



*A hemipteran pest killed by an insect-killing fungus. The white fluffy mass is fungal material growing out of the insect's body.*



*Note the parasite egg (arrow) that has been laid on the surface of the body of a larval pest.*

## BIOLOGICAL CONTROL



Lady beetle larva feeding on aphids



*An adult lady beetle. Feeding on aphids.*



*A crab spider feeding on an insect pest. Photo by E. Memmler.*

## BIOLOGICAL CONTROL

Biological control is the use of living organisms - natural enemies such as predators, parasites and pathogens - to regulate pests. Some crops and their pests are better suited to biocontrol than others. Biocontrol agents regulate pests by consuming them (predators), parasitizing them (parasites, parasitoids), or infecting them (pathogens). Several types of organisms are available for greenhouse use, including insects, mites, bacteria, fungi, and nematodes.

### The Advantages:

- Reduced reliance on pesticides
- Reduced health risks to workers and the environment
- Few phytotoxicity problems
- Delayed development of pesticide resistance
- No re-entry delays after application or release
- Increased crop value

### The Disadvantages:

- Requires some specialized knowledge
- May not completely eliminate the pest
- Must be used with other IPM tactics
- May cost more than some pesticide treatments
- Sensitive to temperature and environmental conditions
- Not always compatible with chemical pesticides
- Pest population reduction occurs slowly

**Keys to Success.** Biologicals do not work in the same way as chemicals and it takes time to learn how to use them effectively. They are best used in the early stages of an infestation, as a preventative means of control, not after an outbreak has occurred. Regular scouting, pest

identification, and an understanding of the pest and natural enemy biology are critical for success. Some pesticides may be compatible with biological control if applications are made at the right time. Some important points to remember when considering using biological control:

- Identify the pest(s); some biologicals are pest-specific.
- Develop a plan before you start.
- Start small, don't try to solve all of your pest problems with biological control the first time.
- Know the history of the greenhouse; persistent pesticides can kill many biological control agents.
- Select a reliable biocontrol supplier (one who can also provide technical support).
- Place your order in advance so natural enemies arrive on time.
- Purchase only what you need and use them promptly, some cannot be stored.
- Handle natural enemies properly to ensure their survival.
- Follow recommended release rates and schedules.
- Make sure temperature, humidity and lighting are right for the beneficial at the time of release.
- Monitor and record success with natural enemies.

Before using biological control, a grower must explore options for the pest. Biological control information is available from the Assoc. of National Biological Control Producers ([www.anbp.org](http://www.anbp.org)), P.O. Box 1609 Clovis, CA 93613-1609 Tel: (559) 360-7111. For a list of commercial sources of biological control agents on the web: [http://www.cdpr.ca.gov/docs/pestmgt/ipminov/ben\\_supp/contents.htm](http://www.cdpr.ca.gov/docs/pestmgt/ipminov/ben_supp/contents.htm)

Additional references and useful websites are listed at the back of the book. When talking to a supplier, you will be asked for details on the target pest, level of infestation, crop type, area to be treated, etc., before calculations on release rates can be made.

## BASIC INFORMATION ON BIOLOGICAL CONTROL AGENTS

### Lady Beetles

Adults and larvae are predators of soft-bodied insects such as aphids, scales, and whiteflies. Adults (0.06-0.4 in. long) come in various colors. There are >500 naturally occurring species in North America. Wild lady beetles may enter greenhouses and live there if pesticides are used selectively.



Adult ladybird beetle

Species commercially available:

*Coleomegilla maculata* (pink-spotted ladybird beetle)

*Adalia bipunctata* (two-spotted ladybird beetle)

*Hippodamia convergens* (convergent ladybird beetle)

