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Attraction of thrips (Thysanoptera) to colored sticky traps in a Florida olive grove

Sandra A. Allan[1*] *and Jennifer L. Gillett-Kaufman*[2]

Abstract

A study was conducted in 4 plots within a newly established olive grove in Florida to assess surveillance methods for insects present around the period of olive bloom. Over 99% of thrips collected were *Frankliniella bispinosa* (Morgan) (Thysanoptera: Thripidae), with occasional collections of predacious *Leptothrips pini* (Watson) (Thysanoptera: Phlaeothripidae). Collections of thrips using sticky traps or in tap or brush samples were high at the time of bloom, with low numbers before bloom and very low numbers after bloom. No differences in collections were seen among plots for thrips numbers when sampled using sticky cards. However, one plot had higher thrips numbers when sampled using tap and brush samples. Overall, and especially during bloom, blue sticky traps were most attractive, followed by yellow and then white sticky traps. Clear (color-free) traps collected the fewest thrips. Using tap samples, more thrips were collected on the edges than in the middle of the grove. Highly localized high densities of thrips were detected by the tap samples. Although sticky traps were highly effective for collecting thrips, only tap samples detected the localized hot spots.

Key Words: Surveillance, *Frankliniella bispinosa*, *Leptothrips pini*, olives

Resumen

Se realizó un estudio en 4 parcelas dentro de un huerto de olivos recién establecido en la Florida para evaluar los métodos de vigilancia de los insectos presentes durante el período de floración del olivo. Más del 99% de los trips colectados fueron *Frankliniella bispinosa* (Morgan) (Thysanoptera: Thripidae), con colecciones ocasionales del depredador, *Leptothrips pini* (Watson) (Thysanoptera: Phlaeothripidae). Las colecciones de trips que utilizan trampas adhesivas o en muestreo por golpe o cepillado las plantas fueron altas en el momento de la floración, con pocos números antes de la floración y números muy bajos después de la floración. No se observaron diferencias en las colecciones entre las parcelas de los números de los trips cuando se tomaron muestras con tarjetas adhesivas. Sin embargo, una parcela tuvo un mayor número de thrips cuando se tomaron muestras de por golpe o cepillado de las plantas. En general, y especialmente durante la floración, las trampas pegajosas azules fueron las más atractivas, seguidas de las trampas pegajosas amarillas y luego blancas. Las trampas transparentes (sin color) recolectaron la menor cantidad de trips. Utilizando muestras de por golpe de la planta, se recolectaron más trips en los bordes que en el medio del huerto. Las muestras por golpe de la planta detectaron altas densidades de trips muy localizadas. Aunque las trampas adhesivas fueron muy efectivas para recolectar trips, solo las muestras por golpe de la planta detectaron los puntos calientes localizados de trips.

Palabras Clave: Vigilancia; *Frankliniella bispinosa; Leptothrips pini;* aceitunas

The commercial olive industry in the USA is well established in California, with production focused primarily on canned table olives but production of olive oil is expanding (Warnert 2011; Yokoyama 2012). Recently, there is increasing interest in development of olive oil production in the southern states of the USA, and olive groves have been established in north central Florida and southern Georgia. This has necessitated development of pest monitoring and management strategies, as these regions differ greatly from California and other olive-growing regions of the world. Arthropods associated with olives in California have been well documented, and until detection of the olive fruit fly, *Bactrocera oleae* (Rossi) (Diptera: Tephritidae) in 1998, pest management was accomplished primarily through biological and cultural approaches (Daane et al. 2005). Currently, neither of the 2 main pests of olives, the olive fruit fly and the olive psyllid, *Euphyllura olivina* (Costa) (Hemiptera: Liviidae), are known to be present in the southeastern states (Yakoyama 2012; Bryon & Gillett-Kaufman 2016; Halbert & Genc 2017). Because the insect fauna of Florida differs from that of California, exposure of olive trees to these Florida insect species may reveal new potential pests for olive production in Florida. A compilation of insect pest species associated with olives in Florida based on a preliminary survey did not detect the olive fruit fly or olive psyllid, and also did not include thrips species (Gillett-Kaufman et al. 2014).

Flower thrips are abundant and important pests of various agricultural crops in Florida, particularly around the period of bloom. Damage by thrips to flowers through feeding and oviposition damage negatively affect developing fruit of crops such as blueberries (England et al. 2008), oranges (Childers & Achor 1991), grapefruit (Childers & Frantz 1994), and avocado (Fisher & Davenport 1989), and also potentially result in premature flower drop (Childers & Achor 1991). Although flower thrips have not been considered major pests of olives, flower thrips infestations have been implicated in scarred or misshapen olive fruit (Spooner-Hart et al. 2007). Sampling directly from flowers provides a good estimate of thrips populations present in blueberry fields (Arévalo & Liburd 2007b), but strong correlations have been found between thrips counts on sticky cards and counts from flowers (Arévalo-Rodriguez 2006). Destructive sampling of flowers in commercial orchards

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often is not advisable, so the use of sticky cards can provide a desirable approach to sampling. Because there have not been detailed studies of thrips on olive trees in Florida or in other locations, particularly around bloom, this study was initiated to assess surveillance methods for pests that may be present during the period of bloom. To advance this goal, different colors of sticky traps were assessed for optimal collection of thrips, and additional thrips sampling methods were used to compare sensitivity of detection of thrips in olive groves.

