Management of Flower Thrips in Florida Strawberries with Steinernema feltiae (Rhabditida: Steinernematidae) and the Insecticide Sulfoxaflor

Authors: Renkema, Justin M., Evans, Braden, and Devkota, Shashan

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Management of flower thrips in Florida strawberries with *Steinernema feltiae* (Rhabditida: Steinernematidae) and the insecticide sulfoxaflor

Justin M. Renkema, Braden Evans, and Shashan Devkota*

Abstract

Flower thrips (mainly *Frankliniella* spp.) (Thysanoptera: Thripidae) are common in Florida strawberries, causing bronzed fruit and reduced yields. As control relies on just a few insecticides, there is a need to evaluate novel management options and insecticides. The entomopathogenic nematode *Steinernema feltiae* (Filipjev) (Rhabditida: Steinernematidae) has been shown to be effective on flower thrips larvae in other plants, and the new insecticide sulfoxaflor has been effective on thrips in other crops. In winter 2016, *S. feltiae* was evaluated at 2 foliar application rates (2.47 and 4.94 billion infective juveniles per ha) in combination with and without the insecticide spinetoram by counting thrips in strawberry flowers and assessing numbers of damaged fruits. A second experiment was conducted to compare sulfoxaflor, spinetoram, and *S. feltiae* applications based on flower thrips thresholds. High and low *S. feltiae* rates did not reduce or suppress thrips and did not reduce fruit damage. Sulfoxaflor reduced thrips by 60 to 70% compared to the reduction caused by spinetoram. Hot, dry conditions likely limited the survival and effectiveness of *S. feltiae*. Sulfoxaflor appears to be a promising insecticide for flower thrips, and may reduce reliance on spinetoram by strawberry producers.

Key Words: *Frankliniella bispinosa*; Florida flower thrips; Closer; Radiant; spinetoram; Nemasys

Resumen

Los trips de las flores (principalmente *Frankliniella* spp.) (Thysanoptera: Thripidae) son comunes en las fresas de Florida, causando frutos bronceados y rendimientos reducidos. Como el control depende de unos pocos insecticidas, existe la necesidad de evaluar nuevas opciones de manejo e insecticidas. Se ha demostrado que el nematodo entomopatógeno *Steinernema feltiae* (Filipjev) (Rhabditida: Steinernematidae) es efectivo contra las larvas de trips de las flores en otras plantas, y el nuevo insecticida sulfoxaflor ha sido efectivo contra los trips en otros cultivos. En el invierno del 2016, se evaluó *S. feltiae* a 2 tasas de aplicación foliar (2,47 y 4,94 mil millones de juveniles infecciosos por ha) en combinación con y sin el insecticida spinetoram contando los trips en las flores de fresa y evaluando la cantidad de frutos dañados. Se realizó un segundo experimento para comparar las aplicaciones de sulfoxaflor, spinetoram y *S. feltiae* en función de los umbrales de los trips de las flores. Las tasas altas y bajas de *S. feltiae* no redujeron ni suprimieron los trips y no redujeron el daño de la fruta. Sulfoxaflor redujo los trips en un 60 para 70% en comparación con la reducción causada por el spinetoram. Las condiciones secas y calientes probablemente limitaron la sobrevivencia y la efectividad de *S. feltiae*. El sulfoxaflor parece ser un insecticida prometedor para los trips de las flores, y puede reducir la dependencia del espinetoram por parte de los productores de fresas.

Palabras Clave: *Frankliniella bispinosa*; trips de las flores de Florida; Closer; Radiant; spinetoram; Nemasys

Thrips (Thysanoptera) are small, slender "fringe-winged" insects, of which many species are plant feeders, and some are significant pests of crops and commodities worldwide (Childers 1997). Thrips in the genus *Frankliniella* (Thysanoptera: Thripidae) (flower thrips) feed on swollen buds, open flowers, and developing fruits of many vegetables, fruits, and ornamentals, therein causing necrosis, cellular collapse, distortion, discoloration, silvering, or fruit abortion (Childers & Achor 1991; Childers 1997; Shipp et al. 2000). In strawberry, *Frankliniella* spp. and other genera have been linked to flower damage and fruit bronzing and scarring in many production regions, including the United States, Europe, Australia and Japan (Steiner & Goodwin 2005). The cosmopolitan *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) may have the greatest economic impact on strawberry, but relationships between *F. occidentalis* density and crop damage are variable (Steiner & Goodwin 2005; Coll et al. 2006; Atakan 2011). *Frankliniella occidentalis* has been established in Florida, USA, since 1982 and has affected strawberry production in the state since 2004 (Kirk & Terry 2003; Whidden 2004). In addition, the native *Frankliniella bispinosa* Morgan (Thysanoptera: Thripidae) occurs in strawberry in the southern half of Florida and likely causes flower and fruit damage, as it does in blueberry and bell pepper (Reitz et al. 2003; Rhodes and Liburd 2011). *Frankliniella* spp. can be difficult to manage because of their cryptic behavior, rapid reproduction, and the ability of *F. occidentalis* to develop resistance to insecticides (Immaraju et al. 1992; Broadbent & Pree 1997). Therefore, new approaches and tools for thrips management are needed for Florida strawberries.

