

Greenhouse Peppers: Guidelines for Biological Control

Biological controls have been used in greenhouse peppers since the crop began to be grown in BC in the mid-1980's. Biological control is most effective when used in an Integrated Pest Management (IPM) program (see Sheet 160). As in any IPM program, success depends upon correct identification of pest problems, regular monitoring, careful timing and integration of complementary control measures. It also depends on good clean-up, sanitation and other measures that remove breeding sites for pests and prevent them from entering the greenhouse.

The primary pests in greenhouse peppers are fungus gnats (*Bradysia* spp.), western flower thrips (*Frankliniella occidentalis*), two-spotted mites (*Tetranychus urticae*), green peach aphid (*Myzus persicae*) and greenhouse whitefly (*Trialeurodes vaporariorum*). Lygus bugs, cabbage loopers, and other species of aphids also occur.

Pepper plants have three characteristics that enhance the use of biological controls:

- The presence of pollen and nectar in the flowers. This provides an alternative food source for some biological controls (i.e. predatory bugs and mites, such as 'Orius' and 'Cucumeris' making them easier to establish.
- Smooth leaves. This means that predators are able to travel freely over the leaves and between plants, without being hindered by hairs as they are on cucumber and tomato leaves.
- Limited leaf pruning is necessary. This retains leaves of all ages, allowing all stages of biological controls to reproduce and complete their life cycles without disturbance.

The following guidelines contain practical tips for achieving good results using biological controls against pests in greenhouse peppers. Recommended release rates for each biological control are shown in Table 1. More detailed information on pests and biological controls can be found in the separate information sheets for each species.

Start Right with Pepper Seedlings

IPM for peppers begins with seedling production. It is important that propagators establish the fungus gnat predator, 'Hypoaspis' (see Sheet 230) at the seedling stage. Other biological controls should also be used early if pests, such as thrips, spider mites or aphids occur, rather than applying pesticides. Propagators must supply information about all pesticides that have been used on seedlings. This is critical information as most pesticides interfere with, and can seriously limit, later use of biological controls. This is especially true of residual pesticides (for effects of pesticides on biological controls, see Sheet 180).

General Monitoring

There are two main ways to monitor for common pepper pests:

- Trapping pests on sticky cards or ribbons. Yellow traps are used to monitor for fungus gnat, thrips, whitefly and Lygus bugs. Blue traps are also used for thrips, but yellow traps are usually preferred because they can be used for other insects as well.

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Inspect traps weekly; replace every 3-4 weeks as glue becomes less effective. Place traps at the top of the plant canopy for whiteflies and thrips; place them about 25 cm (1 foot) above the growing media for fungus gnats.

- Visual inspection of plant leaves. This should be done weekly for signs of two-spotted mites, aphid infestations, cabbage looper damage, *Lygus* nymphs and other problems. At the same time, record the presence or absence of biological controls in infested areas.

FUNGUS GNATS

Fungus gnats can cause significant damage in soil-less or sawdust bag cultures. In peppers, most damage is caused by the larvae feeding on tender roots. As root area is lost, pepper plants become more susceptible to drought stress and root rot infections. Adult fungus gnats can also transmit root rot and other diseases (for more on fungus gnats, see Sheet 320).

Monitoring Tips

- Use yellow sticky cards at a rate of 1 trap/500 m² (5,000 ft²).
- Place cards about 25 cm (1 ft) above the soil or rockwool surface.
- Check traps weekly and record the number of adult fungus gnats; replace traps every 3-4 weeks as the glue dries out.

Identify

It is important to distinguish between fungus gnats and shore flies because biological controls for fungus gnats do not work on shore flies (for descriptions, see Sheet 310).

Release Biological Controls

The following three species of biological controls are compatible with each other and can be used together.

'Hypoaspis': This soil-dwelling predatory mite feeds on fungus gnat larvae. The best way to use *Hypoaspis* is to establish it in the greenhouse before fungus gnats appear. Apply to pepper seedlings in flats or cubes at the start of the growing season, and then again when planting out. By feeding on other soil organisms, *Hypoaspis* populations can build up to high numbers that are effective in keep fungus gnat populations low. (For more information, see Sheet 230).

