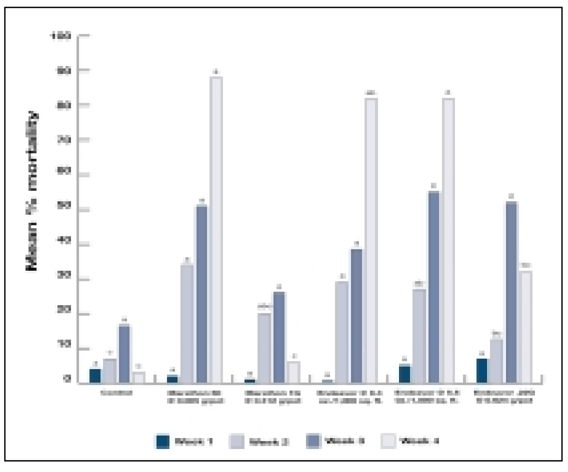
Figure 2. Mean percent mortality of silverleaf whitefly nymphs one, two, three and four weeks after treatment. Poinsettias were treated with selected insecticides. Treatments were made directly to the soil as a drench or granular treatment.



with pest-free plants, and exclude the pest, if possible, with exclusion screens. Many weeds are good hosts for whiteflies. Therefore it is important to keep the growing area clean and free of weeds. Biologicals are also a good control method for whiteflies; see the sidebar at the right for information about biologicals.

All whitefly stages typically occupy the undersides of leaves of infested plants. The more susceptible stages are the younger nymphs. The later stages, such as the fourth instar and redeye stage, are more difficult to control. Therefore, the best control is achieved when a maximum effort is made to contact the undersides of leaves with repeated spray applications (about every six days) targeting the earlier, susceptible stages for a period of about three weeks. Heavier infestations may require more applications for a more extended period of time.

An effort should be made to hold whitefly populations in check early in the cropping cycle. Contact insecticides, including soaps and oils, may be more effective early in the growth cycle when the foliage is less dense and contact with young nymphs is more likely. Later in the cropping cycle, when dense foliage is present, a systemically acting material may be more efficient in reaching the insects.

CHEMICAL CONTROLS

Figures 1-4, pages 58-62, are summaries of recent whitefly trials conducted at the University of California-Riverside. Some of ➧

Table 1. Whitefly Control Methods.

Pesticide Common name	Chemical Class	Manufacturer	Trade Names
Beauveria	Biological	Mycotech	BotaniGard
pyrethrin/PBO	botanical	Whitmire MicroGen, Agrevo	PT 1100, Pyrenone Crop Spray
Pyrethrin/Rotenone	Botanical	Webb Wright	Pyrellin EC
Imidacloprid	Chloronicotinyl	Olympic Horticulture	Marathon
Azadiractin	IGR	Themo Trilogy	Azatin XL
S-kinoprene	IGR	Wellmark	Enstar II
Diflubenzuron	IGR	Crompton/Uniroyal	Adept
Novaluron	IGR	Crompton/Uniroyal	Pedestal
Pymetrozine	Pyridine	Syngenta	Endeavor
Pyriproxifen	Pyridine	Valent, Whitmire MicroGen	Distance, Pyrigro
Neem oil	Oil	Thermo Trilogy	Triact 90
Horticultural oil	Oil	Whitmire MicroGen	Ultra-Fine Oil
Endosulfan *	Organochlorine	Gowan	Endosulfan
Chlorpyrifos/Cyfluthrin	Organophos./pyreth.	Whitmire MicroGen	PT Duraplex TR
Acephate	Organophosphate	Valent, Whitmire MicroGen	Orthene, PT 1300
Sulfotep *	Organophosphate	Plant Products Inc.	Plantfume 103
Diazinon	Organophosphate	Cleary	KnoxOut
Dimethoate	Organophosphate	various	various
Malathion	Organophosphate	various	various
Bifenthrin *	Pyrethroid	Whitmire MicroGen	Talstar
Cyfluthrin	Pyrethroid	Olympic Horticulture	Decathlon
Fenpropathrin *	Pyrethroid	Valent	Tame
Fluvalinate	Pyrethroid	Wellmark	Mavrik Aquaflow
Permethrin	Pyrethroid	FMC	Astro
Pyridaben	Pyridazinone	BASF	Sanmite
Soap	Soap	Micro-Flo, Olympic Hort.	Insecticidal Soap

* *Restricted use material.*

Silverleaf whitefly nymphs. The nymph at the bottom left has been parasitized by Encarsia formosa.

