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

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ABUNDANCE OF ADVENTIVE *THRIPS PALMI* (THYSANOPTERA: THIRIPIDAE) POPULATIONS IN FLORIDA DURING THE FIRST SIXTEEN YEARS[§]

DAKSHINA R. SEAL^{1,*}, VIVEK KUMAR², GARIMA KAKKAR³ AND SIMONE COSTA MELLO⁴

¹University of Florida-IFAS, Tropical Research and Education Center, Homestead, FL 33031, USA

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

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

⁴Universidade de Sao Paulo/ESALQ, SP, Brazil, CEP 13418-900

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

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ABSTRACT

Thrips palmi Karny (Thysanoptera: Thripidae), invaded Miami Dade-county in 1990 and caused significant economic damage by defoliating various vegetable crops. It commonly occurs on the abaxial surface of host leaves where eggs are deposited individually inside the leaf tissues. Highest abundance of *T. palmi* was recorded on bean and eggplant in 1991-1994 in Tropical Research and Education Center research plots and commercial fields in Miami-Dade County. Density of *T. palmi* decreased significantly in subsequent years after the use of spinosad and other effective chemical insecticides. *Thrips palmi* populations increased in 2008 in spite of use of spinosad and showed increasing pattern causing crops loss at economic level. *Orius insidiosus* Say population was low in both TREC research fields and commercial fields due to harsh chemical management program, where insecticides belonging to various chemical classes were used alone (TREC fields) or in combination (commercial fields) to control *T. palmi* and other insect pests. None of the commonly used available insecticides alone or in combination provided satisfactory control of *T. palmi* in the early stage of invasion. Amongst various insecticides tested spinosad provided significant control of *T. palmi* on the crops until 2008 after which there was reduced effect of the chemical due to frequent use for managing multiple pests.

Key Words: melon thrips, population abundance, insecticides, minute pirate bug

RESUMEN

Thrips palmi (Thysanoptera: Thripidae) invadió el sur de Florida en 1990 y causó daño económico significativo al defoliar varios cultivos de hortalizas. Esta especie ocurre con frecuencia en la superficie abaxial de las hojas de las plantas hospederas, donde deposita los huevos individualmente dentro de los tejidos de las hojas. Se registró la mayor abundancia de *T. palmi* sobre la habichuela (*Phaseolus vulgaris* L., Fabaceae) y la berenjena (*Solanum melongena* L., Solanaceae) entre 1991-1994 en las parcelas de investigación y campos comerciales del Centro de Investigación Tropical y Educación en el Condado de Miami-Dade en la Florida. La densidad de *T. palmi* disminuyó significativamente comenzando en 1996 por el uso de spinosad y otros insecticidas eficaces. La población de *Thrips palmi* incrementó a partir de 2008 a pesar de la utilización de spinosad y causó pérdidas de cultivos económicamente importantes. La población de *Orius insidiosus* fue baja en los campos de investigación y de campos comerciales, debido al programa intensivo de manejo con sustancias químicas, donde se utilizó insecticidas de diferentes clases de químicas solos (en los campos de investigación) o en combinación (en los cultivos comerciales) para el control de *T. palmi* y otros insectos plagas. Ninguno de los insecticidas aplicados solos o en combinación proporcionó un control satisfactorio de *T. palmi* en las etapas tempranas de invasión. Entre los varios insecticidas probados el spinosad proporciona un control significativo de *T. palmi* en el campo comercial hasta el 2008, pero después su eficacia se disminuyó debido a su uso frecuente en el manejo de varias plagas.

Palabras Clave: *Thrips palmi*, abundancia de la población, insecticidas, *Orius insidiosus*

