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Western Flower Thrips in Commercial Greenhouses

Western flower thrips (WFT) are probably the most serious pest of floriculture crops in the world (Parrella 1995b). WFT damage plants directly by feeding and laying eggs on the plant, and indirectly by acting as vectors for tospoviruses such as tomato spotted wilt virus (TSWV) and impatiens necrotic spot virus (INSV).

A recent survey of Midwest greenhouse operators identified WFT as the most difficult greenhouse pest to manage (Wawrzynski and Ascerno, in review). Daughtrey (1997) summarized the WFT-tospovirus problem at a recent conference of the Society of American Florists as follows: growers who recognize the disease symptoms and concentrate on disease management still may suffer some losses from the virus periodically, but those who fail to become well informed about thrips and virus management are courting disaster.

Appearance

Adult WFT are less than 1/20th of an inch (< 2mm) long (Govena and Flint 1996). Male adult WFT are light yellow, and have narrow abdomens; female adult WFT are larger than the males and vary in color from light yellow, yellow with brown splotches, to dark brown (Parrella 1996). Adult WFT have slender bodies with two sets of narrow, clear, nearly veinless wings that have dark, hairy, fringes (Johnson and Lyon 1991). WFT is the most prevalent species of thrips in U.S. greenhouses.

Biology, Life Cycle, and Behavior

Depending on environmental conditions and nutrient levels, female WFT lay 130 - 230 eggs during their lifetime (Robb 1989). The female WFT has an external ovipositor with two opposable serrated blades that are used to cut through the plant epidermis and deposit eggs in the tissues below (Childers and Achor 1995). Eggs are deposited in leaves, bracts, and petals and hatch in 2 to 4 days (Pfleger et al. 1995). The eggs of WFT are fairly well protected and few pesticide sprays are effective against them.

WFT do not overwinter outdoors in the Upper Midwest but overwinter in soil and clover in the Mid-Atlantic states and southern Pennsylvania (Felland et al. 1995). Under greenhouse conditions, WFT probably reproduce continuously throughout the year.

WFT give birth to large numbers of young, have rapid reproductive cycles, and increase their population faster than their predators, so early detection and control is essential (Mound and Teulon 1995). The life cycle of WFT consists of five stages: egg, two feeding larval instars, nonfeeding prepupa and pupa instars, and adult (Figure 1). The development time from egg to adult is 7 to 13 days when temperatures range from 62 to 98F (Robb 1989).

