Biological Control: Greenhouse Pests and their Natural Enemies

Pests and Natural Enemies: Parasites and Predators

Biological control uses natural enemies that are parasitoids, predators and/or pathogens to manage insect and mite pest populations. Biological control is used as part of a total integrated pest management program (IPM), that includes scouting, using disease resistant plants, sound cultural practices and compatible pesticides. There are three types of beneficials used in greenhouse production, predators, parasitoids and pathogens.

- Predators are insects and mites that feed on pests but do not reproduce in them. They eat more than one pest as they develop throughout their life cycle to adults. Predators are less host-specific than parasitoids and often deposit their eggs near pests so when they hatch there is a food source nearby.
- Parasites are insects that deposit eggs in or on a pest. The parasite develops in the pest and kills it. The adult parasite emerges from the pest and the cycle continutes. Parasitoids are very host-specific and eat only a single pest as they develop.
- Pathogens are organisms that cause a fatal disease in pests. They are beneficial pathogens that include fungi, bacteria and viruses.

Greenhouse whitefly *(Triaulerodes vaporariorum)* . This species of whitefly has been controlled effectively for decades in Europe on tomato and cucumber crops by early season inoculative releases of the aphelinid wasp *Encarsia formosa*. This species is not currently the whitefly of usual concern on flower crops. The main whitefly on flower crops is sweet potato whitefly B-biotype (*Bemisia tabaci*) formally called the silverleaf whitefly (*Bemisia argentifolii*). *Encarsia formosa* is less effective on tomatoes with hairs because the hairs make it difficult for the parasitoid to detect whiteflies and for the adult females to leay eggs in whitefly nymphs.

Encarsia formosa: Adult females lay eggs in whitefly nymphs; larvae emerge from eggs and consume the internal contents of the whitefly (one encarsia in each parastized whitefly nymph). Larvae eventually pupate and emerging adults creat a circular hole with their mouthparts, which they use to exit from the parasitized whitefly. Adult females also feed on young nymphs. Parasitized whiteflies are black. *Encarsia formosa* is most effective at temperatures between 70-80F and 50-80% relative humidity. Adults do not fly when air temperature is below 65F and survival is reduced at temperatures greater than 86F. It has been advised not to use yellow

sticky cards for 3-4 days following release to avoid capturing adults, however, some growers use sticky cards at the onset of releases but avoid placing cards beside wasp releases. Most *E. formosa* are commercially available as pupae glued to small paper cards.

Checking for quality: Place a single card into a jar with a tight lid. Expose the jar to room temperature (70-75F) out of direct sunlight. After 5 days, count or estimate the number of adult parasitoids that have emerged from the pupae. About 95% of adults should have emerged from the pupae.

Releasing *E. formosa* into a crop: The cards are hung in the lower canopy of plants to avoid desiccation from direct sunlight. Adults emerge from the pupae and fly upward. Use *E. formosa* weekly beginning when whiteflies are first detected. Continue making releases until 80% of the whitefly population has been parasitized. Parasitized pupae are black. *E. formosa* are very sensitive to pesticides.

Sweet potato whitefly *(Bemisia tabaci)* and a biotype of *B. tabaci*, the Q-biotype, was reported in 2006. This biotype is known to be resistant to a number of commonly used insecticides. This is the principal whitefly on flower crops, especially poinsettias. The commercial strain of *Encarsia formosa* provides partial control but is insufficient.

Eretmocerus eremicus wasps are used for *B. tabaci.* They kill whiteflies two ways: parasitism and "host feeding" (acting like a predator and eating whiteflies). *E. eremicus* attacks both sweet potato B-biotype and greenhouse whiteflies.

Checking for quality: Place a few cards individually into clear jars and place them in the shade until the tiny wasps are seen walking around the inside of the jar. A sticky trap can be placed insided the jar and inspected for wasps. If loose parasitized pupae are used, place approximately 2% of the total volume of the contents into a jar with a tight lid. 95% of adults should have emerged from the pupae.

Releasing *E. eremicus* onto a crop: *E. eremicus* is sold as pupae glued to paper cards or loosely in sawdust. If using pupae in sawdust, gently pour a portion of the mixture in styrofoam coffee cups, clipped to stakes that are attached to pots or flats. Some growers avoid using yellow sticky cards for 4 days after releases, while other growers continue to use yellow sticky cards, but place them away from wasp releases. Optimum temperatures are 77-84F. The parasitoid is inactive at temperatures greater than 86F. When scouting look for parasitized whiteflies. Greenhouse whitefly pupae are yellow and sweet potato whtiefly B-biotype pupae are yellow-brown.