Thrips palmi Karny (Thysanoptera: Thripidae) is a polyphagous pest of much economic importance (Kirk 1997). It has a wide host range that includes at least 50 different plant species (Wang & Chu 1986). Damage caused by *T. palmi* is primarily due to feeding by adults and immatures on leaves and fruits of its host crop. Feeding may result in damaged terminals of the host, bronzing of leaves, which at the time of severe infestation may completely dry and die off, as well as production of scarred and deformed fruits. *T. palmi* may also cause host damage by transmitting at least 6 of the known tospoviruses (Nagata et al. 2002). Worldwide serious infestation of *T. palmi* has been detected on plants from family Solanaceae (eggplants, pepper, and potato), Cucurbitaceae (cucumber, watermelon, cantaloupe, and squash), and Leguminosae (kidney bean, snap bean, broad bean, cowpea, soybean, and whiteclover) (Nakahara 1984; Talekar 1991). In family Solanaceae, tomato is reported as a host of *T. palmi* only in the Caribbean (Capinera 2000) as the breeding population of *T. palmi* on tomato has not been reported elsewhere. Additional hosts include onion, cotton, avocado, citrus, peach, plum, muskmelon, hairy gourd, carnation and chrysanthemum (Gutierrez 1981; Riddle-Swan 1988; Ruhendi & Listinger 1979; Wangboonkong 1981; Yoshihara 1982). In south Florida, *T. palmi* has been reported as an devastating pest of bean, squash, cucumber, eggplant, pepper, potato and okra (Seal & Baranowski 1992).

Thrips palmi is native to Southeast Asia, specifically Sumatra and Java (Indonesia) where it was reported by Karny (1925) as a pest of tobacco

(Fig. 1). Its distribution was limited to Southeast Asia until the mid 1970s (Capinera 2008) when a serious outbreak occurred in southern Japan (Sakimura et al. 1986). Subsequently, it became established in most of the Asian countries; Bangladesh, Brunei Darussalam, China, Hong Kong, India, Japan, Malaysia, Myanmar, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan and Thailand. Currently, *T. palmi* has a wide distribution around the globe and it occurs in almost all the habitable landmarks of the world: Australia, Guam, New Caledonia, Samoa, Wallis and Futuna (Oceania); Netherland (Europe); Mauritius, Nigeria, Reunion, and Sudan (Africa); Brazil, Guyana, and Venezuela (South America); Antigua and Barbuda, Barbados, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Martinique, Puerto Rico, St. Lucia, St. Kitts and Nevis, Trinidad and Tobago (Central America and Caribbean); Hawaii and Florida (North America) (CABI 1998). Within the continental United States, the field population of *T. palmi* is limited to the south of Orlando (Capinera 2000).

The wide host range of *T. palmi* provides abundant resources for it to dwell and survive throughout the year. *Thrips palmi* generally appears with the onset of cropping season on the newly emerged leaves of its host plant and inhabits the field until the maturation of the host crop (Capinera 2000). In South Florida irrespective of the host, populations of *T. palmi* are reported to be abundant from Jan to Mar and decrease after the month of May which could be because of the rainy season in this region that extends from mid-May to mid-Sep. Information on temporal vari-

