Horizontal and Vertical Distribution of Flower Thrips in Southern Highbush and Rabbiteye Blueberry Plantings, with Notes on a New Sampling Method for Thrips Inside Blueberry Flowers

H. A. ARÉVALO[1] AND O. E. LIBURD

Department of Entomology and Nematology, University of Florida, Gainesville, FL 32611

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ABSTRACT The dispersal behavior of flower thrips was studied during two field seasons within blueberry (*Vaccinium* spp.) plantings in Florida and southern Georgia. A "shake and rinse" technique used to extract thrips from inside the blueberry flowers was not significantly different from the conventional dissecting technique, but the time taken to complete the extraction of thrips was significantly shorter. Overall, the highest concentration of thrips was captured inside the canopy of blueberry bushes. Using a grid of traps to monitor the dispersal of thrips during the blueberry flowering season, we analyzed their dispersion with graphical and analytical methods to determine and describe their distribution within blueberry plantings. Thrips began to form "hot-spots" 5–7 d after bloom initiation. A hot-spot is defined as a large number of thrips concentrated in a small area of the field, whereas the rest of the field has a low population. The behavior of the population inside these hot-spots fit a Gaussian tendency and a regression was conducted to describe this tendency. Green's and Standardized Morisita's indices were used to determine thrips level of aggregation. Results showed significantly aggregated populations of thrips in both years. Formation of hot-spots in blueberry plantings seemed to be random. However, the formation of hot-spots was higher in places where more than seven thrips per day were captured on sticky traps, 5 to 7 d after the bloom begins. With these results, producers will be able to monitor thrips populations and locate and manage hot-spots before they become a more serious a problem on blueberry farms.

KEY WORDS thrips, blueberries, sampling, hot-spots, distribution

Blueberry production in Florida has increased by 50% over the last decade. Southern highbush (SHB), *Vaccinium corymbosum* L. × *V. darrowi* Camp, and rabbiteye (RE), *Vaccinium ashei* Reade, are the two main types of blueberries grown in the southern states (Lyrene 2005, NASS-USDA 2006). Currently, SHB is planted on ≈85% of the blueberry acreage in Florida. Alternatively, ≈75% of the blueberry acreage in Georgia is planted with RE. Blueberries are harvested during April and May, making Florida and Georgia the only U.S. states that produce a significant amount of early-season blueberries.

In a survey conducted in 2003, 25% of the blueberry growers from Florida and southern Georgia identified flower thrips as a priority pest that requires immediate attention (Finn 2003). Currently, only a few extension articles have been published on thrips management in early-season blueberries (Liburd and Arévalo 2005, Arévalo et al. 2006). Generally, information on thrips in SHB and RE blueberries is very limited, and in most cases unavailable. Finn (2003) initiated preliminary work on sampling techniques for flower thrips in SHE and RE blueberries and reported that there were no significant differences between the number of thrips captured in unbaited yellow, blue, and white sticky traps in the blueberry plantings studied. A white sticky trap was recommended as the monitoring tool for thrips in SHB and RE blueberries due to the contrast between thrips and the white trap background compared with blue sticky traps. Generally, flower thrips have been monitored by using sticky traps of various colors. The two colors most commonly used are yellow and blue (Diraviam and Uthamasamy 1992, Cho et al. 1995, Hoddle et al. 2002, Finn 2003).

Insect distribution depends on the mobility of insects and highly mobile insects display a more random distribution compared with insects with low mobility, which are more inclined to be clumped (Flint and Gouveira 2001). In terms of dispersal, two primary dispersal mechanisms have been implicated in thrips movement. Artificial dispersal is usually human-assisted; thrips are transported inadvertently by farm equipment, workers clothing, and so on The second method involves natural forms of self-dispersal; the most common and efficient method for insects is flying. Thrips have been reported to fly at 6–30 ms^{-1}

[1] Corresponding author: Department of Biological Sciences, 5722 Deering Hall, University of Maine Orono, ME (e-mail: arevalo.ha@gmail.com).

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depending on the species. Natural dispersal over long distances is generally accomplished via wind (Lewis 1997).

Despite the small size of thrips and their apparent lack of controlled flight patterns, due to wind interaction, there is good evidence that thrips have some control over their landing (Lewis 1997). Kirk (1984) used various colored traps on the ground separated by 5 m to demonstrate that thrips can choose where to land. The author reported a 20-fold difference between flower thrips and grass-dwelling thrips in their color selection for landing. Flower thrips were attracted to bright colors such as white, whereas grass-dwelling thrips were attracted to colors that were closer to green (Kirk 1984, Teulon and Penman 1992).

There are two main species of flower thrips captured in early-season blueberries, which are separated by geographical boundaries. In Florida, *Frankliniella bispinosa* (Morgan) is the dominant species, accounting for 83.6% of the thrips captured in sticky traps in blueberries. In Georgia, *Frankliniella tritici* (Fitch) is the most abundant species representing 94.0% of the thrips captured in sticky traps (Arévalo 2006, Arévalo et al. 2006). Other species captured in blueberries include *Frankliniella fusca* (Hinds), *Frankliniella occidentalis* (Pergande), and *Frankliniella hawaiiensis* (Morgan).

The attraction of thrips to colored traps can be further enhanced by taking advantage of olfactory stimuli. The use of various odors, including anisaldehyde (for flower thrips) or ethyl nicotinate [for *Thrips obscuratus* (Crawford)], can significantly increase the trapping of the respective thrips compared with the controls (Kirk 1985, Teulon 1988).

Here, we studied thrips abundance, as well as the horizontal and vertical distribution of thrips in blueberries as it relates to blueberry phenology. A better system to monitor flower thrips activity and knowledge of their dispersal behavior in SHB and RE blueberries will lead to more effective management tactics for blueberry growers.

