



Western Flower Thrips Management: Have We Reached An Impasse?

by Raymond Cloyd

It goes without saying that nearly all greenhouse producers are familiar with one of the most destructive insect pests of greenhouses, the western flower thrips (WFT), *Frankliniella occidentalis*. Western flower thrips are still the primary thrips species encountered by greenhouse producers. They feed on a wide variety of horticultural crops grown in both commercial and research greenhouses. This insect pest has been included in greenhouse pest control brochures since 1949; however, it was initially not considered a major insect pest of greenhouse-grown crops until the 1980s. Since then, more articles have been published on WFT than almost any other greenhouse insect pest. This article will cover a wide-range of topics associated with WFT, including biology and damage, scouting, cultural and physical management, pest control material management, resistance, and biological management.

Biology and Damage

Knowledge of western flower thrips biology and damage are important in understanding the challenges associated with developing a “sound” pest management program. WFT are small (approximately 2.0 mm in length) insects with piercing-sucking mouthparts (Figure 1). The life cycle consists of an egg stage, two nymphal stages, two pupal stages, and an adult (Figure 2). Development from egg to adult is temperature dependent, with the optimum range between 80°F and 85°F. Under these given temperatures, the life cycle from egg to adult may be completed in 7 to 13 days. In general, the life cycle (egg to adult) takes two to three weeks to complete. Females can live up to 45 days and lay between 150 and 300 eggs during their lifetime. The eggs are



Figure 1. Western flower thrips are small (approximately 2.0 mm in length) insects with piercing-sucking mouthparts.

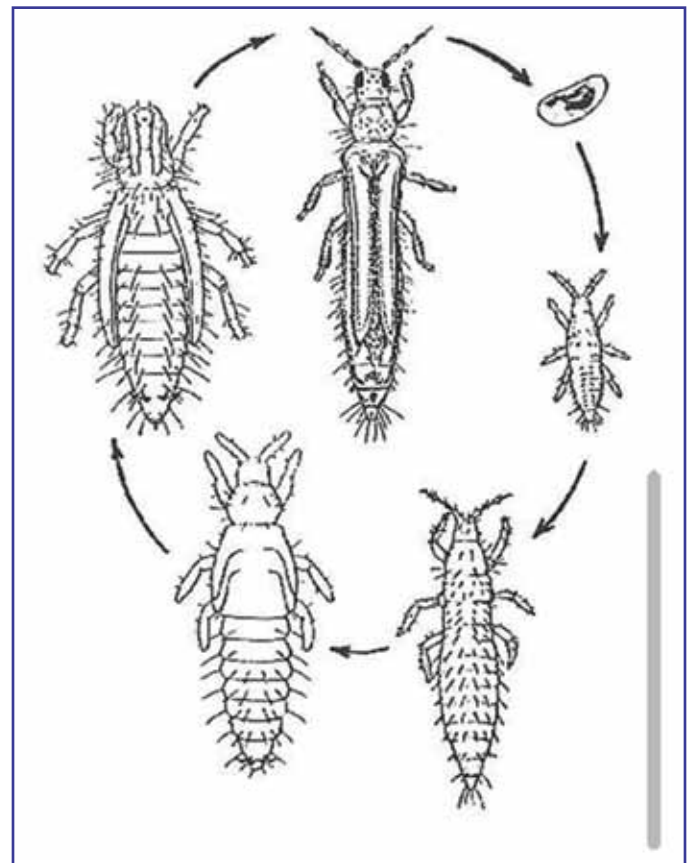


Figure 2. The life cycle for western flower thrips consists of an egg stage, two nymphal stages, two pupal stages, and an adult stage.

typically laid underneath the epidermal layer of the leaf surface or in flower tissues and hatch in two to four days. The nymphs feed on both leaves and flowers. The first nymphal stage lasts one to two days while the duration of the second nymphal stage is two to four days. The second instar nymph eventually migrates to the base of a given plant and enters the growing medium to pupate. WFT will also pupate in leaf debris and in the open flowers of certain plant types including chrysanthemum. There are actually two “pupal” stages: a prepupae (or propupae) and pupae. The pupae stage is very tolerant or immune to most insecticides commonly applied to manage WFT. Adults emerge from the pupal stage after approximately six days.