Supplement *Hypoaspis* with other biocontrols (below) if fungus gnat populations are high.

Insect Parasitic Nematodes: *Steinernema carpocapsae*, *S. feltiae*, and *Heterorhabditis* spp. are beneficial nematodes sold to control fungus gnats and other insects (see Sheet 280). They can be applied to the soil through conventional sprayers or through the irrigation system. Nematodes are effective against high populations of fungus gnats but, unlike *Hypoaspis*, will not reproduce or remain in the growing media and must be reapplied.

- Apply nematodes or BTI (see below) when yellow sticky traps average over 20 fungus gnat adults per trap, weekly, or while fungus gnat populations appear to be increasing.

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- If root diseases are a problem in the crop, apply nematodes sooner to reduce the risk of disease transmission by fungus gnat larvae.
- Three applications, 7-10 days apart, are usually required. Nematode products vary, so always follow product recommendations for rates. Calculate application on the actual growing area, not greenhouse area.

Note: The actual growing area for rockwool cultures with plant densities of 1.2-1.4 plants/m² (10 ft²), is typically 1/3 to 1/4 of the total floor space.

Bacillus thuringiensis israelensis (BTI): A strain of this bacteria that infects fungus gnat larvae is available (Vectobac®). It is applied in water to the soil or growing media after fungus gnats are established (follow instructions on the product label).

Other Measures

- It is essential to eliminate wet spots in the greenhouse where fungus gnats can breed by improving drainage, repairing leaks in plumbing, adjusting automatic irrigation equipment, etc.
- Control is usually better in greenhouses with white plastic floors because fewer breeding sites are available for fungus gnats.
- Control fungus gnats in other crops in adjacent greenhouses.

WESTERN FLOWER THRIPS & ONION THRIPS

Western flower thrips (WFT) damage leaves and distort the fruit of peppers by feeding and laying eggs in leaf and flower tissues and young developing fruit. When western flower thrips populations are high the adults may be found in high numbers in the pepper flowers. Onion thrips will also attack peppers but the damage is usually confined to the older leaves and is less severe (for more on thrips, see Sheet 320).

Monitoring Tips

- Use yellow or blue sticky cards (using the same yellow cards for whitefly monitoring saves time) at a rate of 1 trap/50-100 m² (500-1000 ft²). Place traps at the top of plant canopy.
- Count the number of thrips on traps weekly; replace traps every 3-4 weeks as the glue dries out.
- Examine a minimum of 20 leaves from mid-plant level in each infested area. Look for presence or absence of both thrips and Cucumeris predatory mites. When each leaf with thrips also has predators present, it is an indicator that the thrips population should begin to decline.
- When an average of 1 Orius/week are being caught on traps, it is an indication that Orius numbers have increased and adult thrips numbers should decline.

Release Biological Controls

The following three species of biological controls are compatible and can be used together.

'Hypoaspis': This soil-dwelling mite feeds on the immature stages of thrips in the soil or growing media. *Hypoaspis* alone cannot control thrips infestations, but it contributes to

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the effectiveness of biological control when used with other predators (for more on *Hypoaspis*, see Sheet 230).

'Cucumeris': The predatory mite *Amblyseius cucumeris* feeds on immature stages of thrips as well as pepper pollen. Once pollen is present, Cucumeris can usually be established on peppers. Cucumeris is available in a loose bran carrier, which is sprinkled onto leaves or on young plants without pollen. Small piles of carrier containing Cucumeris can also be placed next to plant stems. Releases should start as soon as the first flowers are set and continue until there is a 1:1 ratio of thrips to Cucumeris on leaves, as determined by monitoring (see above). For more on Cucumeris, see Sheet 220.

It usually takes 4-6 weeks before changes in thrips numbers caught on traps will be noticeable as a result of releasing Cucumeris.

Avoid using Cucumeris on pepper plants where spider mites are also a problem. This is because Cucumeris, which also feeds on spider mite eggs, can increase to such high populations on peppers that they reduce the amount of food available for spider mite predators such as *Persimilis*. To control thrips where spider mites are also a problem, it is better to use the predatory mite, 'Degenerans' (see below).