Entomopathogenic nematodes have been widely assessed for suppression of life stages of agricultural pests that are spent primarily in the soil, where free-living infective juvenile nematodes occur (Gothro 2000). When the host insect's habitat is suitably humid and cryptic, entomopathogenic nematodes have shown some efficacy for suppression of above-ground pests (Olthof & Broadbent 1992; Williams & Walters

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University of Florida, Gulf Coast Research and Education Center, 14625 County Rd. 672, Balm, Florida, 33598, USA; E-mails: justin.renkema@ufl.edu (J. M. R.), braden.evans@ufl.edu (B. E.), devkotasashan@ufl.edu (S. D.)
*Corresponding author; E-mail: justin.renkema@ufl.edu

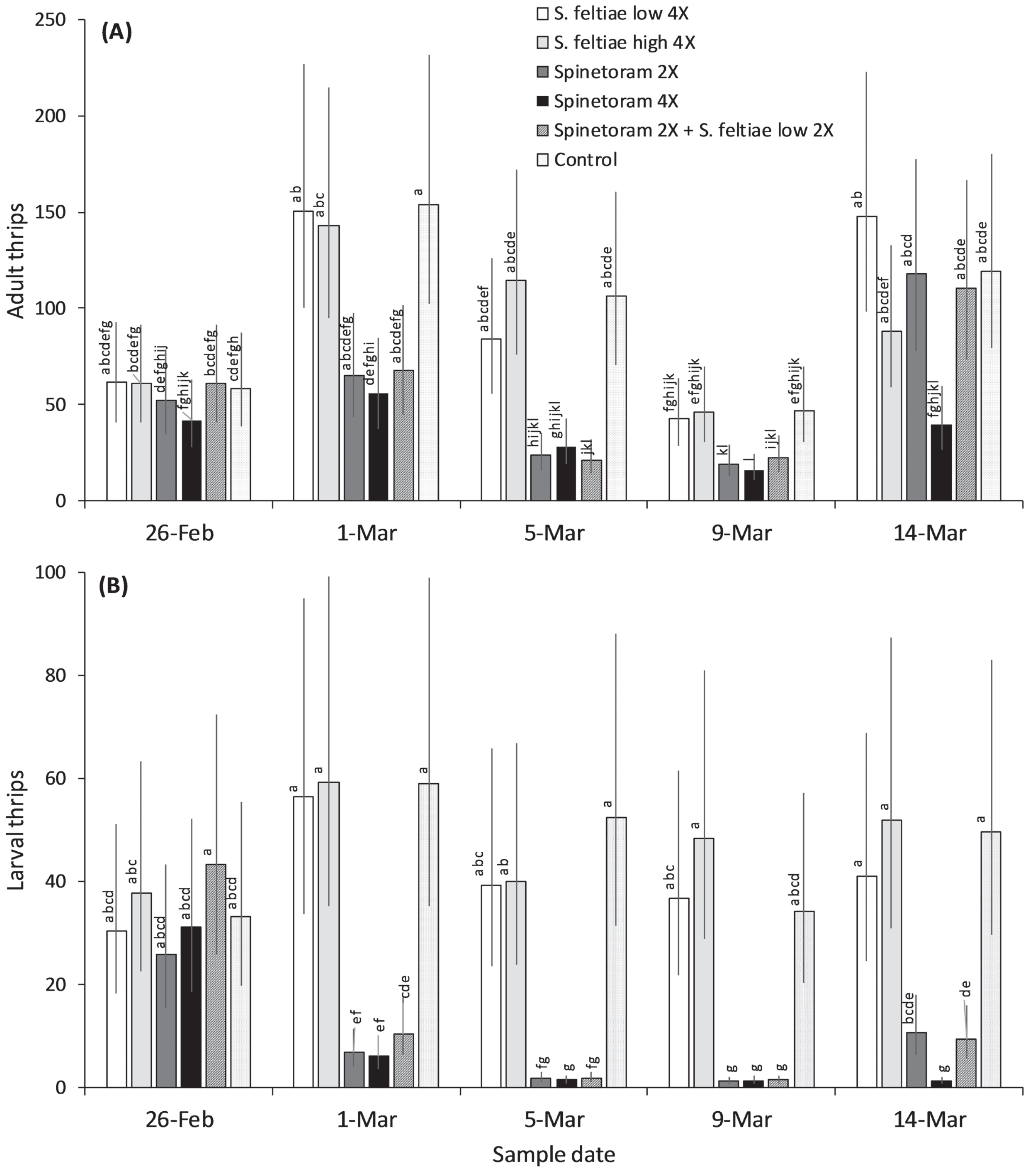

Fig. 1. Least square means (± 95% confidence intervals) for (A) adult and (B) larval thrips (*Frankliniella bispinosa*) per 10 strawberry flowers from research plots near Balm, Florida, sprayed 26 Feb, and 1, 5, and 9 Mar 2016 with *Steinernema feltiae* or insecticides. Means in each panel with the same letter are not significantly different (Tukey's HSD test, α = 0.05) (Experiment 1).

2000; Shapiro-Ilan et al. 2006). Several entomopathogenic nematode species attack soil-dwelling pupae of *F. occidentalis* (Ebssa et al. 2001), and *Steinernema feltiae* (Filipjev) (Rhabditida: Steinernematidae) is capable in the laboratory of causing mortality to the larval and pre-pupal stages (Buitenhuis & Shipp 2005). Wardlow et al. (2001) reported effective control of *F. occidentalis* with weekly applications, but Buitenhuis & Shipp (2005) reported no reduction of *F. occidentalis* after a foliar application in chrysanthemum, *Dendranthema grandiflora* Tzvelev (Compositae), flowers. Factors that affect entomopathogenic nematode efficacy include the innate infectivity of nematode species, differences in susceptibility of thrips developmental stages, differences among thrips species, the complexity of flowers and degree of concealment for entomopathogenic nematodes afforded by flowers, and addition of adjuvants that may facilitate entomopathogenic nematode movement and host finding by reducing rates of drying and desiccation (Kaya & Gaugler 1993; Broadbent & Olthof 1995; Baur et al. 1997; Buitenhuis & Shipp 2005; Cuthbertson et al. 2005).