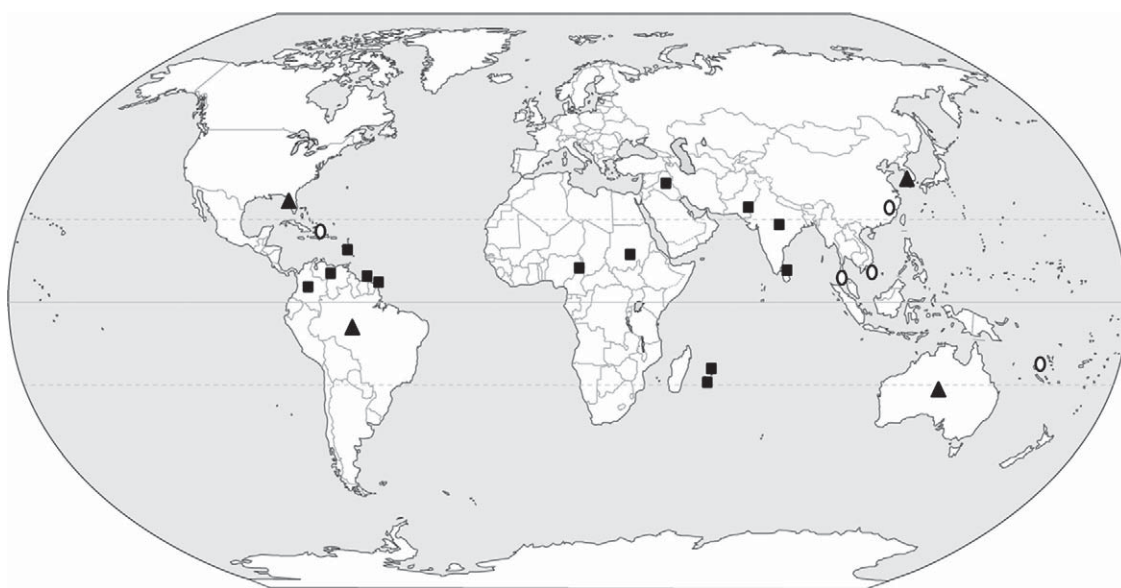


Fig. 1. Global distribution of melon thrips, *Thrips palmi* Karny.

■ = Present, no further details; ○ = Widespread; ▲ = Localized; △ = Occasional or few reports.

ability in the *T. palmi* population is imperative for early planning and time management in order to avoid substantial monetary loss due to the pest damage.

Use of chemical insecticides is considered as a primary mode of management for this pest, however, frequent application of the foliar insecticides have resulted in reduced susceptibility of *T. palmi* to a broad spectrum of insecticides over time. Pyrethroids, inorganic and chlorinated hydrocarbons are ineffective in managing *T. palmi*, and chemical groups such as organophosphates and carbamates have only limited effect on this pest (Seal & Baranowski 1992). Widely used insecticides such as Azinphos-methyl, Methomyl and Oxamyl also do not provide control of *T. palmi* and are known to achieve only 45-60% reduction of this pest. However, fermentation products such as abamectin (Seal & Baranowski 1992; Seal 1997) and spinosyn (Seal & Sabines 2012) have been quite effective in managing *T. palmi* in comparison to other classes of insecticides. Although *T. palmi* is not a recent invasive pest in south Florida, there is not much information on effective control strategies for this pest. In the present study we have summarized the population trend of *T. palmi* on beans and eggplants in Homestead, Florida during the first 16 years of its introduction. In addition, the abundance of minute pirate bug *Orius insidiosus* Say (Anthocoridae) - a naturally occurring predator of *T. palmi* - was also monitored in the agro-ecosystem and its compatibility with various insecticides used in managing *T. palmi* is presented.

MATERIALS AND METHODS

Population Abundance of *T. palmi*

Studies on population abundance of *T. palmi* on 2 major host crops-snap bean (*Phaseolus vulgaris* L.; Fabaceae) and eggplant (*Solanum melongena* L.; Solanaceae) were conducted beginning 1994 to 2010. 'Pod Squad' snap beans were planted in field plots at the University of Florida, Tropical Research and Education Center (TREC), Homestead, Florida. The planting was done in the first wk of Jan each year, where each planting lasted for 2 months. Field plots consisted of twelve 48 m-long rows where seeds were sown 15.2 cm apart within the row and 91.4 cm between rows. Plants were irrigated once daily using a drip system. Fertilizer (N-P-K mix) was applied at 224-56-269 kg per ha.

'Black Beauty' eggplant seedlings were transplanted 45 cm apart within row on raised beds 91 cm wide, 15 cm high, and 182 cm between centers. All other cultural practices were as described for the propagation of snap beans. Both crops were treated with azadirachtin, in rotation with abamectin, methomyl and spinosad. Data were also

collected from commercial fields at the same time as our experimental data, from farms located in the Homestead area (within 2 miles [3.2 km] diam of TREC). Commercial fields were managed by growers using standard cultural practices. Insecticide programs for managing *T. palmi* were variable using 2 to 3 insecticides in a tank mix which consisted inter alia of methomyl, azinphos-methyl, oxamyl, endosulfan and pyrethroids. Spinosad was added to the management program after 1996.

The experimental fields for both the crops in TREC and growers fields were divided into 4 equal blocks for the ease of sampling. Sampling was initiated 3 wk post planting and 4 samples of 10 full grown young bean leaves or 5 eggplant leaves (one leaf/plant) were collected from each block. All leaf samples belonging to each plot were placed in a separate ziplock® bag marked with the date of collection and plot. Samples were transported to the laboratory and processed as described by Kakkar et al. (2012). The total number of *T. palmi* adults and larvae in each sample were recorded using a binocular microscope (10X). The mean number of thrips from the samples collected in a season are presented in the figures.

