Effects of Southern Highbush Blueberry Cultivar and Treatment Threshold on Flower Thrips Populations

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J. Econ. Entomol. 105(2): 480–489 (2012); DOI: http://dx.doi.org/10.1603/EC11265

ABSTRACT In Florida, southern highbush (SHB) blueberries (*Vaccinium corymbosum* L. × *Vaccinium darrowi* Camp) are grown for a highly profitable early season fresh market. Flower thrips are the key pest of SHB blueberries, and *Frankliniella bispinosa* (Morgan) is the most common species found. Flower thrips injure blueberry flowers by feeding and ovipositing in all developing tissues. These injuries can lead to scarring of developing fruit. The objectives of this study were to determine the relationship between thrips and yield in different SHB blueberry cultivars and to determine an action threshold. Experiments were conducted during early spring 2007 and 2008 on four farms; a research farm in Citra, FL; and three commercial farms, two in Hernando Co., FL., and one in Lake Co., FL. At the Citra farm, 'Emerald', 'Jewel', 'Millennia', and 'Star' blueberries were compared in 2007, and all but Star were compared in 2008. On the Hernando and Lake Co. farms, two treatment thresholds (100 and 200 thrips per trap) and an untreated control and four cultivars (Emerald, Jewel, Millennia, and 'Windsor') were compared. Emerald consistently had more thrips per trap and per flower than the other cultivars on all four farms. However, this did not always lead to an increase in fruit injury. Thrips numbers exceeded the threshold on only one farm in 2007, and there was a significantly lower proportion of injured and malformed fruit in the 100 thrips per trap threshold treatment compared with the control on this farm.

KEY WORDS flower thrips, *Frankliniella bispinosa*, southern highbush blueberry, *Vaccinium corymbosum* × *Vaccinium darrowi*, economic injury level

Several species of flower thrips, including *Frankliniella bispinosa* (Morgan); western flower thrips, *Frankliniella occidentalis* (Pergande); *Frankliniella tritici* (Fitch); and *Scirtothrips ruthveni* Shull, have recently become known as pests of cultivated blueberries (*Vaccinium* spp.) (Spiers et al. 2005). The three *Frankliniella* species are pests of both rabbiteye (RE), *Vaccinium virgatum* Aiton, and southern highbush (SHB), *Vaccinium corymbosum* L. × *Vaccinium darrowi* Camp, blueberries in Florida (Liburd and Arévalo 2005). *F. bispinosa* is the key pest and by far the most abundant thrips species, comprising ≈90% of thrips sampled both on sticky traps and in flowers (Liburd and Arévalo 2005). The others are only occasional pests.

Flower thrips infest not only blueberries but many other crop and noncrop host plants (Arévalo et al. 2006). *F. bispinosa* is the most abundant thrips species found in citrus (*Citrus* spp.) flowers in Florida (Childers et al. 1990). Several Florida blueberry growers have observed that the population of thrips in blueberry flowers increases as the citrus bloom declines (G.K.E., personal observation). In a study to determine alternate hosts for *F. bispinosa* in blueberry plantings, Rhodes and Liburd (2011) recorded immature thrips together with adult *F. bispinosa* from several flowering weeds adjacent to a blueberry planting. The presence of the immatures indicated that these plants are reproductive hosts of *F. bispinosa* with the potential to inoculate blueberry plants.

Flower thrips injure flowers in two ways: feeding and boring. Larvae and adults feed on all parts of the flowers, including ovaries, styles, petals, and developing fruit (Arévalo-Rodriguez 2006). This feeding injury can reduce the quality and quantity of fruit produced. Females also cause injury to fruit when they lay their eggs inside flower tissues. The newly hatched larvae bore holes in flower tissue when they emerge.

Economic injury levels (EILs) are an integral part of integrated pest management (IPM) strategies. Several terms are important in understanding this concept including economic damage (ED) and economic threshold (ET). Stern et al. (1959) defines ED as "the amount of injury that will justify the cost of artificial control measures." The EIL is "the lowest population density that will cause this damage" and the ET is "the density at which control measures should be initiated to prevent an increasing pest population from reaching the EIL." The EIL can be calculated using the equation $EIL = C/(V * I * D)$, where C is the cost of control, V is the value of the product, I is the injury per

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insect value, and D is the damage per unit injured (Pedigo et al. 1986). Arévalo-Rodriguez (2006) used this equation to determine the EILs for 'Climax' and 'Tifblue' RE blueberries in Georgia, which are ≈13 and 14 thrips per 10 flowers, respectively, when Malathion 5 EC (Micro Flo Company LLC, Memphis, TN) is used as the control measure and 17 and 19 thrips per 10 flowers, respectively, using spinosad (SpinTor 2 SC, Dow Agrosciences, Indianapolis, IN). Using his regression equations, Arévalo-Rodriguez (2006) calculated this to be 45 thrips per trap for Tifblue and 50 thrips per trap for Climax when malathion is applied and 64 thrips per trap for Tifblue and 73 thrips per trap for Climax when SpinTor 2 SC is applied. No EILs have been calculated for SHB blueberries.

The objectives of this study were to determine 1) the relationship between populations of thrips and fruit injury in several different SHB cultivars and 2) an action threshold for thrips in SHB blueberries. In Florida, several SHB cultivars are grown together on the same farm to increase pollination efficiency. These cultivars differ in fruit and flower characteristics and in the timing and length of flowering period (Williamson and Lyrene 2004). This may lead to differences in thrips numbers and thrips injury among the cultivars. If this is the case, EILs may need to be developed for each cultivar or among cultivars with similar flowering periods.

Materials and Methods

Relationship Between Thrips Numbers and Fruit Injury in Different SHB Cultivars. This experiment was conducted at the University of Florida Plant Science Research and Education Unit (PSREU) in Citra, FL. There were four 0.13-ha plots of SHB blueberries that contained eight rows of blueberry bushes. Five bushes of each cultivar are planted in each row. The bushes are spaced 1.2 m apart with 1.5 m between rows. The plants were ≈4 yr old and 1 m in height in 2007.

