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MANAGEMENT OF MELON THRIPS, *THRIPS PALMI* KARNY (THYSANOPTERA: THRIPIDAE): AN INTEGRATED APPROACH USING CHEMICAL, CULTURAL, AND BIOLOGICAL AGENTS

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Abstract. **The melon thrips (*Thrips palmi* Karny) is a significant pest of various vegetable crops in the south Florida. The lack of proper management program against *T. palmi* is a great concern to the vegetable growers. Various studies were conducted to manage *T. palmi* in an efficient way. Spintor® at 8.0 oz/acre in combination with Joint Venture, a mixture of organosilicone surfactants, provided significant reduction of *T. palmi* adults. Spintor (4 or 8 oz/acre) in combination with sticker and surfactants provided significant control of *T. palmi* larvae. The effectiveness of Novaluron, an insect growth regulator, did not differ from Spintor in controlling *T. palmi* adults and larvae. V10132 significantly reduced *T. palmi* adults. Among off-season hosts, Lantana and Aster had the lowest and amaranth had the highest numbers of *T. palmi* populations. *T. palmi* populations were consistently present in okra and Thai eggplants across the growing season. Among various host crops, minute pyrate bug (*Orius insidiodus)* populations were higher in cucumber, eggplant, and squash than other vegetable crops. The above information is essential to manage *T. palmi* by integrating chemical, cultural and biological tools.**

The melon thrips (*Thrips palmi* Karny) is a significant key pest of vegetable crops. This pest invaded Miami-Dade County, Fla. in 1990 and caused serious damage to all vegetable crops, except tomato (*Lycopersicon esculentum* Mill.; Seal, 1997; FAO, 1991). In several instances, it caused total defoliation of the host crops in south Florida (Seal and Baranowsky, 1992). Since its appearance in 1990, this pest has migrated towards the north. In the spring of 1993, *T. palmi* caused severe damage, 77% crop loss, to pepper (*Capsicum annuum* L.) crops in Palm Beach County. In the southern Palm Beach area, growers incurred an estimated loss of $3.9 million due to the melon thrips together with *Frankliniella occidentalis* (Pergande) (Nuessly and Nagata, 1995). It was also reported as an important pest of vegetable crops in Southeast Asia (Yoshihara, 1982), Puerto Rico, Dominican Republic, and West Indies (Ciomperlik and Seal, 2004; Sakimura et al., 1986). Severe infestations of *T. palmi* were recorded in Hawaii on cucurbits, eggplants (*Solanum melongena* L.), pepper, and *Amaranthus spinosus* L. in 1982 and 1983 (Nakahara, 1984). At about the same time (1981-82), Riddle-Swan (1988) reported *T. palmi* infestation on hairy gourd [*Benincasa hispida* (Thunb.) Cogn.] in Hong Kong.

Melon thrips has a wide range of geographical distribution. It is a native to the island of Sumatra (Nakahara, 1994), and has dispersed throughout the world (Lewis, 1997; Mound, 1997). It has been reported as a pest in Asia, Africa, Central and South America (Anonymous, 1989; Cermeli and Montagne, 1990; Hall et al., 1993; Jones, 1990; Kawai, 1990; Mound, 1997; Nakahara, 1984; Walker, 1992; Wang and Chu, 1986; Yoshihara, 1982), the Caribbean (Etienne et al., 1990; Guyot, 1988). It has also been reported from the Netherlands (Seal and Klassen, 1995).

The melon thrips is polyphagous with wide host range. Its infestation has been detected on Solanaceae plants, Cucurbitaceae plants and Leguminosae plants (Nakahara, 1984). In addition to the previously mentioned vegetable hosts, melon thrips has been found on onion (*Allium cepa* L.), cotton (*Gossypium hirsutum* L.), avocado (*Persea americana* Mill.), citrus (*Citrus* spp.), peach [*Prunus persica* (L.) Batsch.], plum (*Prunus* × *domestica* L.), muskmelon (*Cucumis melo* L.), carnation (*Dianthus caryophyllus* L.), and chrysanthemum [*Dendranthema* × *gran-*

diflora Tzvelv. (= *Chrysanthemum* × *morifolium* Ramatuelle)] in different countries (Bournier, 1983; Gutierrez, 1981; Ruhendi and Litsinger, 1979; Wangboonkong, 1981; Yoshihara, 1982).