Materials and Methods

EXPERIMENTAL SITE

This study was conducted in a newly established olive planting in Volusia County in central Florida (Fig. 1). The site contained a total of 11,160 trees on 8.09 ha and was divided into 4 equal plots of 2.0 ha with rows in a north–south orientation. Mown grass strips (8.2 and 19.4 m) divided the north–south plots and east–west plots, respectively. A swath of approximately 19 m of mown grass was maintained between the outer edge of the plots and the surrounding vegetation. Each plot contained 2,790 trees in 30 rows in a north–south orientation. The planting was surrounded by flatwoods areas (primarily pine [*Pinus* spp.; Pinaceae], oak [*Quercus* spp.; Fagaceae], saw palmetto [*Serenoa repens* [Bartram]; Arecaceae], wax myrtle [*Myrica cerifera* L.; Myricaceae], and gallberry [*Ilex glabra* [L.]; Aquifoliaceae]) on 3 sides, with partial forest and pasture on the south side. An abandoned citrus orchard (approximately 0.72 ha) was located 100 m from the southeastern edge of the plots on the other side of the pasture. A commercial fern farm (approximately 3.2 ha) was located 60 m from the southeastern edge of the plot through a forested area. Olive trees were a mix of Arbiquina (80%), Arbosana (10%), and Koriniki (10%) varieties with placement of the 2 latter varieties (for pollination) in an east–west orientation across rows. Trees were 2-3 m in height and planted 1 m apart and in rows that were 3.2 m apart. Trees were from Agromillora (Spain) and planted from liners 3 yr prior to the initiation of the study. Plants were provided with drip irrigation. Lines of olive trees were maintained clear of herbaceous weeds by mowing in the row middles and herbicide (glyphosate) application around tree trunks. No herbicides or insecticides were applied during the study.

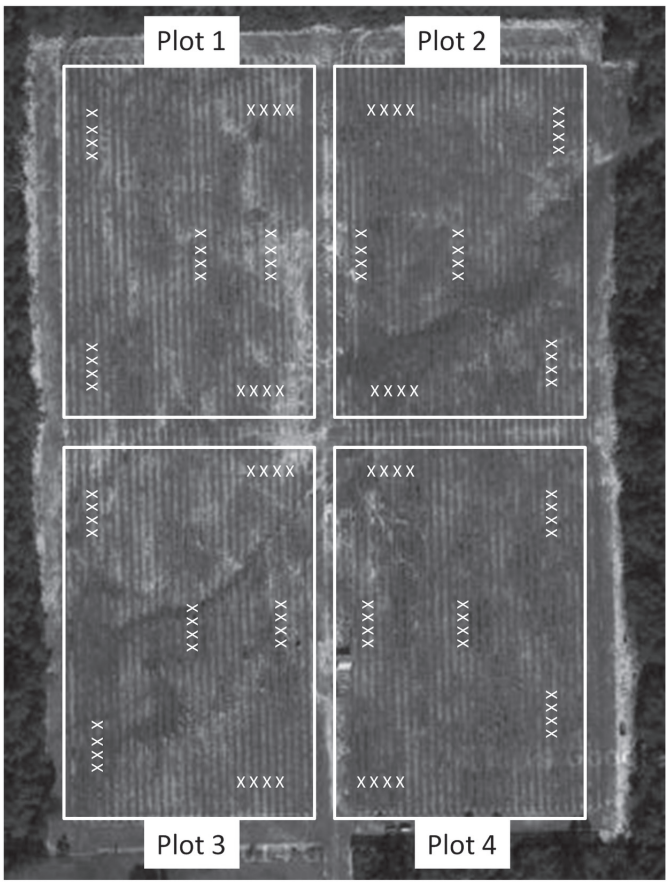


Fig. 1. Diagrammatic representation of the olive grove with sampling plots and locations of trap series within each plot. Location of individual traps is represented by an X.

MONITORING USING STICKY TRAPS

Reflectance spectra of the sticky cards were determined using a concave grating spectrometer (UV-VIS BLACK-Comet, StellaNet Inc, Tampa, Florida, USA). Reflectance of clear sticky panels was obtained by subtracting reflectance of a clear sticky panel placed against white paper from reflectance of the white paper. Additional spectra were obtained from the top and bottom of mature olive leaves. All measurements for transmission were obtained using a xenon arc lamp (400 watt) as a light source with quartz light guides for light delivery and magnesium oxide as a reflectance standard. Three measurements were obtained and averaged for each measurement reported.