Population Abundance of *O. insidiosus*

This study was conducted in same fields used to determine population abundance of *T. palmi*. A count of nymphs and adults of *O. insidiosus* was recorded by visually observing 20 randomly selected plants from each plot in a field.

Effectiveness of Insecticides against *T. palmi*

Insecticides of various chemical classes were evaluated for their efficacy in controlling *T. palmi* on snap beans and eggplants planted in TREC experimental field during a period extending from 1994-2006 (Table 1). Various chemical classes included in this study were: 1) neonicotinoid, 2) glycoside and fermentation products, 3) carbamates, 4) organophosphates, 5) benzoylphenyl urea, 6) pyrethroids, and 7) others.

The experimental plots consisted of two 9 m-long and 91 cm-wide rows. Snap beans and eggplants were planted at 15 cm and 45 cm within row spacing (respectively), and 91 cm between centers. Bean was planted on the flat ground and eggplant was planted on raised beds. All treatments were applied 4 times at weekly intervals using a backpack sprayer with 2 nozzles delivering 70 gpa (786 L/ha). Treatments were evaluated 48 h post application by randomly collecting 10 leaves (one leaf/plant) in each treatment plot. All leaf samples belonging to each plot were placed in a separate ziplock® bags marked with date of collection and treatment plot. Samples

TABLE 1. VARIOUS INSECTICIDES USED DURING THE EARLY STAGE OF INVASION OF SOUTH FLORIDA BY *THRIPS PALMI*, AND THEIR EFFICACY LEVELS ON THE THRIPS AND *ORIUS* POPULATIONS.

| Chemical name | Trade name | Class | IRAC Group | Efficacy level (%) | Effect on <i>Orius insidiosus</i> |
|---------------------------|---------------|--------------------|------------|--------------------|-----------------------------------|
| Imidacloprid | Admire | Neonicotinoid | 4A | 30-55 | Low-medium |
| Abamectin | AgriMek | Glycoside | 6 | 55-65 | Low-medium |
| Oxamyl | Vydate | Carbamate | 1A | 52-58 | Low-medium |
| Formetanate hydrochloride | Carzol | Carbamate | 1A | 85-98 | Medium-high |
| Methiocarb | Methiocarb | Carbamate | 1A | 35-52 | Medium-high |
| Methomyl | Lannate | Carbamate | 1A | 55-65 | Medium-high |
| Carbofuran | Furadan | Carbamate | 1A | 37-48 | Low-medium |
| Endosulfan | Thiodan | Cyclodiene | 2A | 38-48 | Medium-high |
| Dimethoate | Cygon | Organophosphate | 1B | 35-52 | Medium-high |
| Methidathion | Supracide | Organophosphate | 1B | 35-45 | Medium-high |
| Dimethyl phosphate | DDVP | Organophosphate | 1B | 35-52 | Medium-high |
| Mevinphos | Phosdrin | Organophosphate | 1B | 35-45 | Medium-high |
| Malathion | Malathion | Organophosphate | 1B | 38-45 | Low-medium |
| Azinphosmethyl | Guthion | Organophosphate | 1B | 55-60 | Medium-high |
| Acephate | Orthin | Organophosphate | 1B | 45-52 | Medium-high |
| Oxythioquinox | Morestan | Chinomethionate | B2 | 25-35 | Medium-high |
| Diatomaceous earth | — | Inorganic | 13 | 35-50 | Low-medium |
| Cyromazine | Trigard | Triazine IGR | 17 | 25-32 | Low-medium |
| Azadirachtin | Align | Botanical | 18B | 25-52 | Low |
| Diffubenzuron | Dimilin | Benzoylphenyl urea | 15 | 32-52 | Low-medium |
| Flucycloxuron | Andalin | Benzoylphenyl urea | 15 | 32-45 | Low-medium |
| Teflubenzuron | Teflubenzuron | Benzoylphenyl urea | 15 | 32-42 | Low-medium |
| Novaluron | Rimon | Benzoylphenyl urea | 15 | 42-52 | Low-medium |
| Esfenvalerate | Asana XL | Pyrethroid | 3A | 20-42 | Medium-high |
| Lambdacyhalothrin | Karate | Pyrethroid | 3A | 20-42 | Medium-high |
| Simmondsia chinensis | Jjoba oil | Wax | 13 | 25-45 | Low |
| Fenpropathrin | Danitol | Pyrethroid | 3A | 20-42 | Medium-high |
| Fipronil | Regent | Phenylpyrazoles | 2B | 25-35 | Low-medium |
| Spinosad | SpinTor | Spinosyn | 5 | 80-95 | Low-medium |