Eretmocerus mundus is another parasitioid that only parasitizes sweet potato whitefly B-biotype. This parasitoid is active at a wider range of temperatures than *E. eremicus.*

Other natural enemies for whiteflies include, *Amblyseius swirskii* which feeds on whitefly eggs and nymphs and thrips. The predatory ladybird beetle, *Delphastus catalinae* is a small ladybird beetle with a black body and brown heat. It needs a lot of fooe (more than 150 whitefly egg/day) to sustain and establish itself. Delphastis in not usually recommended due to cost and requires the whitefly populations to be too high, however, it could be used to clean up large infestations of whitefly.

Fungal Pathogens are entomopathogenic fungus that are commercially available. Applications must be initiated before whitefly populations are high. *Beauveria bassiana* (BotaniGard, Mycotrol O), *Isaria fumosoroseus* (Preferal, NoFly WP) are appled as a foliar spray and good coverage of the undersides of the leaves is important to reach the immobile nymphal stages of whiteflies. Several applications will be needed. Humidity should be above 80% for germination of the fungal spores which penetrate the whitefly, causing infection and death. Avoid using fungicides for several days before and after applications - follow label directions for specific products.

Western flower thrips *(Frankliniella occidentalis*). Biological control of thrips is more difficult than most greenhouse pests. Western flower thrips and many other thrips species may be suppressed on greenhouse crop by releasing (*Amblyseius (Neoseiulus) cucumeris*), *Amblyseius swirskii* or predatory bugs, Minute pirate bug (*Orius insideosus*).

Amblyseius (Neoseiulus) cucumeris), *Amblyseius swirskii:* These predatory mites attack a wide variety of tiny arthropods and especially the smallest lifestages of thrips. A swirskii works better at warmer temperatures while A. cucumeris is better at cooler temperatures. *A. cucumeris* feed only on the first instar nymphs so must be released early in the crop cycle before thrips populations are high. The predatory mite *Ambylseius swirskii*, feeds on thrips and whiteflies and has demonstrated to be effective in greenhouse-grown peppers, cucumbers and several ornamental crops. The soil dwelling predatory mite, *Hypoaspis miles* may feed on thrips pupae in the growing medium in addition to fungus gnat larvae. A single preventative release at planting is generally recommended to supplement above ground releases of *A. cucumeris*. The rove beetle, *Atheta coriaria* is a generalist predator that may feed on thrips pupae, along with fungus gnat and shore fly larvae.

Checking for quality: Predatory mites are mixed into a carrier such as bran or vermiculite and shipped in bottles or in little paper bags. Check for predatory mites inside the lid of the container or in the bran carrier under 10-15 X magnification. Healthy predators are light tan and move more quickly than the food source mites,

which are smaller, slow moving and white or translucent. If you open a container and it smells strongly of ammonia, the mites are probably not in good condition.

Releasing onto a crop: Mites in bottles are intended for broadcasting over the crop canopy. This can be done by hand or with a dispersal device. Regular repeated releases are needed. Predatory mites in sachets or small bags contain food and are intended to release over several weeks ("slow release"). The sachets can be spaced amond the plant canopy and replaced every several weeks. See detailed directions from your supplier.

Hypoaspis miles is a small predatory mite that inhabits the top layer of soil and feeds on a wide variety of tiny soil dwelling insects and mites (fungus gnat eggs, larvae and pupae, springtails, root aphids) and also thrips pupae in the soil.

Checking for quality: The predators are tan and move very quickly, compared to their food source mites, which are smaller, slow moving and white or translucent. Evaluate a small sample of the contents to see whether the mites are alive and whether you received the correct quantity. First, gently rotate the contents of the package to mix the predatory mites with the bran carrier. Pour a small amount of the material onto a white sheet of paper and gently spread the contents out using a small soft paint brush. Count the tan, predatory mites that move. For example, if the entire package fills five paper coffee cups, select 1/8 cup or 2.5% of the material for observation. No need to count the grain mites, and be sure to check the rim of the container for live mites.

Releasing onto a crop: Mites arrive in bottles and can be sprinkled out on the soil surface or beneath benches or sprinkled onto soil surface of containers at planting. Usually only one or two releases are needed for the mites to become established. They can survive several weeks without food.

Orius species (Minute pirate bugs) tend to establish slowly on bedding plants, and are best used on crops that produce pollen or by releasing them onto flowering ornamental pepper plants that are in flower which serve as a banker plant, attracting the thrips and harboring the predators. Orius attack a wide variety of insects (whiteflies, aphids, lepidoptera eggs) and mites including each other. The adults are small black and white and the nymphs are orangish.