The presence and population density of various thrips and other insect species were monitored using double-sided blue, yellow, white, and clear (transparent) sticky traps (10 × 15 cm). Yellow and blue sticky traps were commercially available polyvinyl products (Disposable Sticky Strips™, Olson Products, Medina, Ohio, USA). White traps were made from white painted posterboard and clear traps from Plexiglas. Both were coated with Tangle-trap (The Tanglefoot Company, Grand Rapids, Michigan, USA). Blue, yellow, and white traps were included in the study because they had been previously reported to attract various thrips species and orchard pests in various settings such as greenhouses and orchards (Childers & Brecht 1996; Hoddle et al. 2002; Chen et al. 2004; Liburd et al. 2009). Clear traps were included to provide information on random flight interception. All traps were hung from olive branches at a height of 1.5 m. After collection, traps were wrapped in clear plastic wrap and returned to the laboratory. Thrips were identified to species and life stage with a key published by Childers and Beshear (1992), with identification of representative samples confirmed by the Florida Department of Agriculture and Consumer Services. If thrips numbers on 1 side of a trap were above 200, subsamples of thrips were counted and the total number was calculated. Clear acetate sheets marked with a grid were placed over the traps and thrips within random squares were counted. At least 24% of the surface area of the trap face was counted because this was determined by Liburd et al. (2009) to provide adequate precision for sampling. Thrips numbers were determined for both sides of the traps and a trap total used in analysis.

EXPERIMENTAL DESIGN

Traps were placed in a series of the 4 differently colored sticky traps (3.1 m apart) with trap order random and trap positions rotated at each collection period. Six series of traps were placed in each plot (Fig. 1) with 2 series in each plot facing the outer east–west edges of the grove. In each plot, 1 series faced an adjacent plot with another series facing the outer north–south edge of the plot. The 5th series was located in the center of the plot in a north–south orientation. For the edge

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series, 2 trap series were placed in 1 row, 3.2 m from the outer edge of the grove (facing woods) with 1 series placed 10 trees in from the north edge of the plot and 1 series 10 trees in from the south edge of the plot. For each plot, 3 series represented the outer edge of the grove and 3 represented the inner edges of the plots within the grove. Traps were deployed in 2015 before bloom (Mar 27; flower buds tight and not open) and collected during bloom (Apr 8; all buds open with some blossom drop) (heavy bloom set) and after all blossoms had dropped (Apr 22; no blossoms on trees).

MONITORING BY PLANT SAMPLING

Sampling consisted of both non-destructive and destructive sampling methods, and samples were obtained at the same time as the traps were placed and collected. Non-destructive sampling consisted of tapping foliage and flowers over a white plastic tray (18 × 25 cm; adapted from Pearsall & Meyers 2000). Vegetation was tapped 5 times against the tray for each of 3 trees located at each trap series location. All collected insects were rinsed from the tray with 70% isopropyl alcohol and placed in vials (50 ml) for storage until examined in the laboratory. Additionally, tree trunk brushing (modified after Childers & Nakahara 2006) was conducted to collect potential thrips and predators. This was conducted by making 10–15 firm downward strokes using a paintbrush (5 cm wide) into a white plastic tray from the main trunk and from branches of 3 trees interspersed between the sticky traps. Material from the trees was combined and rinsed from the tray and stored in 70% alcohol for subsequent identification.

Destructive samples also were obtained at the time of trap placement from plants adjacent to each trap. Three samples, each consisting of 5 leaves, were obtained at each series location and immediately placed into 70% alcohol in a vial. At each sampling location adjacent to each trap series during bloom, flower and fruit collections were made for characterization. Three flower clusters were collected along a stem with numbers of flowers and their position (proximal to distal) noted. In mid-May, when fruit were present, numbers of fruit and abscission scars were obtained from the same branches.

STATISTICAL ANALYSIS

Thrips collections primarily (> 99%) consisted of 1 species, so data for all species were combined for analysis. Because trap data represented different lengths of trap periods, all trap data were corrected (trap counts per day). Data were tested for normality (Shapiro-Wilk test) and if not normal, data were transformed (square root × + 0.01) to stabilize variances before 1-way analysis and normality verified by testing or non-parametric tests applied (Kruskal-Wallis ANOVA on ranks, Mann-Whitney U-tests). For data that were normal, comparisons between means were examined by 1-way ANOVA with means separation by Tukey's test or paired t-tests. Untransformed means and standard errors are presented in tables and figures. Data were analyzed by Sigmastat (Systat, San Jose, California, USA) or SAS (SAS, Cary, North Carolina, USA).

Results

TRAP COLLECTIONS

The reflectance pattern of sticky cards is presented in Figure 2. White cards were broadly reflective across the visible spectrum, whereas yellow cards had the greatest reflectance at 550 nm and above. Blue traps had a peak reflectance at 450 nm, and clear traps had low reflectance and equal reflectivity across the spectrum. The abaxial (underside) surface of olive leaves were broadly and highly reflective across the visible spectrum with a maximum at 548 nm. The adaxial (upper) surface of olive leaves similarly had maximum reflectance at 548 nm but had lower reflectance.

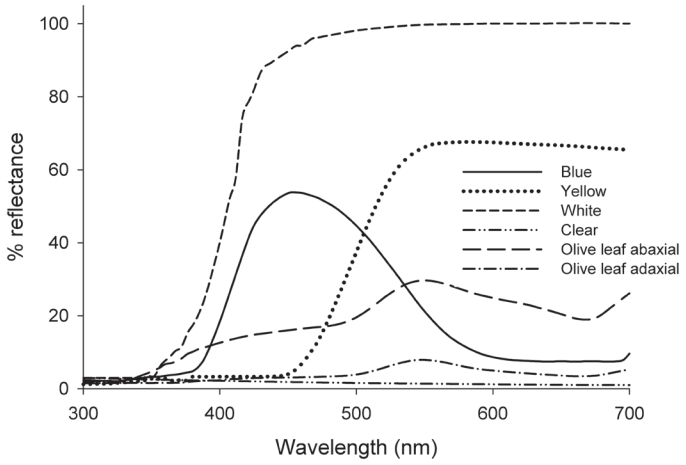


Fig. 2. Spectral reflectance of sticky card traps (white, blue, yellow, and clear), and abaxial and adaxial surfaces of olive leaves.