PUTTING MOTHER NATURE TO WORK

Biological control methods

By Stanton Gill

With restricted re-entry intervals, and fear of resistance development, many growers are looking for alternative methods for controlling whiteflies, and some of them are turning toward biologicals. The most interesting new developments in biological control are with natural enemies such as parasitoids, predators and pathogens, though there are also a number of oils, soaps and other biological agents (see Table 1, left for a listing of controls and manufacturers).

PARASITOIDS

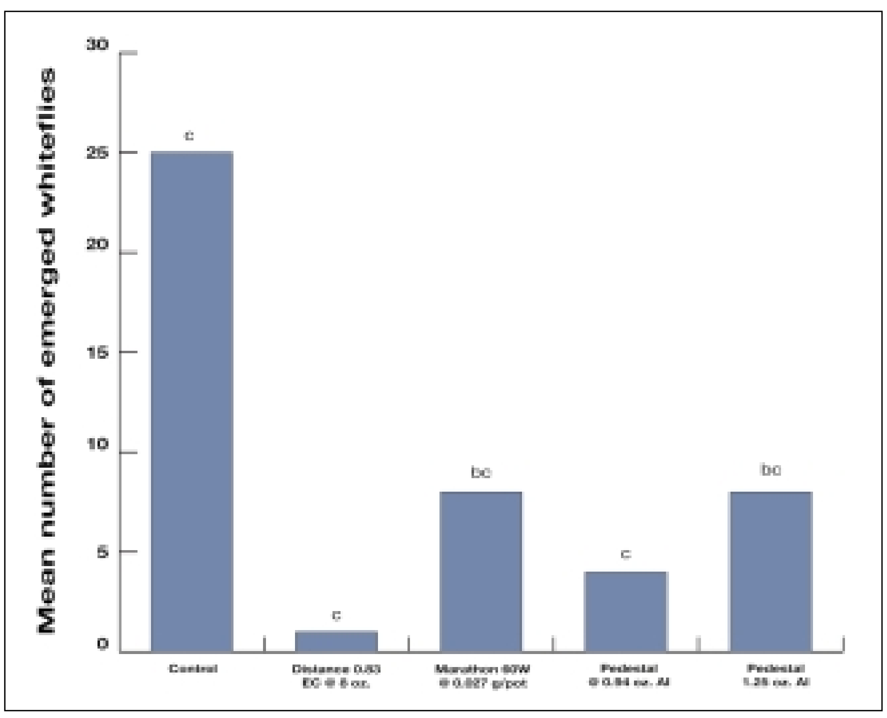
Several species of whitefly parasitoids occur naturally in the United States and may migrate into greenhouses and attack whiteflies. However, the degree of control is usually insufficient. Augmentative releases of commercially reared parasitoids are typically more effective.

Parasitoids that have been used successfully in greenhouse crops include tiny wasps of several Encarsia and Eretmocerus species. These wasps attack whitefly nymphs, killing them in one of two ways. First, the female wasp uses her needle-like ovipositor to lay an egg within or beneath a whitefly nymph. *Encarsia sp.* prefers the third to fourth instar whiteflies. The egg hatches, and the parasitoid maggot feeds on the nymph. Pupation occurs within the nymph. When the adult wasp emerges from the whitefly pupa, it chews a round exit hole through the cuticle at one end of the whitefly pupa. Second, the female wasp punctures the whitefly nymph with her ovipositor, killing the nymph, and feeds from the fluids that exude from the wound. The wasps do not attack adult whiteflies. ➧

the pesticides are registered for use on the intended target; others are experimental. We do not always use labeled rates in our trials because these trials are for experimental purposes — to increase our knowledge about the products and their capabilities. Labels constantly change; therefore, it is always the pesticide applicator's responsibility to follow all label directions. No endorsement is intended for products mentioned, nor is criticism meant for products mistakenly omitted.