were transported to the laboratory and processed as described above. Effectiveness of each insecticide was presented as a range of percent control = ([numbers in treatments/numbers in control]*100).

Effect of Insecticides on *O. insidiosus*

Laboratory bioassays were conducted to determine effect of insecticides on *O. insidiosus*. A solution of each insecticide (500 mL) from field spray was set aside before the initial spray in our insecticide evaluation study. Host leaves were dipped in the solutions and air dried to remove excess water. Four 1 cm-diam treated host leaf discs were then placed in a Petri dish. Four *O. insidiosus* nymphs (second instars) were then placed in a Petri dish with treated leaves and replicated 4 times. Nymphs were checked every day at 24 h intervals to record mortality. Effect of each insecticide was expressed as low, medium

and high for 5-20%, 21-50%, 51-100% mortality of *O. insidiosus*, respectively. For the present study *O. insidiosus* nymphs were collected from a laboratory colony maintained on eggplant infested with silverleaf whitefly, *Bemisia argentifolii* Bel-lows and Perring (Aleyrodidae).

Statistical Analysis

Data from field studies on each crop are pre-sented and analyzed for the years 1994, 1996, 2000, 2002, 2004, 2006, 2008 and 2010. Data on the abundance of *T. palmi* and *O. insidiosus* were averaged for all samplings. The mean numbers of immatures and adults on each crop were com-pared separately using one way analysis of vari-ance (ANOVA) (PROC GLM, SAS Institute Inc. 2003). Data were analyzed independently for lar-vae and adults. Data were transformed by square root (x + 0.25) before analysis. Untransformed means are reported in the figures. The Duncan

Multiplex K ratio t test was used to separate treatment means where significant ($P < 0.05$) differences occurred (Waller & Duncan 1969).

RESULTS

Population Abundance of *T. palmi*

On beans, the *T. palmi* population (ca. 500 larvae/10 leaves; 100 adults/10 leaves) was observed to be the highest in 1994 (Fig. 2). Thereafter, decreases in thrips density were observed until 2006 and the population started to build up and higher number of thrips was sampled in 2008 and 2010. Both immature and adult thrips followed the same pattern of population abundance over the yr. Similar to thrips densities in the fields at TREC, the highest abundances of *T. palmi* (ca. 900 larvae/10 leaves) were observed in 1994 in commercial bean samples (Fig. 3).

Population abundance of *T. palmi* on eggplants corresponded to the thrips density on beans. In the TREC fields, the highest population abundance (ca. 1,000 larvae/10 leaves) was observed in 1994 (Fig. 4), which declined thereafter, and populations remained at low levels between 2000 (ca. 100 larvae/10-leaf sample) to 2008 (ca. 112 larvae/10-leaf sample). Similar to the TREC eggplant field results, the highest number of *T. palmi* larvae and adults were recorded in commercial fields in 1994 (Fig. 5). Mean numbers of *T. palmi* larvae fluctuated between 70-100/10-leaf samples during 2000 to 2006, which increased in 2008 and 2010.