A total of 466,039 thrips were collected on sticky traps, with over 99.2% of thrips identified as *Franklinliella bispinosa* (Morgan) (Thysanoptera: Thripidae). The remaining thrips identified were *Leptothrips pini* (Watson) (Thysanoptera: Phlaeothripidae) (0.4%) or others (0.4%) which also included other predacious thrips. Because most thrips represented 1 species, all species and life stages were combined. There were no differences in trap collections among plots (F = 1.64; df = 3,287; P = 0.18) (Fig. 3) and data for all plots were combined for analysis. There were significant differences between collection dates (F = 97.85; df = 2,287; P < 0.001) (Fig. 4) with greatest collections during the bloom period, moderate collections pre-bloom, and very few thrips collected after bloom. Overall, there were significant differences between trap color (H = 66.38; df = 3; P < 0.001) (Fig. 5) with more thrips collected on blue traps, followed by yellow and white traps. All colors of traps collected more thrips than clear traps, which served as flight interception traps. During the bloom period, when significantly more thrips were collected, a similar order of thrips collection was seen with blue traps being the most effective and clear traps the least effective (Fig. 5). The effect of trap location within the grove was examined during the bloom period, by combining all trap collections and comparing those on the inner collection sites (113.12 ± 17.32) in the grove to the sites on the outer edges (142.18 ± 20.76). There were no significant differences (U = 9390; n = 144; P = 0.167) between these collection locations. Similarly, when comparing blue traps alone between inner (233.70 ± 51.91) and outer (289.06 ± 63.28) trapping positions, there were no differences (U = 571.5; n = 36; P = 0.392).

PLANT COLLECTIONS

There were 4,692 thrips collected with tap samples, consisting of 99.34% *F. bispinosa* and 0.66% *L. pini*. Numbers of thrips collected in plot 4 were significantly greater than in other plots (F = 1.75; df = 395; P = 0.16) (Fig. 3). Numbers of thrips in collections differed with date of collections (F = 2.87; df = 3,95; P = 0.04) with greater thrips numbers during the bloom period as compared to the pre and post-bloom periods (Fig. 4). When tap samples at the grove were divided into outer collections (sample sites adjacent to outer edge of grove) or inner col-

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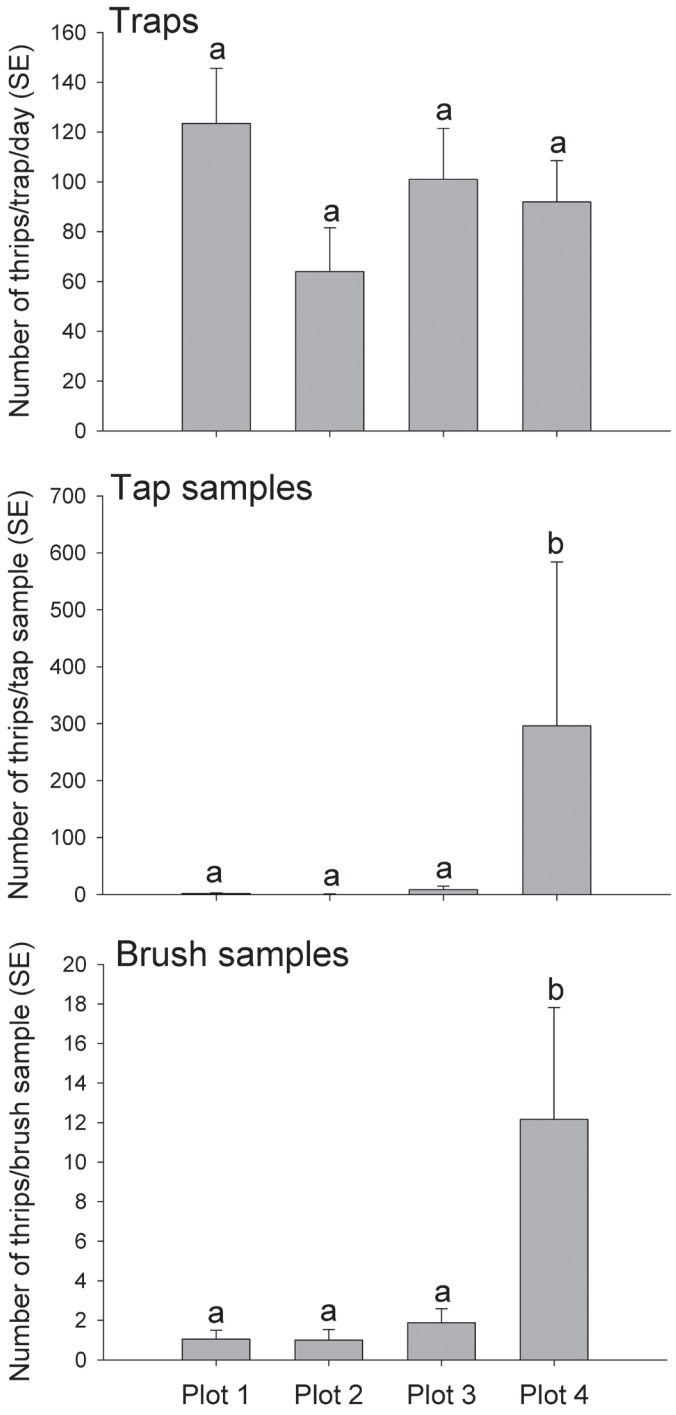