There are a relatively large number of insecticides available for chemical control of whiteflies, providing many options for rotation (see Table 1, page 59). In addition to Marathon (imidacloprid), several new chloronicotinoids like acetamiprid (Aventis), Forte (a new formulation of imidacloprid, Bayer), thiamethoxam (Syngenta) and thiacloprid (Bayer), have been registered recently or are in the development phase. All of these materials are very effective against whiteflies. In addition, a new Novaluron from Crompton/Uniroyal (Pedestal) looks very promising (see Figures 3-4, pages 60-62).

Figure 3. Mean number of emerged adult silverleaf whiteflies from treated poinsettias three weeks after treatment.



Whiteflies typically have several generations each year, especially in a greenhouse environment. They take about 21-25 days to develop to an adult, depending on temperature. Because the nymphs are on the plants for a long time and passing through many molts, whiteflies are susceptible to pesticides that act as IGRs like Distance (pyriproxifen, Valent USA) and Pedistal (novaluron, Crompton/Uni-royal). For optimal control on a long-term crop, pesticide class should be rotated every generation or two, or about every 4-6 weeks.

Although many effective ➧

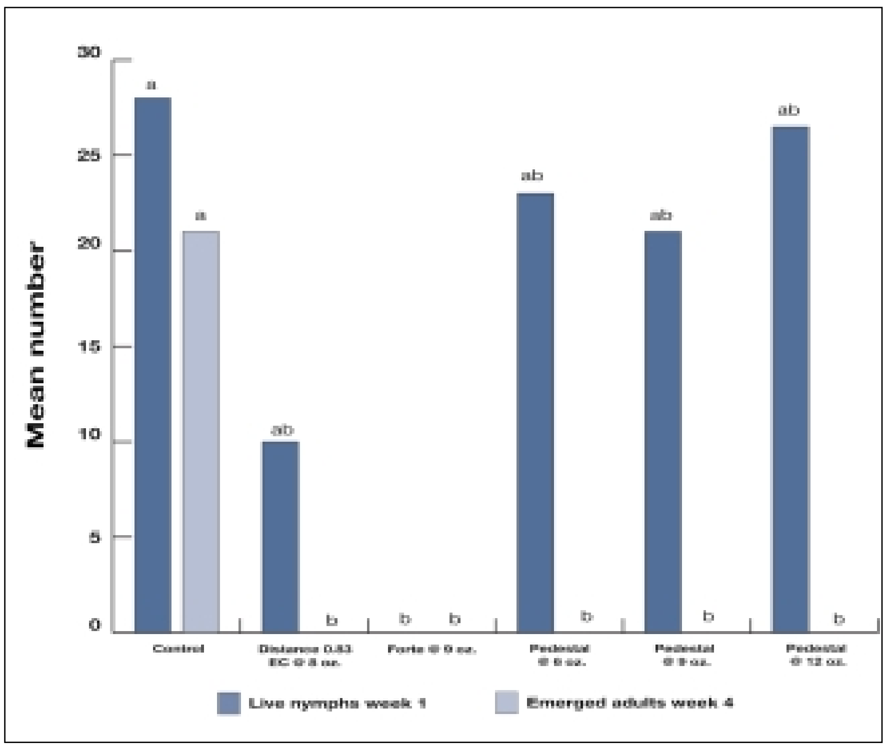
Encarsia formosa is a very tiny wasp (0.6 mm), with a black head and thora, a pale yellow abdomen and transparent wings. Females give rise to females; males are rare. Greenhouse whitefly pupae that have been parasitized by *Encarsia formosa* turn black; silverleaf whitefly pupae turn amber-brown. The adult wasps are rarely noticed and should not be a deterrent in sale of the plants. This parasitoid is widely used for biological control of greenhouse whitefly on greenhouse vegetables. Release rates vary from 3-6 wasps per square foot of growing area with repeated releases at 7- to 14-day intervals. Encarsia will reproduce on many greenhouse crops once populations are established. The cost of *Encarsia formosa* can be equal to foliar pesticide applications or slightly higher.