Both adults and larvae of *T. palmi* infest the lower surface of the leaves and other aerial plant parts to suck the sap from host plants (Seal, 1997). Initial feeding damage looks like silvery glittering from the upper surface of the leaves along the midrib and veins. In severe cases of infestation, plants show a bronzed appearance.

T. palmi females oviposit singly inside plant tissue. Adult females oviposit 2 to 5 eggs per day (Tsai et al., 1995). All stages of *T. palmi* develop at 15 °C to 32 °C. At 25 °C and 65% relative humidity, eggs hatch in 4 d and the two larval instars are completed in 3.3 d (Cardona et al., 2002). *T. palmi* adults have an average life span of 17 d (range, 6-35). Reproduction in *T. palmi* occurs both sexually and parthenogenetically.

Management of *T. palmi* is difficult to achieve. Growers commonly use conventional insecticides to combat this pest (Seal, 1994). In most instances, various insecticides are used in combination or in alternation once or more than once per week. Irrational use of insecticides causes development of resistance and appearance of secondary pests. Spintor™ (Spinosad, 2SC; Dow AgroSciences, Indianapolis, Ind.) is effective in controlling *T. palmi* but repeated applications are needed. To reduce reliance on a single chemical and to delay development of resistance, addition of effective chemicals and other methods of control should be used in integration with Spintor to achieve sound management of *T. palmi.* There is some potential in the use of entomopathogens (Castineiras et al., 1996). In our preliminary study, we observed that *Orius insidiosus* (Say) is an effective predator of *T. palmi.* Cultural practices that increase population of *O. insidiosus* should be encouraged to develop an integrated management program against *T. palmi.* Our objectives in this study were to: a) conduct studies to evaluate insecticides; b) determine potentiality of *O. insidiosus*; and c) find weed hosts with low level of *T. palmi* abundance.

Materials and Methods

Insecticide evaluation. Two studies were conducted to determine effectiveness of various treatments in controlling *T. palmi.* In the first study, 'Black Beauty' eggplants were transplanted into a Rockdale soil on raised beds covered with white plastic mulch. The plants were spaced 18 inches within the bed and 72 inches between beds, and were maintained using recommended cultural practices. Treatment plots consisted of two beds, each 30 feet long; the treatments were arranged in a randomized complete block design with four replications. A 5-ft.-long planted area separated the replications. Treatments evaluated in this study were: 1) Spintor™ at 4 and 8 oz/acre in combination with either Cohere® at 6.0 oz/acre (Nonionic spreader-sticker blend; Helena Chemical Co., Memphis, Tenn.) or Joint Venture® at 16.0 oz/acre (mixture of organosilicone surfactants; Helena Chemical Co.); 2) R-40598 at 3.17 oz/acre (a new chemical, 20% SC, Nichino America, Hamburg, Pa.); and 3) a nontreated control. Treatments were applied on four dates between 8 and 30 Apr. 2004 using a CO_2 backpack sprayer delivering 100 gpa at 30 psi. Treatments were evaluated by collecting randomly selected 10 leaves, one leaf per plant, from each treatment plot. Leaves from each plot were separately placed in zip-lock bags and were transported to the laboratory. Leaves were then washed with 70% ethanol to separate *T. palmi* adults and larvae. A binocular microscope at 10× was used to record numbers of adults and larvae.

