Western Flower Thrips

Management on Greenhouse-Grown Crops

Kansas State University Research and Extension

Greenhouse producers worldwide are familiar with the western flower thrips, *Frankliniella occidentalis* (Pergande), one of the most destructive insect pests of greenhouse-grown crops. Western flower thrips, the primary thrips species encountered by greenhouse producers, is extremely polyphagous, feeding 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. It was not considered a major insect pest of greenhouse-grown crops until the 1980s. This publication addresses biology and damage; scouting; and cultural, physical, insecticidal, and biological management. The issues discussed should provide insight on the importance of dealing with western flower thrips holistically instead of solely relying on insecticides.

Biology and Feeding Damage

Knowledge of biology and damage is important in understanding the challenges associated with developing a sound pest management program. Western flower thrips are small (approximately 2.0 mm in length) insects that possess piercing-sucking mouthparts (Figure 1). The life cycle consists of an egg stage, two nymphal stages, two pupal stages, and an adult (Figure 2).

Figure 1

In general, the life cycle (egg to adult) takes two to three weeks to complete. However, time from egg to adult depends on temperature, with the optimum range between 26 and 29°C (79 and 84°F). Under these conditions, the life cycle may be completed in seven to 13 days. Females can live up to 45 days and lay (oviposit) between 150 and 300 eggs during a lifetime. Females primarily feed on flower pollen, which may contain nutrients such as carbohydrates, proteins, sterols, and vitamins that enhance development rate and reproductive ability.

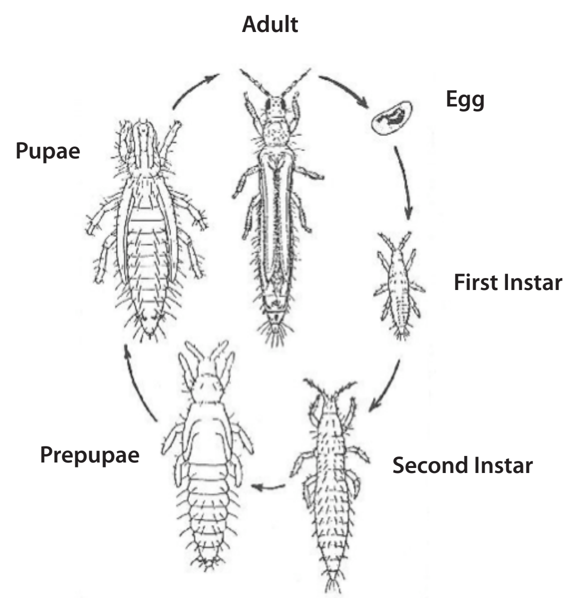
Western flower thrips may attack plants with elevated concentrations of nitrogen because of the abundance of amino acids and proteins, and female egg production is higher after feeding on plants containing abundant levels of amino acids. Females typically lay eggs underneath the epidermal layer of the leaf surface or in flower tissues, which protects them from exposure to contact insecticides.

Eggs hatch in two to four days. Nymphs feed on both leaves and flowers. The first nymphal stage lasts one to two days; the second nymphal stage, two to four days. Second instar nymphs are typically more active and tend to feed more than first instar nymphs. The second instar nymph eventually migrates to the plant base and enters the growing medium to pupate. Western flower thrips also pupate in leaf debris, on the plant, and in the open flowers of certain types of plants including chrysanthemum. There are actually two "pupal" stages: a prepupa (or propupa) and pupa. Both stages commonly occur in growing medium or soil underneath benches.

Growing medium or soil type and pH and pupation depth may influence pupal survival. Pupation depth depends on growing medium or soil type. Pupae stages do not feed and are tolerant or immune to most insecticides commonly applied to manage western flower thrips nymphs and adults.

Adults emerge from the pupal stage after approximately six days. Although adults have wings, they do not fly well, but may be dispersed throughout a greenhouse via air currents created by horizontal airflow fans or wind entering from outside. Adults are attracted to certain flower colors (yellow, blue, and white), plant volatiles (E-ß-

Figure 2. Western flower thrips life cycle



farnesene), and flowering plant types (chrysanthemum, gerbera, marigold, and rose). Western flower thrips exhibit thigmotactic behavior, meaning the body needs to be in constant contact with a surface, which is why they are located in secluded habitats on plants. This also protects them from exposure to contact insecticides.

