° F.
- ◆ Most active under warm, sunny conditions.
- ◆ Less effective on tomato and other crops with glandular trichomes (hairs).
- ◆ Repeated releases (introductions) are usually required.
- ◆ Release 1 to 2 larvae or adults per square foot.

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# Commercially Available Biological Control Agents for Whiteflies

## Parasitoids

*Encarsia formosa*



Parasitic Wasp

- ◆ Most widely used parasitoid for greenhouse whiteflies.
- ◆ Most effective at higher temperatures (>70° F).
- ◆ May be ineffective on plants with honeydew (clear, sticky liquid).
- ◆ Make releases when greenhouse whitefly populations are low.
- ◆ Adult females will host feed on nymphs.
- ◆ Release parasitoids every 1 to 2 weeks.
- ◆ Release 2 wasps per 15 square feet every 1-2 weeks for prevention.

*Eretmocerus eremicus*



Parasitic Wasp

- ◆ Parasitizes sweet potato and greenhouse whitefly.
- ◆ Females prefer laying eggs into 2<sup>nd</sup> or 3<sup>rd</sup> nymphal instars.
- ◆ Tolerates higher temperatures and does more host-feeding than *Encarsia formosa*.

*Amblyseius swirskii*



Predatory Mite

- ◆ Feeds on the eggs and nymphs of whiteflies and larvae of western flower thrips.
- ◆ May also feed on pollen in the absence of prey.

## Predators

*Delphastus catalinae*



Predatory Beetle

- ◆ Most effective when whitefly populations are high.
- ◆ Can feed on >150 whitefly eggs per day.
- ◆ Will not attack parasitized whitefly.
- ◆ May be sensitive to pesticide residues.

*Dicyphus hesperus*



Predatory Mirid Bug

- ◆ Feeds on greenhouse whitefly.
- ◆ Reared on mullein banker plants: requires a minimum of 8 weeks to establish a sufficient population.

**\*All release rates are benchmarks – they will vary with crop type and infestation level.**

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