Materials and Methods

Blueberry Farms. Experiments and sample collection were conducted on three commercial farms in Florida—farm FL01, located in south-central Florida (N 28° 04′ W 81° 34′); farm FL02 (N 29° 40′ W 82° 11′) and farm FL03 (N 29° 43′ W 82° 08′) located in north-central Florida—and one commercial farm in Georgia, farm GA01, located in southern Georgia (N 31° 31′ W 82° 27′).

New Sampling Method. A more efficient system is needed to rapidly and accurately process floral samples in blueberries due to the high number of thrips that are usually associated with SHB and RE blueberries during the flowering season. We hypothesized that the number of thrips collected using a new "shake and rinse" sampling method will not be significantly different from the thrips collected using the more labor-intensive dissection technique. However, the shake and rinse method will be a more rapid process to assess thrips population inside blueberry flowers.

To test this hypothesis, we compared the "shake and rinse" method with the dissection technique to determine whether there is a difference in the number of thrips recorded between the two techniques. Twenty randomly collected samples consisting of five flower cluster per sample (each flower cluster has eight individual flowers) were collected from SHB plantings FL02 and FL03 for comparison. Samples were collected when the thrips populations were at their highest.

Shake and Rinse Method. Flower clusters were collected randomly by cutting their pedicels with the rim of a 50-ml Corning plastic tubes (Fisher Scientific, Pittsburgh, PA) vial and allowing the flowers to drop inside a vial with 70% ethanol. Each vial was manually shaken for approximately 1 min before the contents were emptied into a 300-ml white polyethylene jar (B & A Products, Ltd. Co., Bunch, OK). The jar consisted of a plastic screen (6.3- by 6.3-mm mesh), which acted as a filtering system, allowing only thrips and a small debris to pass through, while leaving floral tissues behind. The remains left on the screen were given a second and a third rinse to ensure maximum collection of thrips. Corollas and calyxes from the flowers were manually separated before the second rinse to ensure that all of the thrips are extracted from the floral tissues. After each rinse, the thrips found in the water were collected and counted. Finally, the rinse water was then transferred to a container with a black background to ensure that the thrips missed with the white background could be found by contrast. This technique is based on a combination and improvement of the techniques used by Finn (2003) and Funderburk and Stavisky (2004).

Dissection Technique. The number of thrips was initially measured using shake and rinse method. The samples were then dissected to determine how many thrips were missed with the initial shake and rinse procedure. Floral tissue (described above) was observed under a 10× dissecting microscope (Leica MZ12.5, McBAin Instruments, Chatsworth, CA). Using forceps and dissecting pins, floral tissues were separated and individually observed for the presence of thrips. When thrips were located, they were collected using a fine paintbrush counted and recorded.

Statistical Analysis. To facilitate the analysis and reduce the variability of randomly collected samples, which will bias the comparison, the number of thrips recorded from the dissection technique was assumed to be equal to the number of thrips counted with the shake and rinse method plus the thrips collected under the microscope using the dissection technique (on the remaining flower tissues). A paired *t*-test was used to compare the total number of thrips collected using the shake and rinse procedure with the thrips obtained by dissection, because both samples were collected from the same individual (SAS Institute 2002).

Vertical Distribution of Flower Thrips in Blueberry Fields. To determine vertical distribution of flower thrips within blueberry fields, 10 sampling sta-

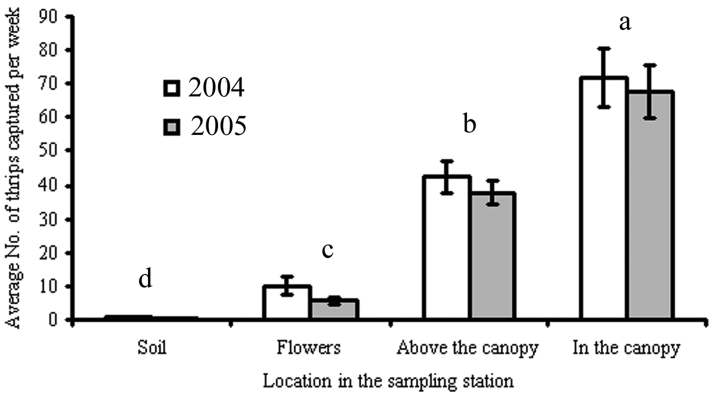

Fig. 1. Vertical distribution of thrips in southern highbush blueberry bushes in south-central Florida. Different letters represent significant differences among the groups by using least significant difference (LSD) mean separation test, $\alpha = 0.05$.

tions were placed randomly in each of two commercial blueberry farms. One set of sampling stations was located at farm FL01 in south-central Florida (N 28° 04′ W 81° 34′), which was planted with highbush blueberries. A second sampling station was located on southern Georgia on Farm GA01 (N 31° 31′ W 82° 27′), which was planted with rabbiteye blueberries. Each commercial farm site measured ≈1 ha. A sampling station consisted of three white sticky traps (each trap 23 by 17 cm of effective area) (Great Lakes IPM, Vestaburg, MI). One of the traps was placed on the ground under the canopy of the bush in an inverted V shape with the sticky surface toward the ground, a second trap was located inside the canopy approximately in the middle of the same bush, and the third trap was ≈40 cm above the canopy of the same bush. The traps above the canopy were hung from an inverted L shape half-inch electrical metallic tube. A flower sample was collected from the same bush containing the sampling station on the day that the sticky traps were collected. The flower sample consisted of five flower clusters (approx.. eight flowers per cluster). Flower clusters were placed into 50-ml Corning plastic tubes filled with 70% ethanol as described above. Flower samples were processed using the shake and rinse method described above, and the total number of thrips was recorded. Sampling stations were randomly moved to a new position in the field every week by using random number tables based on the number of rows and the number of plants in each row. The data were collected from bloom to petal-fall 2004 and 2005. The number of thrips caught on the sticky traps was determined by counting the number of thrips in 16 of the 63 squares (each square is 6.45 cm^2), under a dissecting scope as determined by Finn (2003).