Fig. 3. Differences in mean numbers of thrips (± SE) collected by tap and brush samples between plots. Bars with different letters indicate significantly different means ($P < 0.05$).

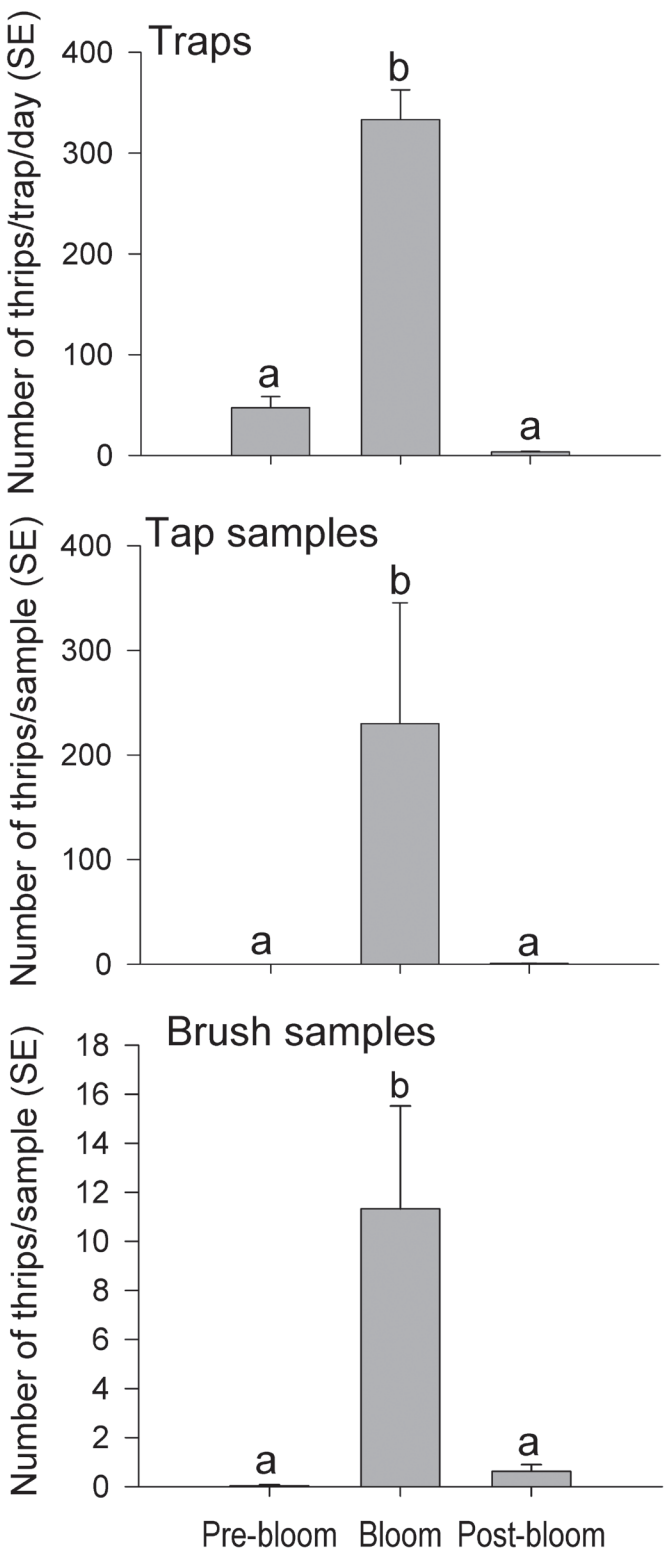


Fig. 4. Comparison of mean numbers of thrips (± SE) collected by sticky traps, tap samples, or brush samples between pre-bloom, bloom, and post-bloom sampling periods. Bars with different letters indicate significantly different means ($P < 0.05$).

lections (sample sites closer to inner section of grove), there were no differences when all dates were combined ($P > 0.05$). However, when examining tap samples during the bloom period, there were more thrips in the outer or perimeter collections than in the interior collections ($U = 23$; n = 48; $P = 0.005$). Highly localized high densities of thrips distribution are seen when total thrips numbers collected at each site are plotted (Fig. 6).