In the second study, cucumber (*Cucumis sativus* L.) was directly seeded into raised beds of Rockdale soil in a TREC research plot using recommended cultural practices on 12 Mar. 2004. Beds were covered with white plastic mulch. Seeds on the beds were spaced 12 inches apart within the bed and 72 inches between the beds. Treatments used in this study were: 1) Baythroid® 2 at 2.4 oz/acre (Cyfluthrin; Bayer Corp., Kansas City, Mo.); 2) Baythroid® XL at 2.8 oz/acre (Cyfluthrin, 1EC; Bayer Corp.); 3) Mustang™ at 4.0 oz/acre (Zeta-cypermethrin, 1.5 EW, FMC, Philadelphia, Pa.); 4) Sevin® XLR at 2.0 pt/acre (Carbaryl; Bayer CropScience, Research Triangle Park, N.C.); 5) V10132 at 9.0 oz/acre (research material, Valent USA Corp., Walnut Creek, Calif.); 6) Diamond at 12.0 oz/acre (Novaluron, 0.83EC, Crompton Corp., Middlebury, Conn.); 7) Spintor™; 8) CX 2016 at 1 pt/acre (a *Bacillus thuringiensis*-based insecticide, Certis USA, Columbia, Md.); and 9) a nontreated control. Treatment plots consisted of two beds, each 30 feet long. Treatments were arranged in a randomized complete block design with four replications. A nonplanted buffer area 5 feet wide separated the replications. Treatments were applied on 16 and 23 Apr., and 1 and 8 May 2004 using a CO_2 backpack sprayer delivering 70 gpa at 30 psi. Treatments were evaluated by randomly collecting 10 leaves, one per plant, per treatment plot. Processing of samples for *T. palmi* was as in the previous study.

Alternate hosts of T. palmi. Population abundance of *T. palmi* was studied on five different weeds near vegetable fields: Spiny Amaranthus (*Amaranthus spinosus* L.), Mexican prickle-poppy (*Argemone mexicana* L.), Aster (*Parthenium hysterophorus* L.), variegated Bauhinia (*Bauhinia variegate* L.), Hairy daisy (*Bidens pilosa* L.), and two commonly grown summer vegetables, okra [*Abelmoschus esculentus* (L.) Moench.] and Thai eggplants (*Solanum melogena* L.). The weeds were from naturally occurring wild populations. Okra and Thai eggplants were planted in two commercial fields and a TREC experimental plot on 28 Apr. 2004. Each host plant was selected in three different locations near vegetable fields in Homestead. Ten plants were selected in each area and were sampled for *T. palmi* by collecting 50 leaves, 5 leaves per plant on four dates- 2, 12 and 22 June and 2 July 2004. Leaves were placed in zip-lock bags and transported to the laboratory. The leaves were then washed with 70% ethanol to separate *T. palmi* using a binocular microscope at 10×.

Abundance of Orius insidiosus. Pepper (cv. Jalapeno), eggplant cv. Black Beauty), snap bean (*Phaseolus vulgaris* L.), squash (Yellow crookneck; *Cucurbita pepo* L.), cucumber, and okra were transplanted on 4 Mar. 2004 on raised beds of Rockdale soil in TREC experimental plots. The beds were covered with white plastic mulch. Plants were spaced 16 inches within the bed and 72 inches between the beds. All crops were maintained by using recommended cultural practices. The transplants were arranged in a randomized complete block design with four replications. Each crop was evaluated for *O. insidisus* abundance by thoroughly checking five randomly selected plants per crop treatment plot on four dates at 7-d intervals between 6 and 29 Apr. 2004.

Data analysis. Data were analyzed using software provided by statistical Analysis System (release 6.03, SAS Institute Inc. Cary, N.C.; SAS Institute, 1988). General linear model prodedures were used to perform analysis of variance. Means were separated by Duncan Multiple Range Test (DMRT) at the 0.05 level.

Table 1. Mean numbers of *Thrips palmi* adults per sample of eggplants treated with various treatments.

