K-STATE
Research and Extension

Whiteflies

Management in Greenhouse Production Systems

Whiteflies are major insect pests of many greenhouse-grown horticultural crops (ornamentals and vegetables) including basil, chrysanthemum, cucumber, dahlia, eggplant, fuchsia, geranium, hibiscus, lantana, petunia, poinsettia, salvia, tomato, transvaal daisy, and verbena. The primary whitefly species encountered in greenhouses are the greenhouse whitefly, *Trialeurodes vaporariorum*, and the sweetpotato whitefly, *Bemisia tabaci*. Both species are prevalent worldwide and feed on a wide range of ornamental and vegetable plants grown in greenhouses. This publication discusses whitefly identification, biology, plant damage, movement in greenhouses, and provides management strategies that will help alleviate problems with whiteflies in greenhouses.

Figure 1. Greenhouse whitefly adult. (Photo: Lance Osborne, University of Florida)

Identification

Greenhouse and sweetpotato whiteflies can be identified using the pupa (fourth instar nymph) and adult stages. The greenhouse whitefly adult has a white body and white wings that are held horizontally over the body (Figure 1). The greenhouse whitefly pupa has parallel sides that are perpendicular to the leaf surface, resembling a cake or pillbox. The pupa also has long waxy filaments around the periphery (Figure 2).

The adult sweetpotato whitefly has a light-yellow body with white wings. The wings are retained roof-like over the body at a 45-degree angle (Figure 3). The sweetpotato whitefly pupa is flattened with no parallel sides. In addition, the pupa does not have long waxy filaments around the periphery (Figure 4).

Figure 3. Sweetpotato whitefly adult (Photo: Lance Osborne, University of Florida)

Figure 2. Greenhouse whitefly pupa (Photo: Lance Osborne, University of Florida)

Figure 4. Sweetpotato whitefly pupae. (Photo: Lyle Buss, University of Florida)

Biology

Whitefly adults are 1/13 to 1/9 inches (2 to 3 mm) long, depending on the species, with white to yellow bodies and four wings covered with a white, waxy powder (Figure 5). Adults disperse short distances when plant leaves are disturbed. All life stages (eggs, nymphs, pupae, and adults) are located on the undersides of young and mature leaves (Figures 6 and 7). Adult females lay up to 20 eggs per day, which are arranged in a crescent-shaped pattern on the underside of leaves. Females can lay up to 200 eggs during their 30- to 45-day lifespan. Female longevity and the number of eggs laid are dependent on temperature and host plant quality. Eggs are attached upright on the leaf surface by means of a thin stalk. Greenhouse whitefly eggs are green to purple, whereas sweetpotato whitefly eggs are white to yellow-brown with a darkened tip.

Figure 5. Whitefly adult. (Photo: Raymond Cloyd)

Nymphs (crawlers) hatch from eggs in five to 12 days when temperatures are between 65 and 75°F (18 and 24°C), then search for feeding sites on plants. After finding a suitable feeding site, nymphs insert their piercing-sucking mouthparts into leaf tissues (phloem sieve tubes) and withdraw plant fluids. Nymphs are flattened, oval, and transparent to yellow-green (Figure 8). The nymphs are stationary for two to three weeks and molt three times before becoming pupae or fourth instar nymphs. At this time, the red eyespots of the developing adult are visible through the transparent pupal case (Figure 9). After about a week, adults emerge (eclose) from the pupae.

Adult females begin laying eggs within two to seven days. The life cycles (egg to adult) of the greenhouse and sweetpotato whitefly are similar and can be completed in three to four weeks depending on temperature and host plant quality. The life cycle takes less time to complete from spring through fall. In addition, there can be multiple, overlapping generations per cropping cycle that lead to rapid increases in whitefly populations.