In addition to non-chemical controls, new insecticides with novel modes of action will be useful for developing an effective management program for thrips in strawberries. The sulfoximines, in particular sulfoxaflor, act on insect nicotinic receptors, similar to other insecticide classes (spinosysns, neonicotinoids), but have a number of different structure-activity relationships that confer a unique mode of action (Watson et al. 2011; Sparks et al. 2013). Sulfoxaflor has potent insecticidal activity on many sap-feeding insects, and has not exhibited cross-resistance when tested on imidacloprid-resistant strains of sweetpotato whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) and brown planthopper, *Nilaparvata lugens* (Stål) (Hemiptera: Delphacidae) (Babcock et al. 2011). For thrips control, 4-insecticide rotations including an application of sulfoxaflor were as effective as rotations without sulfoxaflor for suppression of flower thrips species in Florida strawberries; however, sulfoxaflor-specific data was not presented (Cleuver et al. 2016). Sulfoxaflor reduced melon thrips, *Thrips palmi* Karny (Thysanoptera: Thripidae), in eggplant (Seal 2012); citrus thrips, *Scirtothrips citri* (Moulton) (Thysanoptera: Thripidae), in navel oranges and southern highbush blueberries (Haviland & Rill 2015; Van Steenwyk et al. 2016); and *F. occidentalis* in iceberg head lettuce (Natwick & Lopez 2014). Sulfoxaflor may be an effective alternative to commonly used insecticides for thrips in Florida strawberries, such as spinetoram and acetamiprid, but further testing is needed.

Thrips have become a major challenge for Florida producers of winter (Nov–Mar) strawberries (Cluever et al. 2016). As seasonal temperatures have been above historical average and freezing events rare in recent years in strawberry producing areas (FAWN 2017), flower thrips populations do not decline but remain high throughout the season. Wild hosts are common around fields; wild radish, *Raphanus raphanistrum* L. (Brassicaceae), seems to be increasing in abundance and produces flowers almost continuously throughout the strawberry season, acting as a reservoir for *F. bispinosa* (Cleuver et al. 2016). Chilli thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae), is a recent Florida invader of subtropical/tropical origin (Dickey et al. 2015) that damages new foliage of young strawberry plants and is having an increased impact with fall and winter temperatures, generally above-normal in recent years. Furthermore, the same insecticides are typically effective on flower and chilli thrips, so growers must carefully manage the timing of a limited number of applications. The objective of this study was to evaluate foliar applications of *S. feltiae* and the insecticide sulfoxaflor in Florida strawberries for suppression of flower-inhabiting thrips, and on strawberry yield. This research was conducted in an effort to provide Florida strawberry growers with additional tools to rotate with existing products and practices for thrips control.