Western flower thrips have a haplo-diploid breeding system, which means females develop from fertilized eggs and males develop from unfertilized eggs. Unmated females can produce males (sons) parthenogenetically (without mating) whereas females must be mated in order to produce additional females (daughters). Female western flower thrips also may mate with their own offspring. The sex ratio (females to males) is dependent on the population density, with males tending to be more prevalent at "low" population densities and females typically more abundant at higher densities. Increasing population densities of western flower thrips 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. But as adult females age, they tend to produce more males.

Western flower thrips cause direct damage by feeding on plant leaves and flowers. Western flower thrips possess piercing-sucking mouthparts, but 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 to puncture cells, and then insert a set of paired stylets, which lacerate and damage cell tissues and function to imbibe cellular fluids. As a result, western flower thrips feed on a multitude of food types within plants. Symptoms of feeding include leaf scarring, distorted growth, sunken tissues on leaf undersides (Figure 3), and deformed flowers (Figure 4). Flowers and leaves have a characteristic "silvery" appearance due to the influx of air after the removal of plant fluids (Figure 5). Black fecal deposits may be present on leaf undersides. Damage to plant leaves may also occur when females, using their sharp ovipositor, insert eggs into plant tissue. And wounds created during feeding or oviposition may serve as entry sites for plant pathogens such as fungi.


Figure 3

Western flower thrips also cause indirect damage by vectoring the tospoviruses: tomato spotted wilt virus and impatiens necrotic spot wilt virus. The first and second instar nymphs acquire the virus, which is then transmitted by adults. Both direct and indirect damage may result in an economic loss to greenhouse producers.


Figure 4


Figure 5

Distribution of infested plant material is one of the primary means of long-distance spread of this pest. Western flower thrips are difficult to manage in greenhouses for a number of reasons including broad host range, high female reproductive capacity, rapid life cycle (egg to adult), small size (approximately 2.0 mm long), unusual feeding habits, preference for secluded habitats (unexpanded leaves and 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 using a holistic approach, implementing a variety of strategies including scouting and cultural, physical, insecticidal, and biological management.

Scouting

Scouting or monitoring is important to determine the numbers of thrips present in the greenhouse. Additionally, scouting will detect seasonal trends in populations throughout the year and assess the effectiveness of management strategies implemented. The main technique used to scout for western flower thrips adults is to place either blue or yellow sticky cards above the crop canopy (Figures 6 and 7). Cards are counted weekly and numbers of 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 nymphs and adults. Gently blowing into open flowers will agitate western flower thrips and increase movement making them easier to detect. But a relationship between numbers of western flower thrips captured on colored sticky cards and the abundance present in flowers has not been established.

Greenhouse producers can establish action thresholds — the number of thrips detected either on colored sticky cards or visually — that warrant implementation of a pest management strategy.

In a two-year greenhouse study, an action threshold of 20 western flower thrips adults per blue sticky card per week in a cut carnation (*Dianthus caryophyllus*) crop was established to determine the need for insecticide applications. Western flower thrips numbers — based on blue sticky card counts from December through March 1994 and 1995 — were below the action threshold resulting in no insecticides being applied. This likely reduced selection pressure placed on the western flower thrips population and minimized the chance of resistance.

Figure 6

Figure 7

Thresholds may vary from 10 to 40 western flower thrips per sticky card per week depending on crop susceptibility to viruses vectored by the pest. Other factors that may affect sticky card counts and action thresholds include plant attractiveness, presence of flowers, sticky card placement, population age structure, migration into greenhouses, and crop growth stage. Consequently, the use of action thresholds may not be reliable in greenhouse production systems.

Cultural and Physical Management

Sanitation practices such as removing weeds, old plant material, and growing medium debris are the first defense in minimizing problems with western flower thrips. Certain weeds, particularly those in the Compositae and Solanaceae families and those with yellow flowers, not only attract adults, but serve as reservoirs for viruses transmitted (vectored) by adults. Weeds must be removed from both inside and around the greenhouse perimeter.

