CONTROLLING *FRANKLINIELLA BISPINOSA* (THYSANOPTERA: THRIPIDAE) ON FLORIDA CITRUS DURING BLOOM AND INCREASED FRUIT SET ON NAVEL AND 'VALENCIA' ORANGES

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ABSTRACT

Four field experiments were conducted during 1995 and 1996 to evaluate increased fruit set of navel and 'Valencia' oranges or 'Marsh' grapefruit varieties by controlling *Frankliniella bispinosa* (Morgan) (Thysanoptera: Thripidae) on citrus flowers during bloom. In three experiments, Chlorpyrifos 4EC at 4.68 liters/ha provided 5, 5, and 4 days of effective residual control of *F. bispinosa* adults on citrus flowers and 3 or more days at 3.16 liters/ha in the remaining experiment. Corresponding lengths of larval thrips control were 12, 12, and 8 days, respectively. The Chlorpyrifos 4EC treatments at 3.16 liters/ha applied on 25 March in the fourth experiment provided 11 or more days of larval thrips control. Use of a single, properly timed insecticide application between maximum bud swell and full bloom, when *F. bispinosa* or *F. kelliae* adults are increasing, will increase fruit set. Preventing establishment of larval thrips populations appears to be important.

Key Words: citrus; pest management; flower thrips; flowering

RESUMEN

Durante 1995 y 1996 se efectuaron cuatro experimentos de campo para incrementar el amarre de fruta en naranja 'navel' y 'Valencia' y en toronja 'Marsh' mediante el control del thrips *Frankliniella bispinosa* (Morgan) (Thysanoptera: Thripidae) en las flores. En tres experimentos, Chlorpyriphos 4EC a 4.68 litros/ha demostró un control residual efectivo de adultos en las flores por 5, 5, y 4 días. En el cuarto experimento, Chlorpyriphos 4EC a 3.16 litros/ha tuvo mostró control por 3 o mas días. El control de larvas con la dosis alta de Chlorpyriphos fue de 12, 12, y 8 días, mientras que la dosis baja, aplicada en Marzo 25, mostró control de larvas por 11 días. Una aplicación sencilla del insecticida entre las fases de yema hinchada y floración completa, cuando las poblaciones de *F. bispinosa* y *F. kelliae* van en aumento, incrementa el amarre de fruta. La prevención del establecimiento de poblaciones de larvas se considera importante.

Three species of *Scirtothrips* (Thysanoptera: Thripidae) are recognized as economic pests on citrus in different parts of the world (Lewis et al. 1997). They feed on citrus leaves and developing citrus fruits, and include *S. aurantii* Faure in South Africa (Samways et al. 1987, Gilbert 1990), *S. dorsalis* Hood in Japan and Africa (Takagi 1981, Gilbert 1986), and *S. citri* (Moulton) in California and Arizona (Tanigoshi & Nishio-Wong 1982, Arpaia & Morse 1991). More recently, the effects of flower and fruitlet drop on navel orange caused by *Frankliniella bispinosa* (Morgan) and *F. kelliae* Sakimura (Thysanoptera: Thripidae) were evaluated in Florida (Childers et al. 1990, Childers & Achor 1991a, Childers & Beshear 1992, Childers et al. 1994). The results demonstrated that thrips feeding damage (Childers 1992) and a fungal pathogen *Colletotrichum acutatum* J. H. Simmonds (Sonoda & Pelosi 1988, Brown et al. 1996) were associated with postbloom fruit drop in Florida.

Increased fruit set occurred where thrips and disease were controlled separately or together on navel orange (Childers 1992). In some years, control of thrips with insecticides on navel orange during flowering provided higher fruit set based on late June-early July frame counts compared with 1 or 2 fungicide (benomyl 50WP) applications for postbloom fruit drop disease control alone. Although the pathogen was present in these groves, disease pressure was not assessed.

Field cage studies followed by scanning and transmission electron microscopy have shown that larvae and adults of *F. bispinosa* feed on the ovary, style, floral disk, petals, and anthers of swollen buds and open flowers of navel orange (Childers & Achor 1991a, b). Thrips oviposition and subsequent eclosion were recorded from the pistil, calyx, petals, and filaments of both flowers and swollen buds. Population suppression of *F. bispinosa* during the flowering cycle and increased fruit set of navel oranges was shown by Childers (1992).