Figure 6. All whitefly life stages (eggs, nymphs, pupae, and adults) are located on leaf undersides. (Photo: Raymond Cloyd)

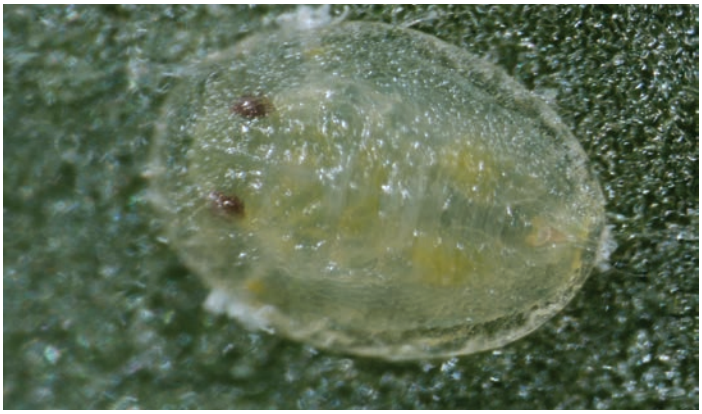

Figure 8. Whitefly nymph. (Photo: Lance Osborne, University of Florida)

Figure 7. All whitefly life stages (eggs, nymphs, pupae, and adults) are located on leaf undersides. (Photo: Raymond Cloyd)

Figure 9. Red eyes of developing adult visible through the pupal case. (Photo: Raymond Cloyd)

Plant Damage

Whitefly nymphs and adults damage plants when feeding on plant fluids within the phloem sieve tubes, resulting in leaf yellowing, leaf distortion (Figure 10), plant wilting, stunting, and possibly even death. While feeding, nymphs and adults excrete a clear, sticky liquid called honeydew (Figure 11) that is a growing medium for black sooty mold (Figure 12). Black sooty mold inhibits the plant's ability to manufacturer food by means of photosynthesis, and reduces the aesthetic quality of plants. Moreover, high numbers of whitefly adults on plants, especially on leaf undersides, can be visually unappealing and reduce the aesthetic value and marketability of the crop.

Whiteflies can damage ornamental and vegetable crops indirectly by transmitting plant pathogens such as viruses. The sweetpotato whitefly can transmit several viruses to ornamentals and vegetables including *Ageratum yellow vein* virus, *Cucurbit leaf curl* virus, *Rose leaf curl* virus, *Squash leaf curl* virus, and *Tomato yellow leaf curl* virus. The greenhouse whitefly also transmits several viruses such as *Abutilon yellows* virus, *Sweet potato chlorotic stunt* virus, and *Tomato yellow leaf curl* virus. There is no cure for a virus. Consequently, infected plants should be disposed of immediately to prevent further spread of the virus.

Figure 10. Leaf distortion on basil plant associated with whitefly feeding. (Photo: Raymond Cloyd)

Figure 11. Honeydew on plant leaf. (Photo: Raymond Cloyd)

Movement in Greenhouses

Whitefly adults can migrate into greenhouses through doors, vents, and louvers from susceptible plants, and weeds located outdoors. During the growing season, whiteflies can spread or disperse from one greenhouse to another on infested plant material or the clothing of greenhouse workers. Yellow-colored clothing may be attractive to whitefly adults.

Management

Whiteflies can be managed in greenhouse production systems using a combination of strategies. These include isolation, scouting, cultural, physical, applying insecticides, and/or releasing biological control agents.

Isolation

Plant material received from suppliers should be isolated in a separate area of the greenhouse operation for approximately two weeks before introducing plants into the main production greenhouse. Plants should be inspected regularly for eggs, nymphs, pupae, and adults using a 10 or 16x hand lens (Figure 13). Once plants have been determined to be "whitefly free," they can be moved into the main greenhouses and placed among the other plant material.

Figure 12. Black sooty mold on leaf. (Photo: Raymond Cloyd)

Figure 13. A 16x handlens should be used to inspect plants for whiteflies. (Photo: Raymond Cloyd)

Scouting

Scouting crops early in the growing season helps determine the number of whiteflies present in the greenhouse. In addition, scouting can track seasonal trends in whitefly populations throughout the year. Yellow sticky cards should be placed vertically just above the crop canopy to capture adults (Figure 14). The yellow sticky cards can be attached to bamboo stakes using clothespins so they can be adjusted as plants grow taller.

