Common Blossom Thrips, Frankliniella schultzei (Thysanoptera: Thripidae) Management and Groundnut Ring Spot Virus Prevention on Tomato and Pepper in Southern Florida

Authors: Seal, Dakshina R., Kumar, Vivek, and Kakkar, Garima

Source: Florida Entomologist, 97(2) : 374-383

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.097.0206

COMMON BLOSSOM THRIPS, *FRANKLINIELLA SCHULTZEI* (THYSANOPTERA: THRIPIDAE) MANAGEMENT AND GROUNDNUT RING SPOT VIRUS PREVENTION ON TOMATO AND PEPPER IN SOUTHERN FLORIDA

DAKSHINA R. SEAL[1], VIVEK KUMAR[2] AND GARIMA KAKKAR[3]
[1]University of Florida-IFAS, Tropical Research and Education Center, Homestead, FL, USA 33031

[2]University of Florida-IFAS, Mid-Florida Research & Education Center, Apopka, FL, USA 32703

[3]University of Florida-IFAS, Ft. Lauderdale Research & Education Center, Davie, FL, USA 33314

*Corresponding author; E-mail: dseal3@ufl.edu

Summarized from a presentation and discussions at the "Thrips: small players with big damage", Symposium at the Annual Meeting of the Florida Entomological Society, 16 July 2013, Naples, Florida.

ABSTRACT

The common blossom thrips, *Frankliniella schultzei* (Trybom), has been recently reported as an agronomic pest in South Florida. It poses a serious threat to tomato and pepper growers due to its ability to transmit Groundnut ring spot virus (GRSV). In the wake of the current problem 3 trials were undertaken to control *F. schultzei* using conventional and novel insecticides of different modes of action. Specifically, the efficacies of neonicotinoid, diamides, spirotetramat, spinosyn/spinosad and *Chenopodium ambrosioides* were evaluated with the aim of controlling *F. schultzei* and minimizing the transmission of the virus. In the first trial, imidacloprid (IRAC Group 4) applied at planting as a soil drench followed by drip irrigation application of cyazypyr showed some reduction of the *F. schultzei* population and of the transmission of GRSV on tomato. The change in the method of application of cyazypyr from drip irrigation to direct application on the foliage in the second trial improved both the control of *F. schultzei* and the reduction of GRSV on tomato. In the third trial, the foliar applications of spirotetramat, spinetoram and *Chenopodium ambrosioides* did not control *F. schultzei* populations nor reduce the transmission of GRSV on pepper. Results from this study will help in the development of a management program using imidacloprid and cyazypyr in rotation with spirotetramat, spinetoram and *Chenopodium ambrosioides.* The development of such a program to suppress *F. schultzei* populations thrips and prevent transmission of GRSV will be challenging, but an effective IPM program would also serve as a strong insecticide resistance management program for *F. schultzei*.

Key Words: tomato thrips, common blossom thrips, GRSV, thrips control

RESUMEN

Se ha reportado recientemente el trips común de las flores, *Frankliniella schultzei* (Trybom), como una plaga agronómica en el sur de la Florida. Esto representa una amenaza seria para los cultivadores de tomate y chile dulce, debido a su capacidad de transmitir el virus de la mancha anillada de nueces subterráneas (VANS). A raíz del problema actual, se realizó 3 ensayos para el control de *F. schultzei* utilizando insecticidas convencionales e innovadores de diferentes modos de acción. Específicamente, se evaluó la eficacia de neonicotinoide, diamidas, espirotetramat, espinosina/espinosad y *Chenopodium ambrosioides* con el objetivo de controlar *F. schultzei* y minimizar la transmisión del virus. En el primer ensayo, imidacloprid (Grupo 4 de IRAC) aplicado a la siembra en un regado al suelo seguido por una aplicación de cyazypyr por un riego de goteo mostró una reducción de la población de *F. schultzei* y de la transmisión del VANS en tomate. El cambio en el método de aplicación de cyazypyr de riego por goteo a una aplicación directa sobre el follaje durante el segundo ensayo mejoró tanto el control de *F. schultzei* y la reducción del VANS en el tomate. En el tercer ensayo, la aplicación foliar de spirotetramat, spinetoram y *Chenopodium ambrosioides* no controló la población de *F. schultzei* ni redujó la transmisión del VANS en chile dulce. Los resultados de este estudio ayudarán en el desarrollo de un programa de manejo utilizando imidacloprid y cyazypyr en rotación con spirotetramat, spinetoram y *Chenopodium ambrosioides*. El desarrollo de un programa como este para suprimir la población del trips *F. schultzei* y prevenir la transmisión de VANS será un reto, pero un programa eficaz de MIP también servirá como un programa sólido de manejo de resistencia a los insecticidas para *F. schultzei*.

