# Management of the Western Flower Thrips (Thysanoptera: Thripidae) in Fruiting Vegetables

Author: Funderburk, Joe

Source: Florida Entomologist, 92(1) : 1-6

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.092.0101

# MANAGEMENT OF THE WESTERN FLOWER THRIPS (THYSANOPTERA: THRIPIDAE) IN FRUITING VEGETABLES

JOE FUNDERBURK
North Florida Research and Education Center, University of Florida, 155 Research Road, Quincy, FL 32351

ABSTRACT

Feeding by the western flower thrips, *Frankliniella occidentalis* (Pergande), causes damage to the fruits of vegetables, and the species is the key vector of *Tomato spotted wilt virus*. *Frankliniella tritici* (Fitch) and *Frankliniella bispinosa* (Morgan) are not pests of fruiting vegetables. Both species compete with *F. occidentalis*. Effective management of *F. occidentalis* in pepper integrates conservation of natural populations of the predator, *Orius insidiosus* (Say), with the use of reduced-risk insecticides such as spinetoram for the control of western flower thrips and other pests. Naturally occurring *O. insidiosus* are very effective predators and their effectiveness is predictable based on the number of the predator relative to the number of thrips prey. Populations of *F. occidentalis* resurge when natural enemies and competing thrips are killed. Some insecticides especially pyrethroids have beneficial effects on the development and reproduction of *F. occidentalis*. The predator *O. insidiosus* does not prefer tomato, and numbers remain too low in fields to suppress thrips. Tomato growers primarily rely on the use of ultra-violet reflective mulch combined, if needed, with the use of effective insecticides. Additional management efforts are needed in the future to manage *F. occidentalis* and other difficult pests in space and time. Management of the pepper weevil (*Anthonomus eugenii* Cano) is proving a challenge to pepper growers in central and southern Florida trying at the same time to manage *F. occidentalis*. Growers need to emphasize sanitation and other cultural tactics over the use of broad-spectrum insecticides that kill *O. insidiosus* and induce *F. occidentalis* in other ways. The identification of thrips in scouting programs also is critical as the use of broad-spectrum insecticides against populations of the non-pest flower thrips is inducing *F. occidentalis* to pest status.

Key Words: *Frankliniella occidentalis*, pepper, eggplant, tomato, IPM

RESUMEN

La alimentación del trips occidental de las flores, *Frankliniella occidentalis* (Pergande), causa daño a los frutos de verduras y a su vez la especie es el vector clave del virus de la marchitez manchada del tomate. *Frankliniella tritici* (Fitch) y *Frankliniella bispinosa* (Morgan) no son plagas de verduras que producen frutos. Ambas especies compiten con *F. occidentalis*. El manejo efectivo de *F. occidentalis* en chile se integra con la conservación de poblaciones naturales del depredador, *Orius insidiosus* (Say) con el uso de insecticidas de riesgo reducidos como el "spinetoram" para el control del trips occidental de las flores y otros plagas. Cuando *O. insidiosus* ocurre son depredadores muy efectivos y su efectividad es previsible basado sobre el numero de depredadores en relación al numero de trips (presa). Poblaciones de *F. occidentalis* resurgen cuando se matan los enemigos naturales y trips competidores. Algunos insecticidas especialmente los piretroides tienen unos efectos benéficos sobre el desarrollo y reproducción de *F. occidentalis*. El depredador *O. insidiosus* no prefiere el tomate y el numero de individuos se mantiene demasiado bajo en campos para suprimir los trips. Los productores de tomate dependen primariamente sobre el uso de mantillo reflectante de ultra violeta combinado, si es necesario, con el uso de insecticidas efectivos. Se necesita esfuerzos adicionales en un futuro para manejar *F. occidentalis* y otras plagas difíciles en un espacio y un tiempo. El manejo del gorgojo (picudo) de chile (*Anthonomus eugenii* Cano) esta haciendo un desafío para los productores de chile en el centro y sur de la Florida, quienes tratan a la vez de manejar el trips *F. occidentalis*. Los productores necesitan enfatizar mas la sanidad y otras tácticas culturales que en el uso de insecticidas de amplio espectro que elimina *O. insidiosus* e induce *F. occidentalis* en otras maneras. La identificación de trips en programas de muestreo también es crucial puesto que los insecticidas de amplio espectro contra poblaciones de diferentes trips de flores que no son plaga esta induciendo *F. occidentalis* a nivel de plaga.