One important aspect of managing *F. bispinosa* is determining when to apply (proper timing) an insecticide to increase fruit set. Also, additional field experimentation was desired to determine if fruit set increase could be obtained on 'Valencia' orange or grapefruit varieties by controlling flower thrips. Therefore, field experiments were conducted during 1995 and 1996 to evaluate: (1) timing of insecticides for thrips control, and (2) differences in fruit set on navel and 'Valencia' oranges and grapefruit varieties.

Materials and Methods

Experimental Design

Four experiments were conducted during 1995 and 1996 in 3 different grove sites with previous or suspected problems of postbloom fruit drop. Experiment 1 was performed at the Duda farm in the Felda vicinity, Hendry County during March 1995. Navel orange trees were 5 to 6.1 m tall with a 5.2 by 7.3 m tree spacing (264 trees/ha). Plot size consisted of 12 rows by 15 trees per row (180 trees/plot). Treatments were applied in 1.169 kliters/ha with an airblast sprayer. Experiment 2 was conducted at the Butler farm in the LaBelle vicinity in Hendry County during March-April 1995. 'Valencia' orange trees were 3.6 to 6.1 m tall with a 4.6 by 7.6 m tree spacing (287 trees/ha). Treatments were assigned to 8 rows by 20 to 30 trees within the row (160-240 trees per plot). Treatments were applied in 2.3 kliters/ha. Experiment 3 was performed at the Cracker Trail farm in western St. Lucie County about 4 km north of highway 68 and within 4 km of the Okeechobee County line. 'Marsh' grapefruit trees were 3.7 to 5.3 m tall with a 5.5 by 7.3 m tree spacing (249 trees/ha). Plot size consisted of 6 rows by 16 trees within the row or 12 rows by 9 trees within the row (96-108 trees per plot). Treatments were applied in 1.17 kliters/ha. Experiment 4. The 'Valencia' orange trees were the same block as in experiment 3 and conducted during March-May 1996. Plot size consisted of 8 rows by 20 to 40 trees within the row (160-320 trees per plot). Treatments were applied 25 March in 1.6 kliters/ha. Other treatments were applied on 29 March or 9-10 May in 2.3 kliters/ha.

Treatments

A standard grove spray program for disease, insect, and mite control was maintained throughout the season after application of the experimental treatments during the flowering cycle at each grove site. The only difference was the pesticide treatments applied during flowering and 0-6 wk immediately following petal fall. Pesticide treatments are shown as formulated weights or volumes per hectare and were applied to plots in a randomized complete block design with 6 replicates (Table 1). In experiment 4, Mattch 12% aqueous flowable (AF) (Mycogen Corp., San Diego, CA) consisting of a blend of 127.2 g/liter of delta endotoxins of *Bacillus thuringiensis* Berliner encapsulated in killed *Pseudomonas fluorescens* (Trevisan) Migula was applied at 4.68 liters/ha in treatments 2 and 3 on 9 May.

Sampling

Populations of *F. bispinosa* and *F. kelliae* were sampled at various time intervals before and after spray applications by collecting a maximum of 4 open flowers at random from around the canopy of each of 5 trees in the center of each treatment replicate. Each flower of the 20 flower sample was immediately immersed in one jar containing 70-80% ethanol and a label indicating collection site, date, and treatment replicate. Following petal fall, small fruitlets were collected in the same way as open flowers. In the laboratory, flowers and alcohol from each jar were poured into a dish, floral parts were separated, and adult and larval thrips were counted and removed using a stereomicroscope at 10-12× magnification.

Thrips were recorded as *Frankliniella* spp. and "other" thrips. *Frankliniella bispinosa* was the dominant thrips species on infested floral buds and open flowers of citrus accounting for 92% of the slide-mounted specimens subsampled from over 80 citrus growing areas in Florida (Childers et al. 1990, Childers & Beshear 1992).

Fruit set differences between treatments were determined in each test by using a 1 m^3 frame constructed of 12.5-mm diameter pvc pipe with an attached vertical pipe 1.37 m in length. This supported the frame at a fixed height. This procedure was modified from Stout (1962) for determining the bearing surface of a tree and to estimate the number of fruits per tree (Childers 1992). The frame was placed into the canopy at approximately 45° angles from the tree row at each of the 4 corners in each of 10 trees per plot (treatment replicate) in late June or early July during 1995 and 1996. The majority of premature fruit drop usually occurred shortly after petal fall and during June (Lima & Davies 1981). All fruits except obviously very small late-bloom fruit within each frame per treatment replicate were counted and recorded.