Palabras Clave: trips de tomate, trips común de las flores, VANS, control de trips

The common blossom thrips or tomato thrips, *Frankliniella schultzei* (Trybom) (Thysanoptera: Thripidae), is an emerging pest of various vegetable crops in south Florida. Although this thrips species has been present in the region for a long period, not much attention was given to it until recently when it was found to be associated with increased cases of tomato chlorotic spot tospovirus (TCSV) (Londoño et al. 2012) and groundnut ring spot tospovirus (Webster et al. 2010) in Florida. Worldwide *F. schultzei* has been reported feeding on 83 species of ornamental and vegetable plants in 55 families (Palmer 1990; Milne et al. 1996). In the south Florida, it has been reported to infest tomato, squash cucumber, and bean (Kakkar et al. 2012a, b). *Frankliniella schultzei* causes direct and indirect damage on leaves, flowers and fruits of its host plants. Direct damage is caused by feeding and oviposition on leaves, flowers and fruits resulting in necrotic spots on tender leaves and dark dotted blemishes in fruits (Kakkar et al. 2010). Oviposition causes brown lesions on fruits and flowers, and at high densities it may lead to premature abscission of flowers and fruits. Indirect damage by this thrips is caused by its transmission of viral diseases to the host plants. *Frankliniella schultzei* is a known vector of several plant damaging virus including Tomato spotted wilt tospovirus (TSWV) (Sakimura 1969; Wijkamp et al. 1995), Tomato chlorotic spot tospovirus (TCSV), groundnut ring spot tospovirus (GRSV) (Wijkamp et al. 1995), Tobacco streak ilarvirus (TSV) (Klose et al. 1996), Stem necrosis virus and Capsicum chlorosis virus (Horticulture Australia 2005).

In Miami-Dade County in 2012, *F. schultzei* caused economic damage to some tomato and pepper plantings by transmitting Groundnut ring spot virus. It is the first record in the United States of *F. schultzei* causing large scale destruction (30-60%) of tomato and pepper production due to virus transmission (Londoño et al. 2012). During our study we found that *F. schultzei* can cause significant damage to tomato and pepper by transmitting virus even at the low population density of 1 adult/10 plants) (D.R.S. personal observation). Plants affected in an early stage of development may die before bearing fruits; while infection at a late stage causes malformed, unmarketable fruits with ring like lesions. Considering the increased cases of *F. schultzei* in the area and its wide host range, it is imperative to initiate the development of effective management practices to avoid economic losses from thrips-induced plant diseases.

Thrips are opportunistic insects; small size is advantageous for them to acquire microhabitats on both primary and alternative hosts. In Brazil, Guimaraes et al. (1997) observed higher incidence of TSWV when tomato was planted near a maize windbreak, which sheltered this pest. In such cases, roguing of infected plants has been found to be useful in reducing rates of new infestations (D.R.S. personal observation). Cultural practices can be helpful in providing some control over thrips and associated virus damage to the crops, for example, temporary flooding was reported to cause reduction of *F. schultzei* population by killing soil inhabiting pupae (Bournier 1994). Biological control using generalist predators such as minute pirate bug or phytoseiid mites could be effective but their potential as a solution against this pest still needs to be evaluated. In commercial farming with high value crops and low aesthetic thresholds, a rescue program is essential to reduce economic losses. Moreover, when dealing with an insect pest whose low population abundance can cause significant damage by transmitting viral diseases, it is important to control such a pest species at the incipient stage of an infestation.

In this study we evaluated the efficacy of various conventional and novel insecticides of diverse mode of actions in managing *F. schultzei*. Specific objectives of the study were to evaluate 1) effectiveness of insecticides of diverse mode of action in rotation, 2) methods of application of these insecticides, and 3) timing of applications during cropping season. The outcome of this study might provide better management of this thrips, reduce the transmission of the viral disease, and avoid the rapid development of insecticide resistance.

Materials and Methods

Three chemical trials were conducted varying in host crops, insecticide treatments, application methods, and application time. Two studies were conducted on tomato (*Solanum lycopersicum* L.) and one on bell pepper (*Capsicum annuum* L.). All studies were conducted in the research plots of Tropical Research and Education Center (TREC), Homestead, Florida. The soil type of all experimental plots was Krome gravelly loam (loamy-skeletal, carbonatic hyperthermic lithic Udorthents), which consists of about 33% soil and 67% pebbles > 2mm.

Trial 1: Effectiveness on Tomato of Diamide Insecticides vs a Neonicotinoid Insecticide Applied by Soil Drenching followed by Drip Application

This study was designed to determine effectiveness of application of a new class (anthanilic diamide) of insecticides against the standard (neonicotinoid) in achieving control of common blossom thrips. Application methods of insecticides were at planting soil drench followed by drip application.

Field preparation and planting. Raised soil beds each 6 in (15 cm) high and 36 in (91 cm) wide with 6 feet (183 cm) spacing between bed centers were prepared and covered with black on white 1 mL polyethylene mulch (Grower's Solution LLC., 1211 A Boyd Farris Rd., Cookeville, Tennessee). Beds were provided with 2 parallel lines of drip tape (T-systems, DripWorks, Inc., 190 Sanhedrin Circle, Willits, California) having 5 in (13 cm) spacing to supply 1,500 gallons (5,678 L) of water/acre/day. The T-tapes were placed 12 in (30 cm) apart straddling the center of each bed to irrigate and fertigate the plants. At the time of preparation of beds, granular fertilizer 8:16:16 (N: P: K) at the rate of 1,200 pounds/acre (1360 Kg/ha) was broadcast on the upper surface of a bed and incorporated mechanically within the upper 4 in (10 cm) of the soil. 'BHN 585' tomato seedlings were planted 18 in (46 cm) apart within rows. Plants were drip irrigated and fertigated with 4-0-8 (N: P: K) by applying 0.5 lb (0.227 Kg) N/day/acre starting at 4 weeks after planting and progressively increasing this rate by the increment of 0.25 lb (0.113 Kg) every 2 weeks until 4.0 lb (1.81 Kg) N/acre/day when plants were bearing fruit. Each treatment plot consisted of 2 beds, 30 ft long (99.14 m) and was arranged in a Randomized Complete Block (RCB) design with 4 replications. A 5 ft (1.52 m) wide fallow area separated the blocks from each other.