Materials and Methods

Two experiments to test efficacy of insecticides and an entomopathogenic nematode on flower thrips were conducted in plots of winter strawberries at the Gulf Coast Research and Education Center, Balm, Florida, USA (27.7621°N, 82.2258°W). Bare-root strawberry transplants (cv. 'Radiance') were set 14 Oct 2015 at 38 cm spacing in raised, black plastic-mulched beds at 1.2 m spacing. Fumigation with Telone® C-35 (1,3-dichloropropene + chloropicrin) occurred at bed formation on 20 Aug 2015. Plants were overhead irrigated for 10 d following transplanting and drip-irrigated and fertigated with 0.27 and 0.34 kg N per d from Nov to Jan and Feb to Apr, respectively. Round-up® (glyphosate) and Chateau® (flumioxazin) were applied to row aisles before transplanting to control weeds. Plants received weekly applications of fungicides and occasional applications of DiPel® DF (*Bacillus thuringiensis*, subsp. *kurstaki*) Berliner (Bacillales) to control lepidopteran larvae.

Each strawberry plot was a 10 m double-row, single bed (50–54 plants). Plots were laid out in 5 adjacent beds in a randomized complete block design, with a 1 m and 2 m unplanted buffer on the ends of plots within blocks and between blocks, respectively. Experiment 1 was conducted on the first, third, and fifth row, and Experiment 2 on the second and fourth row, so that there were unsprayed strawberry rows between plots for both experiments.

Treatments were applied at 940 L per ha with a CO_2-powered backpack sprayer (R & D Sprayers, Opelousas, Louisiana, USA) at 60 PSI using a hand-held wand sprayer with 2 nozzles without filters. Insecticides, entomopathogenic nematodes, and controls (water) were mixed with the non-ionic surfactant, Induce® (0.25% v/v) (Helena Chemical Co., Collierville, Tennessee, USA). Applications were made 1 h prior to sunset to facilitate entomopathogenic nematode survival in flowers. Treatment efficacy was evaluated by randomly selecting 10 open flowers per plot and quickly placing them in plastic centrifuge tubes (50 mL) half-filled with 70% ethanol. In the laboratory, flowers were poured from tubes into Petri dishes and each flower was held with forceps and washed with additional ethanol before discarding it. Adult and larval

Table 1. Analysis of variance results and means (95% confidence limits) for thrips (*Frankliniella bispinosa*) and insidious flower bugs (*Orius* spp.) per 10 flowers, and thrips-damaged strawberries from plots sprayed with *Steinernema feltiae*, spinetoram, or both treatments 26 Feb to 9 Mar 2016 near Balm, Florida (Experiment 1). Means within columns followed by the same letter are not significantly different (Tukey's HSD, α = 0.05).

Treatment, rate, applications		Total thrips	Adult thrips	Larval thrips	Insidious flower bugs	% damage
S. feltiae, low, 4X		129.8 (93.9-179.4)a	86.7 (62.4-120.4)a	40.0 (29.3-54.6)a	3.6 (2.3-5.1)	1.6 (0.9-2.3)ab
S. feltiae, high, 4X		133.8 (96.8-185.0)a	83.6 (60.2-116.1)a	46.8 (34.3-63.9)a	3.8 (2.5-5.4)	1.5 (0.8-2.2)ab
Spinetoram, 2X		50.9 (36.8-70.3)bc	44.8 (32.2-62.2)bc	5.3 (3.9-7.2)b	3.0 (1.8-4.4)	0.7 (0.3-1.2)bc
Spinetoram, 4X		38.8 (28.0-53.6)c	33.5 (24.1-46.5)c	3.3 (2.4-4.5)c	2.1 (1.1-3.3)	0.1 (0.0-0.5)c
Spinetoram, 2X + *S. feltiae*, low, 2X		55.3 (40.0-76.5)b	46.6 (33.6-64.7)b	6.5 (4.7-8.8)b	1.8 (1.0-3.0)	0.8 (0.4-1.3)abc
Control		134.2 (97.1-185.5)a	88.1 (63.4-122.3)a	44.4 (32.5-60.7)a	4.1 (2.7-5.7)	2.0 (1.3-2.8)a
Treatment, df = 5, 87	*F*	63.9	31.7	127.7	2.8	7.9
	P	<0.0001	<0.0001	<0.0001	0.021	<0.0001
Treatment × date, df = 20, 87	*F*	6.7	4.1	11.3	0.6	1.2
	P	<0.0001	<0.0001	<0.0001	0.925	0.248