There are over 5000 described species of thrips (Thysanoptera). About 87 species of thrips are pests of commercial crops because they feed on leaves, fruits, and flowers causing discoloration, deformity, and reduced marketability (Mound 1997). Over 20 of these species of thrips are now cosmopolitan (Mound 1997), including recent invasive species in Florida, the chilli thrips, *Scirto-*

*thrips dorsalis* (Hood), and a legume pest, *Megalurothrips mucunae* (Priesner) (Diffie et al. 2008). Global trade in greenhouse plants rapidly spread the western flower thrips, *Frankliniella occidentalis* (Pergande), around the world in the 1980s. The species is native to the southwestern US, and it is the key vector of *Tomato spotted wilt virus* (Kirk & Terry 2003). The insect and the virus emerged as the key pest problems of tomato, pepper, peanut, tobacco, and other crops in northern Florida in 1986. In 2006, the western flower thrips (but not the virus) emerged as a key pest problem in fruiting vegetables in central and southern Florida.

The adults of *F. occidentalis* inhabit the flowers of tomato, pepper, and eggplant, where they feed on pollen and flower tissues. The female lays eggs individually in the small developing fruit of the flower. A small dimple sometimes surrounded by a halo remains in the developing fruit after egg hatch (Salguero Navas et al. 1991b). The dimple, but not necessarily the halo, remains on mature fruits. Direct feeding by larvae also causes aesthetic damage referred to as 'flecking' (Ghidiu et al. 2006). This damage occurs on the parts of the fruit touching a leaf or stem due to the cryptic habits of the larvae. Thrips damage can result in cull-out and lowering of grade of the harvested fruit, with tolerance based on price and demand in the marketplace. Plants infected by *Tomato spotted wilt virus* display chlorosis, necrosis, ringspotting, and other symptoms, and fruits of infected plants are not marketable.

Other species of thrips occur in large numbers in the flowers of fruiting vegetables in Florida. The most common species in northern Florida is *Frankliniella tritici* (Fitch) (Reitz 2002; Salguero Navas et al. 1991a). The species does not damage fruits even in very large numbers (Salguero Navas et al. 1991b), and it is not a capable vector of *Tomato spotted wilt virus* (de Assis Filho 2005). The most common species in central and southern Florida is *Frankliniella bispinosa* (Morgan) (Hansen et al. 2003). The species is a capable vector of *Tomato spotted wilt virus* (Avila et al. 2006). The tobacco thrips, *Frankliniella fusca* (Hinds), occurs in low numbers in fruiting vegetables in northern Florida, and *Frankliniella schultzei* (Trybom) occurs in low numbers in central and southern Florida (Hansen et al. 2003). These species are capable vectors of *Tomato spotted wilt virus*.

The unusual virus-vector relationship is a particular challenge in efforts to manage *Tomato spotted wilt virus*. The virus is acquired only by the larvae, and the adults transmit it to host plants. Usually primary spread of the disease is due to infections caused by incoming viruliferous adults to a crop from outside sources that include uncultivated and cultivated plant hosts. Adults persistently transmit, and their control with insecticides does not prevent transmission due to the short time of feeding for infection to occur (Momol et al. 2004). Secondary spread is caused by viruliferous adults that acquired the virus as larvae feeding on an already infected plant. For secondary spread, thrips need to colonize and reproduce on infected plants within a crop. Control of the larvae before their development to adults is effective in preventing secondary spread. Most viral infections in tomatoes in northern Florida are the result of primary spread, although some secondary viral infections occur late in the season (Momol et al. 2004). The lack of epidemics of tomato spotted wilt disease in vegetables in central and southern Florida suggests that *F. bispinosa* is not an efficient vector capable of acquiring the *Tomato spotted wilt virus* from uncultivated plant species.