Treatments: Three insecticides - imidacloprid (neonicotinoid, IRAC Group 4A; Admire®, Bayer CropScience, Research Triangle Park, North Carolina), cyazypyr (anthrnilic diamide, IRAC Group 28; Verimark®, DuPont Crop Protection, Wilmington, Delaware) and rynaxypyr (anthranilic diamide; IRAC Group 28; Coragen®, DuPont Crop Protection, Wilmington, Delaware) were evaluated either alone or in rotation with each. Information about rate, date and mode of application has been included in Table 1. Methods of applying insecticide treatments were soil drenching at planting delivering 100 GPA (909.1 L/ha), and drip application post planting by delivering 120 GPA (1,090.1 L/ha). Evaluation of treatments was made once a week for a period of 6 weeks by randomly collecting 10 full grown leaves from each treatment plot. All leaves from a treatment plot were placed in a zip-lock bag and were marked

TABLE 1. VARIOUS TREATMENTS APPLIED IN THE FIRST TRIAL ON 'BHN 585' TOMATO ALONG WITH THEIR BRAND NAMES, MANUFACTURERS, RATES, MODE AND TIMING OF APPLICATION.

Treatment #	Common name	Trade name	Manufacturer	Rate [oz]/acre	Mode of application	Time of application
1	Imidacloprid	Admire Pro	Bayer CropScience	10.5	Drench	At planting
	Cyazypyr	Verimark 20SC	Dupont	10.0	Drip	14 and 28 DAP[1]
2	Imidacloprid	Admire Pro	Bayer CropScience	10.5	Drench	At planting
	Rynaxypyr	Coragen	Dupont	7.0	Drip	35 and 49 DAP
3	Imidacloprid	Admire Pro	Bayer CropScience	10.5	Drench	At planting
4	Cyazypyr	Verimark 20 SC	Dupont	13.5	Drench	At planting
5	Cyazypyr	Verimark	Dupont	13.5	Drench	At planting
	Imidacloprid	Admire Pro	Bayer CropScience	10.5	Drip	14 DAP
6	Control	—	—	—	—	—

[1]DAP = Days after planting

with date, treatment and block number. While collecting in the field, the samples were temporarily placed in an icebox (28 × 16 × 16 in [71 × 41 × 41 cm]) to avoid desiccation. At the end of collection, all samples were transported to the laboratory. Leaf sample in each zip-lock bag was soaked in 50 mL of 70% ethanol for 15-25 min to separate thrips from the leaf/flower samples. Leaf samples were rinsed out of alcohol by continuous and smooth swirling to avoid any escape of thrips from the sample. All thrips left in the alcohol were separated by a 500 mesh (26 micrometer) nematode extraction sieve (W. S. Tyler® Industrial Group, Mentor, Ohio). Finally, thrips specimens in the sieve were transferred to a Petri dish with 5-10 mL ethanol (70%) to count numbers of adults and larvae by a binocular microscope at 10X-20X. Numbers of tomato plants infected with GRSV per plot were recorded on 2 dates: 13 and 20 May.

Trial 2: Effectiveness on Tomato of an Imidacloprid Soil Drench Followed by Foliar Sprays of Either Cyazypyr or Dinotefuran

The study was conducted to determine effectiveness of 2 classes of insecticides (anthranilic diamide and neonicotinoid) in a program for achieving control of the common blossom thrips for an extended period of time. In each program, neonicotinoid (imidacloprid) was applied at planting as a soil drench followed by cyazypyr and dinotefuran as a foliar spray.

'BHN631' tomato seedlings were transplanted in the soil beds. Preparation of beds, maintenance of crops, application of treatments, collection of samples and their further processing were the same as described in the first study. A RCB design was employed to provide 5 replicates each for 5 treatments using a plot size of 3 rows, each 50 ft (15.25 m) long. Three insecticides - imidacloprid, cyazypyr and dinotefuran were tested in this study (Table 2). Imidacloprid was applied as a soil drench, and cyazypyr and dinotefuran were applied as foliar sprays. Three rates of cyazypyr (13.46, 16.82 and 20.5 oz/acre) were used to determine rate response in controlling *F. schultzei*. Soil application of imidacloprid was accomplished by delivering a volume of 120 GPA (1,090.1 L/ha) at the time of planting. Cyazypyr (Exirel®) and dinotefuan were each applied on the foliage on 4 dates at weekly intervals after transplanting. Foliar treatment of cyazypyr was applied by a CO_2 backpack sprayer with 2 nozzles at 30 psi delivering 70-100 GPA (636-909 L/ha). Evaluation of treatments was initiated 10 days after planting and continued at 5-day intervals for 40 days. Treatments were evaluated by randomly collecting 10 leaves per treatment plot for common blossom thrips. On each sampling date of thrips all plants in a plot were thoroughly checked for the presence of GRSV.