The experimental setup was a completely randomized block design, with 12 replicates (three rows from each plot) of four (2007) or three (2008) cultivars. In 2007, the four SHBs 'Emerald', 'Jewel', 'Millennia', and 'Star' were sampled for thrips and fruit injury. In 2008, only Emerald, Jewel, and Millennia were sampled because many of the Star plants were small and produced too few flowers to provide consistent samples. There were five plants per cultivar in each replicate.

Four white sticky traps (Great Lakes IPM, Vestaburg, MI) were placed in each replicate (one per cultivar, for a total of 48 for the experiment). The traps were hung from the center plant in each cultivar and were replaced weekly. Each week, 10 flowers were sampled from the middle bush and placed in 50-ml plastic tubes containing 15 ml of 70% ethanol. In 2007, samples were collected for 7 wk from 29 January until 12 March. In 2008, samples were collected for 5 wk from 14 February to 14 March.

The traps and flower samples were brought back to the Small Fruit and Vegetable Laboratory at the University of Florida in Gainesville for processing. In the laboratory, flowers were sampled using the "shake and rinse" method developed by Arévalo and Liburd (2007). Adult thrips collected from flowers were identified to species by using a key developed for Florida SHB blueberries by Arévalo et al. (2006). Thrips that did not match the character descriptions in the key were sent to the Division of Plant Industry in Gainesville, FL, for identification.

At harvest time, 30 berries per cultivar in each replicate were randomly harvested from the three middle plants of each sampling site and examined, in the field, for thrips injury and marketability. A fruit was considered unmarketable if there was obvious scarring, or it was deformed. The number of total injured and unmarketable fruit was divided by 30 to give proportion of total injured and unmarketable fruit per plant. Total injured fruit included both those that were still marketable and the unmarketable fruit.

Action Threshold for Thrips in SHB Blueberries. Samples were taken from two commercial farms in Hernando Co., FL, during early spring 2007. In early spring 2008, samples were taken from one commercial farm in Hernando and another in Lake Co., FL. Blueberry plants at both Hernando Co. farms were 4–7 yr of age, and those at the Lake Co. farm were only 1 yr old. A 5-ha area on farm 1 in Hernando Co. was sampled only in 2007. The cultivars on this farm are arranged in blocks of six to nine rows. A 2.5-ha area of the second farm in Hernando Co., farm 2, was sampled during both years. Blueberry plants on this farm are grown in alternating rows of different cultivars. A 2.5-ha area of the Lake Co. farm was sampled only in 2008.

On each farm, the four most popular SHB cultivars—Emerald, Jewel, Millennia, and 'Windsor'—were divided into three treatments: T100, T200, and an untreated control. If the number of thrips per trap exceeded 100 in the T100 treatment or 200 in the T200 treatment, SpinTor 2 SC was applied at the label rate of 0.438 liters/ha. The 100 thrips per trap threshold is only slightly higher than the EIL calculated by Arévalo-Rodriguez (2006) for RE blueberries when SpinTor 2 SC is applied. The treatment thresholds encompassed a row of each of the cultivars. There were three replicates containing each threshold–cultivar combination, and they encompassed all of the samples from the beginning, middle, and end of the rows. A sticky trap was placed in each threshold–cultivar combination. Five flowers from each of two plants closest to the trap also were sampled. Flowers were dissected and adult thrips collected were identified to species as in the previous study.

In 2007, sticky trap samples were collected weekly for 6 wk beginning on 1 and 2 February on farms 1 and 2, respectively. Flower samples were collected weekly until the majority of plants were in fruit set. On farm 1, both treatments were above threshold after the first week of sampling. Applications of SpinTor 2 SC were made on 9 February and 23 February. Thrips numbers on farm 2 remained below threshold throughout the sampling period, so SpinTor 2 SC was not applied.

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In 2008, sticky trap samples were collected weekly for4 wk from the Lake Co. farm and for 3 wk from the Hernando Co. farm (farm 2 from 2007) beginning on 14 and 21 February, respectively. Flower samples were collected weekly until the majority of plants were in fruit set. The number of thrips per trap did not exceed either of the treatment threshold levels on any date, so SpinTor 2 SC was not applied on either farm.

At harvest time, 25 berries from the two previously sampled plants and from two adjacent plants were chosen randomly and examined for thrips injury and marketability in the field. The number of total injured and unmarketable fruit from each sample was divided by 25 to give proportion of total injured and unmarketable fruit per plant. The proportions from the four samples were then averaged. Total injured fruit included both those that were still marketable and the unmarketable fruit.

Statistical Analysis. For the data from the thrips versus fruit injury study, average thrips per trap, and average thrips larvae and adults per flower were analyzed using repeated measures under proc GLM (SAS Institute 2002). Means were separated using the least significant difference (LSD) test.

Average proportion of injured and unmarketable fruit were transformed as necessary to meet the assumptions of the analysis and compared among cultivars using a one-way analysis of variance (ANOVA) with proc GLM (SAS Institute 2002). Means were separated using the LSD test.

The thrips versus fruit injury study data were also examined for a linear relationship between numbers of thrips (larvae and adults) per flower pooled over all dates versus proportion of total injured fruit per plant using least squares regression in SAS (SAS Institute 2002).

During the course of the threshold study, average thrips per trap exceeded the threshold only on Hernando Co. farm 1 in 2007. Therefore, average thrips per trap, average thrips larvae and adults per flower, and average proportion of total injured and unmarketable fruit per plant were transformed as necessary to meet the assumptions and compared among treatments and cultivars by using a two-way ANOVA (SAS Institute 2002). If no interaction was present, main effects of both factors were compared using the LSD means separation test. If interaction was present, then simple effects were compared for the factor that was significant. Thrips per sticky trap, thrips larvae per flower, and thrips adults per flower were analyzed by week.