Treatments	Rate (oz/acre)	Mean number of adults per sample				Mean
		9 April 2004	16 April 2004	23 April 2004	29 April 2004	
Spintor + Cohere	4.0 + 6.0	30.00 a	32.50 a	27.50 a	11.00 ab	25.25 a
Spintor + Cohere	8.0 + 6.0	32.50 a	20.00 a	22.50 a	8.50 ab	20.88 ab
Spintor + Joint Venture	4.0 + 16.0	15.00 a	22.50 a	10.00 a	9.25 ab	14.19 ab
Spintor + Joint Venture	8.0 + 16.0	17.50 a	7.50 a	10.00 a	4.75 b	9.94 b
R-40598	3.17	23.75 a	30.00 a	10.00 a	13.50 a	19.31 ab
Control		53.00 a	17.50 a	22.50 a	11.50 ab	26.13 a

Means within a column followed by the same letter do not differ significantly (P > 0.05; DMRT).

Results and Discussion

Insecticide evaluation. In the first study, none of the treatments provided satisfactory control of *T. palmi* adults on eggplants (Table 1). This might have been due to the re-infestation by *T. palmi* adults from the nearby vegetable fields. Spintor at 4 oz/acre in combination with Cohere significantly reduced *T. palmi* larvae for the first two sampling dates; thereafter this treatment did not differ from nontreated control (Table 2). On the other hand, Spintor at 4 oz/acre in combination with Joint Venture significantly reduced *T. palmi* larvae for the first three sampling dates, which was similar to the performance of Spintor at 8 oz/acre in combination with Cohere. Spintor at 8 oz/acre in combination with Joint Venture provided significant reduction of *T. plami* larvae across the sampling dates. R-40598 did not provide satisfactory reduction of *T. palmi* larvae.

In the second study, pyrethroid-based chemicals did not provide any control of *T. palmi* (Tables 3 and 4). Sevin XLR did not control *T. palmi* and V10132 significantly reduced *T. palmi* when compared with the nontreated check. Spintor and Novaluron provided the highest levels of control of *T. palmi* on cucumber.

Alternate hosts of T. palmi. T. palmi adults and development stages were collected from various weeds and vegetables (Tables 5 and 6). All development stages of *T. palmi* were significantly more abundant in Amaranth than other weeds (adult: $F = 41.54$; $df = 6,77$; $P = 0.0001$; larva: $F = 76.92$; $df = 6,77$; $P = 0.0001$). Adults and larvae of this insect were collected from Amaranth in all sampling sites. *T. palmi* adults and larvae were significantly fewer in Mexican prickle-poppy and Aster than Amaranth; a few thrips were collected from red clover and hairy daisy in two sites, but the numbers of adult were few in each weed. Okra and Thai eggplant are common hosts of

Table 2. Mean numbers of *Thrips palmi* larvae per sample of eggplants treated with various treatments.

Treatments	Rate (oz/acre)	Mean number of larvae per sample				Mean
		9 April 2004	16 April 2004	23 April 2004	29 April 2004	
Spintor + Cohere	4.0 + 6.0	260.0 bc	205.0 bc	310.0 ab	47.25 b	205.56 b
Spintor + Cohere	8.0 + 6.0	325.0 bc	50.00 d	17.50 c	14.00 bc	101.63 bc
Spintor + Joint Venture	4.0 + 16.0	125.0 c	125.00 cd	117.50 bc	22.25 bc	97.44 bc
Spintor + Joint Venture	8.0 + 16.0	130.0 c	50.00 d	39.50 c	7.50 c	56.75 c
R-40598	3.17	500.30 b	350.00 b	445.00 a	93.50 a	347.19 a
Control		1166.30 a	672.50 a	532.50 a	35.00 b	601.56 a

Means within a column followed by the same letter do not differ significantly (P > 0.05; DMRT).

Table 3. Mean numbers of *Thrips palmi* adults per 10-leaf sample of cucumber treated with various insecticides.