Statistical Analysis. Data were analyzed using repeated measures model and analysis of variance (ANOVA) tables (SAS Institute 2002). Soil traps were not used in Georgia, because the results in Florida showed that the number of thrips captured was too low for a robust analysis and comparison. Data were transformed to comply with the assumptions of the analyses. The data for 2004 and 2005 in Florida and 2005 in Georgia were transformed using the natural logarithm of the original data plus 1; for 2004 in Georgia, the transformation used was the square root of the number of thrips captured. The data presented here are the untransformed means ± SE.

Horizontal Distribution of Flower Thrips in Blueberry Plantings. To investigate the horizontal distribution of flower thrips in blueberry plantings, we

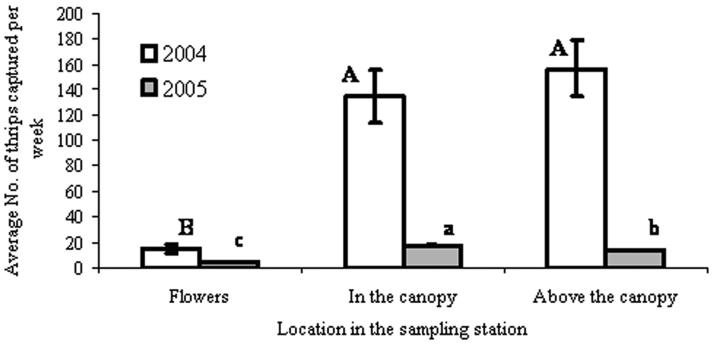

Fig. 2. Vertical distribution of thrips in rabbiteye blueberry bushes in southern Georgia. Different uppercase letters represent significant differences among the groups in 2004; lowercase letters represent significant differences among groups in 2005 by using LSD mean separation test, $\alpha = 0.05$.

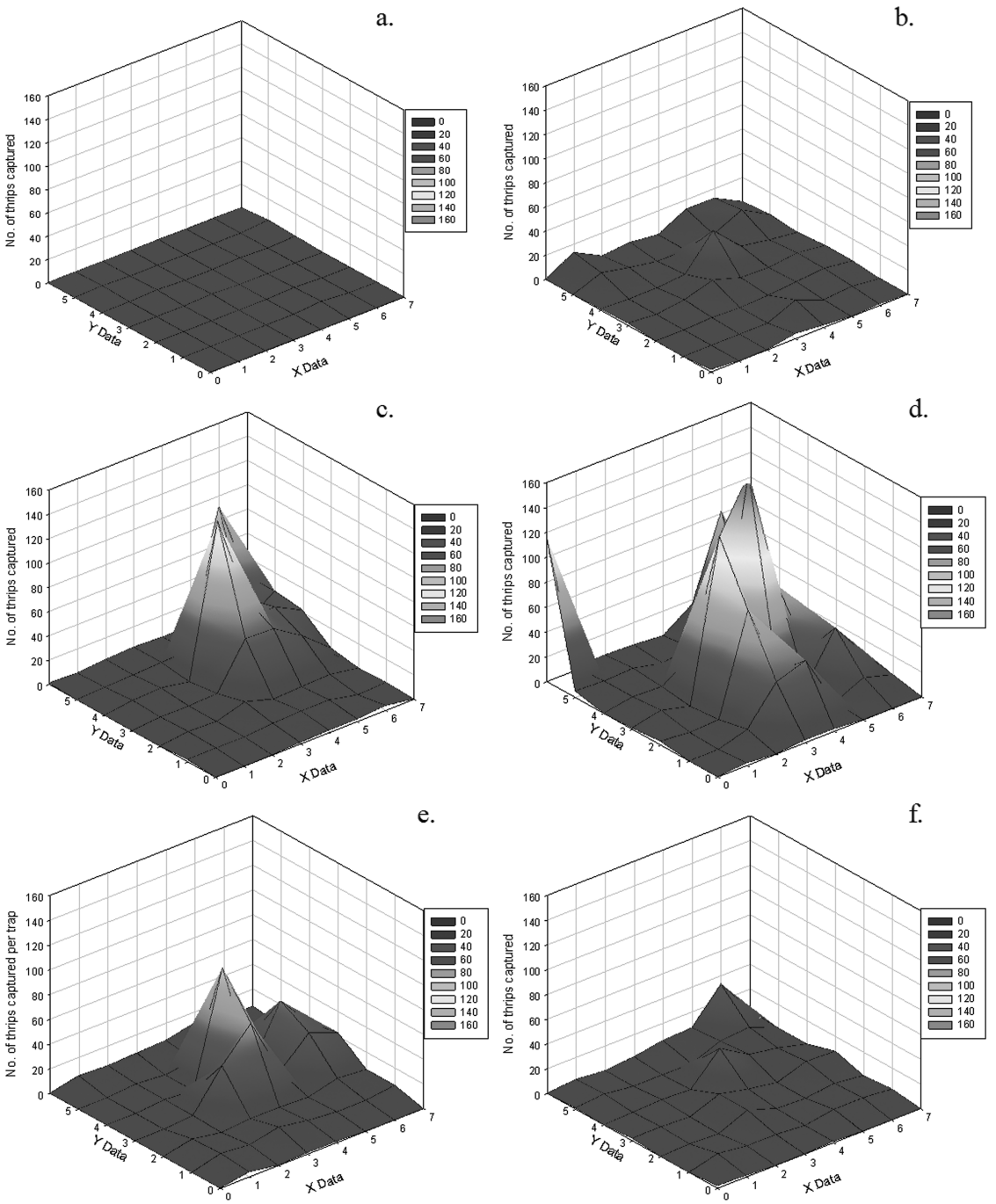

Fig. 3. Number of thrips captured at two (a), eight (b), 14 (c), 16 (d), 18 (e), and 22 (f) days after bloom began and their location on the blueberry plot on farm FL02 in 2004. The intersections of coordinates *x*-data and *y*-data represent the location of a white sticky trap.