TABLE 2. INSECTICIDE TREATMENTS APPLIED IN THE SECOND TRIAL ON 'BHN 585' TOMATO ALONG WITH THEIR BRAND NAMES, MANUFACTURERS, RATES, MODE OF ACTION AND TIMING OF APPLICATION.

Treatment #	Common name	Trade name	Manufacturer	Rate [oz]/acre	Mode of application	No. of applications & interval between them
1	Imidacloprid Cyazypyr	Admire Pro Exirel 10SE	Bayer CropScience Dupont	10.50 13.46	Soil drench Foliar spray	At planting & weekly, 4x
2	Imidacloprid Cyazypyr	Admire Pro Exirel 10SE	Bayer CropScience Dupont	10.50 16.82	Soil drench Foliar spray	At planting & weekly, 4x
3	Imidacloprid Cyazypyr	Admire Pro Exirel 10SE	Bayer CropScience Dupont	10.50 20.50	Soil drench Foliar spray	At planting & weekly, 4x
4	Imidacloprid Dinotefuran	Admire Pro Venom	Bayer CropScience Valent BioSciences	10.50 5.0	Soil drench Foliar spray	At planting & weekly, 4x
5	Control	—	—	—	—	—

Trial 3: Effectiveness on Pepper of Foliar Applications of the Combination of 3 Insecticides vs. Spinetoram

This study was conducted to determine effectiveness of joint foliar applications of spiromesifen, *Chenopodium ambrosioide* compared to spinetoram in controlling common blossom thrips and its transmitted GRSV on pepper.

'Bell' pepper seedlings were transplanted 12 in (30 cm) apart on 8 in (20 cm) high and 36-in (90 cm) wide beds of Rockdale soil. The beds were supplied with drip irrigation lines and covered with 1.5-mL thick black polyethylene mulch. Pepper plants were irrigated once daily using a drip system as described in the first study. Fertilizer (N-P-K mix) was applied at 200-50-240 lbs/acre. To control weeds trifluralin (Treflan EC, 24 lbs/A) was used once at 10 days before planting, supplemented during the middle of the season with mechanical cultivation.

This study involved the use of 3 insecticides in 2 treatments were:1) spirotetramat (IRAC Group 23; Movento®, Bayer CropScience) in combination with Induce (Helena Chemical Company) followed by *Chenopodium ambrosioides* extract,a terpenoid (Requiem®) (IRAC Group not established, Bayer CropScience) and 2) spinetoram (Radiant®) (IRAC Group 5, Dow AgroScience). Treatment's rates/acre, application methods and application timings are shown in Table 3. Treatment plots consisted of 2 beds, each 30 ft (9 m) long and 3 ft wide. Treatments were arranged in a RCB design with 4 replications. A non-planted 5 ft (1.52 m) area separated each block. Treatments were sprayed on 5 dates at weekly intervals by a CO_2 backpack sprayer with 2 flat (even) nozzles (Spraying Systems Co., Wheaton, Illinois 60189-7900, USA)/row delivering 50-70 GPA (454-636 L/ha) depending on the canopy of the volume of experimental pepper plants. Evaluation of treatments was made 24 h after each application by randomly selecting 20 leaves (one leaf/plant) from each treatment plot. All procedures from collection of leaf samples to counting of thrips were as described in the first study. In this study, data presented in the tables represent combination of adults and larvae.

Statistical Analysis

Data from all studies were transformed to square root x + 0.5 prior to performing the analysis of variance (SAS Institute 2003). The means were separated by the Duncan Multiple Range Test at the $P = 0.05$ level of significance. The non-transformed means are presented in tables for the ease of interpretation.

Results

Trial 1: Effectiveness on Tomato of Diamide Insecticides vs a Neonicotinoid Insecticide Applied by Soil Drenching

TABLE 3. VARIOUS TREATMENTS APPLIED IN TRIAL #3 ON 'BELL' PEPPER ALONG WITH THEIR BRAND NAMES, MANUFACTURERS, RATES, MODE OF ACTION AND TIMING OF APPLICATION.

Treatment #	Common name	Trade name	Manufacturer	Rate	Mode of application	No. of applications
1	Spiromesifen	Movento	Bayer CropScience	5.0 oz/acre	Spray	Weekly, 4x
	*Induce	Induce®	Helena Chemical Company	0.25% v/v	Spray	Weekly, 4x
	Chenopodium ambrosioides	Requiem	Bayer CropScience	2.0 qt	Spray S	Weekly, 4x
2	Spinetoram	Radiant	Dow AgroSciences	8.0 oz/acre	Spray	Weekly, 4x
3	Control	—	—	—	—	—

*Induce is a spreader and an adjuvant.