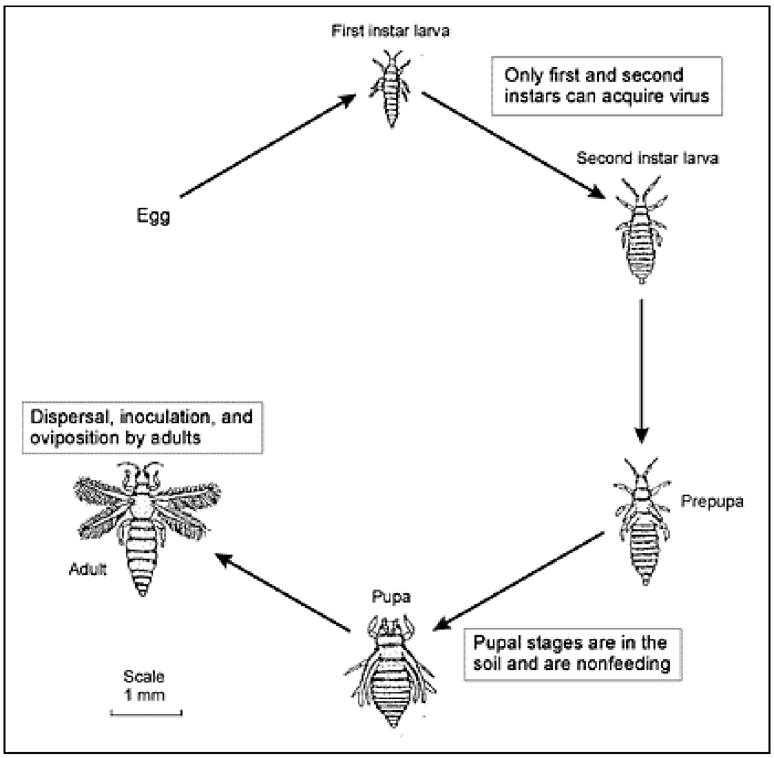
Plant Damage

Leaf scars and specks of black feces are a good way of diagnosing the presence of WFT on plants. Depending on the host species, feeding injuries occur on fruit, flowers, flower buds, leaves, and leaf buds (Childers and Achor 1995). In some host species, WFT feeding causes flower or leaf buds to abort or emerging leaves to become distorted. Feeding does not always result in immediately visible damage because many flowering species do not show injury until flower buds open. When WFT feed on flowers, symptoms include streaks and discoloration of the petals with dark flowers showing light streaks and light flowers showing dark streaks (Pfleger et al. 1995).

Mouthpart Anatomy and Plant Virus Transmission

The mouthparts of WFT have been variously described as rasping-sucking or piercing-sucking. Recent research, however, shows WFT have piercing-sucking, multi-purpose mouthparts. The mouthparts are used to pierce leaves, flowers, seeds, pollen grains, and fruit, as well as to drink open liquids such as nectar, water, or insect secretions (Kirk 1995). Moreover, WFT are opportunistic feeders and eat mite eggs, adult mites, other thrips species, and even members of their own species.

The anatomy of the mouthparts explains why WFT carry tospoviruses from plant to plant. In WFT the mouthparts are composed of a single mandibular stylet, which extends to punch feeding holes in the plant, and two maxillary stylets. These stylets, which are extended or retracted independently or simultaneously of the mandibular stylet contain a feeding/salivary channel (Mound and Teulon 1995). During feeding, saliva is injected into the plant cell and the contents withdrawn (Childers and Achor 1995). When tospoviruses are present in the saliva, these are transmitted to the plant during the feeding process.



Tospoviruses

Tospoviruses are a major problem in commercial greenhouses for a number of reasons. Tospoviruses infect a very wide range of plants, cause significant economic losses when infections occur, and are transmitted from plant to plant by WFT, a common pest of commercial greenhouses. There are two major types of tospovirus, the tomato spotted wilt virus (TSWV) and the impatiens necrotic spot virus (INSV), which can be identified using on-site test kits. The best way to control tospoviruses in the greenhouse is to eliminate WFT.

Host Plant Species and Virus Transmission

Of the ten known types of tospoviruses, only two TSWV and INSV infect ornamental plants, but both infect over 600 species of ornamental plants (Daughtrey et al. 1997; Ullman 1998). Thrips species transmit both types of viruses in greenhouse and field crops (German et al. 1992).

Seven species of thrips are vectors for TSWV, but the only confirmed vector for INSV is WFT (Daughtrey et al. 1997). WFT acquire tospoviruses by feeding on infected host plants during the two larval instars and remain infected for life (Bandla et al. 1994). Adult WFT, however, are not infected by feeding on tospovirus-infected plants because tospoviruses pass right through the gut (Bandla et al. 1998; Ullman 1996). As a result, tospoviruses do not enter the salivary fluid and, thus, cannot infect plants (German et al. 1992).

A partial list of plant species infected by tospoviruses is shown in Table 1 on the back of the accompanying laminated card that is part of this folder. (The laminated card can be bought separately as publication # MI-7375-C.) Host plants are categorized by crop type such as bedding, foliage, non-ornamental, ornamental, and perennial plants. A "+" notation in the respective TSWV or INSV column indicates the plant is susceptible to that particular virus. Some plants, such as gloxinia, are very sensitive to INSV. Gloxinia seedlings are rapidly killed and, when older plants are infected, total crop losses are not unusual (Daughtrey et al. 1997).

Several host plants are susceptible to both TSWV and INSV, but it is important to note that not all plants susceptible to TSWV or INSV are hosts for WFT. Although WFT may probe non-host plants, they do not continue to feed and do not lay eggs. If thrips do not lay eggs (even though that plant is susceptible to tospovirus), that particular plant is not considered as a reservoir for either tospovirus. A complete host list for WFT has not been established but finding any WFT larvae during plant inspections serves as warning that control measures are needed.

Tospovirus Symptoms in Plants

It is difficult to diagnose tospovirus infections of greenhouse plants using visual symptoms alone. Symptom expression varies depending on plant species, cultivar, developmental stage of the plant, and environmental conditions (Daughtrey et al. 1995). Tospovirus symptoms often mimic symptoms caused by other problems such as nutrient deficiencies.