Brush samples yielded 293 thrips, all of which were *F. bispinosa*. The largest collections came from plot 4 ($F = 3.36$; df = 3,95; $P = 0.02$) (Fig. 3). Thrips in brush samples differed with collection date ($F = 6.87$; df = 2,96; $P < 0.001$) with the most collected at the time of bloom (Fig. 4). There was no difference in collections from the inner and outer portions of the plots when all collection dates were combined ($U =$

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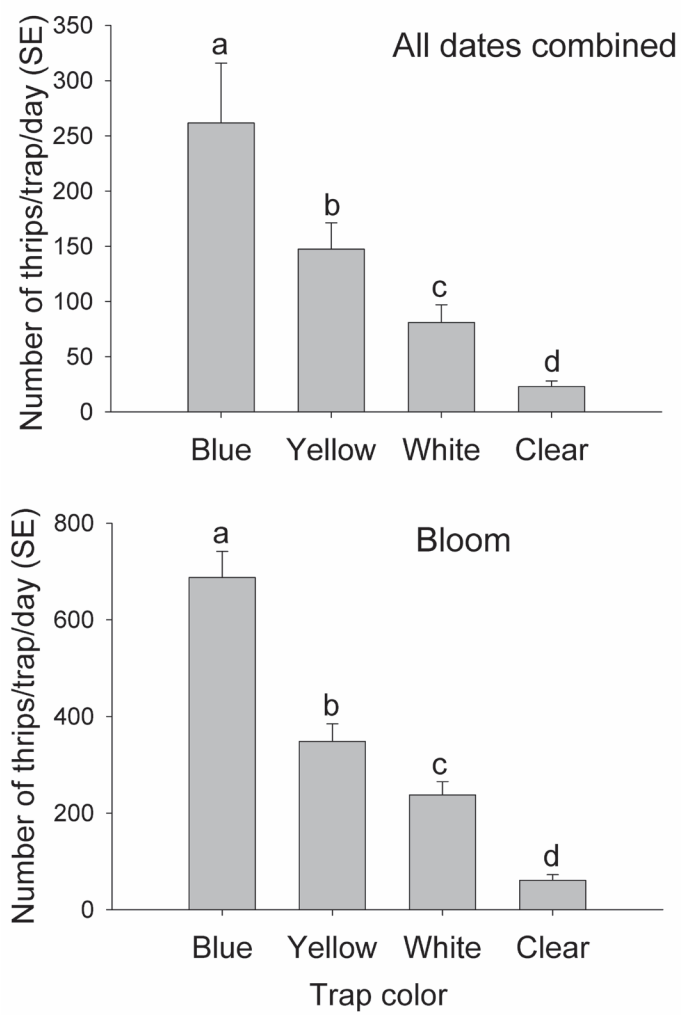


Fig. 5. Collection of mean numbers of thrips (± SE) (all species and stages combined) from differently colored sticky traps with combined data from all collection dates, or collections from bloom period alone. Bars with different letters indicate significantly different means ($P < 0.05$).

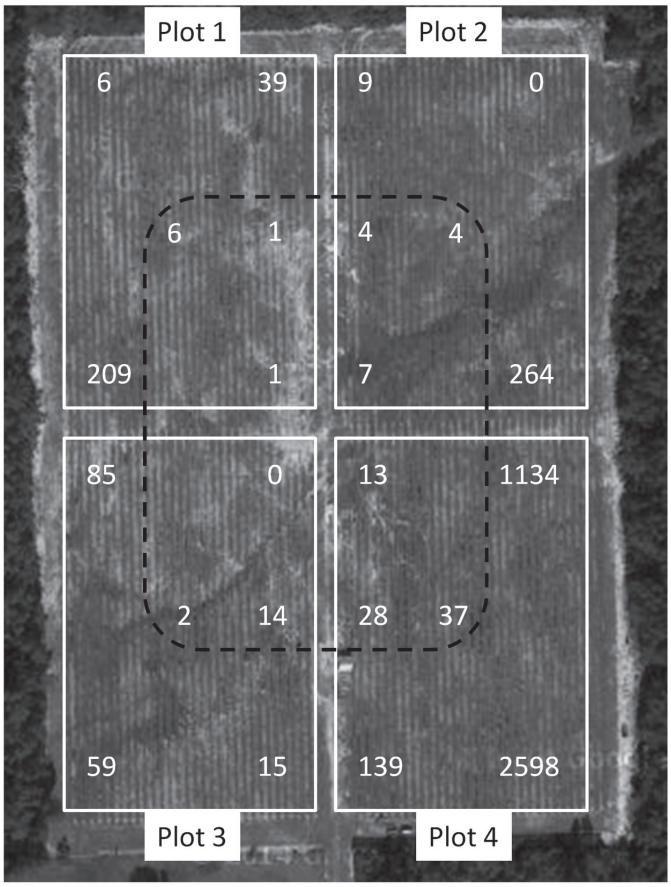


Fig. 6. Total thrips collected from sticky cards at each sampling station during olive bloom. For analysis, sampling positions within the dotted line were considered to be interior, whereas those on the outside were considered to be outer sites.

1023.0; n = 48; $P = 0.256$) or only during bloom time ($U = 61.5$; n = 12; $P = 0.56$). There was no difference in numbers of thrips collected in tap and brush samples pre-bloom ($U = 263$; n = 24; $P = 0.292$); however, significantly more thrips were collected by tap sampling for both the bloom ($U = 149.5$; n = 24; $P < 0.01$) and post-bloom period ($U = 97.5$; n = 24; $P < 0.001$).