WFT have a haplo-diploid breeding system, which means the females develop from fertilized eggs, and males develop from unfertilized eggs. Unmated females can produce sons partheno-

genetically (without mating) whereas females must be mated to produce daughters. Female WFT may also mate with their own offspring. The sex ratio (females:males) is dependent on the population density with males tending to be more prevalent at “low” population densities whereas females are typically more abundant at higher densities. Increasing population densities of WFT in greenhouses enhances the probability of females encountering and mating with males immediately after emerging from the pupal stage. High population densities create an age structure consisting of young, fecund females producing a predominance of daughters. However, as adult females age, they tend to produce more males. WFT females feed on pollen, which contains abundant proteins and provides a high-quality food source affecting oviposition, development rate, and larval growth.

WFT cause direct damage by feeding on plant leaves and flowers. Although WFT have piercing-sucking mouthparts, they do not feed exclusively in the phloem sieve tubes. Instead, they tend to feed on the mesophyll and epidermal cells of leaf tissues using a single stylet in the mouth and then inserting a set of paired stylets, which lacerate and damage cell tissues and imbibe cellular fluids. As a result, WFT feed on a multitude of food types within plants. Symptoms of WFT feeding include leaf scarring, distorted growth, sunken tissues on leaf undersides (Figure 3), and deformation of flowers (Figure 4). Flowers and leaves have a characteristic “silvery” appearance. Black fecal deposits may be present on leaf undersides (Figure 5). In addition, WFT cause indirect damage by vectoring impatiens necrotic spot wilt virus (INSV). The first and second instar nymphs acquire the virus, which is then transmitted by adults. Both direct and indirect types of damage may result in an economic loss to greenhouse producers.



Figure 3. Symptoms of western flower thrips feeding include leaf scarring, distorted growth, sunken tissues on leaf undersides (Figure 3), and deformation of flowers (Figure 4). Flowers and leaves have a characteristic “silvery” appearance.

WFT is difficult to manage in greenhouses for a number of reasons, including broad host range, high reproductive capacity, rapid life cycle, small size (approximately 2 mm long), feeding habit, reside in cryptic habitats (unopened flower buds) and resistance to insecticides. As such, the only way to effectively deal with western flower thrips in greenhouse production systems is by taking a “holistic” approach via implementing a variety of strategies including scouting, cultural and physical, pest control material, and biological management.



Figure 4. Symptoms of western flower thrips feeding include leaf scarring, distorted growth, sunken tissues on leaf undersides (Figure 3), and deformation of flowers (Figure 4). Flowers and leaves have a characteristic “silvery” appearance.



Figure 5. Black fecal deposits may be present on leaf undersides of infested plants.

Scouting

Scouting is important to determine the numbers of WFT present in the greenhouse. This helps evaluate the success of a management program. In addition, scouting will detect seasonal trends in WFT populations throughout the year. The main technique used to scout for WFT adults is to place either blue or yellow sticky cards (Figure 6 page 26) above the crop canopy. The cards are counted weekly, and the numbers of WFT adults are recorded. Visual inspection such as looking into open flowers and/or shaking open flowers over a white sheet of paper are additional methods that may be used to scout for WFT adults and nymphs. Furthermore, gently blowing into open flowers will agitate western flower thrips and increase their movement, thus making it easier to observe them.

Greenhouse producers can establish their own “action thresholds” (the number of WFT detected either on colored sticky cards or visually that warrant the implementation of a pest management strategy) that they feel comfortable with. However, sticky card counts (and therefore action thresholds based on them) can yield an inconsistent range of the actual WFT numbers present for several reasons including variable plant attractiveness, presence of flowers, placement of sticky

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Figure 6. The main technique used to scout for western flower thrips adults is to place either blue or yellow sticky cards above the crop canopy.

cards, age structure of western flower thrips population, migration of WFT into greenhouses, and crop growth stage.