It is essential to immediately remove plant material debris from the greenhouse or place plant material debris into containers with tight-sealing lids since western flower thrips adults will abandon desiccating plant material and may migrate onto the main crop. Screening greenhouse openings such as vents and sidewalls will reduce populations entering greenhouses from outside or migrating into other greenhouses. The appropriate screen size or mesh for western flower thrips is 192 µm (0.037 mm^2) or 100 mesh. This may alleviate problems with the thrips possibly moving from weeds and/or field-grown crops (e.g., corn and soybean) and vegetables into greenhouses. It will not be effective if doors are continuously left open or infested plant material is moved among greenhouses.

Alternative cultural and/or physical management strategies that may be implemented include overhead irrigation or misting, which has been shown to decrease the abundance of western flower thrips populations, by creating an environment less favorable for development; use of ultraviolet (UV) absorbing plastic films, which appear to influence adult flight behavior by reducing the levels of UV light entering greenhouses or aluminized reflective fabrics that may inhibit or repel adults from entering greenhouses; mechanical brushing of plants, which has been demonstrated to reduce western flower thrips damage in greenhouse-grown vegetables; leaving greenhouses fallow (empty) for several months and heating for four to five days at 30˚C (86˚F); and placing a weed fabric barrier underneath benches that prevents thrips from entering the soil to pupate. It may also be possible to use mechanical blowers to distribute plant and/or growing medium debris (along with associated western flower thrips pupae) into concentrated areas (piles), which can then be collected, and disposed of promptly to reduce pupae numbers.

Another strategy that may be helpful in managing western flower thrips is the use of trap or lure crops, which are plants (and flowers) that attract thrips away from the main crop. These plants and/or flowers may be sprayed with an insecticide, removed from the greenhouse, or inoculated with biological control agents such as predatory mites or predatory bugs that will feed on the nymph and adult stages residing in the flowers. Research has reported that yellow transvaal daisy, *Gerbera jamesonii,* flowers are attractive to western flower thrips adults compared to other plant types and flower colors. Moreover, the reflectance spectra (reflection of light in relation to wavelength) of yellow transvaal daisy flowers are similar to yellow sticky cards.

Plant material from suppliers should be inspected before introducing into the main crop. However, this is time consuming and may not be possible during normal spring through early fall business hours, especially after receiving large quantities of plant material.

Insecticidal Management

Since the tolerance for western flower thrips damage on most greenhouse-grown ornamental crops is relatively low, the principal management strategy used to deal with this pest in greenhouses involves the use of insecticides. The key to 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 the course of the crop production cycle. Once populations reach high levels, then more frequent applications at three- to five-day intervals may be required. Insecticides must be applied before thrips enter terminal or flower buds. Once they do, it is difficult to obtain adequate control and prevent injury. Insecticides with translaminar or contact activity are generally used to control or suppress western flower thrips populations. Systemic insecticides, when applied to the growing medium, typically do not move into flower parts (petals and sepals) where adults normally feed. Translaminar activity means the material penetrates and resides in leaf tissues forming a reservoir of active ingredient, which provides residual activity even after spray residues have dried.

As a result, translaminar insecticides are likely to be more effective in killing western flower thrips in terminal or flower buds. Applications conducted after flowers open are generally too late because damage has already occurred. High-volume sprays are typically required to reach western flower thrips located in hidden areas of plants such as unopened flower buds.

Most currently available insecticides only kill the nymphs or adults, with no activity on either the egg or pupa stages. As such, repeat applications typically are warranted in order 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 five applications within a seven to 10-day period may be needed to obtain sufficient mortality when populations are high and there are different life stages (eggs, nymphs, pupae, and adults) and/or overlapping generations present. But frequent applications may lead to resistance developing in western flower thrips populations and possible plant injury. Application frequency varies depending on time of year. Cooler temperatures extend the life cycle compared to warmer temperatures in spring through early fall.

Reasons for inadequate control or suppression with insecticides include spray timing, which is associated with the age structure of a western flower thrips population; spray coverage; pH of spray solution; frequency of application; and migration into greenhouses from outdoors. Table 1 lists the insecticides registered for thrips control in the United States and their corresponding modes of action.