followed by Drip Application

Low population abundance of *F. schultzei* was reported during the entire study season (Table 4). During first few samplings, no significant difference in mean numbers of adults was observed in different treatment plots. On the 5th sampling date mean numbers of adults in all treated plots, except imidacloprid treated plots, were significantly lower than control plots. The effect of treatments on larval count was observed in the 6th sampling (Table 5) where mean numbers of larvae in all treated plots except imidacloprid treated plots were significantly lower than the non-treated control

We observed GRSV infected plants in all treatment plots on the first sampling date (Table 6). Only imidacloprid applied at planting as a soil drench followed by 2 drip applications of cyazypyr at 14 and 28 days after planting (Treatment# 1) and cyazypyr (drench) followed by drip application of imidacloprid 14 days after planting (Treatment# 5) significantly reduced GRSV incidence when compared with the non-treated control. Other treatments did not differ from the non-treated control in reducing GRSV incidence. On the second sampling date, Treatment# 1 and Treatment# 2 had significantly fewer incidence of GRSV than the non-treated plants. Other treatments did not differ from the non-treated control.

Trial 2: Effectiveness on Tomato of an Imidacloprid Soil Drench Followed by Foliar Sprays of Either Cyazypyr or Dinotefuran

Population abundance of *F. schultzei* (adults+ larvae) was low during this study as in the first study (Table 7). *F. schultzei* adults + larvae were recorded on all sampling dates in treated and non-treated tomato plants. Imidacloprid applied as a soil drench followed by weekly foliar applications of cyazypyr at the highest rate (20.5 oz/acre) consistently provided significant suppression of *F. schultzei* population after the first sampling date (10 DAP) compared to the untreated control. However, imidacloprid treatments with low rates of cyazypyr (16.82 and 13.46 oz/acre) showed significant reduction in *F. schultzei* population after second (15 DAP) and fourth (30 DAP) dates, respectively suggesting that high rate of cyazypyr can provide effective control against this pest. Imidacloprid followed by weekly foliar application of dinotefuran significantly reduced *F.schultzei* populations after the second sampling date (15 DAP) when compared with the non-treated control.

The mean numbers of GRSV infected plants in various insecticide treatments for first 3 sampling did not differ from the untreated control (Table 8). Fourth sampling date (25 DAP) onwards, mean number of GRSV infected plants were significantly lower in the plots drenched with imidacloprid

TABLE 4. MEAN NUMBERS OF *FRANKLINIELLA SCHULTZEI* ADULTS/10 LEAF SAMPLE OF TOMATO IN THE SIX INSECTICIDE TREATMENTS IN TRIAL #1.

Treatment #	Treatments	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP	49 DAP
1	Imidacloprid + Cyazypyr	0.00 a	0.00 b	0.25 a	0.50 a	1.00 c	2.00 a
2	Imidacloprid + Rynaxypyr	0.00 a	0.16 b	0.75 a	1.00 a	2.00 bc	3.75 a
3	Imidacloprid	0.00 a	0.50 a	1.00 a	1.25a	2.50 ab	2.75 a
4	Cyazypyr	0.00 a	0.00 b	0.50 a	0.75 a	1.50 bc	2.50 a
5	Cyazypyr + Imidacloprid	0.00 a	0.08 b	0.75 a	0.50 a	1.25 bc	2.75 a
6	Untreated control	0.25 a	0.50 a	1.25 a	1.25 a	3.75 a	4.00 a

Means within a column followed by the same letter do not differ significantly ($P < 0.05$; Duncan Multiple Range Test).

TABLE 5. MEAN NUMBERS OF *FRANKLINIELLA SCHULTZEI* LARVAE/10-LEAF SAMPLE OF TOMATO IN THE VARIOUS INSECTICIDE TREATMENTS IN TRIAL #1.

Treatment #	Treatments	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP	49 DAP
1	Imidacloprid + Cyazypyr	0 a	0 a	0.25 a	0.50 a	1.00	0 c
2	Imidacloprid + Rynaxypyr	0 a	0 a	0.50 a	0.25 a	1.75	0 c
3	Imidacloprid	0 a	0.25 a	0.75 a	1.25 a	1.75	1.75 ab
4	Cyazypyr	0 a	0 a	0.50 a	0.75 a	6.00	1.25 b
5	Cyazypyr + Imidacloprid	0 a	0 a	0.25 a	0.50 a	1.00	1.00 bc
6	Control	0 a	0.50 a	1.00 a	1.25 a	2.50	2.75 a

Means within a column followed by a same letter do not differ significantly ($P < 0.05$; Duncan Multiple Range Test).

TABLE 6. PROGRESSION OF GROUNDNUT RING SPOT VIRUS INFECTION OF TOMATO PLANTS TREATED WITH VARIOUS INSECTICIDE TREATMENTS IN TRIAL #1.

Treatment #	Treatments	21 DAP	28 DAP
1	Imidacloprid Cyazypy	0.25 b	2.50 b
2	Imidacloprid Rynaxypyr	1.75 ab	3.00 b
3	Imidacloprid	1.75 ab	5.50 ab
4	Cyazypyr	1.75 ab	7.25 a
5	Cyazypyr Imidacloprid	0.75 b	5.00 ab
6	Control	3.50 a	8.25 a

Means within a column followed by a same letter do not differ significantly ($P < 0.05$; Duncan Multiple Range Test).

and sprayed with highest rate of cyazypyr (20.5 oz/acre) than the non-treated control. Imidacloprid followed by 2 lower rates of cyazypyr (13.46 and 16.82 oz/acre) showed significant reduction in GRSV incidence on the fifth sampling date (30 DAP) onward compared to the untreated control. Effect of dinotefuran treatment in suppressing GRSV incidence was slower than cyazypyr treatments and was found to be effective 35 DAP.