A total of 96 leaf samples were collected over the 4 sampling dates. Only 2 samples yielded thrips, which consisted of a total of 3 *F. bispinosa* adults collected during the bloom period. One sample contained 3 adult black scales (*Saissetia oleae* (Olivier) (Hemiptera: Coccidae). Otherwise, there were only individual collections of 1 or 2 specimens, and 9 samples contained mites (Table 1) of which the olive bud mite, *Oxycenus maxwelli* (Keifer) (Acari: Eriophyidae), is known to have potential for damage to olives.

There were no differences between plots in numbers of flowers (9.9–10.2) ($F = 0.197$; df = 323; $P = 0.89$) or fruit (7.8–8.6) ($F = 0.29$; df = 3,23; $P = 0.83$) in each cluster. There was no difference in the flower numbers between clusters that were from distal to proximal on the branches ($F = 0.03$; df = 2,71; $P = 0.97$). There were more flowers in clusters in the center of the plots (10.55 ± 0.25) compared to the outer edges of the plots (9.61 ± 0.25) ($F = 7.05$; df = 1,71; $P < 0.01$).

Discussion

The most frequently collected species from olives was the Florida flower thrips, *F. bispinosa*. They were collected by all sampling methods, although blue and yellow traps were very effective for sampling. Based on collections from plants, leaf collections were the least sensitive for detection of thrips, with tap samples more sensitive than brush samples. In Florida, the dominant thrips species attacking blueberries is *F. bispinosa*, which has been reported to account for over 93% of collections from sticky traps or flowers (Arévalo & Liburd 2007a; Liburd et al. 2009), and also it is a secondary pest in strawberries (Price et al. 2006). This species has been associated with floral buds and open flowers of citrus, and represented 92% of thrips identified from over 80 citrus groves in Florida (Childers et al. 1990; Childers & Beshear 1992). Suppression of populations of *F. bispinosa* was associated with increased fruit set in citrus (Childers 1992) and it is considered to be an economic pest of orange, strawberries, avocados, vegetables and ornamentals in Florida (Childers & Brecht 1996). While this species is primarily a pollen feeder (Childers & Achor 1991), adults and larvae feed on the ovaries, floral disks, petals, and anthers of navel oranges. The presence of injury beyond the length of maxillary stylets suggests injury due to salivary secretions (Childers & Achor 1991). Premature flower drop and decreased yields of navel and Valencia oranges have been noted in response to this species (Childers & Achor 1991; Childers 1992).

The other insect species collected in significant numbers was *Leptothrips pini*, which is a predacious species commonly associated with

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Table 1. Identification of arthropods collected from traps and sampling in the olive grove.

Collection Method	Species	Common Name	Family
Leaf sample	*Typhlodromips dentilis* (De Leon)	Phytoseiid mite	Phytoseiidae
Leaf sample	*Tydeus* sp.	Tyeid mite	Tydeidae
Leaf sample	Oribatid mite immature		
Leaf sample	*Frankliniella bispinosa* (Morgan)	Florida flower thrips	Thripidae
Leaf sample	*Brevipalpus yothersi* Baker		Tenuipalpidae
Leaf sample	*Oxycenus maxwelli* (Kiefer)	Olive bud mite	Eriophyidae
Leaf sample	*Chrysomphalus dictyospermi* (Morgan)	Dictyospermum scale	Diaspididae
Leaf sample	*Pinnaspis* sp.	Armored scale	Diaspididae
Sticky trap	*Leptothrips pini* (Watson)		Phlaeothripidae

pine in southeastern states (O'Neill 1965). It has been reported from citrus orchards in Florida on sticky cards associated with citrus bloom (Childers et al. 1998) and reported from *Lantana camara* L. (Verbenaceae) in citrus orchards (Childers & Nakahara 2006). Additionally, it has been reported on tobacco in Georgia (McPherson & Beshear 1990). The presence of *L. pini* in the olive grove is presumably related to the presence of pines in the adjacent wooded areas. Despite adjacency to citrus groves, other thrips species associated with citrus (Childers et al. 1990; Childers & Nakahara 2006) were not detected in this study and may have reflected distance from citrus orchards or host preference. Thrips are generally not considered to be pests of olives, other than implicated in damage by *Thrips imaginis* Bagnall (Thysanoptera: Thripidae) and *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) from Australia (Spooner-Hart et al. 2007). However, given the economic impact of *F. bispinosa* on a range of crops in Florida and the abundance of thrips on olive plants, particularly around bloom, further study is warranted to determine if this species will pose an economic threat to olives produced in the southeastern states.

Sticky traps are effective surveillance tools for thrips as well as many other herbivorous insects and the response to colored sticky traps can differ due to factors such as species (Hoddle et al. 2002; Muvea et al. 2014), feeding guilds (Kirk 1984), crop (Cho et al. 1995; Hoddle et al. 2002), trap height (Gillespie & Vernon 1990), and sunlight exposure (Hall 2009). Color preference of thrips also differs between studies (Yudin et al. 1987; Vernon & Gillespie 1990; Cho et al. 1995; Chen et al. 2004). Additionally changes in trap color preference also have occurred within studies (Hoddle et al. 2002; Liburd et al. 2009) and are possibly due to changes in density (Liburd et al. 2009), sex (Vernon & Gillespie 1990; Liburd et al. 2009), visual characteristics of vegetation relating to contrast, or light quality (Hoddle et al. 2002).