The eggs in plant tissue hatch in predaceous nymphs that molt several times before becoming adults. Adults can fly and disperse throughout the greenhouse. They are voracious predators that can kill any mobile stage of thrips that they encounter.

Checking for quality: Shipped as adults mixed with buckwheat hulls in bottles. Opening the bottle should reveal many bugs crawling among the hulls.

Releasing: Broadcast into the crop canopy especially in thrips hotspots. Orius can be introduced curatively in these hot spots. They can be difficult to established in a crop and repeated releases are expensive. Growers use banker plants and habitat planters to maintain populations.

Banker Plants: Growers rear the minute pirate bugs on pollen producing pepper plants and place plants throughout the greenhouse to distribute them. Minute pirate bugs are released at a rate of 60-80 per pepper plant. The minute pirate bugs will lay eggs on the pepper plants in the same area where thrips lay eggs, usually in or near flowers. One pepper plant covers around 1,000 sq. ft. of growing area. As long as the pepper plants are in flower and producing pollen, the minute pirate bugs will reproduce on them. The adults will fan out across the greenhouse and kill 1st and 2nd instar thrips larvae and adult thrips. Only one release of minute pirate bugs onto the banker plants is necessary. Peppers need to be removed about once a month from the pepper plants to keep them flowering, in order for the process to work. Some growers have mentioned that keeping peppers picked off the plants is tedious and time consuming. Research in Canada reported that the cultivar 'Purple Flash'• was more effective as a banker plant than the ornamental pepper variety 'Black Pearl'• .

Habitat Planters: Cosmos 'Sensation White' has been used by growers to encourage Orius populations. Other plants used in habitat planters have included Achillea, lantana, alyssum, catmint, dill and African marigolds.

Fungal Pathogens: Entomopathogenic fungus that are commercially available include *Beauveria bassiana* and *Metarhizium anisoplia*e.

Beauveria bassiana (BotaniGard, Mycotrol) may help to manage whiteflies, aphids and mealybugs. The effectiveness varies depending on relative humidity levels at the plant surface, life stage, application rate, crop type and spray coverage, light intensity, season and temperature. Repeat applications are often needed.

Metarhizium anisopliae Strain F52(Met52): Bioinsecticide on a grain matrix for use against thrips pupae. According to the label, the spores attach to the surface of the insect, germinate, and begin to grow. It will penetrate the exoskeleton of the insect and grow inside the insect, causing the insect to die. The fungal spores will be more persistent when incorporated in the soil, especially in potting media, than when applied to foliage. See label for more information.

S. feltiae is a beneficial nematode that attacks many soil-dwelling insects such as pupating thrips or fungus gnat larvae. Nematodes enter the insect hose through body openings and release a bacterium that kills the host insect. They are sensitive to UV light and dessication and are best applied in the evening or at dusk or on a cloudy, overcast day. Beneficial nematodes can be applied using a sprayer (remove screens and filters), injector, hose end sprayer or even a watering can. If using an injector, set the dilution to 1:100. Remove all filters or screens on the

intake tube. Remove pump filters. Use a small battery powered submersible pump to keep the solution agitated so that the nematodes do not settle to the bottom. Treat early in the production cycle, just after planting.

Checking for viability: Place a small amount of the product in a small dish. Add 1 or 2 drops of room temperature water; wait a few minutes and look for actively moving or swimming nematodes. Use a dark black background and a hand lens or field microscope to see the small nematodes (0.6 mm or 0.02 inches in length). If nematodes are straight (like a pencil) and not moving, then they are not viable. If they have been stored cool, it will take a few minutes for them to warm up before they become active.

Spider mites *(Tetranychus urticae* and others). Commercially available predatory mites for two-spotted spider mites include *Phytoseiulus persimilis*, *Galendromus occidentalis, Amblyseius californicus, Amblyseius andersonii*, *Amblyseius fallacis* and *Feltiella acarisuga*. Each species requires different environmental conditions.

*Phytoseiulus persimilis i*s the most effective predatory mite for control on two-spotted spider mite*. P persimilis* is suitable for use in short term crops such as bedding plants. Releases should be made when two-spotted spider mite populations are low or first detected. Two applications, one week apart may be needed. Make releases near infestaions and concentrate releases near localized hot spots. Optimum temperatures around 68F with 75% relative humidity is needed for this mite to be effective.