Yellow sticky cards should be inspected at least once a week, recording the number of adult whiteflies captured. In general, one yellow sticky card should be placed every 1,000 square feet (90 square meters) of greenhouse space. Position the yellow sticky cards near openings such as vents and doorways where whitefly adults can enter from outdoors.

Plants should be inspected at least twice a week during the growing season (Figure 15). Use a 10 or 16x hand lens to inspect the undersides of old (mature) and young (new) leaves for the presence of eggs, nymphs, and/or pupae. This is especially important for crops highly susceptible to whiteflies including basil, eggplant, fuchsia, hibiscus, lantana, poinsettia, salvia, tomato, and transvaal daisy.

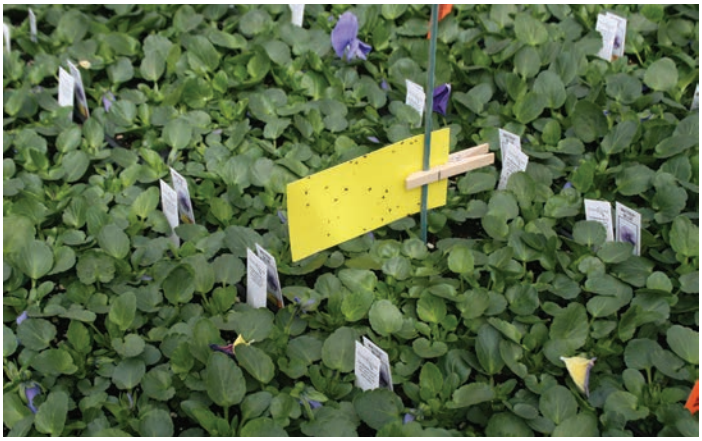

Figure 14. Yellow sticky card placed above the crop canopy. (Photo: Raymond Cloyd)

Figure 15. Inspecting plants for the presence of whitefly eggs, nymphs, or pupae. (Photo: Raymond Cloyd)

Cultural

Proper watering and fertilizing practices can decrease plant susceptibility to whiteflies. For instance, avoid overfertilizing plants, especially with water-soluble, nitrogen-based fertilizers as plants containing high levels of nitrogen can increase female reproduction. The nitrogen source can affect the egg-laying preferences of the female whitefly. For example, more whitefly eggs are laid on poinsettia (*Euphorbia pulcherrima*) plants fertilized with ammonium nitrate than on poinsettia plants fertilized with calcium nitrate.

Proper sanitation practices can reduce problems with whiteflies. Old stock plants can serve as a reservoir for whiteflies and should be removed. All plant debris should be eliminated as whitefly pupae (fourth instar nymphs) can become adults on withered or dried leaves, and then migrate onto the main crop. Discard all plant material debris into garbage containers with tight-sealing lids and keep containers covered (Figure 16).

Whiteflies may be present in greenhouses throughout the growing season, especially when weeds are allowed to grow underneath benches (Figure 17). Weeds such as annual sow thistle (*Sonchus oleraceus*), common chickweed

Figure 16. Garbage container with tight-sealing lid. (Photo: Raymond Cloyd)

(*Stellaria media*), velvetleaf (*Abutilon theophrasti*), and dandelion (*Taraxacum officinale*) can serve as a reservoir for whiteflies. Therefore, all weeds should be removed from inside and around the perimeter of greenhouses.

Physical

Screens placed on greenhouse openings such as vents and sidewalls can exclude whitefly adults from entering a greenhouse from outdoors (Figure 18). The screen holes should be less than 0.018 inches or 462 microns [0.0105 × 0.0322 inches (266 × 818 microns)] in diameter to exclude adult whiteflies. The National Greenhouse Manufacturers Association (NGMA; office@ngma.com) can provide information on installing screening material over greenhouse openings without restricting airflow and damaging fan motors. Screening greenhouse openings is only effective when used in conjunction with other management strategies discussed in this publication.