Numbers of thrips per trap did not reach the threshold on Hernando Co. farm 2 in either year or on the Lake Co. farm in 2008, so SpinTor 2 SC was not applied to any of these farms during the course of the study. Therefore, the previously described data sets were transformed as needed to meet the assumptions of ANOVA and varietal differences were analyzed using a one-way ANOVA. Means were separated using the LSD means separation test. Thrips per sticky trap, thrips larvae per flower, and thrips adults per flower were analyzed by week.

The threshold study data also were examined for any linear relationship between numbers of thrips (larvae and adults) per flower pooled over all dates each year versus total injured fruit per plant by using Theil regression (Hollander and Wolfe 1999) in 2007, because the assumptions of least squares regression could not be met even after data transformation, and least squares regression (SAS Institute 2002) in 2008. Kendall's τ, a nonparametric correlation statistic (Hollander and Wolfe 1999) also was calculated for the 2007 data (Wessa 2008).

Results

Relationship Between Thrips Numbers and Fruit Injury in Different SHB Cultivars in 2007. *Traps.* The time × cultivar interaction was not significant (F = 1.12; df = 18, 335; P = 0.33), so main effects were analyzed. There were no significant differences in thrips per trap among cultivars (F = 0.98; df = 3, 335; P = 0.42). There were an average of 25.8 ± 2.3, 23.1 ± 2.2, 24.7 ± 3.1, and 22.0 ± 2.3 in Emerald, Jewel, Millennia, and Star, respectively.

Flowers. There was no time × cultivar interaction among either thrips larvae or thrips adults per flower (both $F \leq 0.99$; df = 18, 335; $P \geq 0.47$). There were significantly higher numbers of thrips larvae per flower in Emerald (0.06 ± 0.01) and Jewel (0.05 ± 0.01) compared with Millennia (0.01 ± 0.01) (F = 4.54; df = 3, 335; P = 0.009). There was an average of 0.03 ± 0.01 thrips larvae per flower in Star. There was no difference among thrips adults per flower (F = 0.61; df = 3, 335; P = 0.61). There were an average of 0.07 ± 0.01, 0.04 ± 0.01, 0.05 ± 0.01, and 0.06 ± 0.01 in Emerald, Jewel, Millennia, and Star, respectively.

There was a high diversity in adult thrips sampled from the flowers. The majority of thrips adults were *F. bispinosa* (Table 1). Other species sampled included *Frankliniella fusca* (Hinds), *F. occidentalis*, *Franklinothrips* sp., *Haplothrips graminis* Hood, *Microcephalothrips abdominalis* Crawford, *Thrips hawaiiensis* (Morgan), and *Thrips pini* Karny.

Fruit. Emerald (0.23 ± 0.02) and Jewel (0.21 ± 0.03) had a significantly higher proportion of injured fruit (F = 7.53, df = 3, 47, P = 0.0006) than Millennia (0.14 ± 0.02) and Star (0.12 ± 0.02). Emerald (0.08 ± 0.01) also had a significantly higher proportion of unmarketable fruit (F = 11.31, df = 3, 47, $P < 0.0001$) than all of the other cultivars (Jewel, 0.03 ± 0.01; Millennia and Star, 0.02 ± 0.01). Simple linear regression did not show any relationship between thrips per flower and proportion of total injured fruit in any of the cultivars (all $R^2 \leq 0.03$, all $t \leq 1.13$, df = 11, $P_{slope} \geq 0.28$).

Relationship Between Thrips Numbers and Fruit Injury in Different SHB Cultivars in 2008. *Traps.* The time × cultivar interaction was not significant (F = 0.72; df = 8, 179; P = 0.67), so main effects were analyzed. There were no significant differences in thrips per trap among cultivars (F = 2.1; df = 2, 179; P = 0.15). There were an average of 45.4 ± 3.8, 38.5 ±

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Table 1. Species of adult thrips collected from flowers of different SHB blueberry cultivars on the Citra PSREU farm in 2007 and 2008

Thrips species	2007				2008		
	Emerald	Jewel	Millenia	Star	Emerald	Jewel	Millenia
Frankliniella bispinosa	22	18	31	18	46	49	30
F. fusca	0	0	1	2	0	0	0
F. occidentalis	1	0	0	0	0	0	0
Franklinothrips sp.	1	2	2	1	6	6	3
Haplothrips graminis	1	3	0	7	1	1	1
Microcephalothrips abdominalis	0	1	0	1	2	1	0
Thrips hawaiiensis	1	1	0	1	5	13	4
T. pini	4	0	0	3	10	22	1
Total	30	25	34	33	70	92	39

3.4, and 39.6 ± 3.6 in Emerald, Jewel, and Millennia, respectively.

Flowers. The time × cultivar interaction was not significant ($F = 1.13$; df = 8, 179; $P = 0.35$) for thrips larvae per flower. There were significantly more thrips larvae per flower in Emerald (0.12 ± 0.02) compared with Jewel (0.08 ± 0.02) and Millennia (0.06 ± 0.02) ($F = 1.13$; df = 2, 179; $P = 0.35$).

The time × cultivar interaction was significant ($F = 5.08$; df = 8, 179; $P < 0.0001$) for thrips adults per flower, so cultivars were compared on each date. Emerald had significantly more thrips adults per flower compared with Jewel and Millennia on 14 February ($F = 7.2$; df = 2, 35; $P = 0.0039$) (Fig. 1). In contrast, Jewel had significantly higher numbers of thrips adults per flower compared with Emerald and Millennia on 14 March ($F = 7.99$; df = 2, 35; $P = 0.0025$).

The diversity of adult thrips species sampled from flowers was similar to 2007, with *F. bispinosa* comprising the majority of thrips sampled (Table 1). Most of the remaining adult thrips were either *T. hawaiiensis* or *T. pini. Franklinothrips* sp., *M. abdominalis,* and *H. graminis* also were collected.