The symptoms of tospovirus infections in floral crops are listed below (Daughtrey and Casey 1998). The presence of one or more of these symptoms alerts you to potential tospovirus infections.

- Brown, black, or white spots
- Necrosis on the leaf petiole
- Yellow mottling or variegation
- Death of young plants or death of terminal meristems of older plants
- Stunting
- Brown or black cankers on the stem
- Veinal necrosis
- Concentric ring spots
- Mosaics
- Line or zonal patterns

Tospovirus infections may be systemic (i.e., virus symptoms are spread throughout the plant) or non-systemic (i.e., the virus symptoms are confined to a specific part of the plant). Tospoviruses, however, may be present even though the plant shows no symptoms.

Using On-Site Test Kits to Detect Tospoviruses

On-site test kits are used to determine whether or not tospoviruses are present in greenhouse plants. If you suspect a plant is infected with a tospovirus (because it is showing symptoms of a virus infection), collect a tissue sample from those parts of the plant that are showing symptoms. Specifically, collect a sample from the green or chlorotic tissues adjacent to the necrotic area (Daughtrey et al. 1997). Sometimes, when plants are systemically infected, tospoviruses do not spread evenly throughout the plant, so careful selection of tissues is crucial to the success of the test (Daughtrey et al. 1997).

Currently, the only kit available for on-site testing is the Agdia QTA-Tospo test kit, manufactured by Agdia Incorporated, Elkhart, Indiana. This kit uses a linked immuno-sorbent assay (ELISA) to detect the presence of specific viral proteins in the sample tissue. Separate kits are available from Agdia to detect TSWV and INSV. Another option for detecting tospoviruses is to send a plant sample to a plant disease diagnostic clinic.

However, a detailed study of tissue samples sent for analysis to a testing laboratory in Long Island suggests that only 5 to 15 percent of the samples actually contain viruses (Daughtrey 1997), and another problem with testing for viruses is that some host plant species do not express TSWV or INSV symptoms until long after the initial infection. Cyclamen, for example, can show no symptoms for up to two months after infection (Allen and Matteoni 1988, cited in Daughtery 1996).

Distribution and Treatment of Tospoviruses in the U.S.

In most parts of the United States, INSV infections are 10 to 20 times more common than TSWV infections (Daughtrey 1997). In California, however, INSV and TSWV infections occur with equal frequency, which suggests that other states may show regional differences in the distribution of tospoviruses (Daughtrey 1997). Once plants are infected with TSWV and INSV, there are no treatments that will eliminate the virus.

Managing WFT and Tospoviruses

WFT is usually controlled in commercial greenhouses using a combination of sanitation (preventing WFT from entering greenhouses in the first place), cultural controls (managing crop plants, crop plant wastes, weeds, soil, and environmental conditions to eliminate WFT), chemical controls, and biological control (using other organisms, such as insects and fungi) to eliminate WFT. These methods, in combination with early warnings about WFT and tospovirus outbreaks using indicator plants, provide excellent control of both pests.

Managing WFT is difficult because WFT

- are very small and easy to overlook;spend part o
- f their life cycle in the soil;
- prefer to feed on flower parts, where systemic insecticides do not reach them;
- like to hide in flowers, flower buds, and leaf buds making them hard to spot and reach with pesticides;
- live on a wide variety of host plants;
- feed on other insects;
- reproduce rapidly in warm greenhouses;
- hide in plant materials and are transported worldwide;
- transmit tospoviruses to a wide range of plant species; and
- are resistant to a number of insecticides.

Physical Exclusion

Physically excluding WFT from greenhouses is a very effective control measure. To prevent WFT entering green-houses, Robb and Parrella (1995) suggest the following.

- Install screens on all external openings, paying particular attention to areas where air is drawn into the greenhouse.

- Limit access to the greenhouse and install double doors at all entrances.
- Do not move WFT- or virus-infested plants from propagation areas to production areas.

Exclusionary screening enabled the Paul Ecke Poinsettia Ranch to reduce pesticide applications by 40 percent and still maintain a high level of control in poinsettia stock and New Guinea impatiens production areas (Hall 1995).