Trial 3: Effectiveness on Pepper of Foliar Applications of the Combination of 3 Insecticides vs. Spinetoram

Population abundance of *F. schultzei* adults was low during this study (Table 9). Adults were recorded on all sampling dates in the non-treated control plants. In this trial, none of the insecticide treatments was found to be effective in regulating *F. schultzei* population on any sampling date. Mean numbers of adults in the treated plants, irrespective of insecticides, did not differ from the non-treated control on any of the sampling dates. Corresponding to adults' abundance, treatments had no significant effect on the larval abundance in plots (Table 10).

We found that at the low population level of *F. schultzei* it was still able to spread GRSV (Table 11) to pepper crop. Thus, no significant difference in GRSV incidence was observed in insecticide treated and non-treated control plots.

DISCUSSION

We conducted 3 trials on tomato and pepper using 7 insecticides belonging to 5 IRAC groups. Imidacloprid and dinotefuran are neonicotinoid insecticide belonging to IRAC Group 4A; Cyazypyr and Rynaxypyr are diamide insecticides belonging to IRAC Group 28; Spirotetramat is a Tetronic acid derivative belonging to IRAC Group 23; Spinetoram is a spinosyn insecticide belonging to IRAC Group 5, and *Chenopodium ambrosioides* is a plant extract that not been assigned to an IRAC Group. These insecticides have modes of action

TABLE 7. MEAN NUMBERS OF *FRANKLINIELLA SCHULTZEI* (ADULTS + LARVAE)/10-LEAF SAMPLE OF TOMATO TREATED WITH IMIDACLOPRID AS A SOIL DRENCH, CYAZYPYR BY FOLIAR APPLICATION AND DINOTEFURAN BY FOLIAR APPLICATION IN TRIAL #2. DATA PERTAINING TO ADULTS AND LARVAE WERE COMBINED.

Treatment #	Treatment	Rate [oz]/acre	10 DAP	15 DAP	20 DAP	25 DAP	30 DAP	35 DAP	40 DAP
1	Imidacloprid Cyazypyr	10.50 13.46	1.0 a	0.66 ab	1.00 ab	1.00 a	1.00 b	1.00 b	1.00 b
2	Imidacloprid Cyazypyr	10.50 16.82	0.67 a	0.33 ab	0.66 b	0.00 b	0.66 bc	0.00 c	1.00 b
3	Imidacloprid Cyazypyr	10.50 20.5	0.33 a	0.00 b	0.33 b	0.33 b	0.00 c	0.33 bc	0.00 c
4	Imidacloprid Dinotefuran	10.50 5.0	1.33 a	0.33 ab	0.33 b	0.00 b	0.33 bc	0.66 bc	1.00 b
5	Control	—	1.66 a	1.00 a	2.33 a	1.67 a	2.67 a	2.33 a	2.33 a

Means within a column followed by the same letter do not differ significantly ($P < 0.05$; Duncan Multiple Range Test).

TABLE 8. MEAN NUMBERS OF GROUND NUT RING SPOT VIRUS (GRSV) INFECTED TOMATO PLANTS/PLOT THAT WERE TREATED WITH IMIDACLOPRID (SOIL DRENCH), CYAZYPYR (FOLIAR APPLICATION) AND DINOTEFURAN (FOLIAR APPLICATION) IN TRIAL #2.

Treatment #	Treatments	Rate oz/acre	10 DAP	15 DAP	20 DAP	25 DAP	30 DAP	35 DAP	40 DAP	45 DAP
1	Admire Pro	10.50	1.67 a	2.00 a	5.00 a	5.67 a	7.50 b	7.00 b	11.33 b	15.66 b
	Cyazypyr	13.46								
2	Imidacloprid	10.50	1.00 a	1.33 a	3.33 a	5.00 a	4.00 bc	4.00 cd	11.00 b	12.00 c
	Cyazypyr	16.82								
3	Imidacloprid	10.50	1.00 a	0.67a	1.66 a	1.33 b	2.33 c	3.00 d	5.00 c	7.00 d
	Cyazypyr	20.5								
4	Imidacloprid	10.50	2.00 a	0.67 a	3.67 a	3.67 ab	6.00 ab	5.00 bc	9.00 b	10.33 c
	Dinotefuran	5.0								
5	Control	—	0.67 a	1.67 a	4.00 a	6.67 a	7.66 a	10.67 a	15.66 a	29.33 a

Means within a column followed by the same letter do not differ significantly ($P < 0.05$; Duncan Multiple Range Test).