Fruit. There were no significant differences in either proportion of injured ($F = 0.18$; df = 2, 35; $P = 0.83$) or unmarketable ($F = 0.62$; df = 2, 35; $P = 0.55$) fruit among cultivars. Emerald, Jewel, and Millennia averaged 0.14 ± 0.02, 0.16 ± 0.03, and 0.16 ± 0.02 proportions of injured fruit, respectively. All three cultivars averaged a 0.01 ± 0.00 proportion of unmarketable fruit. Simple linear regression did not show any relationship between thrips per flower and proportion of total injured fruit in any of the cultivars (all $R^2 \leq 0.12$, all $t \leq 1.57$, df = 11, $P_{slope} \geq 0.15$).

Action Threshold for Thrips in SHB Blueberries in 2007. *Traps.* There were no treatment × cultivar interactions on any date after treatments were applied (all $F \leq 1.23$; df = 6, 35; $P \geq 0.33$); therefore, each factor was examined separately. There were significantly fewer thrips per trap recorded from the 200 thrips per trap threshold treatment (147.1 ± 52.8) compared with the control (339.7 ± 116.5) on 1 March, 1 wk after the second application of SpinTor 2 SC ($F = 4.1$; df = 2, 35; $P = 0.029$). An average of 230.7 ± 65.5 thrips per trap was recorded from the 100 thrips per trap threshold treatment on this date. There were no significant differences among treatments on any other date (all $F \leq 1.99$; df = 2, 35; $P \geq 0.16$).

On farm 1, Emerald had significantly higher numbers of thrips per trap compared with at least two of the other cultivars on all sampling dates (all $F \geq 4.07$; df = 3, 35; $P \leq 0.018$). There were significantly higher numbers of thrips per trap in Emerald compared with Jewel and Millennia on 1 February (Fig. 2). Windsor also had significantly higher numbers of thrips per trap compared with Millennia on this date. As the season progressed, Emerald had significantly higher numbers of thrips per trap compared with all of the other cultivars. This occurred on 8 February, 15 February, 22 February, and 1 March. Jewel and Windsor also had significantly higher numbers of thrips per trap compared with Millennia on 22 February. On 8 March, Emerald had significantly higher numbers of thrips per trap compared with Jewel and Windsor.

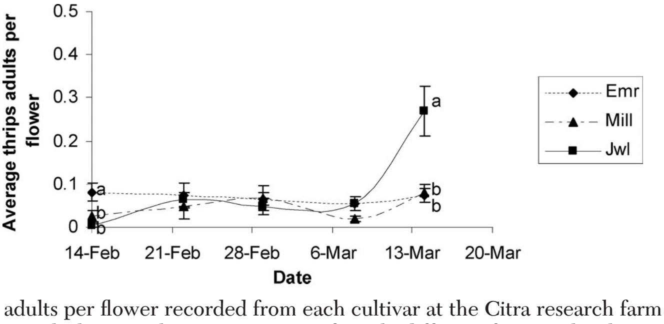

Fig. 1. Average thrips adults per flower recorded from each cultivar at the Citra research farm per week in 2008. Error bars represent SEM. Means with the same letter are not significantly different from each other at the $P = 0.05$ level.

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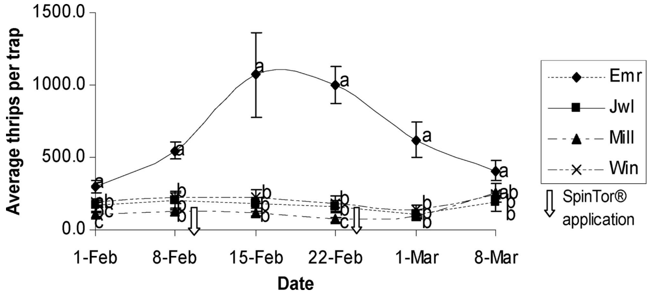

Fig. 2. Average thrips per trap recorded from each cultivar per week on farm 1 in 2007. Error bars represent standard error of the mean. Means with the same letter are not significantly different from each other at the $P = 0.05$ level. Arrows indicate the dates when SpinTor 2 SC was applied.

Similarly, on farm 2, Emerald had significantly higher numbers of thrips per trap compared with all of the other cultivars ($F = 8.53$; df = 3, 35; $P = 0.0003$) on 9 February (Fig. 3). On 16 February, Emerald had significantly higher numbers of thrips per trap compared with Jewel and Windsor. Also, Jewel had significantly higher numbers of thrips per trap compared with Windsor ($F = 16.27$; df = 3, 35; $P < 0.0001$). On 23 February, both Emerald and Jewel had significantly higher numbers of thrips per trap compared with Windsor ($F = 3.32$; df = 3, 35; $P = 0.033$).

Flowers. There were no treatment × cultivar interactions in thrips larvae per flower on any date after treatments were applied (both $F = 0.51$; df = 6, 35; $P = 0.79$) on farm 1. There were no significant differences in thrips larvae per flower among treatments on any date (all $F \leq 2.48$; df = 2, 35; $P \geq 0.11$). However, there were significantly higher numbers of thrips larvae per flower in Jewel compared with the other cultivars ($F = 3.57$; df = 3, 35; $P = 0.029$) on 8 February (Fig. 4a).

For thrips adults, there was no treatment × cultivar interaction on 15 February ($F = 0.78$; df = 6, 35; $P = 0.59$). However, there was treatment × cultivar interaction on 22 February ($F = 3.42$; df = 6, 35; $P = 0.014$). There were no significant differences in thrips adults per flower among treatments on any date (all $F \leq 1.42$; df = 2, 35; $P \geq 0.26$). However, the cultivar trends in thrips adults per flower on farm 1 were similar to thrips per trap. On 8 February, there were significantly higher numbers of thrips adults per flower in Emerald compared with Millennia and Windsor ($F = 5.00$; df = 3, 35; $P = 0.0078$) (Fig. 4b). Emerald had significantly higher numbers of thrips adults per flower compared with all of the other cultivars on 15 February ($F = 10.32$; df = 3, 35; $P = 0.0001$). Jewel had significantly higher numbers of thrips adults per flower compared with Millennia on both of the above-mentioned dates.