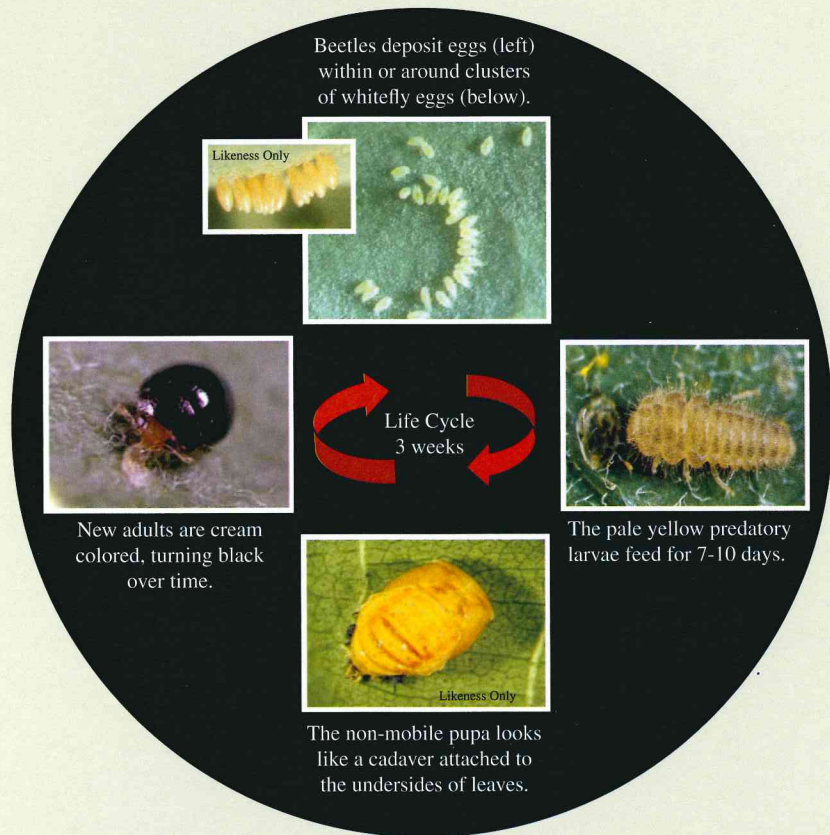


**Lady Beetles cont'd**

**DELPHASTUS.** Adults and larvae attack eggs and nymphs of greenhouse and silverleaf whiteflies, consuming up to 10,000 eggs over its life. Adults are shiny black with a reddish-orange head; larvae are pale yellow. Adults are strong fliers, detecting prey by smell. Females must eat 100 prey/day to reproduce, so beetles will not persist without the host. Beetles recognize and avoid parasitized whiteflies, so they can be used together with parasitic wasps (*Encarsia* and *Eretmocerus*).



*Delphastus* (0.06 in. long) feeding on whitefly.  
Species commercially available:  
*Delphastus pusillus* (= *catalinae*)



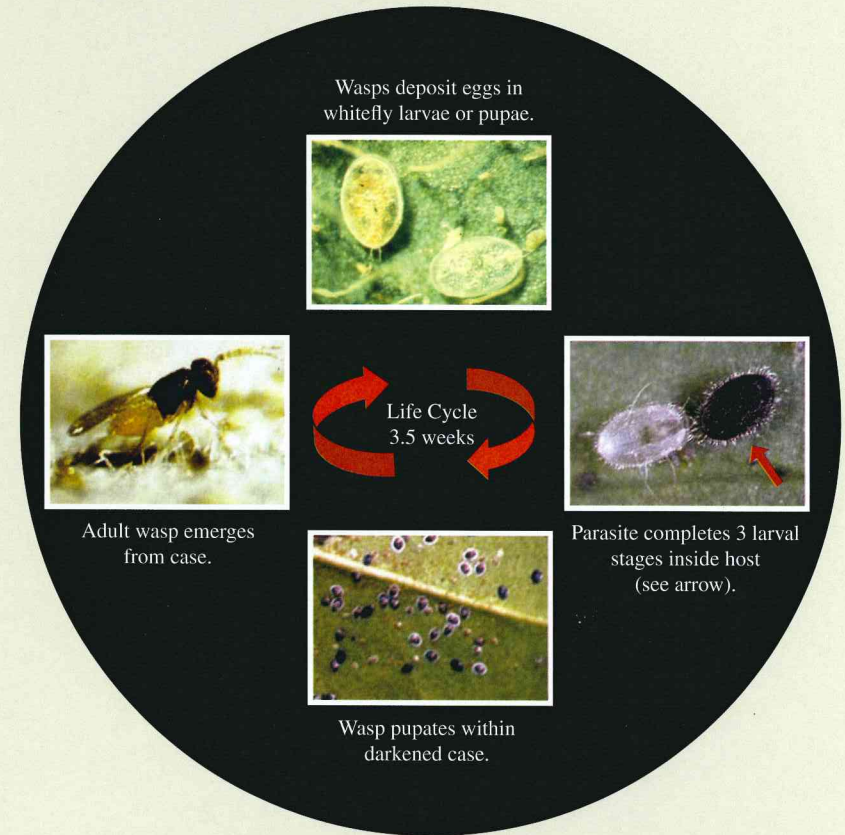
Photos by Jack Kelly Clark, UC IPM Program, Bradley Higbee, John Ruberson, and Ken Grey.  
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**Small Wasps**