(MOA). Neonicotinoid insecticides are neurotoxic, while the diamide insecticide chlorantraniliprole acts on calcium channels in muscles causing uncontrolled calcium release resulting in muscle contraction. Spirotetramat is a new insecticide, which inhibits lipid production causing growth inhibition in immatures and reduced reproduction in adults. Spinetoram (active ingredient spinosad) acts in a manner similar to neonicotinoids. *Chenopodium ambrosioides* is a unique product having multisite mode of action. It degrades the exocuticle and destroys the tracheal lining of soft bodied insects.

In the first trial, none of the treatments provided season long control of *F. schultzei* adults and larvae. Regardless of the inconsistent effectiveness of insecticides in reducing *F. schultzei* population, imidacloprid as a plant drench followed by 2 drip applications of diamide insecticides provided significant reduction of GRSV infection. We speculate that increased thrips abundance at the later stages of the study could be due to the movement of thrips population from neighboring vegetation. Imidacloprid alone did not control *F. schultzei* adults and larvae on tomato, but when imidacloprid treatment was followed by drip application of cyazypyr, greater suppression of the *F. schultzei* population was achieved. Cyazypyr alone applied at planting inconsistently reduced *F. schultzei*. However, use of cyazypyr in a program with imidacloprid was more effective than any insecticide applied alone. In the second trial, application of imidacloprid at planting followed by cyazypyr on foliage provided better control of *F. schultzei* adults and larvae and less transmission of GRSV than soil application of cyazypyr. Also, the higher rate of cyazypyr performed better than the lower rate. In trials involving foliar application, the contact of thrips with the insecticide could be a reason for improved control of thrips and less transmission of the virus. In the last trial conducted on pepper, Spinetoram, Spirotetramat and *Chenopodium ambrosioides* applied on foliage neither reduced the thrips population nor the transmission of GRSV to the plants. The present study result differs from Dow AgroScience's study in Australia where foliar application of Spinetoram and Spirotetramat provided significant reduction of *F. schultzei* population and its transmission of the tomato spotted wilt virus (Dow AgroSciences 2013). In this region, Spinetoram has been used for controlling multiple pests of vegetable, ornamental and fruit crops for more than 15 yr. Due to such prolonged use, reduced efficacy of Spinetoram in controlling melon thrips and other thrips species has been experienced in various studies conducted in South Florida (D.R.S. unpublished data). Thus, in order to delay resistance development in the target thrips species and to keep effective chemistries on the market it is very important to rotate

TABLE 9. MEAN NUMBERS IN TRIAL #3 OF *FRANKLINIELLA SCHULTZEI* ADULTS/20 LEAF OF 'BELL' PEPPER TREATED WITH SPIROTETRAMAT, *CHENOPODIUM AMBROSIOIDE*S, AND SPINETORAM. ALL INSECTICIDES WERE SPRAYED ON THE FOLIAGE.

Treatment #	Treatments	Rate [oz]/acre	Week 1	Week 2	Week 3	Week 4	Week 5
1	Mixture: Spirotetramat, Induce* and *Chenopodium ambrosioides*	5.0 oz 0.25% 2.0 qt or 1.8 L	0 a	0 a	0.25 a	1.00 a	0.50 a
2	Spinetoram	8.0 oz	0 a	0.20 a	0.75 a	2.00 a	1.00 a
3	Control	—	0.25 a	0.25 a	0.50 a	1.25 a	1.25 a

Means within a column followed by same letter letters do not differ statistically ($P < 0.05$; Duncan Multiple Range Test).
*Induce is a spreader and adjuvant.

TABLE 10. MEAN NUMBERS IN TRIAL #3 OF *FRANKLINIELLA SCHULTZEI* LARVAE/20 LEAF SAMPLE OF 'BELL' PEPPER TREATED WITH SPIROTETRAMAT, *CHENOPODIUM AMBROSIOIDE*S, AND SPINETORAM. ALL INSECTICIDES WERE APPLIED ON FOLIAGE.

Treatment #	Treatments	Rate /acre	Week 1	Week 2	Week 3	Week 4	Week 5
1	Spirotetramat, Induce* and *Chenopodium ambrosioides*	5.0 oz or 0.37 0.25% 2.0 qt or 1.8	0 a	0 a	0 a	0.50 a	0.25 a
2	Spinetoram	8.0 oz	0 a	0.6 a	0.50 a	1.00 a	1.33 a
3	Control	—	0 a	0	0.50 a	1.25 a	1.75 a

Means within a column followed by same letter do not differ statistically ($P < 0.05$; Duncan Multiple Range Test).

TABLE 11. MEAN NUMBERS OF GROUNDNUT RING SPOT VIRUS INFECTED 'BELL' PEPPER PLANTS PER PLOTTREATED WITH SPIROTETRAMAT, *CHENOPODIUM AMBROSIOIDE*S, AND SPINETORAM IN TRIAL #3.

Treatment #	Treatments	Rate [oz]/acre	Week 1	Week 2	Week 3	Week 4	Week 5
1	Spirotetramat, Induce*, *Chenopodium ambrosioides*	5.0 oz 0.25% 2.0 qt	0.0 a	0.00 a	0.25 a	0.50 a	1.50 a
2	Spinetoram	8.0 oz	0.0 a	1.00 a	0.75 a	0.75 a	1.00 a
3	Control	—	0.0 a	0.00 a	0.50 a	1.00 a	1.75 a

Means within a column followed by same letters or no letters do not differ statistically ($P < 0.05$; Duncan Multiple Range Test).

the use various insecticides with different modes of action.