On 22 February, main effects showed that Emerald had significantly higher numbers of thrips adults per flower compared with Jewel and Millennia ($F = 9.93$; df = 3, 35; $P = 0.0003$). Jewel also had significantly higher numbers of thrips compared with Millennia. When simple effects were examined, Emerald had significantly higher numbers of thrips adults compared with all of the other cultivars in the untreated control. There were no cultivar differences in the T100 treatment. In contrast, Millennia had significantly fewer thrips adults per flower than all three of the other cultivars in the T200 treatment.

On farm 2, there were significantly more thrips larvae per flower in Emerald compared with Windsor ($F = 3.70$; df = 3, 35; $P = 0.022$) on 9 February (Fig. 5a). On 16 February, both Jewel and Emerald had significantly higher numbers of thrips larvae compared with Millennia and Windsor ($F = 4.99$; df = 3, 35; $P = 0.0063$). Emerald had significantly higher numbers of thrips larvae per flower compared with all of the other cultivars on 23 February ($F = 4.76$; df = 3, 35; $P = 0.0079$). In contrast, Jewel and Windsor had significantly higher numbers of thrips larvae per flower compared with Emerald and Millennia on 2 March ($F = 4.54$; df = 3, 35; $P = 0.0097$).

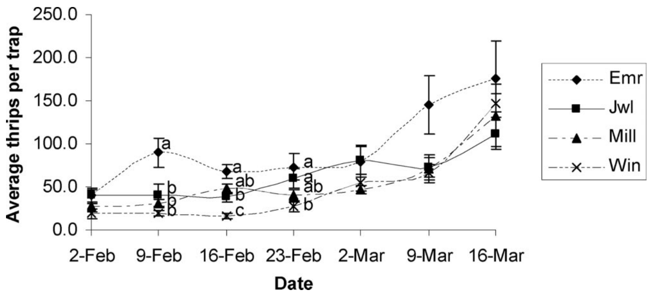

Fig. 3. Average thrips per trap recorded from each cultivar per week on farm 2 in 2007. Error bars represent standard error of the mean. Means with the same letter are not significantly different from each other at the $P = 0.05$ level.

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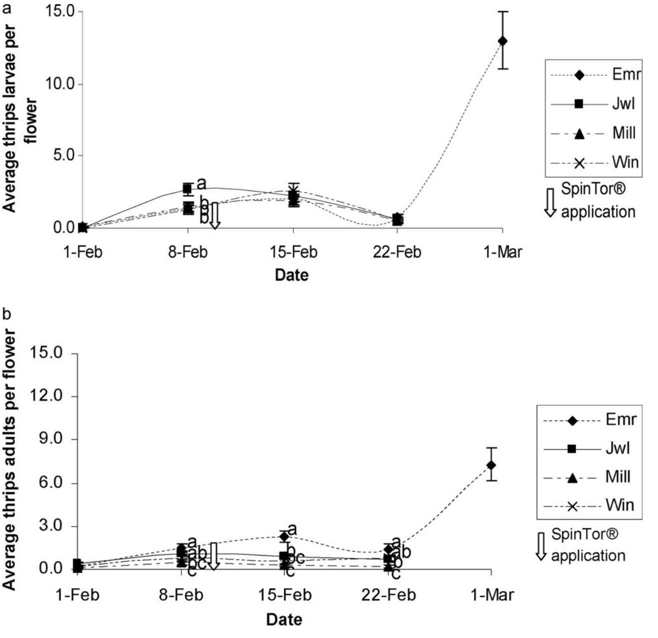

Fig. 4. Average thrips larvae (a) and adults (b) per flower recorded from each cultivar per week on farm 1 in 2007. Error bars represent SEM. Means with the same letter are not significantly different from each other at the $P = 0.05$ level. Arrows indicate the dates when SpinTor 2 SC was applied.

There were significantly more thrips adults per flower in Emerald compared with Jewel and Windsor and significantly more thrips adults per flower in Millennia compared with Windsor ($F = 5.35$; df = 3, 35; $P = 0.0045$) on 16 February (Fig. 5b). On 23 February, Jewel and Windsor had significantly higher numbers of thrips adults per flower compared with Millennia ($F = 3.01$; df = 3, 35; $P = 0.046$).

Farm 1 had an unusually high number of *T. hawaiiensis* and *T. pini* present in the flowers along with *F. bispinosa.* A single *H. graminis* also was collected. In contrast, the majority of thrips adults sampled from

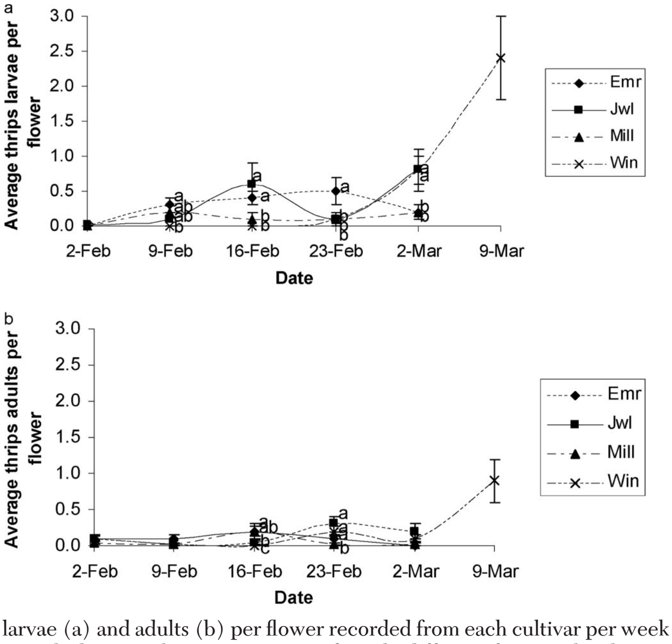

Fig. 5. Average thrips larvae (a) and adults (b) per flower recorded from each cultivar per week on farm 2 in 2007. Error bars represent SEM. Means with the same letter are not significantly different from each other at the $P = 0.05$ level.