Table 2. Analysis of variance results and means (95% confidence limits) for thrips (*Frankliniella bispinosa*) and insidious flower bugs (*Orius* spp.) per 10 flowers, and thrips-damaged strawberries from plots sprayed with *Steinernema feltiae*, spinetoram, or sulfoxaflor 2 to 24 Mar 2016 near Balm, Florida (Experiment 2). Means within columns followed by the same letter are not significantly different (Tukey's HSD, α = 0.05).

Treatment, rate, applications		Total thrips	Adult thrips	Larval thrips	Insidious flower bugs	% damage
S. feltiae, high, 3X		52.3 (42.1-64.8)a	34.1 (24.0-38.1)	17.1 (13.0-22.6)a	2.0 (1.3-2.9)ab	3.05 (1.51-5.14)ab
Spinetoram, 2X		27.9 (22.5-34.7)b	24.5 (19.4-30.9)	3.8 (2.9-5.0)c	1.4 (0.8-2.1)	0.03 (0.00-0.47)c
Sulfoxaflor, 2X		38.9 (31.4-48.3)ab	30.2 (24.0-38.1)	7.8 (5.9-10.3)b	1.3 (0.7-2.0)b	1.35 (0.41-2.83)b
Control		51.3 (41.4-63.6)a	32.9 (26.1-41.5)	16.4 (12.4-21.6)a	3.0 (2.1-4.0)a	4.46 (2.54-6.92)a
Treatment, df = 3, 69	*F*	10.7	2.3	34.0	3.6	15.9[a]
	P	<0.0001	0.090	<0.0001	0.018	0.001
Treatment × date, df = 15, 69	*F*	2.3	1.2	2.9	0.7	—
	P	0.010	0.331	0.002	0.733	—

[a] df = 3, 9

thrips and predatory insidious flower bugs (*Orius* spp.) (Hemiptera: Anthocoridae) in the ethanol were identified and counted under a stereomicroscope. Yield was evaluated by harvesting all ripe strawberries in each plot and evaluating for thrips-related damage, such as bronzing, scarring, or cracking.

EXPERIMENT 1

Treatment applications began when symptoms of flower thrips injury—flower abortion and petal browning or necrotic flecking—were first observed in late Feb and daily temperatures began to increase. Spinetoram (Radiant® SC, 11.7%, Dow AgroSciences, Indianapolis, Indiana, USA) at 85.5 mL active ingredient per ha, and *S. feltiae* (Nemasys®, BASF Corp., Research Triangle Park, North Carolina, USA), prepared according to the manufacturer's specifications in cold water at 2.47 (low rate) and 4.94 (high rate) billion infective juveniles per ha, were applied 26 Feb, and 1, 5, and 9 Mar 2016. Treatments were spinetoram, *S. feltiae* low rate, or *S. feltiae* high rate applied on all dates; spinetoram applied on the first 2 dates followed by water or *S. feltiae* low rate on the final 2 dates; and a water only control on all dates. Flowers were sampled 26 Feb, and 1, 5, 9, and 16 Mar 2016, and strawberries were harvested 1, 5, 9, 14, and 19 Mar 2016.

EXPERIMENT 2

Initial treatments were spinetoram, *S. feltiae* (high rate) and sulfoxaflor (Closer® SC, 21.8%, Dow AgroSciences, Indianapolis, Indiana, USA) at 78.45g per ha. Treatments were re-applied when thrips numbers exceeded a threshold of 5 thrips per flower. Flowers were sampled 2, 7, 11, 15, 20, and 24 Mar 2016. Thrips were counted from at least 2 replications of each treatment to make subsequent application decisions. All treatments were applied 3 Mar 2016, *S. feltiae* was reapplied 7, and 16 Mar 2016, and spinetoram and sulfoxaflor were reapplied 16 Mar 2016. Water was applied to plots when thrips numbers were below threshold. Strawberries were harvested 21 Mar 2016. A subsample of adult thrips were randomly selected from each sample (15% of total, but a minimum of 8 or maximum of 20) and identified to species.