selected two commercial blueberry plantings in north-central Florida: farm FL02 (N 29° 40′ W 82° 11′) and farm FL03 (N 29° 43′ W 82° 08′). Both farms were planted with southern highbush blueberries during 2005. However, during 2004, FL02 was planted with rabbiteye and southern highbush (50% of each crop). The selected plot in FL02 measured 3.9 ha, and the plot in FL03 measured 1.5 ha. Two grids of white sticky traps, one grid of 8 by 7 sticky traps and a second grid of 5 by 6 sticky traps, were deployed on each farm, respectively. The traps were spaced 30.5 m from each other, which covered blueberry plots and adjacent

noncultivated areas (predominantly rye grass, *Lolium* spp., and shrubbery). These traps were replaced every other day at approximately the same time starting from bloom initiation and finishing at petal fall.

The total number of thrips trapped was recorded to monitor the presence of thrips inside and outside of the blueberry fields for two flowering seasons, 2004 and 2005, respectively. In 2004, sampling began on 3 March, and in 2005 it began on 20 February at both locations. The variation in the sampling start dates between the years is due to the differences in the date of flowering of the blueberry bushes. Flowers in 2005 opened 1 to 2 wk earlier than in 2004.

To determine degree of aggregation, we selected the standardized Morisita's coefficient of dispersion (*Ip*) (Smit-Gill 1975) and Green's coefficient of dispersion (*Cx*) (Green 1966), because they have low or no correlation with the mean (Myers 1978, Taylor 1984, Schexnayder et al. 2001). The aggregation indices were calculated for each day that the sticky traps were collected. We used SigmaPlot (Systat Software, Inc. 2006) to graph the amount of thrips captured in each trap per day. Once the hot-spots were graphically identified, we conducted a Gaussian regression to describe the population behavior in each one of the hot-spots through time:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\left[-0.5\left(\frac{x-\mu}{\sigma}\right)^2\right]}$$

In this study, populations were considered to be clumped if Green's index $Cx > 0$, random if $Cx = 0$, or uniform if $Cx < 0$ (Myers 1978, Schexnayder et al. 2001). In standardized Morisita's index, populations were considered to be significantly clumped ($\alpha = 0.05$) if $Ip > 0.5$, not significantly clumped if $0.5 > Ip > 0$, random if $Ip = 0$, not significantly uniform if $0 > Ip > -0.5$, and significantly uniform if $Ip < -0.5$ (Smit-Gill 1975). Overall comparisons were conducted by averaging all the indices calculated and comparing them to 0 for *Cx*, and 0.5 for *Ip* by using a *t*-test (SAS Institute 2002).

Results

Sampling Techniques to Detect Thrips Population inside Blueberry Flowers. We found no significant difference between the shake and rinse method and the dissection technique in terms of the number of thrips recorded ($t = 0.17$; df = 1, 38; $P = 0.869$). We recorded an average of 34.7 ± 4.3 and 35.7 ± 4.3 thrips per five flower clusters for the shake and rinse method and the dissection technique, respectively. However, the time taken to detect thrips by using the shake and rinse method was significantly ($P < 0.05$) shorter than the dissection technique. The dissection technique average 50.1 ± 6.2 min to sample five flower clusters in a sample where as the shake and rinse method average only 12.2 ± 3.1 min to sample the same number of flower clusters. These results allow us to use the shake and rinse procedure in the following experiments with confidence in the data collected.

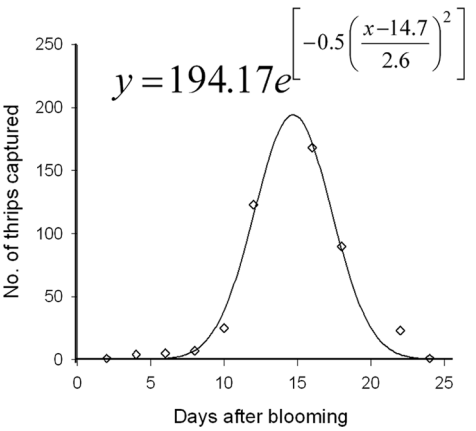

Fig. 4. Population growth inside a hot spot in coordinates (4, 4) of Fig. 3, for 2004 on farm FL02.

Vertical Distribution of Flower Thrips. During 2004, significantly more thrips were recorded on traps placed within the canopy compared with other positions evaluated ($F = 291.13$; df = 3, 157; $P < 0.0001$). Similar results were recorded during 2005. Traps placed within the canopy captured significantly more thrips than other positions evaluated ($F = 197.51$; df = 3, 164; $P < 0.0001$). The traps deployed above the canopy captured the second highest number of thrips, followed by thrips collected from inside the flowers. The least number of thrips were captured by traps on top of the soil (Fig. 1). Thrips distribution within blueberry bushes followed the same pattern independent of the year and the location. In Florida, there were no significant differences between 2004 and 2005 when the same positions within the bush were compared. For traps placed 15 cm above the soil surface ($t = 0.531$; df = 1, 325; $P = 0.595$), for flowers ($t = 1.474$; df = 1, 325; $P = 0.142$), for the traps placed within the bushes ($t = 0.308$; df = 1, 325; $P = 0.7582$), and for the traps above the canopy ($t = 0.438$; df = 1, 325; $P = 0.662$).