Sticky traps were highly effective in detection of *F. bispinosa* in olives, with blue and yellow traps the most effective for sampling. In blueberry plantings in Florida, both blue and white sticky traps were most effective for collection of *F. bispinosa*, followed by yellow and green (Liburd et al. 2009). Yellow traps were most effective early in the flowering season when populations were low, and then preference shifted to blue and white traps. The effectiveness of the white sticky traps as an effective monitoring tool for *F. bispinosa* in blueberries was considered to be related to the high contrast of the traps against the dark vegetation (Liburd et al. 2009). Blue and white sticky cards were considered comparably effective in collection of *F. bispinosa* in citrus (Childers & Brecht 1996) with yellow considered less attractive. Our differences in response may be related to the lack of contrast of the white traps against the olive foliage, which is lighter in color than that of citrus or blueberries, and also due to relatively sparse foliage when trees were young with a thin canopy. Blue and yellow traps may have contrasted more against the olive foliage, and enhanced collections. Background contrast has previously been documented to alter response of *F. occidentalis* to different colors of sticky traps (Vernon & Gillespie 1995). Alternatively, the sources and composition of the white traps differ between studies and include white paper and cardboard (Cho et al. 1995), paint (Yudin et al. 1987; Childers & Brecht 1996), plastic (Yudin et al. 1987) and commercial traps (Hoddle et al. 2002; Arévalo & Liburd 2007b; Liburd et al. 2009; Rodriguez-Saona et al. 2010). Differences in the spectral reflectance from the different traps may have contributed to differences in attraction. In general, *F. bispinosa* appears to respond broadly to hue, as is considered typical for generalistic herbivores (Prokopy & Owens 1983).

Population levels of flower thrips are strongly correlated with the percentage of bloom on crops (Arévalo-Rodriguez 2006) and flower density (Rhodes et al. 2016). The rapid drop in thrips collection noted by *F. bispinosa* in this study after bloom was similar to that noted by Childers & Brecht (1996). The presence of flowering ground cover plants contributes to and maintains thrips populations adjacent to crops (Childers et al. 1990; Northfield et al. 2008) with *F. bispinosa* collected in abundance from 31 vine and cover crop species within citrus orchards (Childers & Nakahara 2006). Thrips were present throughout the year, with peaks in abundance in Apr and Nov in citrus groves (Childers & Nakahara 2006). In a study in Florida blueberry fields on *F. bispinosa* and *Frankliniella tritici* (Fitch) (Thysanoptera: Thripidae), Arévalo & Liburd (2007a) reported low numbers of thrips before bloom, high numbers during bloom and then low collections after bloom, which is similar to the pattern observed in our study.

Differences in thrips collections between plots were not detected on traps; however, they were detected from tap and brush samples. While sticky traps are useful for monitoring thrips activity (Childers & Brecht 1996; Hoddle et al. 2002; Arévalo & Liburd 2007a), additional methods that more directly sample from plants (specifically from blooms) such as tap samples can provide better location of localized aggregations of thrips. Most thrips collected by Rodriguez-Saona et al. (2010) on sticky traps were considered to be flying to or from plants, and are thought to reflect localized movement of thrips. In contrast, tap samples reflect abundance present on and presumably feeding on the vegetation sampled. The larger collections of thrips from tap samples on the outer edges of the grove compared to the inner region of the grove may reflect the movement and establishment of thrips from the surrounding areas that did contain flowering plants. In contrast, the center of the grove consisted mostly of mown grass and likely supported few flower thrips when olives were not in bloom.

Aggregated distributions of thrips in crops have been well characterized (Shelton et al. 1987; Saguero-Navas et al. 1991; Cho et al. 2000). Rodriguez-Saone et al. (2010) reported that thrips counts from vegetation were not correlated with trap catches within blueberry fields. Similarly, in our study, differences within the olive grove between plots during the bloom period were not detected in trap data, but were observed with tap and brush count data. This is likely a re-

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sult of tap and brush collections more accurately reflecting numbers of thrips in the proximity of the vegetation. In a study in Florida in blueberry fields, highly localized high aggregations of thrips (*F. bispinosa* and *F. tritici*) were located in random locations with unknown factors contributing to their occurrence (Arévalo and Liburd 2007b). These aggregations have previously been termed "hot spots" and were considered to consist of large numbers of thrips in a distinct area of the field with the remainder of the field having lower population densities that attained maximum levels about 2 wk after bloom initiation (Arévalo and Liburd 2007b). Population levels of thrips in these hot spots dissipated about 22 d after bloom initiation and corresponded to the overall low levels of thrips collected on our last sampling date. These aggregated spots are challenging to detect by sampling but are of concern for protection of fruit and blossoms from damage. Optimal sampling strategies for such aggregations of thrips have been developed for potato (Cho et al. 2000) and blueberries (Arévalo and Liburd 2007b).

While further study is needed to determine if thrips negatively affect olive production, it is clear that sampling by using blue or yellow sticky traps, and tap sampling, would provide the best assessment of overall populations and occurrence of hot spots for guidance of any control strategies. This study focused on thrips sampling, and further surveys are needed to assess the wider range of phytophagous arthropods that may pose a threat to olives in Florida.

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