DATA ANALYSIS

For each experiment, a mixed-model analysis of variance (ANOVA) was used to test effects of treatments on numbers of total thrips, larval thrips, adult thrips, insidious flower bugs, yield per plant, and proportion of thrips-damaged strawberries. Sample date and date by treatment interaction were included as repeated measures, and block as random effect. Because yield and damage were evaluated only once in Experiment 2, there was no date term in the ANOVA. Numbers of total and adult thrips and yield were log (*x*) transformed, larval thrips log (*x* + 1) transformed, and insidious flower bug and damage square-root (*x*) transformed to normalize error variance and meet ANOVA assumptions. Means were compared using Tukey's HSD test at α = 0.05. Back-transformed means and 95% confidence intervals are displayed. JMP® Pro 12.0.1 (SAS 2015) was used for analysis.

Results

EXPERIMENT 1

All adult thrips in subsamples were *F. bispinosa*; no *F. occidentalis*, *F. shultzei*, or *H. gowdeyi* were identified, as in Cleuver et al. (2016). Applications of spinetoram at 2 times, 4 times, or 2 times the normal rate followed by a low rate of *S. feltiae* at twice the normal rate, reduced total thrips, adult thrips, and larval thrips compared to the control, but low or high application rates of *S. feltiae* did not (Table 1). Adult thrips numbers were lower in all plots on 9 Mar 2016 compared to 1 Mar 2016, whereas larval thrips numbers remained similar among all sample dates for the control and *S. feltiae*-treated plots (Fig. 1A, B). Applications of spinetoram + *S. feltiae* did not reduce adult or larval thrips compared to spinetoram alone (Fig. 1A, B). Numbers of insidious flower bugs differed among treatments, but no significant separation of means was detected using Tukey's HSD test. Four applications of spinetoram resulted in about half as many insidious flower bugs compared to the control (Table 1). There were no differences in total yield among treatments (*F* = 1.1; df = 5,79; *P* = 0.364) or among treatments by harvest dates (*F* = 0.9; df = 20,79; *P* = 0.904). The proportion of thrips-damaged fruit was greater in the control compared to spinetoram only treatments, but there were no differences between the control and *S. feltiae*-treated plots (Table 1).

EXPERIMENT 2

Numbers of total and larval thrips were affected by treatments, but adults were not affected (Table 2). There were about twice as many larval thrips with applications of *S. feltiae* compared to sulfoxaflor, and about half as many larvae when comparing spinetoram to sulfoxaflor (Table 2). Even though there was not a significant treatment by date interaction, adult thrips numbers appeared to be reduced to a greater extent in plots treated with spinetoram and sulfoxaflor compared to *S. feltiae*-treated and control plots. However, after 7 Mar 2016 adult thrips numbers were similar among treatments (Fig. 2A). Larval thrips numbers were reduced by spinetoram and sulfoxaflor as compared to *S. feltiae* treatments, and control was achieved for almost 2 wk following first application on 3 Mar 2016 (Fig. 2B). The number of insidious