Our results on farm GA 01 in southern Georgia were different from those in Florida. There was no significant difference between the number of thrips within the canopy and above the canopy during 2004. However, these values were both significantly higher than the number of thrips captured in the flowers sampled during the same year. In 2005, there was a reduction in the number of thrips captured on farm GA01 compared with 2004 (Fig. 2). However, despite the reduced thrips numbers, significantly higher number of thrips were captured on traps placed within

Table 1. Distribution indices *Cx* and *Ip*, used to describe the level of aggregation of thrips populations on farm FL02 in Florida (2004)

Index	Days after blooming								
	2	4	6	8	10	12	14	18	22
Cx	−0.005	0.438	0.223	0.138	0.227	0.967	1.336	0.207	0.670
Ip	0.518	0.549	0.525	0.517	0.524	0.543	0.539	0.520	0.538

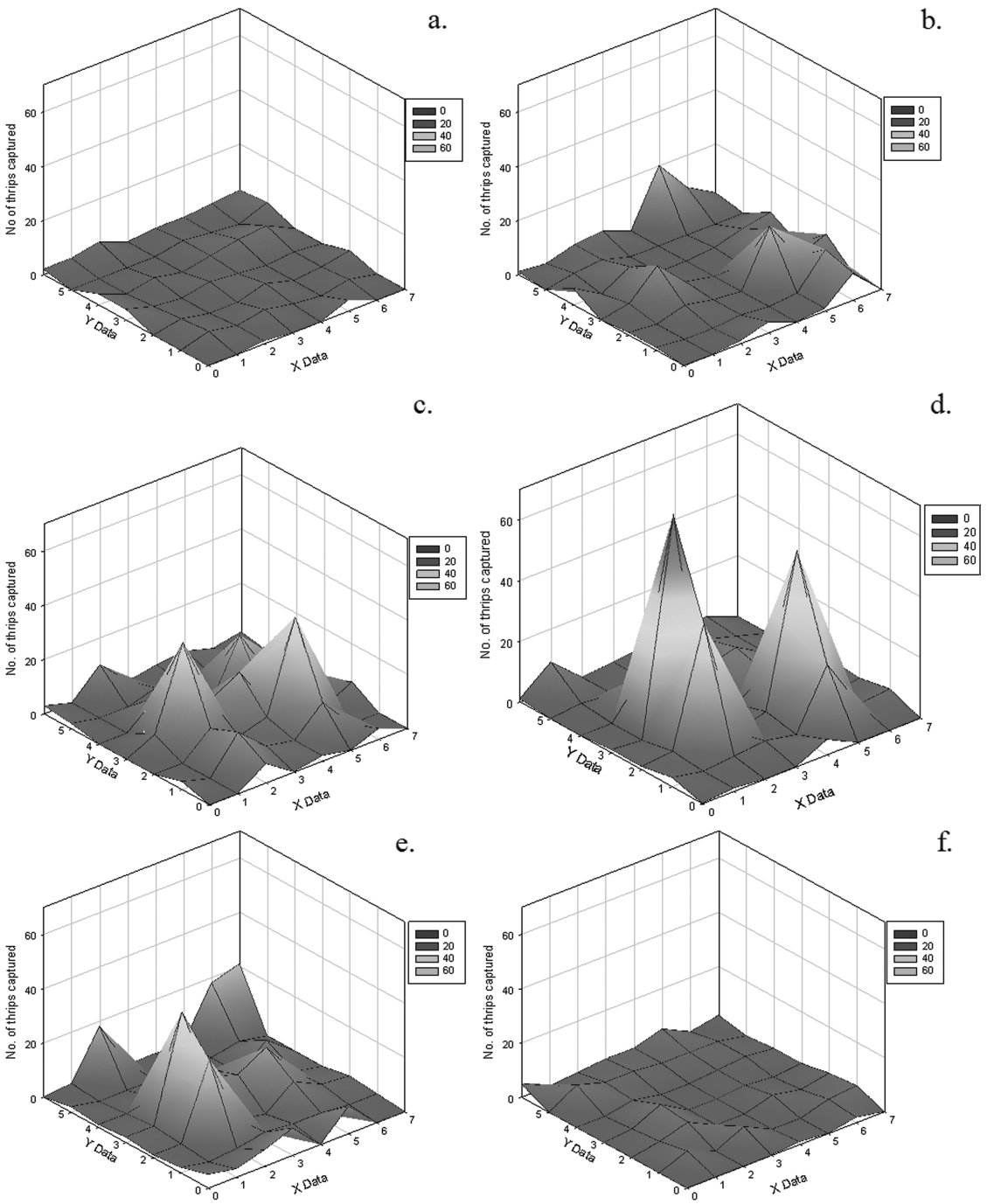

Fig. 5. Number of thrips captured at 2 (a), 8 (b), 14 (c), 16 (d), 18 (e), and 22 (f) days after bloom began, and their location on the blueberry plot on farm FL02 in 2005. The intersections of coordinates *x*-data and *y*-data represent the location of a white sticky trap.

the canopy compared with those placed above the canopy of the bushes in 2005 ($t = 7.3$; df = 1, 14; $P < 0.0001$), when using a Student's *t*-test. As in Florida, we found no significant differences between the number of thrips recorded within the flowers between 2004 and 2005 ($t = 0.682$; df = 1, 144; $P = 0.496$) in Georgia. Traps placed within and above the canopy captured significantly higher number of thrips compared with the thrips found within the flowers (Fig. 2).