Eretmocerus eremicus is an equally tiny wasp but differs from *Encarsia formosa* in that the adult is entirely yellow with green eyes and clubbed antennae. Males have longer, more prominent antennae than females. Parasitized whitefly nymphs appear beige in color. Release rates are 2-3 per sq. ft. of growing area. Repeated releases at 7-14 intervals are often necessary. On most occasions, Eretmocerus will not reproduce in a greenhouse environment, so repeated applications are necessary until the whitefly population is reduced to a desired level. Unfortunately, this parasite is relatively expensive and costs significantly more than applications of pesticides to control whiteflies.

PREDATORS

Delphastus pusillus is a tiny, black ladybird beetle that is a voracious predator of whiteflies. This beetle reproduces quickly, lays many eggs and lives a relatively long time (1 1/2-2 months). Larval and adult beetles eat all stages of the whitefly but concentrate on eggs and immature whiteflies. Adult beetles eat ➧

Figure 4. Mean number of live silverleaf whitefly nymphs on treated poinsettias one week after treatment and the mean number of emerged adults four weeks after treatment.



strategies are available to manage most whitefly pests, the relatively recent introduction of several new whitefly pest species and whitefly-transmitted pathogens emphasizes the need to constantly be on the alert for the spread of these pests or the establishment of new exotic species. GPN

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150-600 eggs or 10-12 fourth instar whitefly larvae per day. Individual beetles can consume as many as 10,000 whitefly eggs or 700 fourth instars during a typical lifetime. Delphastus lady beetles also have potential for integration in control programs with parasitoids because they do not compete. Though Delphastus will eat parasitized whitefly nymphs, they prefer to eat unparasitizied nymphs.

Spiders are the best-adapted arthropod predators to successfully prey on mobile, more visually acute insects such as adult whiteflies. Spiders have had an effect on *Bemisia sp.* adults in field crop situations. In outdoor growing beds, where herbaceous perennials are grown, preserving the spider populations by avoiding broad-spectrum, long residual pesticides will aid in naturally occurring biological control.

PATHOGENS

Microbial insecticides offer an alternative to traditional chemical sprays and drenches. One potential candidate that has received federal registration is a microbial insecticide containing the entomopathogenic fungus, *Beauveria bassiana*. This fungus is a naturally occurring insect pathogen and has been found to be effective in controlling whiteflies, certain aphid species, mites and thrips.

Two different strains of the fungus are commercially available. BotaniGard (GHA strain) is formulated as a wettable powder and an emusifiable suspension. The *B. bassiana* spores in Naturalis-T&O are formulated to mix readily in water and are applied using standard, high-volume spray equipment. The fungus kills insects either by direct contact from the spray equipment or through secondary contact with spores on foliage. When spores come in contact with an acceptable host, a germ tube penetrates the insect's cuticle and feeds from the host body, resulting in death of the host. In most cases, 8-10 fungal spores are needed to cause fungal infection and insect death. The warm temperatures and relatively high humidity in greenhouses are ideal environments for using this fungal pathogen. Because fungal spores kill insects through direct contact, good spray coverage is essential for achieving adequate control.

The entompathogenic fungus, *Paecilomyces fumosoroseus*, is being marketed as PFR-97 (Olympic Chemical Co.). The fungus has been shown to give control of whiteflies, aphids and spider mites in Southern states and in the greenhouse where humidity levels are relatively high.

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