**ENCARSIA.** These tiny wasps are about 0.02 in. long and lay their eggs in whitefly larvae or pupae on the undersides of leaves. Parasitized hosts turn into black or brownish cases. Adults have a black or brown head and thorax. The abdomen is yellow. They are commercially available on hanging paper tags, which should be placed on plants that are highly susceptible to whitefly.



*Encarsia* (indicated by arrow) on hanging tag  
Species commercially available:  
*Encarsia formosa*



Photos by Cheryl Frank, Mark Hoddle, John A. Weidhass, Jack Kelly Clark, and Lance S. Riley.  
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### Small Wasps cont'd

**APHIDIUS.** These small wasps are about 0.08-0.12 in. long that parasitize aphids. They lay many eggs and complete their life cycle quickly. Some species are host-specific, so care must be taken to select the right species for the aphid present in your greenhouse. Some species occur naturally and may enter your greenhouse on their own.



*Aphidius* preparing to parasitize an aphid

Species commercially available:  
*Aphidius colemani*, *Aphidius ervi*,  
*Aphidius matricariae*

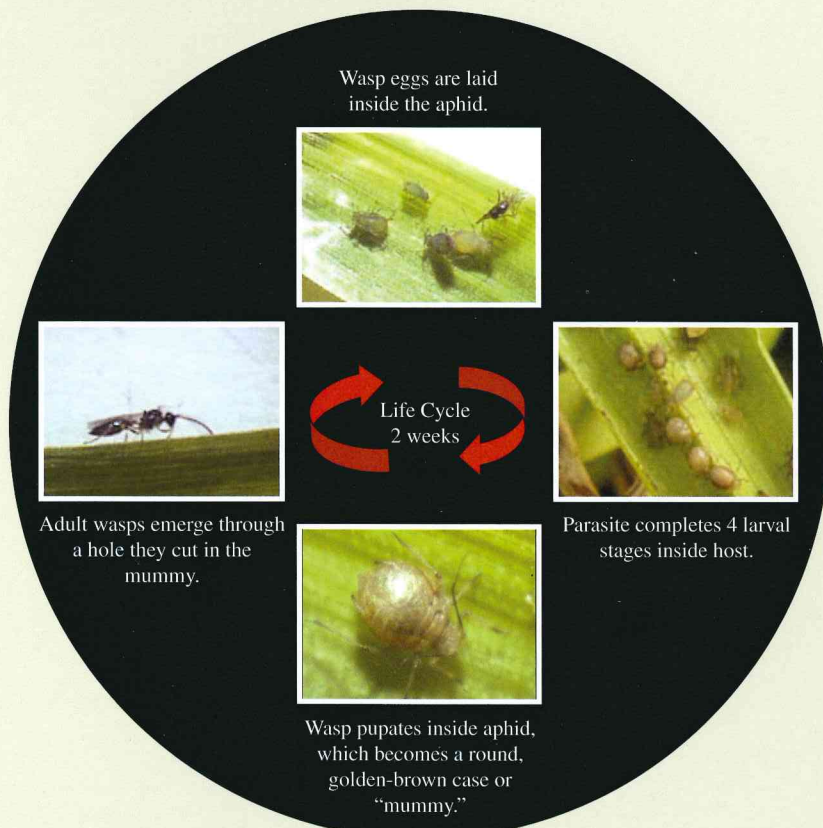
### Small Fly

**APHIDOLETES.** These tiny predators (called gall midges by some) are about 0.1 in. long and attack about 60 different species of pests. When aphids are plentiful they will attack and kill more individuals than they can eat. They inject a poison into the aphid and suck out the contents, leaving a shriveled brown carcass. They do not bite humans. Adults are inactive during the day and swarm at night. Some are temperature and light-sensitive, which limits their use during certain times of the year.