Thrips Dispersion. *2004 Farm FL02.* The graphic analysis of the thrips population on this farm indicated

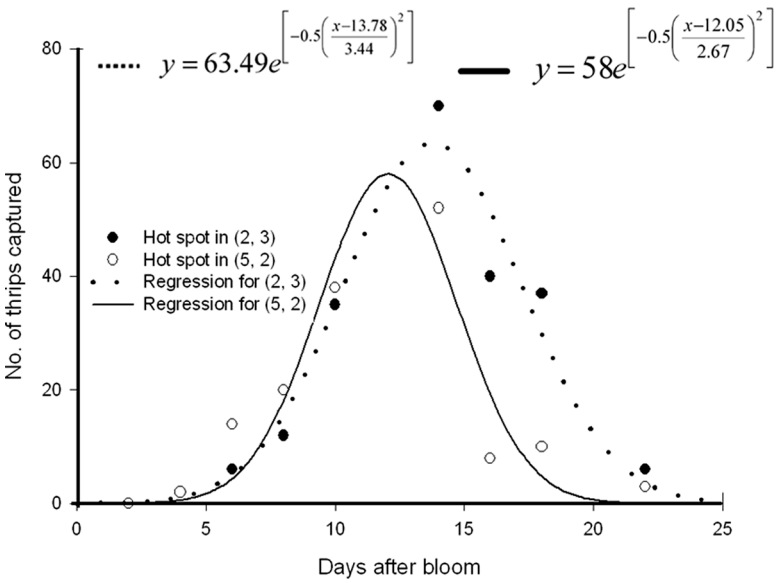

Fig. 6. Population dynamics inside the hot-spot in coordinates (2, 3), and (5, 2) of Fig. 5, on farm FL02 in Florida in 2005.

the presence of only one hot-spot in coordinates (4, 4) (Fig. 3). Thrips aggregation increased over time and peaked 12–14 d after bloom initiation. This peak coincides with the highest population density of thrips 14.7 d after bloom initiation (Fig. 4; Table 1). The data show that the thrips population can be considered clumped from day 4 based on *Cx* value. This observation is reinforced by *Ip*, which shows a significant level of aggregation ($Ip > 0.5$) from the beginning (Table 1). During the 2004 field season, we found only one hot-spot located at the coordinate (4, 4) in Fig. 3. A hot-spot is defined as a large number of thrips in a distinct area of the field, whereas the rest of the field have considerably lower populations. When analyzing this hot-spot during 2004, we found that the dynamics of the thrips population could be described by a Gaussian nonlinear regression, the pattern for the hot-spot for farm FL02 in 2004 is described by the equation represented (Fig. 4). Overall *Cx* 0.467 ± 0.147 is significantly higher than 0 ($t = 3.17$, df = 8, $P = 0.013$) and *Ip* 0.521 ± 0.004 is significantly higher than 0.5 ($t = 7.48$, df = 8, $P < 0.0001$), which shows a significant level of aggregation of the flower thrips on farm FL02 for 2004.

2005. Farm FL02. The thrips population on farm FL02 was lower in 2005 compared with 2004. During 2005, we found two hot-spots located at coordinates (2, 3) and (5, 2) in Fig. 5. The highest aggregation was between days 12 and 14, which again coincide with the days of maximum population (Fig. 6; Table 2). The hot-spots reached their maximum thrips population at 13.8 d after bloom initiation for the coordinate (2, 3) and 12.1 d for coordinate (5, 2) (Fig. 6). The overall indices show a highly significant aggregation for 2005. Green's index, *Cx* = 0.24 ± 0.06, was significantly >0 ($t = 3.87$, df = 9, $P = 0.0047$), and the standardized Morisita's index, *Ip* = 0.52 ± 0.01, was significantly >0.5 ($t = 4.94$, df = 9, $P = 0.0011$).

2004 Farm FL03. Thrips population for farm FL03 was considerably lower than farm FL02 during 2004. We graphically determined the presence of two hot-spots in this farm (Fig. 7): one hot-spot was located at coordinate (0, 4) and a second hot-spot at coordinate (2, 2). The peak population for these hot-spots occurred on different days. For the hot-spot found at (2, 2), the peak occurs at 11.3 d after bloom; and for the hot-spot located at (0, 4), aggregation occurred 17 d after bloom (Fig. 8).

The *Cx* and *Ip* indices showed a tendency toward a random distribution of thrips on farm FL03 in 2004. The overall *Cx* for farm FL03 (0.046 ± 0.041) was not significantly different from 0 ($t = 1.14$, df = 6, $P = 0.298$). The *Ip* value (0.020 ± 0.006) was significantly higher than 0 ($t = 3.21$, df = 6, $P = 0.0184$), but within the region $0 < Ip < 0.5$. This aggregation was not significant on farm FL03 in 2004 (Table 3). The distribution seems to be more aggregated for days 7–15, which again coincides with the peak of the population presented by the equations (Fig. 8).

2005. Farm FL03. The thrips population for this farm was too low to make a robust analysis. The high-

Table 2. Distribution indices *Cx* and *Ip*, used to describe the level of aggregation of thrips populations on farm FL02 in Florida (2005)

Index	Days after blooming								
	2	4	6	8	10	14	16	18	22
Cx	0.124	0.098	0.142	0.185	0.314	0.713	0.320	0.233	0.112
Ip	0.051	0.513	0.518	0.522	0.528	0.556	0.529	0.525	0.511