Cultural Controls

To control WFT and tospoviruses in greenhouses (according to Robb and Parella 1995),

- remove weeds and flowering plants growing near greenhouses because the plants can harbor WFT and tospoviruses;
- avoid continuous cropping, and alternate crop plants with non-susceptible plants;
- remove all plant debris; and
- if soil is present under greenhouse benches, sterilize the soil periodically or treat the soil with a pesticide to eliminate the developmental stages of WFT.

Some growers apply a layer of hydrated lime thick enough to cover the soil beneath the benches because hydrated lime reduces algae, weeds, and insects in this critical area. Although dry hydrated lime may be applied, it may be easier to spray a slurry composed of 1 to 2 pounds per gallon of water (Lindquist 1998).

As an alternative to soil sterilization, close greenhouse vents, keep the house fallow for seven days between crops to accelerate the development of WFT pupae in the soil, and eliminate the emerging adults (Parrella 1995b). Heating the greenhouses to temperatures in excess of 102F for two days will kill adult thrips (Parrella 1995b).

Good Sanitation Controls Tospoviruses

Three common sources of tospovirus outbreaks in the greenhouse are

- asymptomatic carry-over crops such as holiday cactus;
- weeds growing in the greenhouse; and
- infected stock plants, which serve as bridges for virus survival (Daughtrey 1997)

The worldwide spread of WFT and TSWV/INSV is caused in two ways: by shipping tospovirus-infected plants (both propagative and mature) and by shipping plant materials infested with tospovirus-carrying WFT (Parrella 1995a). To minimize the chance of infection, segregate incoming plant material and quarantine plants until they can be inspected. Choose plant vendors with care, and only buy from vendors who have established virus prevention programs.

Monitoring and Indicator Plants

Early warning is critical to the control of WFT and to the prevention of tospovirus infections. Indicator plants and colored sticky cards are the best available means of providing early warning of insect or disease entry into greenhouse production areas. Indicator plants must meet one or more of the following criteria: they must be more attractive to the pest than the producing crop; the pests or pathogen must develop faster on the indicator plants; the indicator must show feeding damage (or virus symptoms) more readily (Powell and Lindquist 1997). In addition, indicator plants should not contribute to the spread of the virus being monitored.

Petunia plants (Petunia x hybrida) are excellent early indicators for the presence of WFT feeding and the transmission of tospoviruses because petunias are not systemically infected with either TSWV or INSV (Ullman 1998). In response to a tospovirus infection, petunias show a hypersensitive response - a rapid death of plant tissues that also kills the invading virus (Robb et al. 1998).

The following petunia cultivars are excellent indicator plants for the detection of tospoviruses (Robb et al. 1998; Daughtrey et al. 1995).

- Calypso
- Super Blue Magic
- Blue Carpet
- Cascade Blue
- Summer Madness
- Burgundy Madness
- Red Cloud
- Super Magic Coral

To set up a monitoring program using petunias, remove flowers from the indicator plants before placing them in production greenhouses because petunia flower petals do not express local lesions and attract WFT away from the leaves (Robb et al. 1998). Flag the indicator plants with blue pie pans or metal sheets to increase the effectiveness of the indicator plants since WFT are more sensitive to blue than to other colors. Look for WFT feeding scars, which are whitish and have an irregular outline. Brown or black-edged lesions will develop on the edges of thrips feeding scars within 3 days if a tospovirus has been transmitted (Ullman 1998).

If a tospovirus outbreak occurs in the greenhouse, look for patterns of injury that correlate with variations in air movement, humidity, and temperature (Daughtrey 1998). Control measures include removal of infected plants, direct WFT control measures such as spraying, or exclusion of thrips. Infected plants should be placed in bags or other containers at the bench to avoid spreading viruliferous [virus-containing] thrips to other areas of the greenhouse during the process of removal (Moyer and Daub 1994).

Biological Controls

Biological control organisms currently under investigation at various research facilities include

- predacious mites such as *Neoseilus* (formerly *Amblyseius*) *cucumeris* and *Neoseilus degenerans* that feed on larval thrips,
- predacious bugs such as *Orius insidiosus,*
- entomophilic nematodes such as *Thripinema nicklewoodii*, and
- entomopathogenic fungi such as *Beauveria bassiana* that attack all WFT life stages and kill in 2 to 14 days.