Statistical Analysis

In all experiments, data were subjected to analysis of variance; Waller-Duncan k-ratio procedures were used to separate treatment means when the ANOVA provided a significant F value ($P > 0.05$) (SAS Institute 1991). Both adult and larval thrips counts per 20 flowers or fruitlets and number of fruits per m^3 from the frame counts were subjected to $Log_{10}(X + 1)$ transformations for statistical analysis. Untransformed means are shown in all tables.

RESULTS

[Experiment 1] Duda, 1995

Low densities of both adult and larval thrips were observed in all plots prior to initiation of treatment applications (Table 2). Chlorpyrifos applied on 22 March (Table 1) provided at least 5 d residual control of adults while larval densities per 20 flowers re-

TABLE 1. PESTICIDE TREATMENT SCHEDULES.

Experiment no.	Treatment no.	Treatment regimes	Formulation	Rate per hectare	Phenology[1]	Application date
1. Duda 1995	1	Chlorpyrifos	4 EC	4.68 liters	50-70% BS	22 Mar
	2	Benomyl	50 WP	2.25 kg	Onset F	10 Mar
	3	Untreated	—	—	—	—
2. Butler 1995	1	Chlorpyrifos	4 EC	4.68 liters	50-70% BS	21 Mar
		Formetanate	92 SP	1.12 kg	FB	29 Mar
	2	Chlorpyrifos	4 EC	4.68 liters	50-70% BS	21 Mar
	3	Formetanate	92 SP	1.12 kg	FB	29 Mar
	4	Chlorpyrifos	4 EC	4.68 liters	FB	29 Mar
		Formetanate	92 SP	1.12 kg	PF	1 Apr
	5	Benomyl	50 WP	2.25 kg	Onset F	14 Mar
		Benomyl	50 WP	2.25 kg	FB	29 Mar
	6	Untreated	—	—	—	—
3. Cracker Trail 1995	1	Chlorpyrifos	4 EC	4.68 liters	50-70% BS	27 Mar
		Formetanate	92 SP	1.12 kg	FB	4 Apr
	2	Chlorpyrifos	4 EC	4.68 liters	50-70% BS	27 Mar
	3	Formetanate	92 SP	1.12 kg	FB	4 Apr
	4	Chlorpyrifos	4 EC	4.68 liters	FB	3 Apr
		Formetanate	92 SP	1.12 kg	PF	11 Apr
	5	Benomyl	50 WP	2.25 kg	Onset F	20 Mar

[1]BS = budswell; F = flowering; FB = full bloom; PF = petal fall; PB = post bloom.

TABLE 1. (CONTINUED) PESTICIDE TREATMENT SCHEDULES.

Experiment no.	Treatment no.	Treatment regimes	Formulation	Rate per hectare	Phenology[1]	Application date
		Benomyl	50 WP	2.25 kg	FB	3-4 Apr
	6	Untreated	—	—	—	—
4. Butler 1996	1	Chlorpyrifos	4 EC	4.68 liters	Maximum BS	25 Mar
	2	Chlorpyrifos	4 EC	4.68 liters	Maximum BS	25 Mar
		Mattch	12% AF	4.68 liters	5-6 wk PB	9 May
	3	Chlorpyrifos	4 EC	4.68 liters	FB	29 Mar
		Mattch	12% AF	4.68 liters	5-6 wk PB	9 May
	4	Chlorpyrifos	4 EC	4.68 liters	Maximum BS	25 Mar
		Carbaryl XLR	4 L	5.85 liters	5-6 wk PB	10 May
	5	Chlorpyrifos	4 EC	4.68 liters	5-6 wk PB	10 May
	6	Untreated	—	—	—	—

[1]BS = budswell; F = flowering; FB = full bloom; PF = petal fall; PB = post bloom.

mained significantly lower than the check through 31 March or per 20 fruitlets on 3 April (12 days after treatment = 12 DAT). Benomyl applied on 10 March did not provide control of either *F. bispinosa* or *F. kelliae* adults or larvae between 21 March and 3 April. Petal fall occurred some time between 31 March and 3 April.

Chlorpyrifos resulted in significantly higher fruit set compared to the untreated trees based on frame counts taken on 25 July (Table 2). The single benomyl application did not significantly increase fruit set per m^3 of canopy.