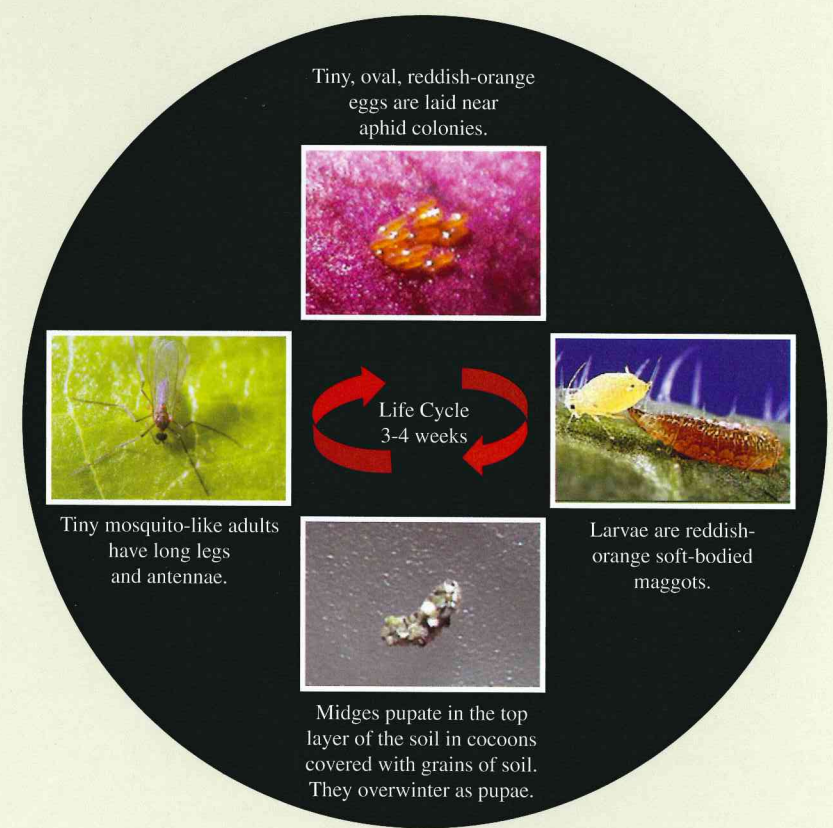


Adult gall midge

Species commercially available:  
*Aphidoletes aphidimyza*



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## Predatory Mites

Many species of mites (which are not insects) occur in greenhouse crops, some are predatory and others plant feeders. As adults they typically have round or oval bodies with 8 legs. Common pests of greenhouses are two-spotted spider mite, russet mite, broad mite, Lewis mite, carmine mite and European red mite. Predatory mites are often slightly larger and a different color from pest mites. They tend to move quickly over plant surfaces in search of prey.



Adult predatory mite (right) with two-spotted spider mite (left).