Cultural and Physical Management

Sanitation practices such as removing weeds, old plant material, and growing medium debris are the “first line of defense” in minimizing problems with WFT. Certain weeds, particularly those with yellow flowers, not only attract WFT adults, but many weeds such as oxalis, chickweed, jewelweed, and ground ivy serve as reservoirs for the viruses transmitted by western flower thrips adults. Remove plant material debris from the greenhouse or place it in containers with tight-sealing lids since WFT will abandon desiccating plant material and migrate onto the main crop. Screening greenhouse openings such as vents and sidewalls will reduce populations of WFT entering the greenhouse from outside. The appropriate screen size or mesh for WFT is 192 microns (132 mesh). This may alleviate problems with WFT moving from field-grown crops such as corn, soybean, and vegetables into greenhouses; however, this technique will not be effective if doors are continuously left open or if plant material already infested with WFT is moved among greenhouses.

An additional strategy that may be helpful in managing WFT is the use of trap crops, which are plants (and flowers) that lure thrips away from the main crop. These plants and/or flowers may either be sprayed with an insecticide or simply removed from the greenhouse. In our research, we have found that yellow transvaal daisy (*Gerbera jamesonii*) flowers are very attractive to WFT adults compared to other plant types and flower colors. In fact, the reflectance spectra of yellow transvaal daisy flowers is very similar to yellow sticky cards.

Pest Control Material Management

The principal management strategy used to deal with WFT in greenhouses involves the use of insecticides. The key to WFT management with insecticides is to initiate applications when populations are “low,” which avoids dealing with different age structures or life stages – eggs, nymphs, pupae, and adults – simultaneously over an extended time period. Once WFT populations reach “high” levels, more frequent applications are required. Insecticides with contact or translaminar activity are generally used to control or regulate WFT, because systemic insecticides typically don’t move into flower parts (petals and sepals) where WFT adults normally feed. Insecticides must be

applied prior to WFT entering terminal or flower buds because it is very difficult to obtain adequate control, and thus prevent injury, once they do. Those insecticides with translaminar activity, which means the material penetrates and resides in the leaf tissues to form a reservoir of active ingredient, provide residual activity even after spray residues have dried. As a result, translaminar insecticides are more likely to be effective in killing WFT in terminal or flower buds. Applications conducted after flowers open are generally too late since damage has already occurred. High-volume sprays are typically used to reach WFT that are located in hidden areas of plants such as unopened flower buds.

Most currently available insecticides only kill the nymphs or adult, with no activity on either the egg or pupae stages. As such, repeat applications are typically warranted to kill the life stages that were not affected by previous applications, such as nymphs that were in the egg stage and adults that were in the pupae stage. This is especially important when overlapping generations are prevalent. Three to 5 applications within a 7- to 10-day period may be needed when WFT populations are “high” and there are different life stages present or overlapping generations. Frequency of application depends on the time of year (season): during cooler temperatures (winter) the life cycle is extended compared to warmer temperatures (spring through early fall).

There are a number of reasons for “poor” control of WFT with insecticides, including spray timing, which is associated with the age structure of WFT populations; spray coverage; pH of spray solution; frequency of applications; and migration of western flower thrips into greenhouses from outdoors. Table 1 lists a number of the insecticides registered for thrips and their corresponding modes of action.

Conserve®

Spinosad (Conserve®) has been the primary insecticide used by greenhouse growers to deal with WFT. The insecticide provided excellent control of WFT when it was introduced for use in greenhouses in 1998. However, since then, the level of control with spinosad has declined (based on feedback from greenhouse producers), in all likelihood due to resistance.