When scouting, check for the presence of live two-spotted mites and eggs. Also look for the predatory mites. They can be observed by shaking plant parts over a white sheet of paper. Adult predatory mites are bright red, pear-shaped with long legs and are larger and more active than two-spotted spider mites. Eggs of two-spotted mites ar round and *P persimilis* eggs are pear shaped. Predatory mites move quickly when disturbed. Pest control materials that have reportedly compatible include, spinosad, pymetrozine, clofentezine.

On greenhouse tomatoes, the sticky trichomes or hairs on the leaves can impede the movement of *P. persimilis*. Some companies provide a strain of *Phytoseiulus* that has been reared exclusively on tomato plants. *Feltiella acarisuga* a predatory gall midge is also an option - see below.

Galendromus occidentalis is effective on two-spoted mites, broad mites and cyclamen mites. It tolerates a wide range of temperatures and relative humidity and is also well adapted to outdoor conditions.

Amblyseius californicus can be used with *Phytoseiulus* or by itself. *A californicu*s eats pollen and can be released preventatively in crops that produce pollen before spider mites appear and can survive several days without food. *A. californicus* is

more tolerant of high temperature and low humidity than *Phytoseiulus* and also works on broad mites and cyclamen mites.

Amblyseius andersonii is effective on two-spotted spider mite. It is active at temperatures as low as 43-46F.

Amblyseius fallacis works in a wide range of temperatures and especially colder conditions compared to other predatory mites. It can overwinter in unheated greenhouses and eats pollen when prey is absent so can be released preventatively.

Feltiella acarisuga is a predatory gall midge for two-spotted spider mite. Females deposit their orange to red color eggs among mite colonies. Eggs hatch into larvae with feed on all life stages of mites (eggs, larvae, nymphs and adults). The larval stage is the the only predaceous stage. Larvae transition into pupae on leaf undersides and adult midges emerge. Although adults do not feed, they can fly to other locations in the greenhouse that contain hot spots of mites. *F acarisuga* is effective on greenhouse tomatoes and are not inhibited by the hairs. *F acarisuga* is active year-round (no winter resting stage). They are shipped as pupae and adults emerge soon after arrival. When scouting look for the nearly white pupal cases near the midrib on the leaf undersides.

Fungus gnats *(Bradysia spp.)* Options include predacious mites *(Hypoaspis miles)*, entomopathogenic nematodes (*Steinernema feltiae),* rove beetle (*Atheta coriaria)* and *Bacillus thuringiensis* var. *israelensis*. All are effective if applied before fungus gnat populations are abundant. The growing medium should be moist (not saturated) before applying these natural enemies.

H. miles prefers to feed on first instar fungus gnat larvae and it prey is not avaialble will feed on plant debris and algae. It is important to make releases early in the growing season before fungus gnat populations are high. Applications can also be directed to the soil beneath the benches. Mixing *H. miles* into the growing media prior to planting decreases survival. When scouting look for reductions in numbers of fungus gnat adults and yellow sticky cards and larvae on potato disks.

S. feltiae is a beneficial nematode that attacks fungus gnat larvae. Nematodes can be applied through a fertilizer injector. it is also helpful to use a small submersible pump to agitate the mixture in a the stock solution so that the nematodes do not settle to the bottom. Remove filters and use a nozzle with large holes. Treat early in the production cycle, just after planting. Use potato disks to monitor for fungus gnat larvae.

Atheta coriaria (rove beetle) is a generalist predator that feeds on fungus gnat and shore fly larvae. They disperse throughout a greenhouse by flying. Both larvae and adults feed on pests, but also may consume natural enemies such as *H. miles*. Temperatures of 65-80F and a relative humidity of 50-85% are optimal for survival.

Both adults and larvae are difficult to detect by scouting since they tend to hide in cracks and crevices of growing medium. Adults can be observed on the surface of the growing medium with their abdomens raised. Once established in a greenhouse, rove beetles may be present year round. Pesticides dinotefuran and thiamethozam are toxic to rove beetle adults. Rove beetles are compatible with beneficial nematodes.

In unsprayed greenhouses, growers may find adult hunter flies(*Coenosia attenuata*) and the parasitoid *Synacra pauperi* on sticky cards. Adult hunter flies are sometimes introduced on new plant material. Hunter flies resemble common house flies. They attack and feed on shore fly, whitefly, leafminer adults and other prey species in flight.

The soil-borne bacterium *Bacillus thuringiensis* spp. *israelensis* (GnatrolWDG) may be used before fungus gnat larval populations are high since it must be ingested to be effective. Applications are more effective on young larvae (1st instar) than mature larvae. Apply weekly until fungus gnat populations decline. *BTi* is not effective on shoreflies.