[Experiment 2] Butler, 1995

Low population pressure of adult thrips was recorded prior to insecticidal applications on 21 and 29 March (Table 3). Significantly lower adult densities per 20 flowers occurred on 27 March and 3 April for treatment 1 (Table 1) compared to the untreated trees while treatment 2 resulted in reduced numbers of adults per 20 flowers on 27 March only. Treatment 3 failed to significantly reduce adult densities on 3 April compared with treatment 1. Treatment 4 provided comparable suppression of adult thrips on 3 April compared with treatment 1. Treatment 5 had significantly lower adults per 20 flowers on 3 April compared with the untreated check trees.

Larval thrips numbers were significantly reduced in treatment 1, treatment 2, and treatment 4 between 23 March and 6 April compared with the untreated trees (Table 3). Petal fall occurred some time between 3-6 April. Larval densities in treatments 3 and 5 were significantly lower only on 3 April compared with the untreated check trees.

Treatment 1, treatment 2, treatment 3, and treatment 4 all resulted in significantly higher fruit sets compared with either treatment 5 or the untreated check trees (Table 3). Treatment 3 did not provide a measurable decrease in either adult or larval thrips counts in this experiment when compared with treatment 5.

[Experiment 3] Cracker Trail, 1995

Low densities of both adult and larval thrips were present in all treatment replicates on 21 March prior to spray applications (Table 4). Treatment 1 (Table 1) provided control of adults on 28 March and significantly lower densities of larvae between 28 March and 4 April compared with the untreated check trees. Treatment 2 had significantly lower numbers of adults on 28 March compared with the untreated check trees. The addition of formetanate in treatment 1 did not result in improved thrips control compared with chlorpyrifos alone in treatment 2. Treatments 3 and 5 did not reduce either adult or larval thrips numbers between 28 March and 4 April compared with the untreated check trees. Treatment 4 resulted in reduced adult thrips densities on 4 April only and larval thrips counts were not significantly reduced between 21 March and 4 April. None of the treatments in this experiment resulted in increased fruit set compared with the untreated check trees (Table 4).

[Experiment 4] Butler, 1996

Low populations of adult and larval thrips were present on the citrus flowers in all treatment replicates prior to onset of spray applications (Table 5). Treatment 1, treatment 2, and treatment 4 all provided significant reductions in adult thrips densities on 27 and 28 March (Table 1). Residual control of adult thrips in all 3 treatments was lost by 1 April. Treatment 3 provided significant reductions in adult thrips populations between 1-10 April compared with the untreated check trees. Larval thrips numbers

TABLE 2. CONTROL OF *FRANKLINIELLA BISPINOSA* (MORGAN) ON NAVEL ORANGE FLOWERS AND MEAN NUMBER OF FRUIT PRESENT WITHIN A ONE CUBIC METER VOLUME OF TREE CANOPY ON 25 JULY AT DUDA, FELDA VICINITY, HENDRY COUNTY, FLORIDA 1995.

Treatment	Formulation	Rate per hectare	Pre-treatment means[1]	Spray dates	Post treatment means[1]				Fruitlets	Mean no. of oranges per m^3
			12 Mar		21 Mar	24 Mar	27 Mar	31 Mar	3 Apr	
					Adults/20 flowers					
1. Chlorpyrifos	4 EC	4.68 liters	29 a[2]	22 Mar	25 a	3 b	4 b	150 a	3 a	13.5 a
2. Benomyl	50 WP	2.25 kg	33 a	10 Mar	21 a	9 ab	24 a	172 a	2 a	12.8 ab
3. Untreated	—	—	29 a	—	21 a	15 a	27 a	155 a	4 a	11.7 b
					Larvae/20 flowers					
1. Chlorpyrifos	4 EC	4.68 liters	2 a[2]	22 Mar	11 a	0 b	0 b	13 b	1 c	—
2. Benomyl	50 WP	2.25 kg	1 a	10 Mar	12 a	4 a	7 a	68 a	17 a	—
3. Untreated	—	—	1 a	—	7 a	2 ab	13 a	54 a	5 b	—

[1]Means within a column followed by the same letter are not significantly different by ANOVA followed by Waller-Duncan K ratio (if ANOVA $P \geq 0.05$).
[2]Mean number of adult or larval thrips per 20 flowers, 20 fruitlets or oranges per m^3 of canopy volume.

TABLE 3. CONTROL OF *FRANKLINIELLA BISPINOSA* (MORGAN) ON 'VALENCIA' ORANGE FLOWERS AND MEAN NUMBER OF FRUIT PRESENT WITHIN A ONE CUBIC METER VOLUME OF TREE CANOPY ON 25 JULY AT BUTLER, LABELLE VICINITY, HENDRY COUNTY, FLORIDA, 1995.