A lack of knowledge of the reproductive host plants serving as sources of thrips invading crop fields in northern Florida has hampered management efforts, but see Paini et al. (2007) and Northfield et al. (2008). Paini et al. (2007) identified only 2 uncultivated plant species serving as reproductive hosts for *F. occidentalis* in the agricultural landscape in northern Florida, while 18 uncultivated plant species served as reproductive hosts for *F. tritici*. Northfield et al. (2008) studied the population dynamics of *Frankliniella* species thrips on 7 common, uncultivated plant species in northern Florida. Only 1.1% of the thrips collected were *F. occidentalis*, while 75.9% were *F. tritici*. The invasive *F. occidentalis* apparently is out-competed by the native *F. tritici* on shared crop and uncultivated plant hosts (Paini et al. 2008). The adults of *F. occidentalis* are not abundant on uncultivated plant species in central and southern Florida (J. E. F., unpublished), which suggests that the abundant *F. bispinosa* is an effective competitor species with *F. occidentalis*.

The invading populations of *F. occidentalis* were largely resistant to most organophosphate, carbamate, pyrethroid, and organochlorine insecticides (Immaraju et al. 1992). Application of these broad-spectrum insecticides may suppress *F. occidentalis* populations initially, but their numbers can increase rapidly a few days after application (Funderburk et al. 2000; Ramachandran et al. 2001; Reitz et al. 2003). Further, insecticidal control of the viruliferous adults proved ineffective in preventing primary spread of *Tomato spotted wilt virus* (Momol et al. 2004). Yet, growers in northern Florida responded (as have growers in most other parts of the world) by spraying insecticides on a calendar schedule. This resulted in an ecological and economic crisis with growers in northern Florida suffering uncontrollable damage due to high thrips populations and epidemics of tomato spotted wilt disease. Eventually, integrated pest management programs were developed for fruiting vegetables, and they proved to be effective, economic, and sustainable. A review of these programs that are widely implemented in northern Florida is given, including a discussion of the mechanisms by which the tactics reduce thrips populations. Recently populations of *F. occidentalis* in central and southern Florida have increased in crops grown during the winter and spring. Large, damaging populations have occurred in fruiting vegetables. The reasons for the emergence of *F.occidentalis* as a key pest of fruiting vegetables in central and southern Florida are discussed. The need for and the potential benefits of additional tactics in the integrated pest management of *F.occidentalis* are evaluated. A case is made that there is a need to vertically integrate management of *F. occidentalis* and other insect pests of fruiting vegetables.

## Integrated Pest Management for Pepper

The naturally occurring minute pirate bugs *Orius insidiosus* are very effective predators of thrips in pepper. Species of *Orius* in the family Anthocoridae are commonly referred to as minute pirate bugs, while the common name for *O. insidiosus* is the insidious flower bug. Their effectiveness is predictable based on the number of the predator relative to the number of thrips prey (Funderburk et al. 2000; Ramachandran et al. 2001). Suppression occurs when there is 1 predator for approximately 180 thrips and control occurs when there is 1 *O. insidiosus* per approximately 50 thrips.

A conservation biological control program was implemented in northern Florida beginning in 1997. This integrated pest management program employs reduced-risk insecticides and natural populations of *O. insidiosus* (Funderburk et al. 2000; Ramachandran et al. 2001; Reitz et al. 2003). There is a lag period once peppers begin flowering in the spring season in which thrips colonize and buildup to large numbers for about a week before there are enough *O. insidiosus* to suppress and control thrips populations (Funderburk et al. 2000; Ramachandran et al. 2001). The number of thrips in flowers can exceed 10 per flower in untreated spring pepper during this lag period, but there is no damage to the pepper fruits.