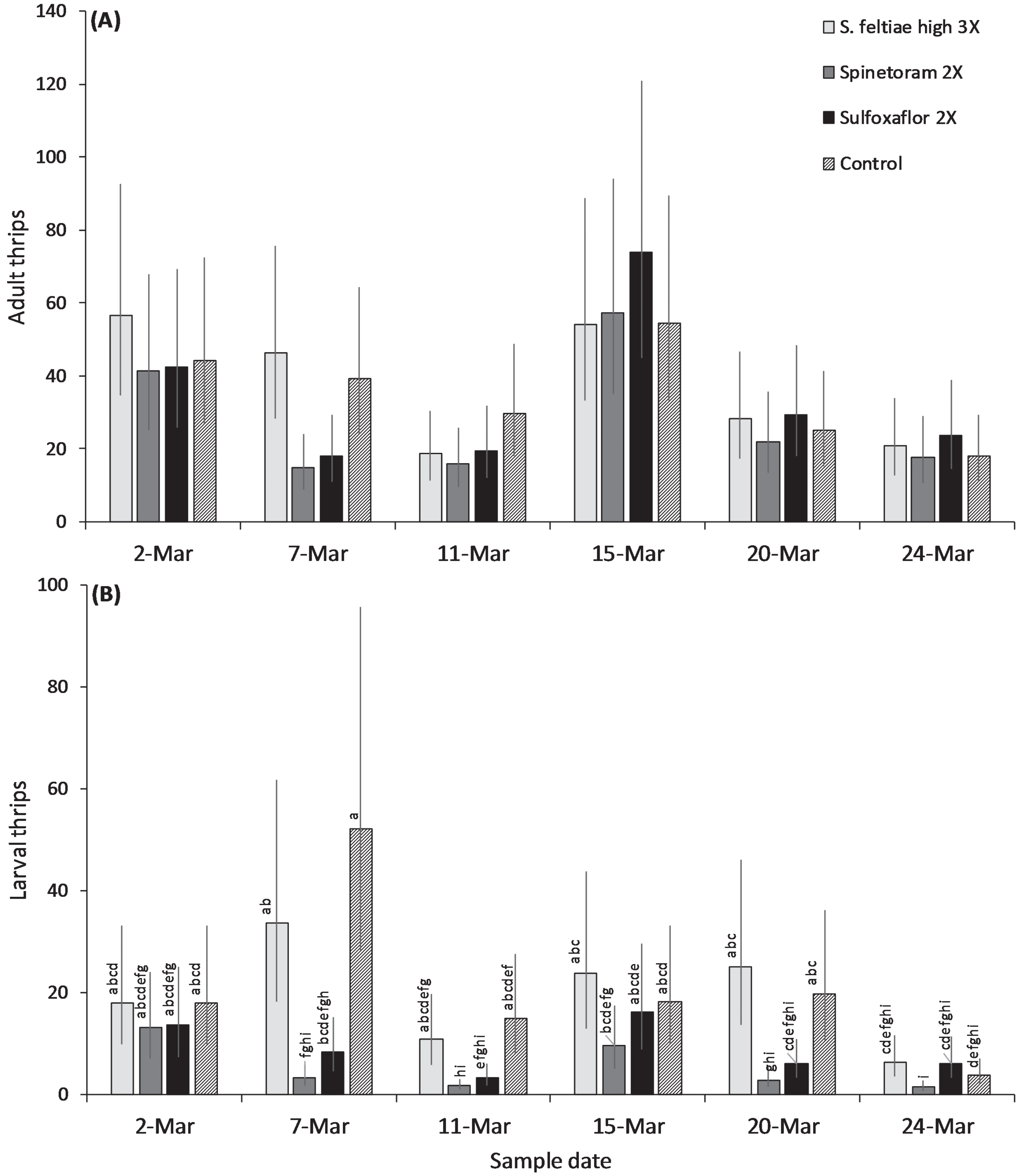

Fig. 2. Least square means (± 95% confidence intervals) for (A) adult and (B) larval thrips (*Frankliniella bispinosa*) per 10 strawberry flowers from research plots near Balm, Florida, sprayed 3, 7, and 16 Mar 2016 with *Steinernema feltiae* and 3 and 16 Mar 2016 with insecticides. Treatments were applied and reapplied when total thrips counts exceeded 5 per flower. Means in lower panel with the same letter are not significantly different (Tukey's HSD test, α = 0.05) (Experiment 2).

flower bugs was affected by treatment, with more than twice as many in control than spinetoram and sulfoxaflor plots (Table 2). Yield was not affected by the treatments ($F_{3,9} = 1.4$; $P = 0.303$). Thrips-damaged fruit was affected by treatment, with almost zero damage when spinetoram was applied, compared to about 1% when sulfoxaflor was applied and 3 to 4.5% in *S. feltiae* and control plots (Table 2).

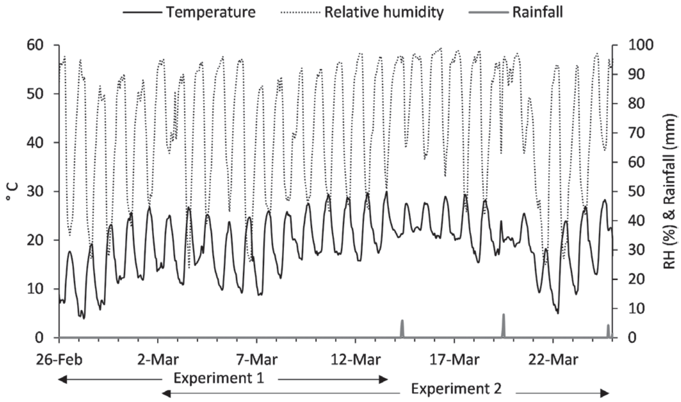

Fig. 3. Hourly temperature (left *y*-axis), rainfall, and relative humidity (right *y*-axis) 26 Feb to 25 Mar 2016 at Balm, Florida.

WEATHER

Hourly weather data for Balm, Florida, USA, was downloaded from the Florida Automated Weather Network (http://fawn.ifas.ufl.edu/). Daytime high temperatures typically ranged between 20 and nearly 30 °C, and nighttime temperatures ranged between about 10 to nearly 20 °C, with only a few nights falling below 10 °C (Fig. 3). Relative humidity was typically high at night (> 90%) and low during the day (40–50%) (Fig. 3). It was dry during both experiments; no rainfall occurred during Experiment 1 and only 2 rain events occurred during Experiment 2 (Fig. 3).