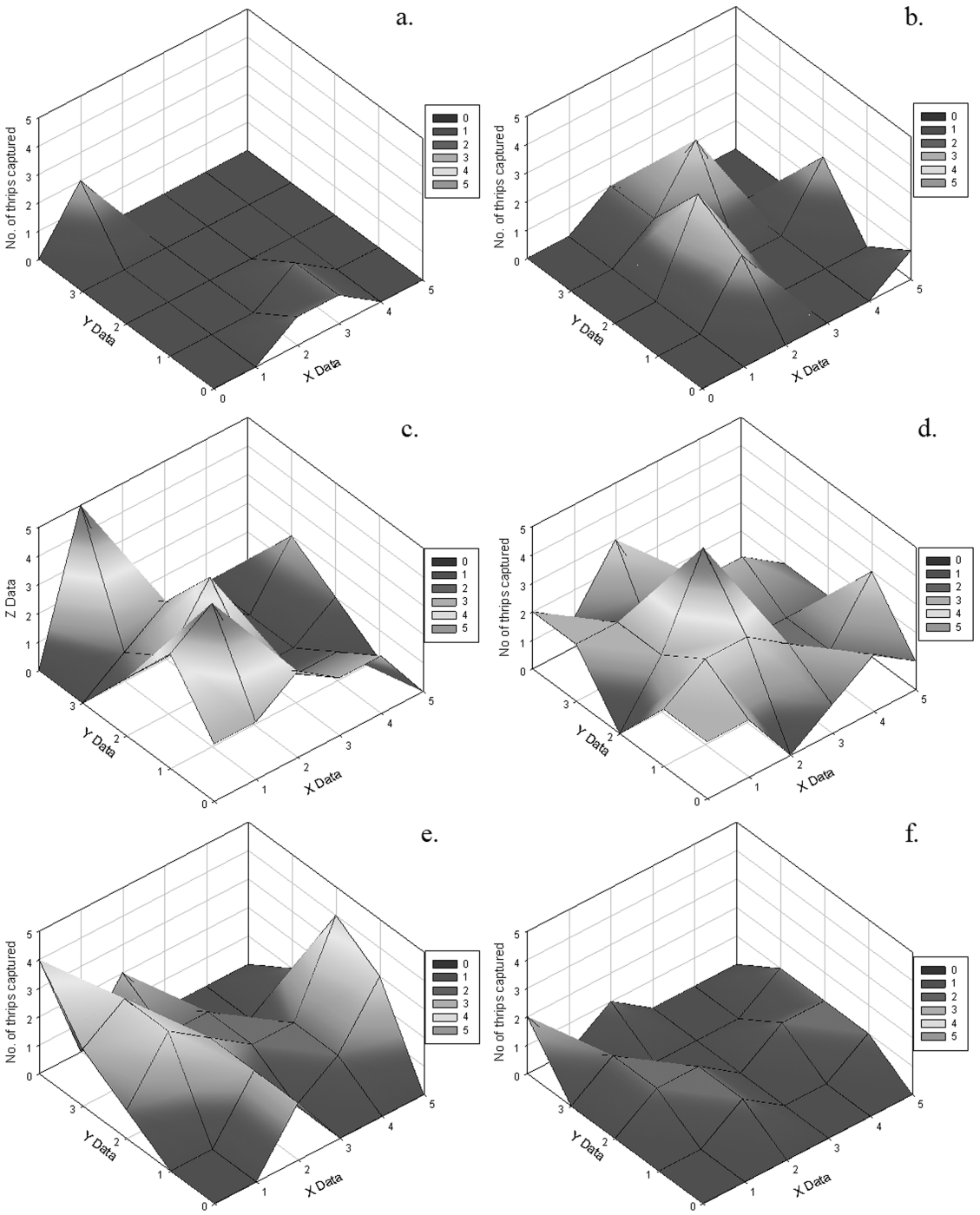

Fig. 7. Number of thrips captured at 2 (a), 4 (b), 8 (c), 14 (d), 16 (e), and 20 (f) days after bloom began, and their location on the blueberry plot on farm FL03 in 2004. The intersections of coordinates *x*-data and *y*-data represent the location of a white sticky trap.

est number of insects captured in one trap was three thrips 15 d after bloom initiation. Most of the other traps did not capture any thrips. Overall, thrips numbers were not high enough to continue with a vertical dispersion analysis.

Discussion

Our results indicate that the shake and rinse sampling method is an appropriate technique to rapidly and accurately detect and determine thrips popula-

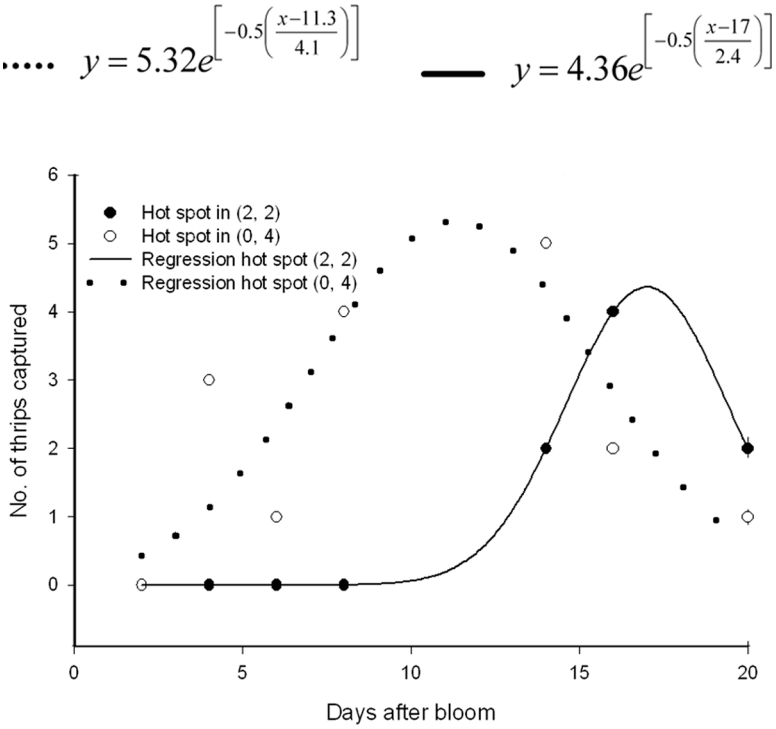

Fig. 8. Population dynamics inside the hot-spots in coordinates (2, 2), and (0, 4) of Fig. 7, in 2004 on the farm FL03 in Florida.