Minute pirate bugs are effective predators of the adults and larvae of each of the *Frankliniella* species (Funderburk et al. 2000; Ramachandran et al. 2001; Reitz et al. 2003), although *O. insidiosus* has distinct prey preferences. The larvae are the first to be suppressed, followed by the adults of *F. occidentalis* (Baez et al. 2003). The adults of *F. tritici* and *F. bispinosa* are the most mobile and best able to escape predation (Reitz et al. 2004).

Populations of *O. insidiosus* occur in large numbers in the landscape in northern Florida from May to Nov, and populations invade spring and fall pepper in numbers sufficient to control thrips (Ramachandran et al. 2001). Populations persist in spring pepper flowers after thrips populations have been suppressed in numbers sufficient to prevent re-building of thrips populations (Funderburk et al. 2000; Ramachandran et al. 2001; Reitz et al. 2003). The numbers of *O. insidiosus* in pepper flowers are sufficient throughout the fall production season to prevent population buildup of thrips (Ramachandran et al. 2001).

The conservation biological control program has been adapted to local conditions throughout the world. This integrated pest management program employs reduced-risk insecticides, natural infestations of minute pirate bugs, and cultural control tactics including ultraviolet-reflective mulch (Reitz et al. 2003). The ultraviolet-reflective mulch repels the migrating adults of *F. occidentalis,* and this reduces the primary spread of *Tomato spotted wilt virus* (Reitz et al. 2003). There is a substantial reduction in the population buildup of thrips. There also is a delay in the buildup of populations of minute pirate bugs, but overall the benefits of the ultraviolet–reflective mulch outweigh the initial reduction in biological control (Reitz et al. 2003).

Spinosyn insecticides represent a unique mode of action (Group V insecticides). The spinosyns spinosad and spinetoram (Dow AgroSciences, Indianapolis, IN) are the most effective insecticides to suppress *F. occidentalis*, and they are reduced-risk insecticides that do not suppress populations of *O. insidiosus* at labeled rates (Funderburk et al. 2000; Reitz et al. 2003; Srivastava et al. 2008). Other reduced-risk insecticides labeled for fruiting vegetables have little or no efficacy against *F. occidentalis*, although 2 with moderate efficacy are soon to be labeled (Table 1). Other reduced-risk insecticides that are not efficacious against *F. occidentalis* but conserve populations of *O. insidiosus*, are useful in the control of lepidopterous and other pests in pepper (Table 1).

A number of insecticides, either alone or in combination, have been documented to result in a significant buildup of populations of *F. occidentalis* in pepper compared to untreated pepper (Table 2). This phenomenon is especially consistent when pyrethroid insecticides are applied, but insecticides in other insecticidal classes also induce populations. The mechanism has been directly related to suppression of populations of the key predator, *O. insidiosus* (Funderburk et al. 2000; Ramachandran et al. 2001; Reitz et al. 2003; Srivastava et al. 2008); however, other mechanisms also are responsible. Populations of *F. tritici* have been shown to out-compete populations of *F. occidentalis* in pepper (Paini et al. 2008). Hormoligosis also appears to be a mechanism, but this has not been documented to the author's knowledge in a refereed journal article.