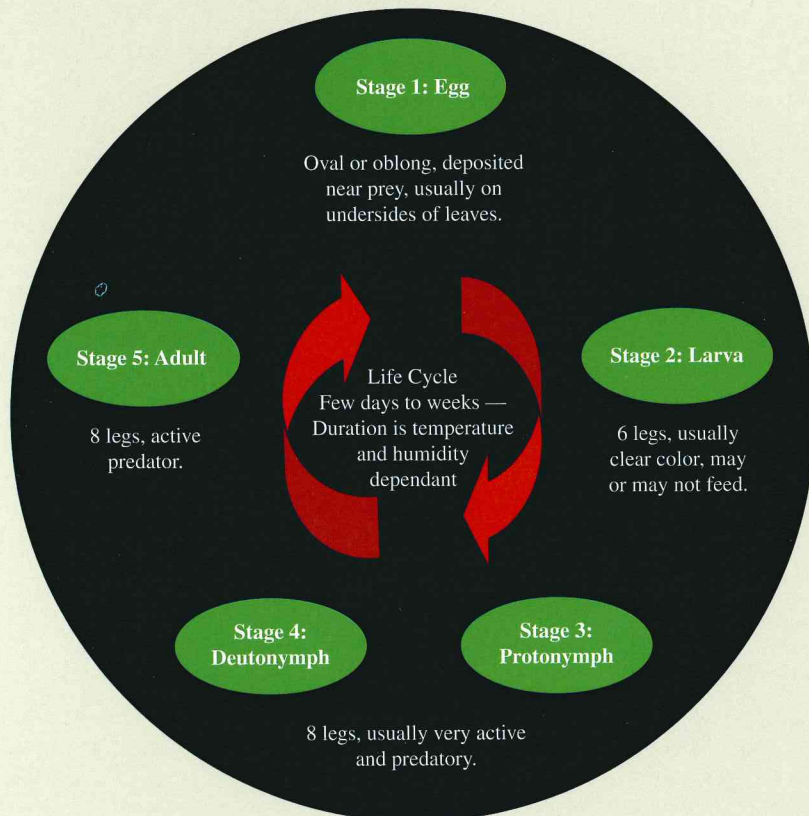


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## COMMONLY USED PREDATORY MITES



### *Neoseiulus (Amblyseius) cucumeris*

- Target pest: Thrips immatures, spider mites.
- Tan-yellowish; survives on pollen and spider mites in the absence of thrips.



### *Neoseiulus (Amblyseius) californicus*

- Target pest: Spider mite, broad mite, cyclamen mite.
- Pear shape; clear to pale yellowish-orange; slower predation rate; also survives on pollen.



### *Neoseiulus (Amblyseius) fallacis*

- Target pest: Spider mite, russet mite, European red mite, cyclamen mite.
- Pear shape; clear until it feeds on prey; high predation rate; survives on pollen without prey.



### *Hypoaspis miles & Hypoaspis aculeifer*

- Target pest: Fungus gnat and thrips larvae and pupae; shorefly larvae.
- Dark tan above, light tan below; soil-dwelling.



### *Phytoseiulus persimilis*

- Target pest: Spider mites (all stages).
- Bright red-orange; fast-moving; very high predation rate.



### *Amblyseius swirskii*

- Target pest: Thrips larvae and whitefly eggs and immatures.
- Whitish; high predation rate; works in cool winter months; can survive on pollen.

Photos by Jack Kelly Clark, UC IPM Program, D.A. Raworth, Agriculture and Agri-Food Canada, Koppert Biological Systems and Syngenta Bioline  
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Banker plants, *Lemon Gem Marigolds* in use for early detection of thrips

## BANKER PLANTS



*Barley acting as banker plants.*

Timing is everything for biological control, and early intervention is critical for success. Banker systems offer cost-effective methods of providing a continuous supply of the beneficial organism, even if the pest population is very low. Research is underway to assess the effectiveness of banker plants as a reservoir for alternate hosts of biological control agents. An example of a banker plant system is the use of barley plants for aphid control.

Barley plants are placed in a greenhouse with an introduced host population of bird cherry aphids already established on the plants. The bird cherry aphids feed only on grasses and are not a threat to most greenhouse crops. *Aphidius*, a tiny wasp commonly used to control greenhouse aphid species, is then released on barley. The *Aphidius* lay their eggs inside the aphids, creating a self-sustaining population of *Aphidius* parasites. These *Aphidius* will then disperse throughout the greenhouse searching for other aphids. Other examples of banker plants are marigolds for sustaining predatory mite populations that feed on spider mites and thrips and papaya plants infested with papaya whitefly as a reproductive site for *Encarsia*, a whitefly-controlling wasp.



*Marigold banker plants.*

## SPECIFIC BIOLOGICAL CONTROL AGENTS<sup>1</sup>

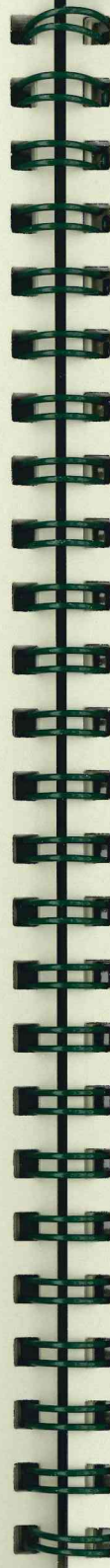
The following tables provide a brief summary of the most commonly used natural enemies for many of the greenhouse pests found in the region. When making a purchase, ask your supplier for additional information that could enhance the effectiveness of the natural enemy you want to use.