Population Abundance of *O. insidiosus*

Low population abundance of *O. insidiosus* was observed on bean and eggplant crops at TREC and in commercial fields (Figs. 6, 7, 8, and 9). In all

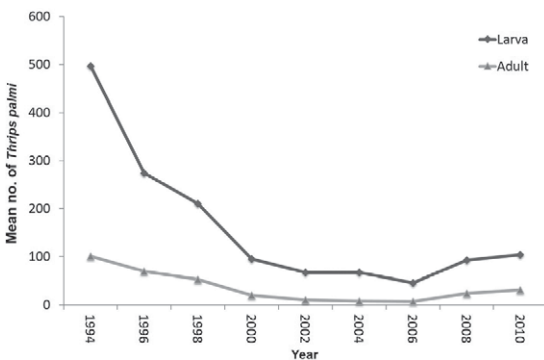


Fig. 2. Mean numbers of *Thrips palmi* adults and larvae in bean fields at TREC (Larvae: $F = 22.23$; $df = 8, 27$; $P < 0.0001$; Adults: $F = 45.69$; $df = 8, 27$; $P = 0.001$).

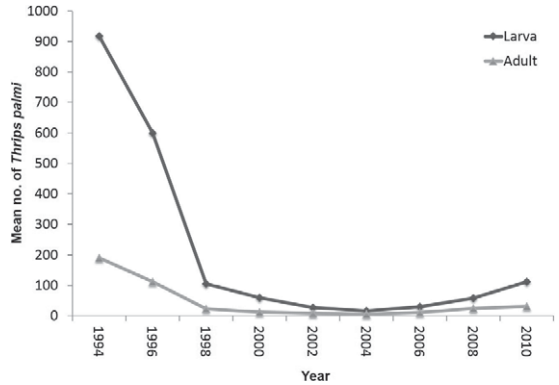


Fig. 3. Mean numbers of *Thrips palmi* adults and larvae in commercial bean fields (Larvae: $F = 52.97$; $df = 8, 27$; $P < 0.0001$; Adults: $F = 71.87$; $df = 8, 27$; $P < 0.0001$).

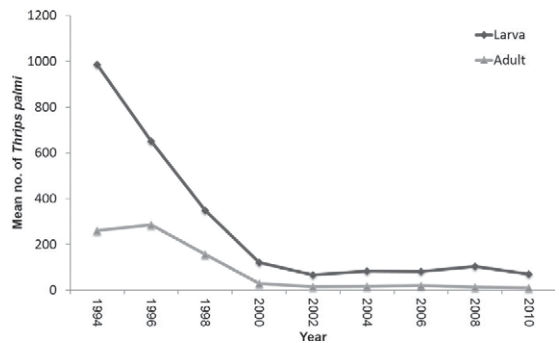


Fig. 4. Mean numbers of *Thrips palmi* adults and larvae in eggplant fields at TREC (Larvae: $F = 65.52$; $df = 8, 27$; $P < 0.0001$; Adults: $F = 78.24$; $df = 8, 27$; $P < 0.0001$).

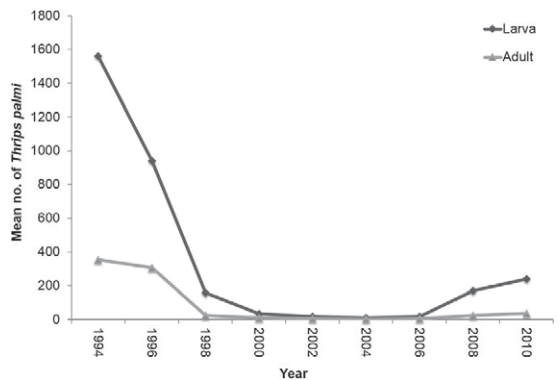


Fig. 5. Mean numbers of *Thrips palmi* adults and larvae in commercial eggplant fields TREC (Larvae: $F = 70.24$; $df = 8, 27$; $P < 0.0001$; Adults: $F = 56.25$; $df = 8, 27$; $P < 0.0001$).

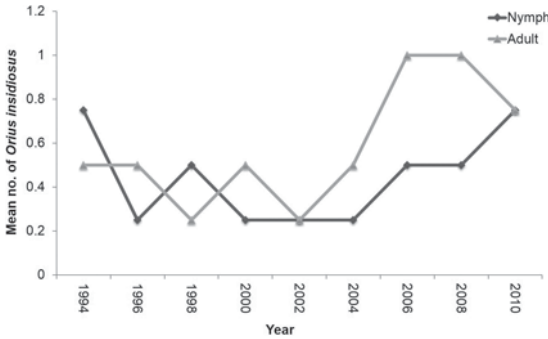


Fig. 6. Mean numbers of *Orius insidiosus* adults and nymphs in bean fields at TREC (Larvae: $F = 0.34$; $df = 8, 27$; $P > 0.05$; Adults: $F = 0.60$; $df = 8, 27$; $P > 0.05$).