			Pre-treatment means[1]		Post treatment means[1]			Fruitlets	Mean no. of oranges per m³
Treatment	Formulation	Rate per hectare	21 Mar	Spray dates	23 Mar	27 Mar	3 Apr	6 Apr	
					Adults/20 flowers				
1. Chlorpyrifos	4 EC	4.68 liters	—	21 Mar	—	—	—	—	—
Formetanate	92 SP	1.12 kg	59 ± 14 a[2]	29 Mar	2 ± 1 a	4 ± 1 b	115 ± 16 cd	2 ± 1 ab	21.8 a
2. Chlorpyrifos	4 EC	4.68 liters	52 ± 17 a	21 Mar	2 ± 0 a	4 ± 1 b	263 ± 69 ab	1 ± 1 b	22.2 a
3. Formetanate	92 SP	1.12 kg	76 ± 20 a	29 Mar	23 ± 10 a	26 ± 7 a	321 ± 87 ab	1 ± 1 b	21.6 a
4. Chlorpyrifos	4 EC	4.68 liters	—	29 Mar	—	—	—	—	—
Formetanate	92 SP	1.12 kg	51 ± 12 a	1 Apr	17 ± 9 a	16 ± 3 a	73 ± 10 d	0 ± 0 b	20.7 a
5. Benomyl	50 WP	2.25 kg	—	14 Mar	—	—	—	—	—
Benomyl	50 WP	2.25 kg	35 ± 9 a	29 Mar	27 ± 16 a	15 ± 4 a	166 ± 14 bc	4 ± 1 a	17.8 b
6. Untreated	—	—	50 ± 11 a	—	9 ± 4 a	18 ± 6 a	410 ± 87 a	2 ± 1 ab	16.5 b
					Larvae/20 flowers				
1. Chlorpyrifos	4 EC	4.68 liters	—	21 Mar	—	—	—	—	—
Formetanate	92 SP	1.12 kg	6 ± 3 a	29 Mar	1 ± 0 b	0 ± 0 b	1 ± 0 cd	0 ± 0 bc	—
2. Chlorpyrifos	4 EC	4.68 liters	7 ± 3 a	21 Mar	0 ± 0 b	0 ± 0 b	8 ± 4 bc	0 ± 0 bc	—
3. Formetanate	92 SP	1.12 kg	5 ± 1 a	29 Mar	5 ± 3 ab	19 ± 12 a	8 ± 5 bcd	2 ± 1 abc	—

[1]Means within a column followed by the same letter are not significantly different by ANOVA followed by Waller-Duncan k ratio (if ANOVA $P \geq 0.05$).
[2]Mean number of adult or larval thrips per 20 flowers, 20 fruitlets or oranges per m³ of canopy volume.

TABLE 3. (CONTINUED) CONTROL OF *FRANKLINIELLA BISPINOSA* (MORGAN) ON 'VALENCIA' ORANGE FLOWERS AND MEAN NUMBER OF FRUIT PRESENT WITHIN A ONE CUBIC METER VOLUME OF TREE CANOPY ON 25 JULY AT BUTLER, LABELLE VICINITY, HENDRY COUNTY, FLORIDA, 1995.

			Pre-treatment means[1]		Post treatment means[1]			Fruitlets	Mean no. of oranges per m^3
Treatment	Formulation	Rate per hectare	21 Mar	Spray dates	23 Mar	27 Mar	3 Apr	6 Apr	
4. Chlorpyrifos	4 EC	4.68 liters	—	29 Mar	—	—	—	—	—
Formetanate	92 SP	1.12 kg	5 ± 2 a	1 Apr	3 ± 1 ab	6 ± 4 a	0 ± 0 d	0 ± 0 c	—
5. Benomyl	50 WP	2.25 kg	—	14 Mar	—	—	—	—	—
Benomyl	50 WP	2.25 kg	4 ± 1 a	29 Mar	12 ± 8 a	4 ± 2 ab	10 ± 4 b	2 ± 1 ab	—
6. Untreated	—	—	8 ± 5 a	—	2 ± 1 ab	4 ± 2 ab	119 ± 54 a	4 ± 2 a	—

[1]Means within a column followed by the same letter are not significantly different by ANOVA followed by Waller-Duncan k ratio (if ANOVA $P \geq 0.05$).
[2]Mean number of adult or larval thrips per 20 flowers, 20 fruitlets or oranges per m^3 of canopy volume.