The management of other insect pests has been vertically integrated with the conservation

TABLE 1. INSECTICIDES LABELED OR UNDER REVIEW FOR FRUITING VEGETABLES THAT ARE COMPATIBLE WITH THE CONSERVATION BIOLOGICAL PROGRAM USING *O. INSIDIOSUS*.

| Insecticide (common name) | Activity | Source |
|---|---|---|
| Spinosad | thrips and other taxa | Funderburk et al. (2000) |
| Spinetoram | thrips and other taxa | Srivastava et al. (2008) |
| Pyridadyl[1] | thrips and other taxa | J. E. F., unpublished |
| Requiem™ (essential oils)[1] | thrips, aphids, whiteflies | J. E. F., unpublished |
| Methoxyfenoxide | Lepidoptera | A. Weiss, unpublished |
| Indoxacarb | Lepidoptera | Reitz et al. (2003) |
| Bacillus thuringiensis | Lepidoptera, Coleoptera | J. E. F., unpublished |
| EcoTrol™ (essential oils) | thrips and other taxa | J. E. F., unpublished |

[1]Registration under review by the U.S. Environmental Protection Agency.

biological control of *F. occidentalis* in pepper in northern Florida. Various species of stink bugs are occasional pests in pepper, but the application of broad-spectrum insecticides for their control late in the production season has not resulted in inducing populations of *F. occidentalis* to damaging levels (J. E. F. personal observation). The pepper weevil, *Anthonomus eugenii* Cano, is an occasional pest in sweet pepper especially in the fall production season that is effectively managed primarily through cultural tactics. The conservation biological control program for thrips has resulted in increased biological control of other pests such as aphids by natural infestations of coccinellid species (J. E. F., personal observation).

## INTEGRATED PEST MANAGEMENT FOR TOMATO

Producers in northern Florida initially responded to the threat of *F. occidentalis* and *Tomato spotted wilt virus* by the calendar application of broad-spectrum highly toxic insecticides. Tomato growers applied insecticides an average 12.3 to 16.4 times per season (Bauske et al. 1998). Yet research revealed that losses were the result of primary infections that were not prevented by such intensive insecticide use (Puche et al. 1995). Salguero Navas et al. (1994) established a threshold of one half of tomato flowers infested by *F. occidentalis* to prevent dimpling and flecking. However, efforts to develop therapeutic strategies were hampered by a lack of a practical method to identify the species of thrips in scouting programs. Usually, most of the thrips in the flowers were non-pest species that are highly susceptible to most insecticides.

In laboratory assays against un-exposed feral populations of *Frankliniella* species baseline toxicities were established for spinosad (Eger et al. 1998). These assays showed that the insecticide was equally toxic to *F.occidentalis*, *F. tritici*, and *F. bispinosa*. The adults of *F. tritici* and *F. bispinosa* are very active and they re-invade insecticide treated fields very quickly, so that there is an apparent rather than real lack of control when short-residual insecticides such as spinosad are applied (Ramachandran et al. 2001). Conversely, the adults of *F. occidentalis* are much less active, preferring to stay on a suitable resource.

The benefits of other management tactics were investigated, and an effective sustainable program was developed that was adopted by tomato growers in northern Florida (Momol et al. 2004). Ultraviolet-reflective mulch is very effective in reducing colonization of *Frankiniella* species thrips onto the tomato plants and in reducing the incidence of tomato spotted wilt. Development of the larval instars is about 5 d, and weekly applications of insecticides are sufficient to prevent successful larva development and subsequent secondary spread of *Tomato spotted wilt virus*. Methamidophos (Monitor, Valent USA Corp. Walnut

TABLE 2. INSECTICIDES AND INSECTICIDE COMBINATIONS KNOWN TO INDUCE POPULATIONS OF *FRANKLINIELLA OCCIDENTALIS* IN PEPPER.

| Insecticide (common name) | Source |
|---|---|
| Fenpropathrin | Funderburk et al. (2000) |
| lambda-cyhalothrin | J. E. F., unpublished |
| Dinotefuran | J. E. F., unpublished |
| zeta-cypermethrin & bifenthrin | J. E. F., unpublished |
| Esfenvalerate | Funderburk et al. (2000); Hansen et al. (2003); Ramachandran et al. (2001); Reitz et al. (2003); Srivastava et al. (2008) |

Creek, CA) and spinosad are in different chemical classes with different modes of action. Alternating applications for thrips control during the season is recommended as an integrated resistance management strategy. Few other insecticides with activity against *F. occidentalis* currently are labeled in tomato. Acibenzolar-S-methyl (Actigard, Syngenta, Inc., Greensboro, NC) is an inducer of systemic resistance and it has some benefit in reducing the incidence of tomato spotted wilt (Momol et al. 2004). It is especially recommended for the control of bacterial disease as a replacement for copper that reduces the ultraviolet reflection from the mulches.