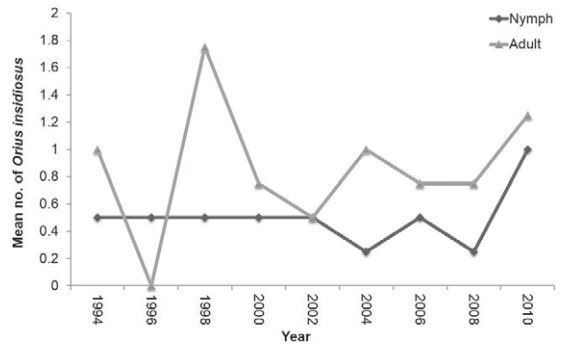


Fig. 8. Mean numbers of *Orius insidiosus* adults and nymphs in eggplant fields at TREC (Larvae: $F = 0.56$; $df = 8, 27$; $P > 0.05$; Adults: $F = 0.62$; $df = 8, 27$; $P > 0.05$).

the plantings, mean number of adults was higher than the mean number of nymphs. In the TREC bean field, *O. insidiosus* nymphs and adults were observed in all the sampling yr (Fig. 6), however in commercial bean fields, nymphs of *O. insidiosus* were always absent, while adults showed irregular population densities over the yr (Fig. 7). In TREC eggplant fields, *O. insidiosus* adults and nymphs were observed in all plantings, although the numbers were low (Fig. 8). In commercial eggplant fields, abundance distribution of adults and nymphs of *O. insidiosus* were irregular during the study period. Large numbers of *O. insidiosus* were collected from 2002 to 2008 (Fig. 9).

Effectiveness of Insecticides against *T. palmi*

Insecticides of various chemical groups caused mortality of *T. palmi* adults and larvae in various studies (Table 1). Imidacloprid (neonicotinoid) and organophosphates provided moderate levels (30-55% and 35-52%, respectively) of *T. palmi* control, while pyrethroids could only suppress

20-45% of the population. Abamectin (glycoside) was a commonly used insecticide for managing vegetable leafminers, and when tested against *T. palmi* it provided a 55-65% reduction of the thrips population. Spinosad provided high levels of control (80-95%) and was commonly used by the vegetable growers for the management of *T. palmi* in vegetable crops. Among the carbamates, formetanate hydrochloride was the most effective in providing highest level (85-98%) of *T. palmi* mortality, followed by methomyl and oxamyl. Other groups of insecticides, shown in Table 1, did not provide satisfactory levels of control of *T. palmi*.

Effect of Insecticides on *O. insidiosus*

At the beginning of the invasion, organophosphates and carbamates were the commonly used insecticides to combat *T. palmi* in vegetable crops. Most of these products caused medium to high levels of mortality in *O. insidiosus* (Table 1). Neonicotinoids applied as a soil drench and on foliage

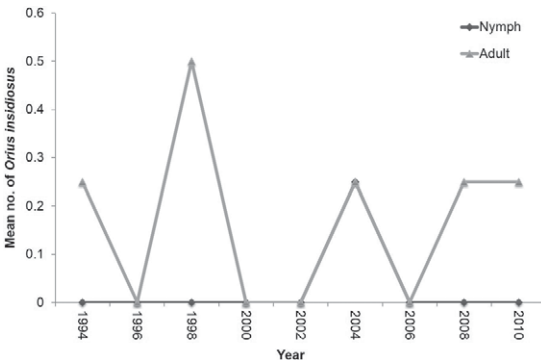


Fig. 7. Mean numbers of *Orius insidiosus* adults and nymphs in commercial bean fields (Larvae: $F = 0.99$; $df = 8, 27$; $P > 0.05$; Adults: $F = 0.84$; $df = 8, 27$; $P > 0.05$).