Spinosad

Spinosad is the active ingredient in the insecticide, Conserve® (Dow AgroSciences LLC; Indianapolis, IN), which has been the primary insecticide used by greenhouse producers in the United States to deal with western flower thrips. This active ingredient has also been utilized worldwide under different trade names (e.g. Success® in Canada). The insecticide provided excellent control of thrips when it was introduced and commercially available for use in greenhouses in 1998. Since then, efficacy against western flower thrips has declined.

Spinosad is derived from a species of Actinomycete bacteria, *Saccharopolyspora spinosa*, which was discovered in the 1980s that creates metabolites called spinosyns during fermentation; two are biologically active compounds, which 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 western flower thrips 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: disrupts the binding of acetylcholine at the nicotinic acetylcholine receptors located at the post-synaptic cell junctures and negatively affects the gamma-amino butyric acid (GABA) gated ion channels. In fact, spinosad has a mode of action that is similar to the neonicotinoid insecticides (imidacloprid, thiamethoxam, acetamiprid, and dinotefuran) and macrocyclic lactone insecticide/miticide (abamectin). But 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.

Because of continual reliance on spinosad for control or suppression of western flower thrips, certain populations have demonstrated diminished sensitivity (or resistance) to spinosad. It has been reported that western flower thrips populations in the United States are resistant to spinosad as well as populations in Australia. In August 2008, Dow AgroSciences, which manufactures spinosad, voluntarily suspended the sale and use of all spinosad-related insecticides in two counties in Florida after it was confirmed that western flower thrips populations had developed resistance to insecticides containing spinosad as the active ingredient.

To preserve or sustain the longevity of spinosad it is imperative that greenhouse producers rotate spinosad with other insecticides having different modes of action. Spinosad is registered for use in a variety of agriculture crops in the United States under several trade names including Success®, SpinTor*, Tracer*, and Entrust® (for organic production).

Potential consequences of failing to rotate insecticides are that western flower thrips, which migrate into greenhouses from field or vegetable crops, may have already been exposed to applications of agricultural formulations of spinosad, increasing the potential for resistance being expressed rapidly when a greenhouse producer applies spinosad.

The future value of spinosad depends on greenhouse producers, so it is important to avoid using spinosad exclusively in order to reduce the selection pressure placed on western flower thrips populations. The best way to avoid unintentional selection pressure is by scouting. The presence of only one adult does not necessarily mean that adults are present throughout the crop. Only by installing and actually looking at either yellow or blue sticky cards regularly will greenhouse producers be able to determine when adults are present. This will help avoid making applications when non-susceptible life stages of western flower thrips are dominant (stages such as eggs or pupae are not affected by spinosad), which will save time and money.

Resistance Management

The first instance in failing to manage western flower thrips with insecticides was reported in 1961 when the chlorinated cyclodiene, toxaphene, was not effective in controlling or suppressing populations. Although since then there have been cases of reduced insecticide efficacy against western flower thrips, the first actual record of resistance occurred nearly 30 years later.

The sole reliance on insecticides to deal with thrips populations in greenhouses will eventually lead to populations developing resistance. For example, certain western flower thrips 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 western flower thrips has a haplo-diploid breeding system, which may accelerate the development of resistance. Haplo-diploid means that genes associated with resistance are fully expressed in haploid (single set of chromosomes) males whereas with entirely diploid (double set of chromosomes) individuals resistance may be partially hidden as recessive or co-dominant traits. The international trade of plant material may not only spread western flower thrips populations but may also indirectly spread populations containing resistance genes or specific resistance mechanisms.

The primary way to prevent or minimize the potential of western flower thrips populations from developing resistance and prolonging the effectiveness of currently available insecticides is by rotating insecticides with different modes of action. However, rotating insecticides with variable modes of action will only be effective in delaying resistance if the insecticides applied select for different resistance mechanisms. In general, rotate different modes of action every two to three weeks or within a generation. But this depends on the time of year because thrips development rate varies depending on the time of year and temperature. Table 1 lists insecticides registered for thrips control in the United States and their corresponding modes of action. Table 2 provides examples of rotation programs involving commercially available insecticides/miticides with different modes of action.