Over-fertilization above recommended rates of nitrogen for optimal production results in an increase in the numbers of vector and nonvector *Frankliniella* thrips and an increased incidence in tomato spotted wilt (Stavisky et al. 2002). The increased level of aromatic amino acids in over-fertilized tomato plants results in an increased preference and performance of the females of *F. occidentalis* (Brodbeck et al. 2001).

Primary spread of *Tomato spotted wilt virus* accounts for most of the incidence of the disease in northern Florida, although secondary spread must also be managed mid and late season (Momol et al. 2004). Cultivars resistant to *Tomato spotted wilt virus* with acceptable yield and fruit quality are available, and growers are rapidly adopting resistant cultivars in northern Florida. Strains of *Tomato spotted wilt virus* that have overcome resistance from the single-gene dominate trait have appeared in other geographical areas (Rosello et al. 1998). An integrated approach therefore is necessary to reduce feeding by thrips and to manage the development of virus strains that can overcome host plant resistance.

## Developing Programs for Central and Southern Florida

The problem with *F. occidentalis* in southern Florida over the past 2 years appears to be in large measure induced by the use of broad-spectrum insecticides, especially pyrethroids (personal observation). This is the result of a shift in attitude by some growers to control rather than manage pests. So, the development and implementation of integrated pest management programs for *F. occidentalis* in fruiting vegetables is a critical issue. Clearly, a therapeutic approach is hampered by the lack of scouting in which thrips are identified to species. The identification of species is necessary in order to eliminate applications of insecticides against *F. bispinosa*. The economic thresholds established for thrips in peppers and tomatoes are largely nominal thresholds (i.e., developed from experience). At least 10 adult thrips of any species can be tolerated in pepper without damage from feeding. Flecking damage results from the feeding of the larvae primarily *F. occidentalis*. An economic threshold of one half of the flowers of tomato infested with *F. occidentalis* is very conservative and more can be tolerated under most market conditions (personal observation). More than 10 adult *F. tritici* or *F. bispinosa* can be tolerated in tomato without damage. Most of the halo-spotting and flecking damage in tomato and pepper is due to *F. occidentalis* rather than *F. bispinosa* (Avila et al. 2006; Ghidhui et al. 2006; Salguero Navas et al. 1991b).

Management efforts in central and southern Florida also are hampered by inadequate knowledge of the population dynamics of *Frankliniella* species and *O. insidiosus*. Especially lacking is knowledge of the reproductive status of *O. insidiosus* during the winter (the females are present but they may be in reproductive diapause). It is possible that there are insufficient numbers of the predator to invade crop fields during Jan and Feb (J. E. F. personal observation).

In southern Florida, management of *F. occidentalis* needs to be vertically integrated with the management of another key pepper pest, *A. eugenii*. This will require growers to emphasize sanitation and other cultural tactics over broad-spectrum insecticides that kill *O. insidiosus* or induce *F. occidentalis* in other ways. Tomato is a poor reproductive host for *F. occidentalis*, and *O. insidiosus* does not prefer tomato. The other key pests of tomato in central and southern Florida are *Bemisia tabaci* (Gennadius) and the whitefly-transmitted viruses. Ultraviolet-reflective mulch and reduced-risk insecticides are examples of tactics useful in the management of *B. tabaci* and *F. occidentalis*. The invasion and establishment of *F. occidentalis* has de-stabilized existing integrated pest management programs worldwide (Morse & Hoddle 2006). The vertical integration of its management with other pests of fruiting vegetables will be key to the development of effective, sustainable integrated pest management programs in central and southern Florida.