TABLE 4. CONTROL OF *FRANKLINIELLA BISPINOSA* (MORGAN) ON 'MARSH' GRAPEFRUIT FLOWERS AND MEAN NUMBER OF FRUIT PRESENT WITHIN A ONE CUBIC METER VOLUME OF TREE CANOPY ON 13-14 JULY AT CRACKER TRAIL, FT. PIERCE VICINITY, ST. LUCIE COUNTY, FLORIDA, 1995.

Treatment	Formulation	Rate per hectare	Pre-treatment means[1] 21 Mar	Application dates	Post treatment means[1] 28 Mar	31 Mar	4 Apr	Mean number of grapefruit per m^3
					Adults/20 flowers			
1. Chlorpyrifos	4 EC	4.68 liters	—	27 Mar	—	—	—	—
Formetanate	92 SP	1.12 kg	37 ± 8 a[2]	4 Apr	4 ± 1 b	51 ± 3 c	213 ± 52 a	11.7 c
2. Chlorpyrifos	4 EC	4.68 liters	43 ± 12 a	27 Mar	5 ± 1 b	70 ± 17 bc	143 ± 31 a	13.7 ab
3. Formetanate	92 SP	1.12 kg	37 ± 6 a	4 Apr	18 ± 5 a	119 ± 23 a	207 ± 57 a	13.5 abc
4. Chlorpyrifos	4 EC	4.68 liters	—	3 Apr	—	—	—	—
Formetanate	92 SP	1.12 kg	55 ± 11 a	11 Apr	11 ± 3 ab	87 ± 19 abc	59 ± 10 b	15.2 a
5. Benomyl	50 WP	2.25 kg	—	20 Mar	—	—	—	—
Benomyl	50 WP	2.25 kg	53 ± 7 a	3-4 Apr	13 ± 3 a	97 ± 9 ab	160 ± 33 a	12.4 bc
6. Untreated	—	—	50 ± 9 a	—	10 ± 4 ab	76 ± 12 abc	147 ± 27 a	13.3 abc
					Larvae/20 flowers			
1. Chlorpyrifos	4 EC	4.68 liters	—	27 Mar	—	—	—	—
Formetanate	92 SP	1.12 kg	5 ± 2 a	4 Apr	2 ± 1 c	1 ± 0 b	5 ± 2 b	—
2. Chlorpyrifos	4 EC	4.68 liters	3 ± 2 a	27 Mar	3 ± 1 bc	2 ± 0 b	4 ± 0 b	—
3. Formetanate	92 SP	1.12 kg	6 ± 2 a	4 Apr	7 ± 1 a	23 ± 9 a	82 ± 38 a	—

[1]Means ± standard errors within a column followed by the same letter are not significantly different by ANOVA followed by LSD (if ANOVA $P \geq 0.05$).
[2]Mean number of adult or larval thrips per 20 flowers or grapefruit per m^3 of canopy volume.

TABLE 4. (CONTINUED) CONTROL OF *FRANKLINIELLA BISPINOSA* (MORGAN) ON 'MARSH' GRAPEFRUIT FLOWERS AND MEAN NUMBER OF FRUIT PRESENT WITHIN A ONE CUBIC METER VOLUME OF TREE CANOPY ON 13-14 JULY AT CRACKER TRAIL, FT. PIERCE VICINITY, ST. LUCIE COUNTY, FLORIDA, 1995.

Treatment	Formulation	Rate per hectare	Pre-treatment means[1]	Application dates	Post treatment means[1]			Mean number of grapefruit per m^3
			21 Mar		28 Mar	31 Mar	4 Apr	
4. Chlorpyrifos	4 EC	4.68 liters	—	3 Apr	—	—	—	—
Formetanate	92 SP	1.12 kg	9 ± 3 a	11 Apr	9 ± 3 ab	28 ± 7 a	16 ± 5 a	—
5. Benomyl	50 WP	2.25 kg	—	20 Mar	—	—	—	—
Benomyl	50 WP	2.25 kg	9 ± 2 a	3-4 Apr	7 ± 2 abc	22 ± 6 a	29 ± 7 a	—
6. Untreated	—	—	22 ± 10 a	—	12 ± 3 a	15 ± 5 a	30 ± 9 a	—

[1]Means ± standard errors within a column followed by the same letter are not significantly different by ANOVA followed by LSD (if ANOVA $P \geq 0.05$).
[2]Mean number of adult or larval thrips per 20 flowers or grapefruit per m^3 of canopy volume.

were significantly reduced in treatments 1 through 4 between 1-5 April when compared with treatment 5 or the untreated check trees. Treatments 1 and 4 had significantly higher numbers of fruit set compared with the untreated check trees (Table 5).