Discussion

Our results showed that sulfoxaflor controlled Florida flower thrips and reduced thrips-related fruit damage in Florida strawberry. However, *S. feltiae* was not effective at reducing or suppressing flower thrips or reducing strawberry damage. As research on management strategies for multiple species of thrips in Florida strawberry progresses, it will be important to rate the relative strengths of insecticides in order to develop optimal season-long rotations. Furthermore, factors affecting or limiting the efficacy and use of biological control organisms need to be explored to enable future research.

Spinetoram is an effective insecticide for control of multiple thrips species in a wide variety of crops, providing rapid-knockdown and sustained suppression of populations (Khaliq et al. 2014; Srivastava et al. 2014; Marasigan et al. 2016). Spinetoram is widely used in Florida strawberry and other horticultural crops, with the result that some *F. occidentalis*, but not *F. bispinosa*, populations have recently developed resistance (D. Sprague personal communication). Even though *F. occidentalis* was not widely reported by growers as a problem in the previous strawberry season, spinetoram is now also routinely used to control *S. dorsalis* early in the season, when strawberry plants first begin to flower. This study has shown that sulfoxaflor reduces flower thrips, reduces damage to strawberry, and does not adversely affect predatory insidious flower bugs, suggesting that it may be a suitable replacement for spinetoram. However, because the level of flower thrips reduction was not as great for sulfoxaflor as for spinetoram, sulfoxaflor may be better suited as a second application following spinetoram, in lieu of 2 successive spinetoram applications. The composition and order of insecticides is currently being evaluated in a season-long program for control of flower and chilli thrips in Florida strawberry crops.

Treatments of *S. feltiae* in strawberry plots resulted in no reduction of any thrips life stage or feeding damage. The most common factors limiting efficacy of foliar entomopathogenic nematode applications are susceptibility of the nematodes to ultraviolet light and desiccation (Gaugler & Boush 1978; Arthurs et al. 2004; Shapiro-Ilan et al. 2006). During these experiments, high temperatures and absence of rainfall likely caused significant desiccation and nematode mortality. An additional potential success-limiting factor is that the foliar environment may not provide sufficient support and leverage for *S. feltiae* to physically penetrate the host's spiracles (Eidt & Thurston 1995; Evans et al. 2015). Control of *F. occidentalis* with foliar applications of *S. feltiae* has been discussed (Shapiro-Ilan et al. 2006), although results have been variable (Arthurs & Heinz 2005; Beck et al. 2015). Only *F. bispinosa* was found in these experiments, and as these congenerics have similar life histories, we expected similar effects of *S. feltiae*. However, to our knowledge, *S. feltiae* has not been tested on *F. bispinosa* in a controlled environment, and subtle behavioral differences between these species may potentially alter their susceptibility to entomopathogenic nematodes. Entomopathogenic nematodes are virulent to soil-dwelling pupae of *F. occidentalis* (Chyzik et al. 1996; Ebssa et al. 2001; Premachandra et al. 2003), and some entomopathogenic nematodes in foliar applications likely land on the soil. However, in a raised-bed, plastic-mulched strawberry system, *Frankliniella* spp. are less likely to pupate in soil than on the plastic, under senescing leaves, or on living plant parts where entomopathogenic nematode survival, and thus infectivity rates, are likely to be low. Nematode species and strain may play a role in thrips suppression as well, as 2 strains of *H. bacteriophora*, for example, conferred very different levels of *F. occidentalis* control (Chyzik et al. 1996). The entomopathogenic nematode's foraging strategy and the location of the pupae in the soil likely play an important role in host infectivity dynamics (Kaya & Gaugler 1993; Chyzik et al. 1996).

Currently, sulfoxaflor (Closer®) is not registered for use in strawberry in the USA. Registration was cancelled late in 2015, but growers with product may still legally apply Closer®. Pending re-registration of Closer® in strawberry, as has occurred in other crops, growers will regain a valuable, additional tool for thrips insecticide rotation programs. Before entomopathogenic nematodes can be used for thrips management in Florida strawberry production, advancements in commercial delivery methods and application technologies will be necessary. For example, the thrips parasitic nematode, *Thripinema nicklewoodi* Siddiqui (Tylenchida: Allantonematidae), applied via infected thrips hosts rather than an aqueous suspension, has been shown to infect high numbers of *F. occidentalis* on foliage and persist for up to 9 generations (Arthurs & Heinz 2006). Overall, an improved integrated approach to thrips management in Florida strawberry is needed, with research focused on developing biological, chemical, and other methods that can be used to provide effective and economical control options.

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