Biological Management

Biological control of western flower thrips relies on using natural enemies including the predatory mites *Neoseiulus* (=*Amblyseius*) *cucumeris*, *Iphiseius* (=*Amblyseius*) *degenerans*, *Amblyseius swirskii*, *Stratiolaelaps scimitus* (=*Hypoaspis miles)*, and *Geolaelaps* (=*Hypoaspis*) *aculeifer*; the minute pirate bug, *Orius insidiosus*; the entomopathogenic or insect-killing nematode, *Steinernema feltiae*; and the entomopathogenic fungus, *Beauveria bassiana*. Table 3 lists commercially available biological control agents and their associated western flower thrips target life stage(s). In regard to the predatory mites, all regulate or suppress populations by feeding on the first and/or second instar nymphs (Figure 9) with the exception of *S. scimitus* and *G. aculeifer*, which are predatory mites that reside in either soil or growing medium feeding on the pupal stage. The use of "Black Pearl" pepper (*Capsicum annuum*) as banker plants is being utilized in certain greenhouses that are implementing releases of the minute pirate bug. Minute pirate bugs (Figure 10) are predaceous bugs that feed on the nymph and adult stages, and will consume pollen from the flowers as a supplemental food source.

Figure 9

Figure10

There are a number of issues associated with using the entomopathogenic nematode *S. feltiae* against western flower thrips including the cost of application, which is primarily dependent on the rates needed to suppress western flower thrips populations, and mortality rates (number or percent of individuals in the population killed) obtained following application, which may be associated with formulation. Research has shown that the initial rates required to obtain sufficient control or suppression (greater than 80% mortality) may be too expensive. But research is examining how to reduce the cost and improve effectiveness so greenhouse producers may eventually utilize insect-killing nematodes as a component of a western flower thrips management program.

The entomopathogenic fungus *B. bassiana* has been used to manage thrips populations in cut flowers such as roses and carnations where the relative humidity is higher and more conducive for infection of western flower thrips than on foliage where the possibility of desiccation is greater. Adult thrips seem to be more susceptible to *B. bassiana* than the nymphs because adults are typically located in flowers, where the relative humidity is higher and conditions are favorable for infection.

Moreover, nymphs appear to have a thicker cuticle than adults, which may delay penetration of the fungus into the body cavity. The nymphs may also prevent penetration of fungal spores through the cuticle by shedding their exuvium (cuticle) during ecdysis (process of casting off old cuticle). However, infection is dependent on the concentration of spores (dose-dependence) that contact nymphs and adults with a higher spore concentration leading to a faster and higher mortality rate, which may significantly reduce the abundance of individuals in future generations.

Despite this, there are concerns related to the use of *B. bassiana* in suppressing populations of western flower thrips such as speed of kill, need for frequent applications, importance of thorough coverage of all plant parts, and low mortality levels obtained even under high relative humidities. For example, a relative humidity of 97 percent resulted in only 60 percent infection of adults and 44 percent infection of nymphs. Effectiveness of *B. bassiana* may be influenced by geographic location, which is affiliated with temperature and relative humidity, and possibly plant type.

When implementing the use of natural enemies for regulation or suppression of western flower thrips populations it is important to be aware of intra-guild predation, which is when one predator feeds on another predator when both are occupying the same habitat. This commonly occurs when generalist predators are used in biological control programs. For example, both *N. cucumeris* and *Orius spp.* will engage in intraguild predation under different cropping systems and may feed on pollen more than on western flower thrips, which will inhibit the regulation of populations among greenhouse-grown crops.

Biological control of western flower thrips, in general, can be very difficult or more challenging than using insecticides. But the key to implementing a successful biological control program is to release natural enemies early enough in the cropping cycle. Releases must be initiated before thrips enter terminal or flower buds. Natural enemies will not regulate or suppress an already established or existing high western flower thrips population because it takes time from release before natural enemies will reduce numbers below damaging levels. Biological control tends to work best on long-term crops such as cut flowers or perennials than crops such as bedding plants, which typically have short production cycles (four to six weeks). Another factor to consider is that biological control agents may not provide sufficient control or suppression (based on percent mortality) of the soil-dwelling life stages (pupae) to significantly impact western flower thrips populations.

Future Strategies

The most recent development in an attempt to deal with this pest is the use of a sex aggregation pheromone lure. There are companies that sell or distribute lures that are suppose to increase the number of adults captured on sticky cards (in this case, blue) or attract thrips out of hiding places such as flowers or buds thus increasing their exposure to insecticide applications — resulting in higher mortality. In general, the pheromone lure is not a control device. But there are still questions or issues associated with longevity of the scent (attractiveness) 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 potential usefulness of the sex aggregation pheromone lure.