tion inside blueberry flowers. The dissection technique is considered to be an absolute count of thrips inside the flowers (Hollingsworth et al. 2002), and no significant differences were recorded between this technique and the shake and rinse method. The shake and rinse technique is an accurate and useful method to detect thrips and rapidly determine population density inside blueberry flowers. Widespread adoption of the shake and rinse technique by growers may be dawdling, because it requires more technical skills compared with floral tapping, the standard grower practice (Finn 2003). The high level of accuracy and less time-consuming features (compared with the dissection technique) may allow the shake and rinse protocol to be adopted by diagnostic and research laboratories. Absolute counts of thrips inside blueberry flowers have been shown to be highly correlated with blueberry fruit injury compared with other sampling methods (Arévalo 2006).

In a related study, Palumbo (2003) compared trapping at canopy level in lettuce, plant beating, direct observations, and whole plant washes. Palumbo (2003) also recorded a significantly higher number of thrips in the absolute method compared with the other methods evaluated. Whole plant washes, similar in part to the shake and rinse method used in this study, were used as the absolute method.

Table 3. Distribution indices *Cx* and *Ip*, used to describe the level of aggregation of thrips populations on farm FL03 in Florida (2004)

Index	Days after blooming						
	2	4	6	8	14	16	19
Cx	−0.011	−0.065	−0.013	0.129	0.062	0.246	−0.021
Ip	0.041	0.042	0.024	0.013	0.006	0.014	−0.0002

In our study on the vertical distribution of thrips, the highest number of thrips was consistently captured within or above the canopy of the blueberry bushes by using sticky traps. The average number of thrips captured varied from year to year and from place to place. Captures of thrips on sticky cards are the net result of a number of different factors, including surrounding vegetation, host plant quality, and random movements within the vegetation. Thrips are attracted to fields where white is the predominant color (Kirk 1984, Lewis 1997), which represents a typical southeastern blueberry planting during the flowering season.

A high number of thrips was recorded on traps in varieties that were in full bloom, which may indicate that plant phenology and level of bloom affect the population of thrips in blueberry plantings. Other factors that can affect the number of thrips on sticky traps include weather (temperature, rainfall, and humidity) and host quality. Furthermore, the highest concentration of blueberry flowers is within the canopy of the bush, and this is the section of the plant where thrips reproduce and feed (Liburd and Arévalo 2005, Arévalo 2006, Arévalo and Liburd 2007).

In 2004, thrips population was higher in Georgia than in southern Florida. However, in 2005, thrips population was higher on farm FL01 located in Florida compared with farm GA01 located in Georgia (Figs. 1 and 2). The reasons for the variation in population between the years and regions are unclear, but they may be related to differences in climatic conditions and crop phenology between 2004 and 2005.

The analysis of the distribution based on Morisita's and Green's indices described the distribution of thrips in the field as aggregated. However, the level of aggregation was lower in cases when peak populations were lower. We observed that hot-spots (when thrips accumulate in large numbers in distinct sections of the blueberry planting) in FL02 begin to form between 7 and 10 d after bloom initiation, and the population at these spots grew beyond 20 thrips per trap every 2 d. After this initial period, the thrips population captured in the traps increased exponentially, reaching a maximum population between 12 and 15 d after bloom initiation. The population then declined at the same rate that it increased, virtually disappearing ≈22 d after bloom started, after most of the flowers had become fruit. Apparently, the formation of hot-spots in blueberry plantings is random. The exact factors that create the environment for the formation of hot-spots are not known, but temperature, crop phenology, wind direction, and speed and the availability of host plants are thought to play an important role.

We did not find any similarities among the locations where hot-spots were formed and the time (years) when they were formed. However, several variables such as flower concentration, soil, fertilization, and wind direction, might be studied to determine a correlation among these variables and hot-spot locations to create a predictive dispersion model of flower thrips on blueberry farms. For now, sampling methods that consider highly aggregated populations, such as sequential sampling and adaptive cluster sampling, should be explored to reduce the variability of the data (Southwood 1989, Tompson 1990, Wang and Shipp 2001).

The exact reason why thrips behavior in blueberry plantings displays an aggregated model is not clear. However, as discussed above, host quality, vegetation, level of bloom, and weather affect thrips behavior within blueberry plantings. Some behavioral observations show the presence of a mating or an aggregation pheromone in thrips (Milne et al. 2002, Kirk and Hamilton 2004). Kirk and Hamilton (2004) showed how virgin females are attracted to the olfactory cues of males and not to females. This situation was interpreted as the presence of some type of sex pheromone in *Frankliniella occidentalis* (Pergande). Salguero-Navas et al. (1994) also found indications of aggregation in tomato plants for virus thrips species, including *F. occidentalis*, and *F. tritici*. However, differences in the degree of aggregation were found between years in their experiment, as in our trials.

In our work, thrips populations were found to be variable within the same region. For example, farms FL02 and FL03 are only 7.02 km from each other, but we recorded significantly different peaks in thrips populations in 2004, averaging 194.2 thrips per trap for 2 days on farm FL02 and 5.3 thrips per trap for 2 days on farm FL03 (Figs. 4 and 8).

That thrips are present in aggregated populations can be interpreted as the opportunity to conduct focal applications for control techniques. We have determined two dates critical for the management of flower thrips in SHB and RE blueberries. If populations are high, a management program can be recommended between 7 and 10 d when hot-spots are defined. A management program also can be instituted 12 and 16 d after bloom initiation, the time when hot-spots reaches their maximum population and can inflict the highest damage to the grower. Systematic sampling using a grid of sticky traps during these critical dates could be a good method to locate and control hot-spots as they are detected.

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