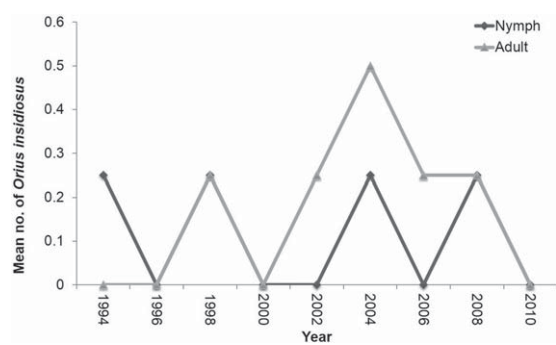


Fig. 9. Mean numbers of *Orius insidiosus* adults and nymphs in commercial eggplant fields (Larvae: $F = 1.02$; $df = 8, 27$; $P > 0.05$; Adults: $F = 0.89$; $df = 8, 27$; $P > 0.05$).

were comparatively benign on *O. insidiosus*. Benzoylphenyl urea insecticides were used on foliage and were low to medium in toxicity to *O. insidiosus*. The botanical insecticide, azadirachtin, used on foliage was highly benign to *O. insidiosus*. Spinosad, one of the most effective labeled insecticide for managing *T. palmi*, provided low to medium levels of *O. insidiosus* mortality.

DISCUSSION

At the beginning of the *T. palmi* invasion in 1990, almost no information was available about the management of this pest (Seal & Baranowski 1992; Seal 1993). To cope with the rapid population increase, insecticides from all available classes were used to control *T. palmi* in commercial vegetable fields. As none of the insecticides were effective enough to suppress this pest below economic injury levels, multiple insecticides were mixed together into individual spray tanks to achieve the highest level of control (D. R. S. personal observation). Nonetheless, use of multiple insecticides in a tank mix could not improve the management of *T. palmi*. For example, the combination of flucycloxuron and malathion did not differ from non-treated controls in regulating *T. palmi* on 'Pod Squad' beans in South Florida (Seal & Baranowski 1992). Because of the lack of desired efficacy of available insecticides, the *T. palmi* population remained dense during 1994 on beans and eggplants in the TREC research fields as well as commercial fields. The *T. palmi* population density was dramatically reduced in all plantings of vegetables in south Florida in 1996 and onwards due to the addition of spinosad in the *T. palmi* management program.

Population levels of *T. palmi* were higher in commercial bean fields (ca. 920/10 leaf samples) than in TREC research fields (ca. 500 larvae/10-leaf samples) in 1994. Similarly, the thrips populations in commercial eggplant fields were greater than those in the TREC eggplant field. The comparatively higher level of *T. palmi* population in commercial fields was caused by the frequent use of multiple ineffective insecticides in tank mixes, which exerted negative effects on the naturally occurring native biocontrol agents. Thus, during this study period we observed very sparse populations of naturally occurring *O. insidiosus* at all the study areas. Once growers started a spinosad program, *T. palmi* populations were consistently suppressed in all commercial fields until 2008. During the period of 1996 to 2006, *T. palmi* populations in commercial fields were consistently less than in the experimental fields. Commercial fields were sprayed weekly with spinosad, whereas, experimental fields were sprayed only as needed. *O. insidiosus* populations were comparatively higher in experimental fields than in the commercial fields irrespective of crop types. The low level

of *O. insidiosus* in commercial bean and eggplant fields reflected the use of harsh insecticides not applied in the experimental fields. In the commercial bean and eggplant fields, *O. insidiosus* nymphs were almost absent. A few *O. insidiosus* adults were observed which might have moved in temporarily from the neighboring fields.

This report summarizes the population trend of *T. palmi* in first 4 quadrennia of its invasion of south Florida, and provides information on the management of this pest by using effective insecticides in a timely manner. Depending solely on a specific insecticide to manage insect pests may cause failure in management programs. In the *T. palmi* management program, spinosad was the most effective tool until 2008. The effectiveness of spinosad has been debilitated by its frequent use during the last 14 years. In light of this study, management programs against a pest insect should be developed by applying multiple effective insecticides in rotation. The use of harsh chemicals should be avoided to preserve the natural biocontrol agents which play a significant role in insect pest management.

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