Screens must be cleaned regularly during the growing season to remove debris that can restrict airflow. Clean screens from the inside of the greenhouse using a hose and low-pressure nozzle. Avoid using high-pressure cleaners or brushes that can expand the size of the holes and affect the functionality of the screening. Do not clean screens while ventilating the greenhouse to avoid plugging up holes in the screen fabric, which can restrict airflow. Be sure to turn off all fans in the evening after ventilation before cleaning screens.

Figure 17. Weeds underneath bench may be a reservoir for whiteflies. (Photo: Raymond Cloyd)

Figure 18. Screening greenhouse openings can exclude adult whiteflies from entering greenhouses. (Photo: Raymond Cloyd)

Insecticides

Insecticides can be used to suppress whitefly populations on greenhouse-grown horticultural crops. Early whitefly nymphs and adults are susceptible to insecticides, whereas the eggs and pupae (fourth instar nymphs) are tolerant of most insecticides. Contact, translaminar, or systemic insecticides can be used to suppress whitefly populations. Contact insecticides kill whiteflies that are directly exposed to spray applications, or when whitefly nymphs or adults walk over a treated surface and encounter insecticide residues on the leaf.

Translaminar insecticides penetrate the leaf surface tissues, forming a reservoir of active ingredient within the leaf. Depending on the product, translaminar insecticides can provide up to 14 days of residual activity even after spray residues have dried. Read product labels to determine which insecticides have translaminar activity.

Systemic insecticides can be applied as a drench or granule to the growing medium, or as a foliar spray. When applied as a drench or granule, the insecticide active ingredient is taken up by the roots and translocated throughout the plant and into plant leaves where whiteflies feed. Applications to the growing medium can suppress whitefly populations for up to eight weeks and foliar applications for up to four weeks. Applications should be made before whiteflies are present on plants. Read the product label to determine which insecticides have systemic activity.

Insecticides are most effective if applied early in the cropping cycle when whitefly populations are low. For smaller plants, coverage of all plant parts is easier with spray applications, especially leaf undersides. Thorough spray coverage of leaf undersides is important, especially with contact insecticides, because all of the whitefly life stages (eggs, nymphs, pupae, and adults) are located on the undersides of leaves. Frequent applications are necessary to maintain whitefly populations at low levels and reduce subsequent plant damage. Read the product label for information regarding intervals between applications.

Rotate insecticides with different modes of action to delay the development of insecticide resistance in whitefly populations. For example, use an insecticide with one mode of action for two weeks, and then switch to an insecticide with a different mode action for the next two weeks, and so on for eight weeks before using the same insecticide that was applied the first two weeks. Insecticides available for use against whiteflies in greenhouses are listed in Table 1.

Biological Control Agents

The biological control agents commercially available for use against whiteflies are listed in Table 2 and include the parasitoids, *Encarsia formosa* and *Eretmocerus eremicus*, and the predators, *Delphastus catalinae* and *Amblyseius swirskii*. Contact a supplier or distributor of biological control agents regarding information on the appropriate procedures for releasing biological control agents in greenhouses to regulate whitefly populations. It is important that biological control agents are released early or preventively before whiteflies are present.

Table 1. Insecticides (common and trade name) labeled for use against whiteflies in greenhouse production systems, insecticide type, and designated mode of action.