## References Cited

De Assis Filho, F. M., Stavisky, J. Reitz, S. R., Deom, C. M., and Sherwood, J. L. 2005. Midgut infection by tomato spotted wilt virus and vector incompetence of *Frankliniella tritici*. J. Appl. Entomol. 129: 548-550.

Avila, Y., Stavisky, J., Hague, S., Funderburk, J., Reitz, S., and Momol, T. 2006. Evaluation of *Frankliniella bispinosa* (Thysanoptera: Thripidae) as a vector of *Tomato spotted wilt virus* in pepper. Florida Entomol. 89: 204-207.

Bauske, E. M., Zehnder, G. M., Sikora, E. J., and Kemble, J. 1998. Southeastern tomato growers adopt integrated pest management. HortTechnology 8: 40-44.

Brodbeck, B. V., Stavisky, J., Funderburk, J. E., Andersen, P. C., and Olson, S. M. 2001. Flower nitrogen status and populations of *Frankliniella occi-*

*dentalis* feeding on *Lycopersicon esculentum*. Entomol. Exp. Appl. 99: 165-172.

DIFFIE, S., FUNDERBURK, J., GOLDARAZENA, A., AND MOUND, L. 2008. New North American records for two oriental thrips (Thysanoptera) species. J. Entomol. Sci. 43: 128-132.

EGER, JR., J. E., STAVISKY, J., AND FUNDERBURK, J. E. 1998. Comparative toxicity of spinosad to *Frankliniella* spp. (Thysanoptera: Thripidae), with notes on a bioassay technique. Florida Entomol. 81: 547-551.

FUNDERBURK, J., STAVISKY, J., AND OLSON, S. 2000. Predation of *Frankliniella occidentalis* (Thysanoptera: Thripidae) in field peppers by *Orius insidiosus* (Hemiptera: Anthocoridae). Environ. Entomol. 29: 376-382.

GHIDUI, G. M., HITCHNER, E. M., AND FUNDERBURK, J. E. 2006. Goldfleck damage to tomato fruit caused by the feeding of *Frankliniella occidentalis* (Thysanoptera: Thripidae). Florida Entomol. 89: 279-282.

HANSEN, E. A., FUNDERBURK, J. E., REITZ, S. R., RAMACHANDRAN, S., EGER, J. E., AND MCAUSLANE, H. 2003. Within-plant distribution of *Frankliniella* species (Thysanoptera: Thripidae) and *Orius insidiosus* (Heteroptera: Anthocoridae) in field pepper. Environ. Entomol. 32: 1035-1044.

IMMARAJU, J. A., PAINE, T. D., BETHKE, J. A., ROBB, K. L., AND NEWMAN, J. P. 1992. Western flower thrips (Thysanoptera: Thripidae) resistance to insecticides in coastal California greenhouses. J. Econ. Entomol. 85: 9-14.

KIRK, W. D. J., AND TERRY, L. I. 2003. The spread of the western flower thrips *Frankliniella occidentalis* (Pergande). Agric. For. Entomol. 5: 301-310.

MOMOL, M. T., OLSON, S. M., FUNDERBURK, J. E., STAVISKY, J., AND MAROIS, J. J. 2004. Integrated management of tomato spotted wilt in field-grown tomato. Plant Dis. 88: 882-890.

MORSE, J. G., AND HODDLE, M. S. 2006. Invasion biology of thrips. Annu. Rev. Entomol. 51: 67-89.

MOUND, L. A. 1997. Biological diversity, pp. 197-215 *In* T. Lewis [ed.], Thrips As Crop Pests. CAB International, New York. 740 pp.