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flowers on farm 2 were *F. bispinosa* (Table 2). *Franklinothrips* sp., *H. graminis, T. hawaiiensis,* and *T. pini* also were present.

Fruit. There were no treatment × cultivar interactions in proportion of total injured ($F = 0.47$; df = 6, 35; $P = 0.82$) or unmarketable ($F = 0.70$; df = 6, 35; $P = 0.66$) fruit on farm 1. Therefore, main effects were analyzed. Interestingly, there was a significantly higher proportion of injured ($F = 5.72$; df = 6, 35; $P = 0.0093$) and unmarketable ($F = 3.53$; df = 6, 35; $P = 0.045$) fruit in the untreated control (0.14 ± 0.02 proportion injured and 0.03 ± 0.01 proportion unmarketable) compared with the T100 treatment (0.06 ± 0.01 proportion injured and 0.003 ± 0.002 proportion unmarketable). The T200 treatment had 0.09 ± 0.01 proportion of injured and 0.008 ± 0.003 proportion of unmarketable fruit.

There were no significant differences in either proportion of total injured or unmarketable fruit among cultivars on farm 1 (injured: $F = 1.05$; df = 3, 35; $P = 0.39$; unmarketable: $F = 0.87$; df = 3, 35; $P = 0.57$) or farm 2 (injured: $F = 1.87$; df = 3, 35; $P = 0.16$; unmarketable: $F = 0.25$; df = 3, 35; $P = 0.86$). On farm 1, there was an average proportion of total injured fruit of 0.09 ± 0.02 and an average proportion of unmarketable fruit of 0.02 ± 0.01 across cultivars. On farm 2, there was an average proportion of total injured fruit of 0.05 ± 0.01 and an average proportion of unmarketable fruit of 0.02 ± 0.002 across cultivars.

Thiel regression showed a significant positive linear relationship between thrips per flower and total injured fruit in all four cultivars (Table 3). Kendall's τ indicated a moderate correlation between the two variables in Emerald and Jewel and a weak correlation in the Millennia and Windsor.

Action Threshold for Thrips in SHB Blueberries in 2008. *Traps.* On the Lake Co. farm, Emerald, Windsor, and Jewel had significantly higher numbers of thrips per trap compared with Millennia ($F = 4.52$; df = 3, 34; $P = 0.0096$) on 21 February (Fig. 6). On 28 February, Windsor had significantly higher numbers of thrips per trap compared with Millennia ($F = 3.09$; df = 3, 35; $P = 0.041$). Windsor had significantly higher numbers of thrips per trap compared with all of the other cultivars on 6 March ($F = 13.68$; df = 3, 35; $P < 0.0001$).

On Hernando Co. farm 2, there were no significant differences in thrips per trap among cultivars on any date (all $F \leq 2.09$; df = 3, 32; $P \geq 0.12$). There were an average of 8.3 ± 1.8, 4.2 ± 1.1, and 10.3 ± 2.2 thrips per trap over cultivar on 21 February, 28 February, and 6 March, respectively.

Flowers. On the Lake Co. farm, there were significantly more thrips larvae per flower in Emerald compared with Millennia on 14 February ($F = 3.4$; df = 3, 34; $P = 0.030$) (Fig. 7a). On 21 February, there were no significant differences among cultivars ($F = 2.1$; df = 3, 32; $P = 0.13$). By 28 February, all of the Emerald bushes had reached fruit set. There were no significant differences among the other three cultivars ($F = 0.08$; df = 2, 21; $P = 0.46$).

There were significantly more thrips adults per flower in Emerald compared with all of the other

Table 2. Species of adult thrips collected from flowers of different SHB blueberry cultivars on Hernando Co. farms 1 and 2 and the Lake Co. farm in 2007 and 2008

Thrips species	2007								2008							
	Farm 1				Farm 2				Lake Co. farm				Hernando Co. farm 2			
	Emerald	Jewel	Millenia	Windsor	Emerald	Jewel	Millenia	Windsor	Emerald	Jewel	Millenia	Windsor	Emerald	Jewel	Millenia	Windsor
Frankliniella bispinosa	33	52	23	35	17	9	10	17	21	10	8	27	2	1	4	21
F. fusca	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0
Franklinothrips sp.	0	0	0	0	0	0	1	1	7	1	0	0	0	0	0	2
Haplothrips graminis	0	0	0	1	1	3	0	1	0	0	1	1	0	0	0	0
Thrips hawaiiensis	79	21	2	23	4	4	0	1	32	9	29	29	5	0	2	1
T. pini	106	31	7	26	0	0	0	1	12	6	13	16	5	0	0	6
Total	218	104	32	85	22	16	11	21	74	26	51	74	12	1	6	30

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Table 3. Thiel regression equation and slope statistics along with Kendall's τ values for thrips per flower versus total injured fruit in each cultivar from Hernando Co. farm 1 in 2007

cultivar	Equation	P_{slope}	Kendall's τ
Emerald	y = 0.0154× + 0.03	0.003	0.41
Jewel	y = 0.004× + 0.04	0.02	0.35
Millennia	y = 0.026× + 0.47	0.056	0.25
Windsor	y = 0.018× + 0.55	0.02	0.3

cultivars on 14 February ($F = 16.41$; df = 3, 34; $P <$ 0.0001) (Fig. 7b). There were no significant differences among cultivars on 21 February ($F = 0.76$; df = 3, 32; $P = 0.53$). There were significantly more thrips adults per flower in Windsor compared with Jewel and Millennia on 28 February ($F = 6.17$; df = 2, 21; $P =$ 0.0086). All of the Emerald bushes had reached fruit set by this date.