'Degenerans': Another predatory mite, *Amblyseius degenerans*, can be used on peppers to control thrips. Release as soon as plants are flowering and pollen is present. Degenerans are best released in clumps at the end and middle of rows as females require repeated mating for egg laying. When pollen is present for this predator will rapidly increase and spread throughout the greenhouse (for more on Degenerans, see Sheet 280)

Note: Degenerans is more susceptible to pesticides than Cucumeris (see Sheet 180).

'Orius': The tiny pirate bug (*Orius* spp.) feeds on all stages of thrips, but it is used in peppers mainly to control the adult thrips that congregate and feed in flowers. Orius is only effective from March to September because they do not reproduce if daylength is less than 16 hours. Orius should be released in March, or as soon as thrips are detected, where thrips numbers are the highest in the greenhouse. Release at least 500 Orius at one time to establish a breeding population (for more on Orius, see Sheet 222).

Other Measures

- Avoid thrips re-infestations by thoroughly cleaning up the crop at the end of the season. Treat the greenhouse with naled (Dibrom®) after the last pick, before removing pepper plants, and again after the greenhouse is empty.
- To starve thrips between crops, maintain a heated greenhouse, empty of plants, which forces adult thrips to emerge from the soil-borne pupal stages.
- If thrips populations were high in the preceding crop, it may be advisable to apply lime to the ground before covering the greenhouse floor with plastic. Care should be taken to overlap and tape, or glue, the floor covering together.
- Do not maintain any ornamental plants in the greenhouse, and maintain a weed-free border, 3-m (10-ft) wide, around the outside perimeter of the greenhouse.

TWO-SPOTTED MITES (TSM)

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Two-spotted mites are common pests of greenhouse peppers (for more on two-spotted mites, see Sheet 300). During warm weather, TSM populations reproduce very quickly.

Monitoring Tips

- Inspect mite damaged leaves under 10-15 X magnification for TSM infestation.
- Some growers use bean seedlings or climbing runner beans as trap plants to detect the first appearance of TSM on new crops. TSM damage is easy to see on bean leaves, which alerts growers that there may be mites on pepper plants. Persimilis are also easily to establish on the bean plants, which act as nursery or banker plants for producing more predators.

Release Biological Controls

'Persimilis': The predatory mite, *Phytoseiulus persimilis*, is a very effective control for TSM in peppers because the predators develop twice as fast as the pest at moderate greenhouse temperatures (for more on Persimilis, see Sheet 200).

- When TSM are first seen, introduce Persimilis onto all infested leaves; continue weekly releases until they are present on all TSM infested plants.
- Use the Persimilis shipped on bean leaves, rather than vermiculite, because the predators survive shipping in better condition and are easier to apply. Place bean leaves with Persimilis on pepper leaves near TSM infestations. Alternatively, apply the concentrated 'HOT SPOT' Persimilis product (which contains high numbers of Persimilis in vermiculite) to each infested site.
- Once Persimilis are established, speed distribution of the predators by picking Persimilis "nursery" leaves and moving them to other plants all around the infested sites and throughout the crop.
- If TSM populations are high spray once or twice with fenbutatin oxide (Vendex®), then release Persimilis when the last spray has dried. Vendex does not kill the egg stage of the spider mites and will not harm predatory mites.

Once spider mite are eliminated, Persimilis will die out. Therefore, other mite predators that can survive on pollen, such as 'Fallacis' (see Sheet 201) or 'Californicus' (see Sheet 280) should be introduced as well. These predators provide some control of TSM, but will not usually control TSM "hot spots"; Persimilis should be reintroduced if these develop.

'Stethorus': The predatory lady beetle, *Stethorus punctillum*, feeds on all stages of TSM and can be used with other biocontrol agents. Stethorus is active over a wide temperature and humidity range (16-30°C and 20-90%RH). They should be released in mite infested sites as soon as TSM are detected (for more information, see Sheet 207).

'Feltiella': The larvae of the predatory midge, *Feltiella acarasuga*, feed on spider mites. They are effective at controlling spider mites early in the season or at times when humidities are high (for more information, see Sheet 280.)