Discussion

In experiment 1 at the Duda site, maximum thrips numbers averaged 172 adults per 20 flowers on 31 March or 8.6 adults per flower compared with 3.4 larvae per flower in the same set of samples (Table 2). Maximum measurable differences in fruit set were 15% in treatment 1 while treatment 2 had 9%.

In experiment 2, the maximum number of adult and larval thrips per 20 flower sample was 410 on 3 April at Butler (Table 3). This averaged 20 adult thrips per flower compared with 6 larvae per flower. Petal fall occurred between 3-6 April and low densities of both adult and larval thrips were recorded on the small fruitlets on 6 April. All 4 insecticide treatments resulted in significant increases in fruit set in this experiment compared with the fungicide only and untreated check trees. Results of this experiment indicate that adult thrips densities approaching 20 or more per flower prior to petal fall resulted in reduced fruit set for this grower. Economic benefit was obtained with at least a 17-26% range of increase in fruit set resulting from 1 or 2 insecticidal applications during flowering in this 'Valencia' orange grove. A single insecticide treatment applied between 21 and 29 March was adequate to provide comparable fruit set increase compared with treatments that received 2 insecticide applications between 21 March and 1 April.

In experiment 3 on 'Marsh' grapefruit, maximum adult thrips numbers averaged 213 adults per 20 flowers in treatment 1 on 4 April (Table4). Maximum larval thrips numbers averaged 82 per 20 flowers in treatment 3 on the same date. Residual activity of adults in treatments 1 and 2 was 4 days while larval suppression was sustained between 28 March and 4 April compared with the untreated check. However, no benefit in increased fruit set was shown.

In experiment 4 on 'Valencia' orange at Butler, treatments 1 through 4 provided significant reductions in larval thrips numbers between 1 and 10 April (Table 5). Only 2 of the 4 treatments (1 and 4) resulted in significant increases in fruit set. However, mean numbers of fruit/m^3 were not significantly different in the 4 insecticide treatments. An approximate 6-8% gain in fruit set on 'Valencia' orange trees was obtained by applying chlorpyrifos during maximum bud swell in 2 of 4 treatments (1 and 4).

Based on these experiments when *Frankliniella* (primarily *F. bispinosa*) adult densities approached 20 per flower and when larval densities were 3 to 5 in the same flowers, then reduced fruit set injury occurred on navel or 'Valencia' oranges in Florida in 3 field trials. Previously published field experiments using insecticides on navel orange demonstrated increased fruit set in earlier trials, too (Childers 1992). For example, maximum adult and larval densities per flower were 55 and 5, respectively, near petal fall during 1990 in the untreated check trees compared with maximum densities of 25 adults and 1 larva per flower in 2 insecticide treatments. Sustained suppression of both adults and larvae was achieved between 1-7 March in 2 treatments receiving formetanate 92 SP at 1.40 kg/ha on 1 March. Both treatments resulted in significant increases of 43 and 42% in fruit set, respectively, compared to the untreated check trees in that experiment. Use of a single, properly timed insecticide application between maximum bud swell and full bloom, when populations of *Frankliniella bispinosa* and *F. kelliae* adults are increasing on flowers, will increase fruit set on navel and 'Valencia' oranges in Florida. Preventing establishment of larval thrips populations from feeding and developing on citrus flowers appears to be important. Use of formet-

TABLE 5. CONTROL OF *FRANKLINIELLA BISPINOSA* (MORGAN) ON 'VALENCIA' ORANGE FLOWERS AND MEAN NUMBER OF FRUIT PRESENT WITHIN A ONE CUBIC METER VOLUME OF TREE CANOPY ON 30-31 JULY AT BUTLER, LABELLE VICINITY, HENDRY COUNTY, FLORIDA, 1996 .