On Hernando Co. farm 2, there were significantly higher numbers of thrips larvae per flower in Emerald (0.8 ± 0.2 larvae) and Windsor (1.1 ± 0.2 larvae) compared with Jewel (0.3 ± 0.1 larvae) and Millennia (0.3 ± 0.2 larvae) ($F = 5.9$; df = 3, 35; $P = 0.0025$) on 21 February. On 28 February, Windsor (0.05 ± 0.01 larvae) had significantly higher numbers of thrips larvae per flower than all of the other cultivars (0 larvae) ($F = 6.32$; df = 3, 22; $P = 0.0037$).

In contrast, there were no significant differences in thrips adults per flower among cultivars on either date (both $F \leq 1.42$; df = 3, 35; $P \geq 0.25$). There was an average of 0.2 ± 0.1 and 0.01 ± 0.008 adults per flower across cultivars on 21 and 28 February, respectively.

All four cultivars on the Lake Co. farm had high numbers of *T. hawaiiensis* and *T. pini* adults (Table 2). Most of the remaining adult thrips were *F. bispinosa. F. fusca*, *Franklinothrips* sp., and *H. graminis* were sampled occasionally. In contrast, *F. bispinosa* was the dominant thrips species sampled from Jewel, Millennia, and Windsor flowers on Hernando Co. farm 2 (Table 2). Most of the thrips sampled from the Emerald flowers were either *T. hawaiiensis* or *T. pini.* Two *Franklinothrips* sp. also were collected.

Fruit. On the Lake Co. farm, Jewel (0.19 ± 0.02) had a significantly higher proportion of injured fruit compared with all of the other cultivars ($F = 15.41$; df = 3, 35; $P < 0.0001$) and Windsor (0.12 ± 0.01) had a significantly higher proportion of injured fruit compared with Emerald (0.08 ± 0.01) and Millennia (0.07 ± 0.01). Jewel (0.028 ± 0.004) also had a significantly higher proportion of unmarketable fruit compared with all of the other cultivars ($F = 13.87$; df = 3, 25; $P < 0.0001$). Emerald, Millennia, and Windsor had 0.003 ± 0.001, 0.007 ± 0.002, and 0.004 ± 0.002 proportions of unmarketable fruit, respectively.

On Hernando Co. farm 2, Jewel (0.14 ± 0.01) and Windsor (0.16 ± 0.01) had a significantly higher proportion of injured fruit compared with Emerald (0.10 ± 0.01) and Millennia (0.06 ± 0.01), and Emerald had a significantly higher proportion of injured fruit compared with Millennia ($F = 18.43$; df = 3, 35; $P < 0.0001$). Jewel (0.044 ± 0.005) also had a significantly higher proportion of unmarketable fruit compared with all the other cultivars ($F = 21.77$; df = 3, 25; $P < 0.0001$). Emerald, Millennia, and Windsor had 0.010 ± 0.002, 0.013 ± 0.004, and 0.007 ± 0.003 proportions of unmarketable fruit, respectively. Simple linear regression, combining the data from both farms, did not show any relationship between thrips per flower and proportion of total injured fruit in any of the cultivars (all $R^2 \leq 0.01$, all $t \geq -1.08$, df = 17, P_{slope} ≥ 0.30).

Discussion

SHB cultivar does seem to influence thrips numbers. At the Citra PSREU, the Emerald cultivar had higher numbers of thrips per trap than one or more of the other sampled cultivars on several dates in both years. Similarly, in 2008, higher numbers of thrips larvae and adults per flower also were recorded from Emerald. The lack of significant differences among thrips per flower in 2007 may indicate that the thrips were migrating into the blueberry flowers from neighboring host plants (Arévalo-Rodriguez 2006, Rhodes and Liburd 2011). Similar results were recorded from the three commercial farms in both years.

F. bispinosa was the most common species sampled from all of the cultivars at the Citra PSREU. This is in agreement with Arévalo-Rodriguez (2006), who found that *F. bispinosa* accounted for ≈80–90% of adult thrips collected from blueberry flowers sampled in Florida. A diversity of other species was also found. This diversity of species was probably due to the wide cultivar of crops grown at the research station.

Regardless of farm and year, Emerald frequently had significantly more thrips per trap and per flower

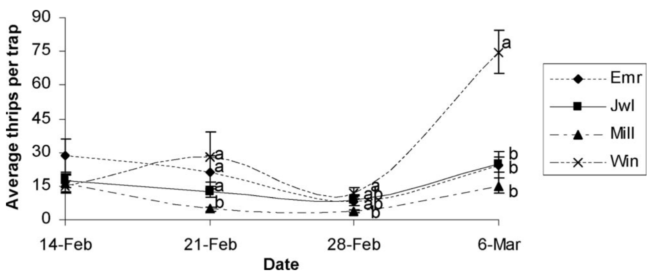

Fig. 6. Average thrips per trap recorded from each cultivar per week on the lake Co. farm in 2008. Error bars represent SEM. Means with the same letter are not significantly different from each other at the $P = 0.05$ level.