Shoreflies *(Scatella stagnalis)* . *Athea coriaria* (rove beetle) and beneficial nematode *Steinernema carpocapsae* are used to manage shoreflies.

Aphids (various species). Aphids are susceptible to many natural enemies, both predators and parasitoids. In general parasitoids are more effective than predators in reducing aphid populations, although parasitoids may fail to provide acceptable control under warm conditions when aphid populations tend to increase rapidly. For information on using biological control for aphids see the fact sheet, Managing Aphids [4]. Biological control options include *Aphidius colemani*, *Aphidius ervi,* ladybird beetles *(Hippodamia convergens, Adalia bipunctata)*, green laceing *(Chrysoperla rufilabris*) the predacious midge *Aphidoletes aphididmyza* and the entomopathogenic fungus *Beauveria bassiana*.

Banker plants are often used to manage aphids by sustaining aphid parasites and predators. Banker plants are used to rear prey that provide a continuing food source for specific natural enemies to ensure that they continue to reproduce. Banker plants for aphids consists of pots of common rye or winter barley on which colonies of grass-feeding aphid species such as the corn-leaf aphid, or bird-cherry aphid are established. Once established, parasitic wasps are released to parasitize the aphids on the banker plants, then the banker plants are placed along walkways and at the end of the benches.

Here are some guidelines for growing aphid banker plants.

- Place orders for banker plants up to 6 weeks before aphids are expected in your greenhouse.

- Transplant the plugs into larger sized pots (10 inch) so that the grass plants have plenty of room to grow.
- Wait one or two weeks for grass feeding aphid populations to grow.
- Lightly release the "aphid mummies" or *Aphidius colemani* adults onto the starter banker plants. For example, 100 hundred *Aphidius* per banker plant before it is divided and repotted. *Aphidius colemani* attacks the grass-feeding aphid, which is not an aphid pest of most greenhouse-grown crops except monocots such as ornamental grasses.
- Check banker plants weekly and look for newly parasitized aphids ("aphid mummies"), which indicate that the parasitoids are establishing on the banker plants.
- Start new banker plants on a regular basis because they will decline and die within a few weeks.
- Inoculate new banker plants by physically transferring aphids from old banker plants onto new ones every 2 weeks.

Banker plants are grown in starter cages to build up the population of grass feeding aphids before releasing *A. colemanii*. Starter cages will protect or isolate replacement banker plants from natural enemies that are either established in the greenhouse or naturally occurring natural enemies that may enter the greenhouse from outdoors during warmer weather.

Note that the bird-cherry aphid (used to rear parasitic wasps) is too small for the parasitoid, *A. ervi,* to develop. *A. ervi* parasitizes larger aphids such as the foxglove or potato aphid. If foxglove or potato aphids are your predominant species, one option is to use the predatory midge, *Aphidoletes aphidimyza* for release onto your banker plants. If using predatory midges, placing the pots in trays with moist sand will help provide pupation sites for the predatory midges. The predatory midges pupate in the soil.

Also note that *A. colemani* is not effective against the foxglove aphid. *Aphidius ervi* is used for large aphids such as foxglove aphid or potato aphid. *Aphidoletes aphidimyza* (predator midge) is also used for foxglove aphid.

Leafminers *(Liriomyza* spp.). The parasites *Dacnusa sibirica* and *Diglyphus isaea* are used for control of these pests. Both of these parasitoides are most effective for long-term crops such as cut flowers and stock plants and should be used preventively to manage leafminer populations.

Mealybugs (mainly citrus mealybug, *Planococcus citri*, and longtailed mealybug *Pseudococcus adonidum*). It is important to identify mealybugs to species before releasing natural enemies. The parasitoid *Leptomastix dactylopii* is only effective for citrus mealybug. The predatory ladybird beetle *Cryptolaemus montrouzieri* is also use to control citrus mealybug, but is less effective for longtailed mealybug.

Scale: Armored (*Diaspididae)* and **Soft** *(Coccus hesperidum*). Biological control of armored an soft scales may be difficult due to the wide range of scale species that may occur simultaneously. Currently, the number of commercialy available natural enemies for control of both armored and soft scale is limited. *Chrysoperla* spp. (green lacewing) and *Rhyzobius lophanthae* are two commercially available predators.

Caterpillars *Bacillus thuringiensis* spp. *kurstaki* (Dipel, Deliver, Javelin)(Bt) is available that provide satisfactory control for some kinds of caterpillars. Bt is a bacterium that must be consumed by the caterpillar to be effective and through coverage is needed. Caterpillars stop feeding within 24-48 hours after eating the bacterium and die after 3-4 days.