Treatment	Formulation	Rate per hectare	Pre-treatment means[1]	Spray dates	Post treatment means[1]							Mean no. of oranges per m³
			14 Mar		27 Mar	28 Mar	1 Apr	2 Apr	4 Apr	5 Apr	10 Apr	
					Adults/20 flowers							
1. Chlorpyrifos	4 EC	3.16 liters	103 ± 10 a[2]	25 Mar	4 ± 1 b	2 ± 1 bc	31 ± 5 bc	61 ± 7 a	185 ± 20 a	321 ± 23 a	406 ± 86 a	26.4 a
2. Chlorpyrifos	4 EC	3.16 liters	—	25 Mar	—	—	—	—	—	—	—	—
Mattch (Bt)	AF	4.68 liters	83 ± 10 a	9 May	4 ± 1 b	3 ± 1 bc	43 ± 5 abc	72 ± 9 a	214 ± 34 a	330 ± 29 a	379 ± 54 a	25.0 ab
3. Chlorpyrifos	4 EC	4.68 liters	—	29 Mar	—	—	—	—	—	—	—	—
Mattch (Bt)	AF	4.68 liters	120 ± 25 a	9 Apr	29 ± 13 b	34 ± 3 a	31 ± 13 c	35 ± 7 b	94 ± 18 b	182 ± 37 b	163 ± 74 b	24.8 a
4. Chlorpyrifos	4 EC	3.16 liters	—	25 Mar	—	—	—	—	—	—	—	—
Carbaryl	4 L	11.70 liters	101 ± 17 a	10 May	3 ± 2 b	1 ± 0 c	42 ± 9 abc	73 ± 15 a	221 ± 35 a	401 ± 25 a	436 ± 67 a	26.8 a
5. Chlorpyrifos	4 EC	4.68 liters	90 ± 14 a	10 May	14 ± 11 b	21 ± 16 ab	71 ± 14 a	83 ± 16 a	269 ± 38 a	385 ± 68 a	333 ± 39 a	24.0 b
6. Untreated	—	—	129 ± 19 a	—	32 ± 14 a	31 ± 14 a	57 ± 14 ab	69 ± 11 a	264 ± 51 a	306 ± 31 a	336 ± 55 a	22.8 b
					Larvae/20 flowers							
1. Chlorpyrifos	4 EC	3.16 liters	10 ± 4 a[2]	25 Mar	1 ± 1 c	3 ± 2 a	0 ± 0 b	0 ± 0 b	1 ± 1 c	4 ± 1 b	191 ± 50 b	—
2. Chlorpyrifos	4 EC	3.16 liters	—	25 Mar	—	—	—	—	—	—	—	—
Mattch (Bt)	AF	4.68 liters	14 ± 7 a	9 May	1 ± 0 bc	2 ± 1 a	0 ± 0 b	0 ± 0 b	3 ± 1 bc	4 ± 1 b	182 ± 30 b	—
3. Chlorpyrifos	4 EC	4.68 liters	—	29 Mar	—	—	—	—	—	—	—	—
Mattch (Bt)	AF	4.68 liters	7 ± 3 a	9 Apr	16 ± 11 a	7 ± 3 a	1 ± 0 b	0 ± 0 b	0 ± 0 c	0 ± 0 c	33 ± 6 c	—
4. Chlorpyrifos	4 EC	3.16 liters	—	25 Mar	—	—	—	—	—	—	—	—
Carbaryl	4 L	11.70 liters	5 ± 1 a	10 May	0 ± 0 c	2 ± 1 a	0 ± 0 b	1 ± 0 b	1 ± 0 c	5 ± 2 b	202 ± 37 b	—
5. Chlorpyrifos	4 EC	4.68 liters	7 ± 3 a	10 May	4 ± 3 bc	8 ± 4 a	1 ± 1 ab	5 ± 2 a	15 ± 7 ab	18 ± 3 a	410 ± 85 a	—
6. Untreated	—	—	12 ± 4 a	—	6 ± 4 ab	10 ± 4 a	8 ± 5 a	9 ± 6 a	17 ± 10 a	16 ± 5 a	261 ± 31 ab	—

[1]Means within a column followed by the same letter are not significantly different by ANOVA followed by Waller-Duncan K ratio (if ANOVA $P \geq 0.05$).
[2]Mean number of adult or larval thrips Å SE per 20 flowers or oranges per m³ of canopy volume.

anate is less desirable due to the highly toxic nature of this insecticide to the predatory mites *Euseius mesembrinus* (Dean) and *Typhlodromalus peregrinus* (Muma) (Acari: Phytoseiidae) (Childers unpublished data). An effective scouting system must be developed to simplify monitoring of adult flower thrips populations in the field.

ENDNOTE

We gratefully acknowledge J. W. Noling, P. A. Phillips, and anonymous reviewers for their constructive reviews of this manuscript. Funding was provided by the Florida Citrus Production Research Advisory Council. Florida Agricultural Experiment Station Journal Series No. R-06659.

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