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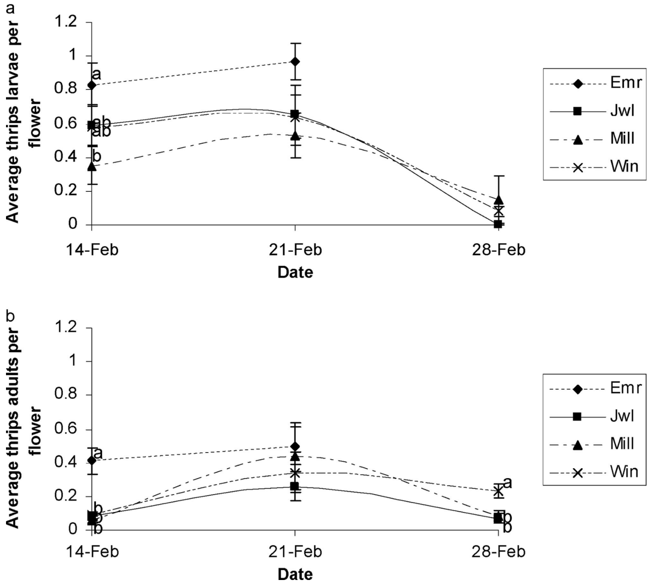

Fig. 7. Average thrips larvae (a) and adults (b) per flower recorded from each cultivar per week on the lake Co. farm in 2008. Error bars represent standard error of the mean. Means with the same letter are not significantly different from each other at the $P = 0.05$ level.

than the other cultivars. Millennia and Star tended to have the lowest numbers of thrips. The differences in thrips numbers among cultivars may be due to the flowering characteristics of the cultivars. Emerald, Jewel, and Millennia reach 50% open flowers ≈16 February in Gainesville, FL. Star and Windsor reach 50% open flowers approximately a week later (Williamson and Lyrene 2004). Unlike the other cultivars sampled, Emerald flowers uniformly. All of the cultivars tested except Millennia reach petal fall around the same time. Millennia reaches petal fall 3–4 d earlier (Williamson and Lyrene 2004). The combination of flowering early and uniformly, when flower thrips are abundant, may make Emerald more attractive to flower thrips.

The differences in thrips numbers among cultivars were not as pronounced on the Citra PSREU farm compared with the Hernando and Lake Co. farms. The four cultivars at the Citra farm are distributed evenly among each other. This may be partially masking the effect of cultivar on thrips numbers. In contrast, farm 1 in Hernando Co. has large blocks of a single cultivar. Farm 2 has an intermediate setup, with only a few rows of the same cultivar adjacent to each other. Our results, in combination with these observations, indicate that inter-planting early and late flowering cultivars may be a tactic that can be used in the future to reduce thrips numbers. However, further research is needed to determine the viability of such a tactic.

The differences in thrips numbers among cultivars were not as distinct on the Lake and Hernando Co. farms in 2008 compared with 2007. There are several possible reasons for this difference. First, sampling was initiated late and only a few weeks of data were collected. Second, there were fewer thrips on the farms in 2008 compared with 2007.

The thrips complex in SHB blueberry flowers in Florida is dominated by *F. bispinosa* (Arévalo et al. 2006). The two Hernando and Lake Co. farms, however, differed from this norm. On farm 1 in 2007 and the lake Co. farm in 2008, high percentages of *F. bispinosa, T. hawaiiensis,* and *T. pini* were collected. Farm 2 was less extreme in its differences from the expected. In 2007, only the Jewel and cultivars had high percentages of the two *Thrips* species in 2007 and 2008, respectively. Further research is needed to determine why the two *Thrips* species occurred in such high numbers on these three farms.

There were differences in fruit injury among cultivars at the Citra PSREU and on the commercial farms, but these did not seem to be related to differences in thrips numbers. There could be several reasons for this. The different cultivars could have different levels of tolerance to flower thrips. It is also possible that some cultivars are more susceptible to diseases than others. Also, the different species of thrips may differ greatly in their effect on the blueberry flowers and subsequent fruits. It has been shown that peppers in Florida can tolerate high numbers of *F. bispinosa* and *F. tritici,* but only a few *F. occidentalis* will cause significant injury (Funderburk 2009).

Significant positive linear relationships between thrips per flower and fruit injury were found in all four cultivars from the Hernando Co. farms in 2007. Neither the Hernando and Lake Co. farms in 2008 nor the Citra PSREU in either year showed a relationship between thrips per flower and fruit injury. This may be due to the low numbers of thrips present at these farms during these years.

Numbers of thrips per trap only exceeded threshold levels on Hernando Co. farm 1 in 2007. On this farm in 2007, there was a significantly smaller proportion of

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injured and unmarketable fruit in the 100 thrips per trap threshold treatment compared with the untreated control. This may indicate that 100 thrips per trap, when the traps are left in the field for 1 wk, is an effective threshold, but more research is needed to confirm this fact. The only significant difference in thrips numbers among treatment thresholds occurred with thrips per trap on 1 March. By this date, flowers were only present on Emerald. The apparent lack of effectiveness of the thresholds may have been caused by thrips from untreated areas of the farms recolonizing the treated rows. Funderburk and Stavisky (2004) note that *F. bispinosa* adults can quickly recolonize a treated area, making the application of an insecticide seem to be ineffective. Varietal differences may also have masked the effects of the thresholds. Arévalo-Rodriguez (2006) found a slightly lower EIL for Tifblue RE blueberries compared with Climax RE blueberries in Georgia. Although we did not test a threshold lower than 100 thrips per trap, an action threshold range may exist in SHB blueberries as well.

The results from these experiments provide evidence that SHB blueberry cultivars may attract different numbers of thrips and may have varying tolerance to thrips injury. If this is the case, then each cultivar would have a different EIL. Because multiple cultivars are grown on the same farm, the lowest EIL could be used to set the threshold level for the farm. There is also anecdotal evidence to suggest that interplanting multiple cultivars may reduce thrips pressure. Further research is needed to determine whether a more diversified cropping system could reduce thrips numbers.

Acknowledgments

We thank G. B. Edwards for help in thrips species identification. We also thank all of the current and previous staff and students of the Small Fruit and Vegetable IPM laboratory for help in collecting samples and harvesting many, many blueberries. We thank Drs. Robert McSorley and Joe Funderburk for initial review of this manuscript. The University of Florida, Institute of Food and Agricultural Sciences 2005–2006 Integrated Pest Management grant funded the project encompassing the Hernando and Lake Co. farms.

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Received 10 August 2011; accepted 8 December 2011.

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