Summary

Western flower thrips is still a difficult insect pest to control or suppress in greenhouse production systems. As such, dealing with western flower thrips requires a holistic approach by diligently implementing scouting, cultural, physical, insecticidal, and/or biological management strategies. This includes proper sanitation practices, rotating insecticides with different modes of action, applying insecticides early to prevent populations from reaching outbreak proportions, and releasing biological control agents early during the crop production cycle. These management strategies can reduce or suppress western flower thrips populations to levels that will allow greenhouse producers to grow and sell a high-value quality crop with minimal aesthetic injury.

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

Active Ingredient (common name)	Trade Name	Mode of Action (IRAC Designation)
Abamectin	Avid	GABA chloride channel activator (6)
Acephate	Orthene/Precise	Acetylcholine esterase inhibitor (1B)
Azadirachtin	Azatin/Ornazin/Molt-X	Ecdysone antagonist (18B)
Bifenthrin	Attain/Talstar	Alter sodium channel gating mechanism (3)
Chlorfenapyr	Pylon	Oxidative phosphorylation uncoupler (13)
Chlorpyrifos	DuraGuard	Acetylcholine esterase inhibitor (1B)
Cyfluthrin	Decathlon	Alter sodium channel gating mechanism (3)
Fenoxycarb	Preclude	Juvenile hormone mimic (7B)
Flonicamid	Aria	Selective feeding blocker (9C)
Fluvalinate	Mavrik	Alter sodium channel gating mechanism (3)
Kinoprene	Enstar II	Juvenile hormone mimic (7A)
Methiocarb	Mesurol	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-It/Pyrethrum	Alter sodium channel gating mechanism (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)

Table 2. Examples of rotation schemes based on using insecticides* with different modes of action[z]. Each insecticide is applied once per week over a two-week period before a new insecticide with a different mode of action is used.

Week 1	Week 3	Week 5	Week 7
Spinosad (Conserve)	Chlorfenapyr (Pylon)	Abamectin (Avid)	Methiocarb (Mesurol)
Novaluron (Pedestal)	Pyridalyl (Overture)	Chlorfenapyr (Pylon)	Spinosad (Conserve)
Beauveria bassiana (BotaniGard/Naturalis/ Mycotrol)	Novaluron (Pedestal)	Acephate (Orthene)	Spinosad (Conserve)
Abamectin (Avid)	Pyridalyl (Overture)	Chlorfenapyr (Pylon)	Spinosad (Conserve)
Chlorpyrifos (DuraGuard)	Novaluron (Pedestal)	Abamectin (Avid)	Bifenthrin (Talstar)

* Trade names are those for the USA.

[z] Modes of action of the designated insecticides: nicotinic acetylcholine receptor agonist and gamma-amino butyric acid (GABA) chloride channel activator (spinosad); oxidative phosphorylation uncoupler (chlorfenapyr); GABA chloride channel activator (abamectin); acetylcholine esterase inhibitor (methiocarb); chitin synthesis inhibitor (novaluron); unknown mode of action (pyridalyl); insect-killing fungus and unclassified mode of action (*Beauveria bassiana*); acetylcholine esterase inhibitor (acephate); acetylcholine esterase inhibitor (chlorpyrifos); and alter sodium channel gating mechanism (bifenthrin).

Table 3. Commercially available biological control agents for use in greenhouses worldwide against the western flower thrips, *Frankliniella occidentalis,* and the target life stage.

Biological Control Agents	Target Life Stage of Western Flower Thrips
Neoseiulus (=*Amblyseius*) *cucumeris*	First instar nymph
Iphiseius (=*Amblyseius*) *degenerans*	First instar nymph
Amblyseius swirskii	First and second instar nymphs
Stratiolaelaps scimitus (=*Hypoaspis miles*)	Pupae
Orius insidiosus	Nymphs and adult
Steinernema feltiae	First and second instar nymphs
Beauveria bassiana	First, second instar nymphs, and adult

Raymond A. Cloyd
Entomologist

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

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