In summary, diamide insecticide (cyazypyr) showed efficacy in managing *F. schultzei*. However, diamide insecticides in a program with neonicotinoid (Imidacloprid) provided better management of *F. schultzei* and GRSV. Foliar application of diamide insecticide was more effective than soil application of the same. Further research should be conducted by using both foliar and soil application of diamide in the same study.

DISCLAIMER

Federal and Florida laws require that all pesticides must be handled and applied in strict accordance with the label and worker protection standards (re-entry times, protective clothing, etc.). For complete information pertaining to use of any insecticides, follow the label. Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the University of Florida.

REFERENCES CITED

BOURNIER, J. P. 1994. Thysanoptera, pp, 381-391 *In* G. A. Matthews and J. P. Tunstall [eds.], Insect Pests of Cotton. CAB International, Wallingford UK.

CABI 2014. Cotton thrips (*Frankliniella* schultzei) Plantwise. http://www.plantwise.org/KnowledgeBank/Datasheet.aspx?dsid=24431 (Accessed: 14-I-2014).

DOW AGROSCIENCES. 2013. Success™ NEO. Tomato spotted wilt virus (TSWV) control. http://msdssearch.dow.com/PublishedLiteratureDAS/dh_08bc/0901b803808bcf62.pdf?filepath=au/pdfs/noreg/012-10836.pdf&fromPage=GetDoc (Accessed: 4-I-2014).

GUIMARAES, A. M., PAVAN, M. A., AND KUROZAWA, E. 1997. Effect of corn wind breaks on the incidence of tospovirus on tomato crop. Fitopatol. Brasileira 22: 142-147.

HORTICULTURE AUSTRALIA. 2005. Capsicum virus diseases. Vegenotes. 2 pp. http://savegido.arris.com.au/uploads/documents/vegenotes/2005/Capsicum%20virus%20Disease%202.pdf. (Accessed: 14-I-2014).

KAKKAR, G., SEAL, D. R., AND KUMAR, V. 2010. Common blossom thrips scientific name: Frankliniella schultzei Trybom (Insecta: Thysanoptera: Thripidae). http://entnemdept.ufl.edu/creatures/veg/thrips/common_blossom_thrips.htm. (Accessed: 14-I-2014).

KAKKAR, G., SEAL D. R., AND KUMAR, V. 2012a. Assessing abundance and distribution of an invasive thrips *Frankliniella schultzei* (Trybom) (Thysanoptera: Thripidae) in South Florida. Bull. Entomol. Res. 102: 249-259.

KAKKAR G., SEAL, D. R., STANSLY, P., LIBURD, O. E., AND KUMAR, V. 2012b. Abundance of *Frankliniella schultzei* (Thysanoptera: Thripidae) in flowers on major vegetable crops of south Florida. Florida Entomol. 95: 468-475.

KLOSE, M. J., SDOODEE, R., TEAKLE, D. S., MILNE, J. R., GREBER, R. S., AND WALTER, G. H. 1996. Transmission of three strains of Tobacco streak ilarvirus by different thrips species using virus-infected pollen. J. Phytopathol. 144: 281-284.

LONDOÑO, A., CAPOBIANCO, H., ZHANG, S., AND POLSTON, J. E. 2012. First record of Tomato chlorotic spot virus in the USA. Trop. Plant Pathol. 37: 333-338.

MILNE, J. R., JHUMLEKHASING, M., AND WALTER, G. H. 1996. Understanding host plant relationships of polyphagous flower thrips, a case study of *Frankliniella schultzei* (Trybom), pp. 8-14 *In* S. Goodwin and P. Gillespie [eds.], Proc. 1995 Australia and New Zealand Thrips Workshop: Methods, Biology, Ecology and Management, NSW Agriculture, Gosford, Australia.

MILNE, M., AND WALTER, G. H. 2000. Feeding and breeding across host plants within a locality by the widespread thrips, *Frankliniella schultzei*, and the invasive potential of polyphagous herbivores. Divers. Distrib. 6: 243-257.

PALMER, J. M. 1990. Identification of the common thrips of Tropical Africa (Thysanoptera: Insecta). Trop. Pest Mgt. 36: 27-49.

SAKIMURA, K. 1969. A comment on the color forms of *Frankliniella schultzei* (Thysanoptera: Thripidae) in relation to transmission of the tomato-spotted wild virus. Pacific Insects 11: 761-762.

SAS INSTITUTE. 2003. SAS® system for Windows, version 9.1. SAS Institute, Inc., Cary, NC.

WEBSTER, C. G., PERRY, K. L., LU, X., HORSMAN, L., FRANTZ, G., MELLINGER, C., AND ADKINS, S. 2010. First report of Groundnut ringspot virus infecting tomato in south Florida. Online. Plant Health Prog. doi:10.1094/PHP-2010-0707-01-BR.

WIJKAMP, I., ALMARZA, N., GOLDBACK, R., AND PETERS. D. 1995. Distinct levels of specificity in thrips transmission of Tospoviruses. Phytopathology 85: 1069-1074.