### Target Pest: Thrips

Thrips are difficult to manage with biological control due to their rapid rate of population increase and low threshold on plants. If trying biological control for the first time, don't experiment with thrips.

| Natural Enemy  | Target Pest  | Advantages  | Disadvantages  | Comments   |
|--|--|---|--|--|
| <i>Amblyseius cucumeris</i><br>(= <i>Neoseiulus cucumeris</i> )<br>Predatory mite  | All thrips species and several pest mite species: larval/immature stages | Inexpensive; active all year, but best Mar.-Nov.; tolerant of many pesticides | May need large number to manage pest                       | Effective at 66-80°F and over 70% rH; survives on pollen if prey is absent; best if released early as preventative                         |
| <i>Amblyseius degenerans</i><br>(= <i>Iphiseius degenerans</i> )<br>Predatory mite | All thrips species and several pest mite species; larval/immature stages | Active over broad temperature range with few prey                             | Expensive; sensitive to some pesticides                    | Effective at 65-85°F; best if released early in season as preventative in pollen-producing crop  |
| <i>Orius insidiosus</i><br><i>Orius majusculus</i><br>Predatory pirate bug         | All thrips species, spider mites, aphids: larval/immature stages         | Broad host range, even will feed on small caterpillars and whiteflies         | Goes dormant with short days; sensitive to some pesticides | Release May-Aug.; most effective at 70-75°F; remove side shoots of plant before release; can survive on pollen; may attack other predators |
| <i>Orius laevigatus</i><br>Predatory pirate bug                                    | All thrips species and spider mites: larval/immature stages              | Survives on pollen and plant sap if prey absent, not dormant in winter        | Sensitive to pesticides                                    | Most effective between 68-86°F; when thrips populations are high, will kill more than they eat   |

1. Go to [http://www.cdpr.ca.gov/docs/pestmg/ipminov/ben\\_supp/contents.htm](http://www.cdpr.ca.gov/docs/pestmg/ipminov/ben_supp/contents.htm) for a list of biological control suppliers in North America.



### Target Pest: Aphids

To be effective, beneficials must be released early! Regular scouting is critical because sticky cards only attract winged adults. Identification of the aphid species is crucial to the successful use of parasitoids, which have a limited host range.

| Natural Enemy   | Target Pest   | Advantages  | Disadvantages  | Comments   |
|---|---|---|--|--|
| <i>Aphidoletes aphidimyza</i><br>Predatory fly or midge   | Over 60 species, mostly greenhouse species, excluding melon aphid | Inexpensive; can be active all year round                       | Goes dormant with short days less than 12 h and cool temperatures less than 40°F; sensitive to pesticides; adults may be mistaken for fungus gnats | Lays more eggs in high humidity and temperatures of 65-77°F; prevent dormancy with 60 watt bulb; requires soil to pupate; provide soil or sand in houses with cement floors or if soil is covered with plastic or ground cloth |
| <i>Chrysoperla carnea</i> ,<br><i>Chrysoperla rufiflabris</i><br>Predatory lacewings or "ant lions" | Many species of soft-bodied insects and mites, esp. aphids        | Attacks immature thrips and spider mites and aphids             | Larvae cannibalistic if pest level low; may "bite" people  | Most active at 60-80°F and greater than 30% rH, primarily nocturnal predators; <i>C. carnea</i> for low crops; <i>C. rufiflabris</i> for tall crops  |
| <i>Hippodamia convergens</i> , <i>Harmonia axyridis</i><br>Predatory lady beetle                    | All aphid species and other soft-bodied insects: all stages       | Broad host range, generally accepted by the public, inexpensive | Tend to disperse out of greenhouse after release   | Release into aphid hot spots in cool evening or spray beetles with soda pop to reduce migration from greenhouse  |
| <i>Aphidius colemani</i><br>Parasitic wasp  | Many species, esp. melon and cotton aphid: adults and immatures   | Will work under cool, low light conditions                      | Sensitive to pesticides; prone to hyperparasites   | Develops in aphid leaving a brown mummy after exiting; most effective at 64-75°F and 80% rH  |