Treatments	Rate (oz)/acre	Mean number of adults/sample			Mean
		4 June 2004	11 June 2004	18 June 2004	
Baythroid2	2.4	40.00 ab	9.50 a	19.25 bc	22.92 ab
Baythroid XL	2.8	53.00 a	8.75 a	35.00 ab	32.25 ab
Mustang Max	4.0	58.00 a	12.25 a	46.50 a	38.92 a
Sevin XLR	32.0	31.75 a-c	7.50 ab	19.75 bc	19.67 a-c
Spintor	7.0	6.75 d	1.50 c	3.25 d	3.83 d
V10132	9.0	13.00 cd	3.25 bc	10.00 cd	8.75 cd
Novaluron	12.0	20.50 b-d	1.50 c	5.75 cd	9.25 cd
CX 2016	16.0	32.50 a-c	3.50 bc	19.50 bc	18.50 bc
Control		61.50 a	3.50 bc	18.25 bc	27.75 ab

Means within a column followed by the same letter do not differ significantly (P > 0.05; DMRT).

Table 4. Mean numbers of *Thrips palmi* larvae per 10-leaf sample of cucumber treated with various insecticides.

Treatments	Rate (oz/acre)	Mean number of larvae per sample			Mean
		4 June 2004	11 June 2004	18 June 2004	
Baythroid2	2.4	208.25 ab	50.75 a	59.00 ab	106.00 a
Baythroid XL	2.8	187.50 a-c	53.50 a	83.75 ab	108.25 a
Mustang Max	4.0	286.50 a	36.00 a	103.75 a	142.08 a
Sevin XLR	32.0	139.75 bc	33.00 a	53.30 ab	75.42 ab
Spintor	7.0	7.75 d	4.00 b	2.00 c	4.58 d
V10132	9.0	109.25 c	8.75 b	19.00 bc	45.67 bc
Novaluron	12.0	11.25 d	2.00 b	17.50 bc	10.25 cd
CX 2016	16.0	162.25 bc	28.50 a	52.25 ab	81.00 ab
Control		205.75 ab	20.25 a	60.50 ab	98.17 ab

Means within a column followed by the same letter do not differ significantly (P > 0.05; DMRT).

Table 5. Mean numbers of *Thrips palmi* adults on various off-season weed and vegetable hosts near vegetable fields, Homestead, Fla.

Hosts	Mean number of adults per sample				Mean
	2 June 2004	12 June 2004	22 June 2004	2 July 2004	
Amaranth	14.67 a	12.67 a	20.33 a	9.67 a	14.33 a
Mexican prickle-poppy	0.39 d	0.00 d	0.33 c	0.67 d	0.33 d
Aster	1.67 cd	0.67 cd	0.00 c	1.00 cd	0.83 d
Hairy daisy Biden	4.67 bc	4.67 b	0.67 c	1.67 cd	2.92 c
Variegated Bauhinia	0.67 d	2.00 bc	0.67 c	1.33 b-d	1.17 d
Okra	2.33 cd	4.00 b	7.67 b	4.00 b	4.50 c
Eggplant	9.67 ab	9.00 a	8.67 b	4.00 b	7.83 b

Means within a column followed by the same letter do not differ significantly (P > 0.05; DMRT).

T. palmi. Adults and larvae of *T. palmi* were collected in all locations from these two hosts.

Abundance of Orious insidiosus. Mean numbers of *O. insidiosus* were more in cucumber and eggplant followed by squash and bean (seasonal mean: F = 14.04; df = 5,292; P < 0.001) (Table 7). *O. insidiosus* populations were low in okra and pepper. Like *O. insidiosus*, *T. palmi* adult (Table 8) (seasonal mean: F = 31.42; df = 5,293; P = 0.0001) and larval populations (Table

Table 6. Mean numbers of *Thrips palmi* larvae on various off season weed and vegetable plants near vegetable fields, Homestead, Fla.