Spinosad is derived from a species of Actinomycete bacteria, *Saccharopolyspora spinosa* that during fermentation creates metabolites called spinosyns; two are biologically active compounds that are responsible for the insecticidal properties: spinosyns A and D. Spinosad works quickly – killing western flower thrips within one to three days after either contact or ingestion with up to two weeks of residual activity. Although the active ingredient may kill WFT on contact, it appears to work best when ingested. The mode of action involves excitation of the insect nervous system, leading to paralysis and death. Spinosad actually has two modes of action: it disrupts the binding of acetylcholine at nicotinic acetylcholine receptors located at the post-synaptic cell junctures, and it negatively affects the gamma-amino butyric acid (GABA) gated ion



Table 1. Pest control materials commercially available and registered for thrips (including western flower thrips) in greenhouse production systems including common name (active ingredient), brand name, and mode of action. The numbers and/or letters in parentheses represent the Insecticide Resistance Action Committee (IRAC) mode of action group designations.

Common Name	Brand Name	Mode of Action
Abamectin	Avid	GABA chloride channel activator (6)
Acephate	Orthene/Precise	Acetylcholine esterase inhibitor (1B)
Azadirachtin	Azatin/Ornazin	Ecdysone antagonist (18B)
Beauveria bassiana	BotaniGard/Naturalis	Insect-killing fungus (unclassified mode of action)
Bifenthrin	Attain/Talstar	Sodium channel blocker (3)
Chlorfenapyr	Pylon	Oxidative phosphorylation uncoupler (13)
Chlorpyrifos	DuraGuard	Acetylcholine esterase inhibitor (1B)
Cyfluthrin	Decathlon	Sodium channel blocker (3)
Fenoxycarb	Preclude	Juvenile hormone mimic (7B)
Flonicamid	Aria	Selective feeding blocker (9C)
Fluvalinate	Mavrik	Sodium channel blocker (3)
Kinoprene	Enstar II	Juvenile hormone mimic (7A)
Methiocarb	Mesurool	Acetylcholine esterase inhibitor (1A)
Novaluron	Pedestal	Chitin synthesis inhibitor (15)
Petroleum oil	SuffOil-X/PureSpray Green	Suffocation (unclassified mode of action)
Pyridalyl	Overture	Unknown mode of action
Pyrethrins	Pyreth-I/Pyrethrum	Sodium channel blocker (3)
Sorbitol octanoate	SorbiShield	Cuticle membrane desiccation and suffocation (unclassified mode of action)
Spinosad	Conserve	Nicotinic acetylcholine receptor agonist and GABA chloride channel activator (5)
Sucrose octanoate esters	SucraShield	Cuticle membrane desiccation (unclassified mode of action)

channels. Spinosad has a mode of action that is similar to the neonicotinoid-based insecticides (imidacloprid, thiamethoxam, acetamiprid, and dinotefuran) and macrocyclic lactone insecticide/miticide (abamectin). However, spinosad acts or attaches to a different target site than either the neonicotinoids or the macrocyclic lactone. Although spinosad has no systemic properties, it does exhibit translaminar movement through leaf tissue. Spinosad is relatively stable at a water pH between 5 and 7 and has a half-life of approximately 200 days at a pH of 9. In addition, spinosad has low-to-moderate water solubility and short persistence in the environment.

Due to continual reliance of spinosad for control of WFT, certain populations of western flower thrips in many states have demonstrated diminished sensitivity (or resistance) to spinosad. In fact, resistance may be more widespread than we know. We, along with other researchers, have shown that greenhouse populations of WFT are actually resistant to spinosad. Furthermore, in August 2008, Dow AgroSciences voluntarily suspended the sale and use of all spinosad-related insecticides in two counties in Florida (Broward and Palm Beach) due to positive identification that WFT populations had developed resistance to

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insecticides containing spinosad. As such, to preserve or sustain the longevity of Conserve®, it is imperative to rotate spinosad with insecticides having different modes of action.

It is important to note that spinosad is registered for use on a variety of agriculture crops under several trade names including Success®, SpinTor®, Tracer®, and Entrust® (for organic production). Why is this important to know? Well, WFT that migrate into greenhouses from field crops or vegetables may have already been exposed to applications of spinosad, thus increasing the potential for resistance being expressed rapidly when a greenhouse producer makes an application of Conserve®.