### Target Pest: Aphids

| Natural Enemy   | Target Pest   | Advantages  | Disadvantages                                | Comments  |
|---|---|---|--|---|
| <i>Aphidius matricariae</i><br>Parasitic wasp and predator  | Many species, esp. green peach aphid: adults and immatures          | Does not go dormant with short days                   | Not effective against cotton or potato aphid | May be attacked by hyperparasites late in the summer  |
| <i>Aphidius ervi</i><br>Parasitic wasp and predator         | Many species; esp. potato and foxglove aphids: adults and immatures | Attacks several aphid species; good searching ability | Not effective above 85°F                     | Best used before aphid populations build up; honeydew from aphids may interfere with searching for prey |
| <i>Aphelinus abdominalis</i><br>Parasitic wasp and predator | Potato and foxglove aphids; adults and immatures                    | Wasps feed on and parasitize them; long lives         | Not highly mobile, they hop rather than fly  | Release on infested plants; parasite mummy is black rather than brown                                   |

### Target Pest: Fungus Gnats and Shore Flies

| Natural Enemy  | Target Pest   | Advantages  | Disadvantages  | Comments   |
|--|---|---|--|--|
| <i>Hypoaspis miles</i><br>Predatory mite                 | Fungus gnats and shore flies: larvae and pupae                                | Feeds on many pests such as thrips, leafminers, nematodes; reproduces quickly                               | Killed by insecticidal drenches; limited dispersal ability | Refrigeration will kill mites; one release may be enough if made before pest populations increase                  |
| <i>Atheta coriaria</i><br>Predatory rove beetle          | Fungus gnats/shore flies, other soil-dwelling pests; all soil-dwelling stages | Adults disperse easily; adapt well to different growth media  | Takes longer to establish than <i>Hypoaspis</i>            | Adults remain active for 3 wk after release; will not survive freezing or flooding                                 |
| <i>Bacillus thuringiensis (Bt)</i><br>Infective bacteria | Fungus gnats: larvae  | Compatible with other beneficials and botanical insecticides; remains viable in refrigerator for 3-6 months | Not compatible with some chemical insecticides             | Remove pre-nozzle filters before making application; keep refrigerated but do not freeze                           |
| <i>Steinernema feltiae</i><br>Infective nematode         | Fungus gnats: larvae also infects soil stages of western flower thrips        | Easy to apply; not visible on foliage   | Not compatible with many pesticides                        | Active in soil or potting mix between 50-85°F; treat when infestations light; refrigerate shipments, don't freeze! |
| <i>Coenosia attenuata</i><br>Predatory fly               | Shore flies, fungus gnats, other flying insects: adults                       | Occurs naturally in some greenhouses, no release needed   | Generalist predator  | Not available commercially, effectiveness is being tested  |

### Target Pest: Whiteflies

| Natural Enemy  | Target Pest  | Advantages   | Disadvantages  | Comments  |
|--|--|--|--|---|
| <i>Delphastus catalinae</i> ,<br><i>Delphastus pusillus</i><br>Predatory lady beetle | Greenhouse and silverleaf<br>( <i>Bemisia</i> ) whitefly: all<br>immature stages       | Feed on aphids and spider<br>mites in absence of white-<br>flies; high predation rate        | Honeydew on leaves<br>impede activity;<br>don't tolerate cold<br>temp.       | Feed on pollen and hon-<br>eydew in absence of prey,<br>most effective between 60-<br>90°F and 75% rH; release<br>in pest hot spots; work best<br>in high populations |
| <i>Macrolophus caliginosus</i><br>Predatory bug                                      | Greenhouse and silverleaf<br>( <i>Bemisia</i> ) whitefly; all<br>immature stages       | Also feeds on thrips,<br>aphids, leaf miners and<br>mites                                    | Slow buildup; may<br>feed on plant sap if<br>prey absent, damage<br>rare     | Release in pest hot spots<br>to speed up establishment;<br>don't use on plants sensi-<br>tive to cosmetic damage  |
| <i>Dicyphus hesperus</i><br>Predatory bug  | Greenhouse and silverleaf<br>( <i>Bemisia</i> ) whitefly; all<br>immature stages       | Feeds on thrips and<br>aphids; active searcher;<br>survives for long periods<br>without prey | If prey absent, needs<br>supplemental food<br>source or may feed<br>on plant | Release in pest hot spots<br>to speed up establishment;<br>don't use on gerbera daisies<br>and other sensitive plants<br>due to feeding damage                        |
| <i>Encarsia formosa</i><br>Parasitic wasp and<br>predator                            | Greenhouse and silverleaf<br>( <i>Bemisia</i> ) whitefly; older<br>immatures, not eggs | Also kills prey by preda-<br>tion; inexpensive   | Sensitive to residues<br>of some pesticides                                  | Better against greenhouse<br>whitefly than <i>Bemisia</i> ;<br>most effective between<br>64-80°F; parasitized host<br>turns black                                     |
| <i>Eretmocerus eremicus</i><br>Parasitic wasp and<br>predator                        | Greenhouse and silverleaf<br>( <i>Bemisia</i> ) whitefly; older<br>immatures, not eggs | Also kills by host feeding;<br>effective against both com-<br>mon species of whitefly        | Expensive; impeded<br>by abundance of<br>honey dew                           | Works best between<br>70-95°F and rH of 60% or<br>less; remains active all year   |