Other Measures

- Chemical control in conjunction with biological control is recommended if mites are clustering in balls or "stringing" down from the plant or detected in high numbers without predators present. Fenbutatin oxide (Vendex®) is safe for use with

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predatory mites such as *Persimilis* and *Fallacis*, but check compatibility table (see Sheet 180) for other pesticides.

- Once *Persimilis* has been released, maintain warm temperatures (optimum 25°C) and high humidity (optimum 80-90% RH) to encourage the predatory mites. Mist the crop if necessary.
- It is important to finish each crop with low populations of TSM. High numbers at the end of the year result in the survival of many diapausing (overwintering stage) spider mites that will re-infest the next crop early in the season. If mites are still a problem in late July, a miticide should be applied in August to prevent diapausing mites from overwintering. Pesticides are less effective against the diapausing form of TSM. Check compatibility table (Sheet 180) before using any pesticides with biological control agents.

If large numbers of overwintered TSM occur, or are anticipated in a new crop, a "pest in first" approach should be used. This means introducing TSM along with *Persimilis* to ensure even establishment and build-up of *Persimilis* populations. A special product, containing leaves with a 20:1 ratio of TSM to *Persimilis* is available from Applied BioNomics. The leaves are placed throughout the crop before most overwintering TSM appear. This product must be ordered in advance, therefore contact your biological control supplier for availability.

APHIDS

Aphids (especially green peach aphid, *Myzus persicae*) can be a serious problem in greenhouse peppers (for more on aphids, see Sheet 340). In peppers new infestations are usually detected first on the oldest (lowest) leaves and on the young shoots of plants. Aphids reproduce quickly on peppers and all three biological control agents listed below are best used together for long term control.

- Release 'Aphidius' parasitic wasp (*Aphidius matricariae*) (see Sheet 242), at low rates as soon as the crop is in the greenhouse.
- Release 'Aphidoletes' aphid midges (*Aphidoletes aphidimyza*) (see Sheet 240) between March 15 and August 15, weekly, until aphids are controlled. For heavy infestations release a minimum of 2000 aphid midges, weekly, in each aphid "hot spot".
- Release the lady beetle, *Harmonia axyridis*, to control all species of aphids. If the aphid infestation is widespread, also release field-collected *Hippodamia convergens* as well (for more on both lady beetles, see Sheet 244).

WHITEFLIES

Whiteflies damage greenhouse peppers by covering fruit and leaves with the sticky honeydew as they feed (for more on whiteflies, see Sheet 310) and reducing the vigour of plants. Whiteflies can be controlled by the parasitic wasp, 'Encarsia', and the predatory beetle, 'Delphastus', by following steps described below.

Monitoring Tips

- Begin in the empty greenhouse, before seedlings are planted out.
- Hang up yellow sticky cards or tapes at the rate of 1 trap/50-100 m² (500-1000 ft²).

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- Check traps weekly for adult whiteflies.

Release Biological Controls

'Encarsia': *Encarsia formosa* is a tiny, 1 mm (1/20 inch) long, wasp that parasitizes immature stages of whitefly. It is sold as parasitized scales glued to cards, from which the adult wasps emerge. As the wasp develops inside, greenhouse whitefly scales gradually turn black. If there is a history of whitefly problems best results are achieved when Encarsia are introduced preventively, at low rates, before whiteflies are found on monitoring traps. Releases continue, usually weekly and are maintained until 80% of whitefly pupae appear parasitized. (For more on Encarsia, see Sheet 210).

In warm regions or areas where a large number of greenhouses have whitefly infestations, the whiteflies may move onto outdoor plants. This makes them more difficult to control as whiteflies continually re-infest the crop plants. Encarsia are less effective during cool weather and overcast periods, therefore whitefly populations must be monitored closely.

'Dicyphus': The predatory bug, *Dicyphus hesperus* is an effective whitefly predator but should not be used on its own to replace other biological control agents. It is best used along with other biological control agents in crops that have, or (because of past history) are expected to have, whitefly, spider mite, or thrips problems.

- Eggs are laid inside plant tissue and are not easily seen.
- Adults are slender (6mm), black and green with red eyes and can fly
- Nymphs are green with red eyes
- Release Dicyphus as soon as whiteflies are found, early in the season at a rate of 0.25-0.5 bugs/m² (10 ft²) of infested area; repeat in 2-3 weeks.