Use of biological control methods should only be implemented as part of a well-planned IPM program. Biological control methods, however, should not be used when TSWV or INSV is already present in the greenhouse. In particular, when INSV is a recurring problem, biological control is inappropriate (Matteoni 1995).

Chemical Control

There are many chemicals available commercially to eliminate WFT, but overuse of pesticides can lead to resistance in the WFT populations you are trying to control.

Controlling WFT with Pesticides

WFT are commonly eradicated using endosulfan, chlorpyrifos, bendiocarb, and synthetic pyrethrinoids (Parrella 1995a). Classes of insecticides registered for use on WFT include organophosphates, carbamates, pyrethrinoids, insect growth regulators, chlorinated hydrocarbons, chloronicotinyls, spinosyns, macrocyclic lactone, microbials, and horticultural oils (Robb 1998).

When chemical control is necessary, spray pesticides 2 to 3 times over a period of five days (Robb and Parrella 1995; Daughtrey et al. 1995). Please note, this recommendation assumes greenhouse temperatures range from 21-29.5C (70-85F). When two sprays are used, reduce the spray interval to 3 days if greenhouse temperatures are higher, and increase the spray interval to 7-10 days when greenhouse temperatures are lower (Robb and Parrella 1995).

After spraying, continue to monitor WFT population levels to determine if continued pesticide applications are necessary. Eggs and pupal stages are unaffected by pesticide sprays, so make sure the spraying program lasts long enough to include emerging larva and adults.

Smaller droplet sizes are recommended because WFT prefer to feed on flowers and flower buds, and smaller droplets are more effective at penetrating flower parts (Robb 1995). Sugar is often used as a feeding stimulant in tank mixes but there is no scientific data to support the practice.

Preventing Resistance

Rotating the use of insecticides among different classes of pesticides remains the single best approach in dealing with insect resistance. A successful pesticide spraying program should

- use a single class of pesticide on a single generation of WFT, which at warmer greenhouse temperatures takes about 14 days to complete its lifecycle;
- use a new class of pesticide on every new generation of WFT, which means the pesticide class is rotated at approximately two- to three-week intervals.

Pesticides labeled for greenhouse use against WFT are listed in Table 1. Please note, the table shows the class of each pesticide to help you plan your pesticide rotation schedule. Note carbamates and organophosphates have the same mode of action and should be treated as the same class. Tank mixes increase resistance problems and should be avoided.

Table 1. Pesticides labeled for WFT in greenhouses.

Class	Common Name	*	Trade Name
BO	azadirachtin (neem)	8	Azatin, Neemazad
BO	nicotine		Fulex Nicotine
C	bendiocarb	4	Dycarb, Turcam
C	fenoxycarb	8	Precision, Preclude
C	methiocarb		Mesurol
CH	endosulfan	5	Thiodan
Mb	Beauveria bassiana	9	Naturalis, Botanigard
ML	abamectin		Avid
OP	acephate		Orthene
OP	chlorpyrifos	7	Duraguard
OP	dichlorvos	2	Vapona, DDVP
OP	naled	2	Dibrom
OP	sulfotep	2	Plantfume
P	bifenthrin	3	Talstar, Attain
P	cyfluthrin		Decathlon
P	fluvalinate		Mavrik
P	fenpropathrin		Tame
P	lambda-cyhalothrin	1	Topcide
P	resmethrin		Resmethrin
S	spinosad		Conserve

1 Limited amount per crop
2 Foliage and blooms must be dry
3 May leave residue
4 Turcam-apply at three-week intervals
5 Labeled for aphids and whitefly; frequently recommended for WFT
6 Labeled for spidermites and leafminer; frequently recommended for WFT
7 Direct spray to open blooms may cause petal drop
8 Acts as insect growth regulator; not effective on adults
9 Check label before applying fungicides; 3-5 applications necessary

BO=Botanical, C=Carbamate, CH=Chlorinated hydrocarbons, Mb=Microbial, ML=Macrocyclic Lactone, OP=Organophos-phates, P=Pyrethroids, S=Spinosyns

Mention of a pesticide does not constitute an endorsement of any product and any omission from this list is unintentional. The pesticide label is the ultimate authority for pesticide use.

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