### Target Pest: Spider Mites

| Natural Enemy   | Target Pest  | Advantages   | Disadvantages  | Comments  |
|---|--|--|--|---|
| <i>Amblyseius fallacis</i><br>(= <i>Neoseiulus fallacis</i> )<br>Predatory mite               | Most pest mites (e.g.,<br>2-spotted spider<br>mite, russet, Euro-<br>pean red, cyclamen<br>mite); all stages | Survives on pollen in<br>absence of prey; re-<br>produces at high (over<br>80°F) and low (48-<br>55°F) temp.; low cost | Enters resting stage<br>when day length less<br>than 14 hr unless<br>temp. over 64°F | Overwinters in greenhouse and<br>will become established if pesticide<br>use is minimized   |
| <i>Amblyseius californicus</i><br>(= <i>Neoseiulus californi-<br/>cus</i> )<br>Predatory mite | Many pest mites<br>(inc., 2-spotted<br>spider mite; broad,<br>russet, and cyclamen<br>mite); all stages      | Active at wide tempera-<br>ture range (47-90°F);<br>survives on pollen if<br>prey absent; pesticide<br>resistant       | Doesn't tolerate<br>freezing   | Ability to disperse over crop; good<br>searching ability; more effective<br>than <i>P. persimilis</i> in hot conditions<br>and can survive longer without<br>food |
| <i>Phytoseiulus persimilis</i><br>Predatory mite  | Two-spotted spider<br>mite: all life stages  | Highly mobile; good<br>searching ability; fast<br>acting low cost  | Needs mites to<br>survive; less effective<br>when over 86°F with<br>low rH           | Reproduces faster than pest at<br>70°F; if mite population is high<br>treat with compatible acaricide<br>before release   |

### Target Pest: Spider Mites

| Natural Enemy  | Target Pest  | Advantages   | Disadvantages  | Comments   |
|--|--|--|--|--|
| <i>Feltiella acarisuga</i><br>Predatory fly or midge | Two-spotted, carmine and red spider mites; all stages          | Good host searching ability; readily disperses throughout crop | Needs rH above 50% and temp. below 86°F; expensive         | Most effective between 66-70°F and 90% rH, remains active when day length short  |
| <i>Stethorus punctillum</i><br>Predatory beetle      | All spider mites: all stages; survives on other pests (aphids) | Good host searching ability; readily disperses throughout crop | Enters diapause when less than 16h of light/day; expensive | Most effective at 61-90°F; adults don't fly below 55°F, use supplemental light to prevent diapause; survives on pollen when prey absent, but won't reproduce |

### Other General Biological Control Agents

| Natural Enemy                                 | Target Pest   | Advantages  | Disadvantages   | Comments   |
|---|---|---|---|--|
| <i>Beauveria bassiana</i><br>Infective fungus | All whitefly, thrips and aphid species; all life stages except eggs | Compatible with many beneficials; broad host range; easy to apply | Relatively slow acting; not suitable for high or building pest populations; not compatible with some pesticides | Apply in late afternoon when it is cool and humid; immature insects may avoid infection by shedding skin |