NORTHFIELD, T. D., PAINI, D. R., FUNDERBURK, J. E., AND REITZ, S. R. 2008. Annual cycles of *Frankliniella* spp. Thrips (Thysanoptera: Thripidae) abundance on North Florida uncultivated reproductive hosts: predicting possible sources of pest outbreaks. Ann. Entomol. Soc. America 101: 769-778.

PAINI, D. R., FUNDERBURK, J. E., JACKSON, C. T., AND REITZ, S. R. 2007. Reproduction of four thrips species (Thysanoptera: Thripidae) on uncultivated hosts. J. Entomol. Sci. 42: 610-615.

PAINI, D. R., FUNDERBURK, J. E., AND REITZ, S. R. 2008. Competitive exclusion of a worldwide invasive pest by a native. Quantifying competition between two phytophagous insects on two host plant species. J. Anim. Ecol. 77: 184-190.

PUCHE, H., BERGER, R. D., AND FUNDERBURK, J. E. 1995. Population dynamics of *Frankliniella* thrips and progress of tomato spotted wilt virus. Crop Prot. 14: 577-583.

RAMACHANDRAN, S., FUNDERBURK, J., STAVISKY, J., AND OLSON, S. 2001. Population abundance and movement of *Frankliniella* species and *Orius insidiosus* in pepper. Agric. For. Entomol. 3: 1-10.

REITZ, S. R. 2002. Seasonal and within-plant distribution of *Frankliniella* thrips (Thysanoptera: Thripidae) in northern Florida. Fla. Entomol. 85: 431-439.

REITZ, S. R., YEARBY, E. L., FUNDERBURK, J. E., STAVISKY, J., MOMOL, M. T., AND OLSON, S. M. 2003. Integrated management tactics for *Frankliniella* thrips (Thysanoptera: Thripidae) in field-grown pepper. J. Econ. Entomol. 96: 1201-1214.

ROSELLO, S., DIEZ, M. J., AND NUNEZ, F. 1998. Genetics of tomato spotted wilt virus resistance coming from *Lycopersicon peruvianum*. European J. Plant Pathol. 104: 499-509.

SALGUERO NAVAS, V. E., FUNDERBURK, J. E., BESHEAR, R. J., OLSON, S. M., AND MACK, T. P. 1991a. Seasonal patterns of *Frankliniella* spp. (Thysanoptera: Thripidae) in tomato flowers. J. Econ. Entomol. 84: 1818-1822.

SALGUERO NAVAS, V. E., FUNDERBURK, J. E., OLSON, S. M., AND BESHEAR, R. J. 1991b. Damage to tomato fruit by the western flower thrips (Thysanoptera: Thripidae). J. Entomol. Sci. 26: 436-442.

SALGUERO NAVAS, V. E., FUNDERBURK, J. E., OLSON, S. M., AND BESHEAR, R. J. 1994. Aggregation indices and sample size curves for binomial sampling of flower-inhabiting *Frankliniella* species (Thysanoptera: Thripidae) on tomato. J. Econ. Entomol. 87: 1622-1626.

STAVISKY, J., FUNDERBURK, J., BRODBECK, B. V., OLSON, S. M., AND ANDERSEN, P. C. 2002. Population dynamics of *Frankliniella* spp. and tomato spotted wilt incidence as influenced by cultural management tactics in tomato. J. Econ. Entomol. 95: 1216-1221.

SRIVISTAVA, M., BOSCO, L., FUNDERBURK, J., OLSON, S., AND WEISS, A. 2008. Spinetoram is compatible with the key natural enemy of *Frankliniella* species thrips in pepper. Plant Health Progress doi:10.1094/PHP-2008-0118-02-RS.

STAVISKY. J., FUNDERBURK, J., BRODBECK, B. V., OLSON, S. M., AND ANDERSEN, P. C. 2002. Population dynamics of *Frankliniella* spp. and tomato spotted wilt incidence as influenced by cultural management tactics in tomato. J. Econ. Entomol. 95: 1216-1221.