Hosts	Mean number of larvae per sample				Mean
	2 June 2004	12 June 2004	22 June 2004	2 July 2004	
Amaranth	51.00 a	53.00 a	89.33 a	43.33 a	59.17 a
Mexican prickle-poppy	0.00 d	0.00 c	0.00 d	0.33 d	0.08 d
Aster	0.00 d	0.33 c	0.00 d	0.00 d	0.08 d
Hairy daisy Biden	8.00 c	10.00 b	12.00 cd	7.33 c	9.33 c
Variegated Bauhinia	1.00 c	0.33 c	1.67 d	1.67 d	1.17 d
Okra	9.00 c	13.67 b	15.67 bc	13.00 b	12.83 c
Eggplant	33.33 b	45.00 a	27.33 b	8.33 bc	28.50 b

Means within a column followed by the same letter do not differ significantly (P > 0.05; DMRT).

Table 7. Mean numbers of *Orius insidiosus*/sample of various vegetables on four sampling dates.

Crops	Mean number *O. insidiosus*				Mean
	7 April 2004	14 April 2004	21 April 2004	28 April 2004	
Squash	0.30 abc	0.60 b	2.20 a	0.40 b	0.62 b
Cucumber	0.55 ab	1.20 a	2.00 a	2.20 a	1.12 a
Eggplant	0.70 a	1.05 a	1.60 ab	2.20 a	1.08 a
Bean	0.00 c	0.30 bc	1.00 ab	0.60 ab	0.28 c
Pepper	0.00 c	0.15 c	0.40 b	1.00 ab	0.18 c
Okra	0.10 c	0.30 bc	0.60 b	1.25 ab	0.33 c

Means within a column followed by the same letter do not differ significantly (P > 0.05; DMRT).

Table 8. Mean numbers of *Thrips palmi* adults per sample in various vegetable crops on four sampling dates.

Crops	Mean number of adults per sample				Mean
	7 April 2004	14 April 2004	21 April 2004	28 April 2004	
Squash	3.60 a	7.95 a	13.80 a	16.80 a	7.68 a
Cucumber	2.70 a	12.75 a	10.00 ab	7.60 ab	7.94 a
Eggplant	3.00 a	7.70 b	11.40 ab	9.20 ab	6.34 ab
Bean	2.90 a	6.50 b	8.00 b	5.80 ac	5.14 b
Pepper	0.65 b	0.95 c	3.40 c	0.80 c	1.06 c
Okra	0.95 b	1.45 c	3.60 c	2.25 c	1.53 c

Means within a column followed by the same letter do not differ significantly (P > 0.05; DMRT).

Table 9. Mean numbers of *Thrips palmi* larvae per sample of various vegetable crops.

Crops	Mean number of larvae per sample				Mean
	7 April 2004	14 April 2004	21 April 2004	28 April 2004	
Squash	16.85 a	33.00 b	59.40 a	41.20 a	30.00 a
Cucumber	13.25 a	40.50 a	62.60 a	41.40 a	31.90 a
Eggplant	11.85 a	34.70 b	56.20 ab	44.40 a	28.68 a
Bean	14.70 a	32.00 b	42.60 b	39.20 a	26.86 a
Pepper	1.60 b	3.25 d	6.00 d	5.40 c	3.08 c
Okra	2.50 b	10.30 c	22.60 c	21.25 b	9.27 b

Means within a column followed by the same letter do not differ significantly (P > 0.05; DMRT).

9) (seasonal mean: $F = 53.74$; $df = 5, 293$; $P = 0.0001$) were significantly high on all sampling dates on squash, cucumber, eggplants, and bean; and low on okra and Thai eggplant.

T. palmi has become a key pest of vegetable crops in Florida. Vegetable growers suffer serious economic losses every year due to the infestation of *T. palmi*, which may worsen if proper control methods combining chemical, cultural, and biological agents are not identified. Based on the present study, *T. palmi* can be managed satisfactorily by rotating Diamond® with Spintor™. Okra and Thai eggplants should properly be managed to create a host-free period. In addition, a population of *O. insidiosus* should be maintained in the vegetable production area by planting favorable crops to reduce complete reliance on insecticides.

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