Common Name (Trade Name)	Insecticide Type*	Mode of Action
Abamectin (Avid)	C and T	Gamma-aminobutyric acid (GABA) chloride channel activator
Acetamiprid (TriStar)	C, T, and S	Nicotinic acetylcholine receptor modulator
Afidopyropen (Ventigra)	C and T	Selective feeding blocker/chordotonal organ TRPV modulator
Beauveria bassiana Strain GHA (BotaniGard)	C	
Buprofezin (Talus)	C	Chitin synthesis inhibitor
Cyantraniliprole (Mainspring)	C, T, and S	Selective activation of ryanodine receptors
Cyclaniliprole (Sarisa)	C and S	Selective activation of ryanodine receptors
Diflubenzuron (Adept)	C	Chitin synthesis inhibitor
Dinotefuran (Safari)	C, T, and S	Nicotinic acetylcholine receptor modulator
Flonicamid (Aria)	C, T, and S	Selective feeding blocker/chordotonal organ modulator
Flupyradifurone (Altus)	C, T, and S	Nicotinic acetylcholine receptor modulator
Imidacloprid (Marathon)	C, T, and S	Nicotinic acetylcholine receptor modulator
Isaria fumosorosea Apopka Strain 97 (Ancora)	C	
Metarhizium brunneum Strain F52 (Met52)	C	
Kinoprene (Enstar)	C	Juvenile hormone mimic
Mineral oil (Ultra-Pure Oil/SuffOil-X)	C	Suffocation or membrane disruptor
Novaluron (Pedestal)	C	Chitin synthesis inhibitor
Potassium salts of fatty acids (M-Pede/Kopa)	C	Desiccation or membrane disruptor
Pymetrozine (Endeavor)	C, T, and S	Selective feeding blocker/chordotonal organ TRPV channel modulator
Pyridaben (Sanmite)	C	Mitochondria electron transport inhibitor
Pyrifluquinazon (Rycar)	C and T	Selective feeding blocker/chordotonal organ TRPV channel modulator
Pyriproxyfen (Distance/Fulcrum)	C	Juvenile hormone mimic
Spiromesifen (Savate)	C and T	Lipid biosynthesis inhibitor
Spirotetramat (Kontos)	C, T, and S	Lipid biosynthesis inhibitor
Thiamethoxam (Flagship)	C, T, and S	Nicotinic acetylcholine receptor modulator

* Insecticide types: C=Contact, T=Translaminar, and S=Systemic.

Table 2. Biological control agents (parasitoids and predators) used against whiteflies in greenhouse production systems.

Parasitoids

Encarsia formosa

A parasitoid used against greenhouse whitefly. Females prefer to lay eggs into third- and fourth-instar nymphs. Adult females feed on nymphs. Parasitized whitefly pupae are black. Optimum temperatures for regulating whitefly populations are 68 to 77°F (20 to 25°C). Development (egg to adult) is completed in 14 days at temperatures greater than 80°F. The parasitoid is less effective in parasitizing whiteflies on plants with trichomes (hairs) such as cucumber.

(Photo: Lance Osborne, University of Florida)

Eretmocerus eremicus

A parasitoid used against greenhouse and sweetpotato whiteflies. Females prefer laying eggs into second- and third-instar nymphs. Adult females will feed on nymphs. *Eretmocerus eremicus* tolerates higher temperatures than *Encarsia formosa*.

(Photo: Paul Langlois, USDA-APHIS PPQ)

Predators

Delphastus catalinae

A predatory ladybird beetle in which both the larvae and adult feed on whitefly eggs and nymphs. Adults will feed on greenhouse and sweetpotato whitefly but prefer sweetpotato whitefly. Females lay between 200 and 300 eggs during their lifetime. Adults live between 45 and 60 days. A single adult can feed on 160 eggs per day. Adults will not feed on parasitized whiteflies.

(Photo: Janine Spies, University of Florida)

Amblyseius swirskii

A predatory mite that feeds on whitefly eggs and nymphs and will feed on pollen as an alternative food source if no whiteflies are present. Optimum temperatures for regulating whitefly populations are 77 to 83°F (25 to 28°C). The life cycle, from egg to adult, can be completed in less than seven days. *Amblyseius swirskii* is less effective in regulating whitefly populations on plants with trichomes (hairs) such as tomato.

(Photo: Anatis Bioprotection)

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