Release batches of 100 adults together in one area where whitefly is present.

'Delphastus': *Delphastus catalinae* is a small, black, 1.4 mm (1/15 inch) long, lady beetle. Both adults and larvae feed on whitefly eggs and immature stages. Delphastus is sold as adults and should be applied as soon as whitefly are detected. Delphastus works well with Encarsia because it avoids feeding on parasitized whitefly scale. (For more on Delphastus, see Sheet 215).

Other Measures

- It is essential to start with a clean crop at the beginning of the season, therefore destroy all crop residues and dispose of them at a site remote from the greenhouse
- If the previous crop was infested with whiteflies, leave the greenhouse entirely empty of plants for 5 days, with heat, to starve whiteflies or kill them with cold by allowing the greenhouse to freeze for a week.
- If a plant-free period is not possible between crops, use a short-residual fumigant such as naled (Dibrom[®]). Apply at the end of the crop, before removing plant debris, and again to the empty greenhouse.
- Keep the greenhouse weed-free, and maintain a 3-m (10-ft) wide, weed-free border around the greenhouse.
- Do not keep ornamental plants in a pepper greenhouse as these are also whitefly hosts.

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- If greenhouse whitefly numbers are high, hang yellow sticky tapes (up to 1 tape per plant) at the top of the plant canopy to trap adult whiteflies.
- If whiteflies are present on outdoor plants, screen all entry points.

LYGUS BUGS

Several species of Lygus bugs attack pepper plants. Their toxic feeding causes abortion or death of the affected growing point.

- Hand pick and destroy any adults or larvae found on the plants.
- If intake fans are used, screen with 5 mm (¼ inch) mesh screen.
- Release Orius (if not already being used for thrips control), which feed on Lygus nymphs.
- Regularly mow the areas around the greenhouse quite short to avoid harbouring Lygus.
- Light traps will also trap Lygus. (For instruction on making a light trap, see Sheet 500).

CATERPILLARS (CABBAGE LOOPERS, ETC.)

The caterpillars of several species of moths and butterflies may become serious pests in peppers if their numbers are allowed to build up.

- Hand pick and destroy any larvae found on young plants; use an ultraviolet (UV) light trap to catch adult moths (For instruction on making a light trap, see Sheet 500).
- If intake fans are used, screen with 5 mm (¼ inch) mesh screen. This will also stop Lygus and other flying pests.

Release Biological Controls

- Spray *Bacillus thuringiensis* (Dipel® or Foray®) at label rates every 3 days, for several weeks, as soon as caterpillars are first detected. Ensure good coverage of both upper and lower leaf surfaces.
- *Trichogramma* spp. parasitic wasps (see Sheet 270) attack moth eggs and can assist in control.
- Predatory bugs, such as 'Podisus' (see Sheet 280) and 'Orius' (see Sheet 222) attack eggs and small stages of caterpillar larvae.
- The parasitic wasp 'Cotesia' (see Sheet 280) attacks caterpillars and may be available for release.

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Summary of IPM Guidelines Greenhouse Peppers

Between crops:

- Treat with naled (Dibrom[®]) after last picking; wash greenhouse structure.
- Remove crop debris, heat empty greenhouse for 3-5 days.
- Cover floors with white plastic.
- Improve drainage to eliminate wet spots.
- Remove all weeds inside and around greenhouse perimeter.
- Screen vents where Lygus bugs are problems.

At start of crop:

- Whitefly: Release Encarsia at low rates.
- Fungus gnats and thrips: Introduce Hypoaspis at the start of the crop.

When pests are detected:

- Fungus gnats: Apply insect parasitic nematodes, BTI.
- Whitefly: Release Encarsia until 80% of whitefly pupae are parasitized; release Delphastus and Dicyphus.
- Two-spotted mites: Apply Persimilis as needed.
- Western flower thrips: Apply Cucumeris as needed; add Orius if thrips numbers high.
- Aphids: Release Aphidius, Aphidoletes and, if aphids numbers are high, Harmonia and Hippodamia lady beetles.
- Loopers/Caterpillars: Spray BTK, release Trichogramma, use UV light traps for adults
- Lygus: Hand-pick all stages, release Orius.