The future value of Conserve® depends on greenhouse producers. Currently, there are no new active ingredients that demonstrate the same or similar level of activity on western flower thrips as Conserve®, so it is important that greenhouse producers avoid always using Conserve® to reduce the “selection pressure” placed on WFT populations. The best way to avoid unintentional “selection pressure” is by scouting. The presence of only one adult WFT doesn’t necessarily mean that adults are present throughout the crop. Only by installing and actually looking at either yellow or blue sticky cards regularly (as opposed to one month after installation when they are covered with “stuff”) will greenhouse producers be able to determine when WFT adults are present. This will help avoid making applications when WFT populations are in stages, such as eggs or pupae, that are not affected by Conserve®, which will also save time and money.

New Pest Control Materials

Primarily due to the expense of developing new active ingredients as well as issues of resistance, there have been very few new products brought to the market within the last 5 years for management of WFT; however, one new active ingredient became commercially available in 2009, and that was pyridalyl (Overture®). This insecticide is labeled for both thrips (including western flower thrips) and caterpillars and is formulated as a 35WP (wettable powder) available in water-soluble packets. Pyridalyl is active as both a contact and stomach poison although contact activity may reduce WFT populations faster than ingestion. This insecticide has translaminar activity on a number of plant types including chrysanthemum, gerbera daisy, hibiscus, and poinsettia. Overture® has a 12-hour REI (restricted entry interval), and the label rate for thrips is 8.0 ounces per 100 gallons. Furthermore, the product label specifically states that there should be no more than three applications per cropping cycle or no more than three applications within six months.

Based on our efficacy trials, pyridalyl does kill WFT adults with mortality ranging from 80% to 90%. It appears that pyridalyl is more toxic to second instar nymphs (2.8 fold) than adults. One major difference between Overture® and Conserve® is the speed of kill. In general, Conserve® will kill WFT one to three days following application whereas Overture® takes at least seven days to kill a majority of WFT, so don’t expect an immediate reduction in populations when using this insecticide.

Another new active ingredient is spirotetramet (Kontos™), which will add thrips to the revised label. The mode of action is a lipid biosynthesis inhibitor (Mode of Action Group No. 23), and the REI is 24 hours. Kontos™ is formulated as a soluble concentrate (SC) and labeled for use on vegetable transplants. This pest control material, which may be applied as a foliar spray or drench to the growing medium, is supposedly fully systemic with the active ingredient moving through the xylem (water-conducting) and phloem (food-conducting) tissues and residing in new shoots and leaves. Kontos™ is primarily active via ingestion and is more effective against nymphal stages than adults. Due to the mode of action, the time it takes to kill a sufficient number of WFT may be similar to Overture®.

Resistance

The first instance of WFT control failure was reported in 1961 with the chlorinated cyclodiene, toxaphene, but the first actual record of resistance occurred nearly 30 years later. Since then, there have been a number of cases of reduced efficacy against WFT with pest control materials. Certain WFT populations have been reported to be resistant to a number of chemical classes including organophosphate, carbamate, pyrethroid, and macrocyclic lactone. The main reason for this is that WFT have a haplo-diploid breeding system, which may accelerate the development of resistance. Haplo-diploid means that genes associated with resistance in haploid (single set of chromosomes) males are directly exposed to “selection pressure” following an insecticide application compared to insects with diploid (double set of chromosomes) individuals.

The primary way to prevent or minimize the potential of WFT populations developing resistance and prolonging the effectiveness of currently available insecticides is to rotate insecticides with different modes of action. In general, rotate different modes of action every two to three weeks or within a generation. However, this depends on the time of year since the development rate is temperature dependent. Again, Table 1 (page 27) lists pest control materials registered for thrips and their corresponding modes of action. Below are examples of a number of rotation programs involving pest control materials with different modes of action:

- * Spinosad (Conserve) ⇔ Chlorfenapyr (Pylon) ⇔ Abamectin (Avid) ⇔ Methiocarb (Mesurol)
- * Novaluron (Pedestal) ⇔ Pyridalyl (Overture) ⇔ Chlorfenapyr (Pylon) ⇔ Spinosad (Conserve)
- * Beauveria bassiana (BotaniGard/Naturalis) ⇔ Acephate (Orthene) ⇔ Spinosad (Conserve)
- * Abamectin (Avid) ⇔ Pyridalyl (Overture) ⇔ Chlorfenapyr (Pylon) ⇔ Spinosad (Conserve)
- * Chlorpyrifos (DuraGuard) ⇔ Novaluron (Pedestal) ⇔ Abamectin (Avid) ⇔ Bifenthrin (Talstar)

Alternative Pest Control Materials

Two commercially available pest control materials are based on certain sugar components: SucraShield™ and SorbiShield™.



The active ingredient in SucraShield™ is sucrose octanoate esters whereas SorbiShield™ contains sorbitol octanoate as the active ingredient. Both products are labeled for control of thrips and are contact insecticides that either desiccate (by dissolving holes in the thrips cuticle or skin) or suffocate thrips. The active ingredient is an extract from the leaf hairs of wild tobacco plants. It should be noted that the REI for SucraShield™ is 48 hours – yet it is permitted for use in organic production systems. We have evaluated both products for control of WFT and have found minimal efficacy against the adult and nymphal life stages.

Biological Management

Biological control of WFT relies on using natural enemies including the predatory mites *Neoseiulus* (= *Amblyseius*) *cucumeris*, *Iphiseius* (= *Amblyseius*) *degenerans*, *Amblyseius* *wirskii*, and *Hypoaspis miles*; the minute pirate bug, *Orius insidiosus*; the entomopathogenic or insect-killing fungus, *Beauveria bassiana*; and the entomopathogenic or insect-killing nematode, *Steinernema feltiae*. In regards to the predatory mites, all are used to regulate WFT populations by feeding on the first and/or second instar nymphs with the exception of *Hypoaspis miles*, which is a predatory mite that resides in either soil or growing medium feeding on the pupal stage. The use of banker plants (“Black Pearl” pepper plants) is being used in certain greenhouses that are implementing releases of the minute pirate bug. Minute pirate bugs will consume pollen from the flowers as a supplemental food source in addition to feeding on WFT. A number of issues are associated with using entomopathogenic nematodes against WFT, including the cost of application, which is primarily dependent on the rate(s) needed for regulation and mortality (number or percent of individuals in the population killed) obtained following application. Studies have demonstrated that the initial rates needed to obtain sufficient control of WFT (≥80% mortality) are too expensive. However, research is ongoing to deal with both issues so that greenhouse producers may eventually utilize insect-killing nematodes as a component of a rotation program.

Biological control of WFT, in general, can be very difficult. The key to implementing a successful biological control program is to release natural enemies early enough in the cropping cycle. Releases must be initiated prior to WFT entering terminal or flower buds. Natural enemies will not control an already

established or “high” WFT population because it takes time from release for natural enemies to lower WFT numbers below damaging levels. It is important to note that natural enemies will not “eradicate” (neither will pest control materials) WFT. Biological control tends to work best on long-term crops like cut flowers or perennials more so than short-term crops such as bedding plants, which are typically out of the greenhouse within four to six weeks.

Future Strategies

The most recent development in an attempt to deal with WFT is the use of a sex aggregation pheromone lure. A number of companies sell or distribute lures that are suppose to increase the number of WFT thrips adults captured on sticky cards (in this case, blue) or attract WFT out of hiding places such as flowers or buds, increasing their exposure to insecticide spray applications and achieving higher mortality. The pheromone lure is not a “control” device, and there are still questions or issues associated with longevity of the scent within a greenhouse during certain times of the year and how effective the pheromone lure is when many different plant types are in flower. As such, further investigation is warranted on the potential usefulness of the sex aggregation pheromone lure.

Conclusion

Western flower thrips are a very difficult insect pest to control in greenhouses; however, taking a “holistic” approach and diligently implementing cultural, physical, pest control material, and/or biological management strategies can reduce WFT populations to levels that will allow greenhouse producers to grow and sell a high-value quality crop with minimal aesthetic injury.

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