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ARTHROPOD MANAGEMENT

Predator-Prey Interactions Between *Orius insidiosus* (Heteroptera: Anthocoridae) and *Frankliniella tritici* (Thysanoptera: Thripidae) in Cotton Blooms

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ABSTRACT

The insidious flower bug, *Orius insidiosus* (Say), is reported to effectively suppress *Frankliniella* species thrips populations. The objective of this study was to determine the effectiveness of this predator in reducing thrips populations in cotton (*Gossypium hirsutum* L.). Population fluctuations of the predator and thrips on the leaves, squares, and flowers were tracked on plots in Quincy and Marianna, FL, in 2006 and 2007, and weekly predator-to-prey ratios were used to assess the effectiveness of the predator in regulating the thrips populations. The bulk (> 95%) of the *Frankliniella* thrips were found in flowers and *F. tritici* (Fitch) constituted > 98% of the adult thrips population. Other thrips recorded were *F. occidentalis* (Pergande) and *F. bispinosa* (Morgan). The highest and lowest weekly predator-prey ratios in the flowers in Quincy were 1:5 and 1:1170, and 1:92 and 1:1900 in Marianna. No correlation was observed between *O. insidiosus* and thrips abundance. Results of this study indicate that *O. insidiosus* may not be an effective predator of *F. tritici* in field cotton during the reproductive stage.

Frankliniella species thrips are among the most important crop pests, and they also are noted as important transmitters of many different pathogens (Kirk, 1997; Mound, 1997). Thrips are important pests of cotton (*Gossypium hirsutum* L.) especially at the seedling stage and are managed primarily at planting with insecticide-treated seed or soil-applied systemic insecticides (Carter et al., 1989). Controlling thrips using insecticides is difficult and expensive, apart from the toxic effects these chemicals usually have on predators of insect pests. The need to determine the effectiveness of insect predators of thrips on cotton as a way of identifying the importance that these thrips population regulation agents play is vital for the formulation of integrated management strategies for thrips.

Predation is one of the most difficult interspecific interactions to estimate (Stuart and Greenstone, 1990). The insidious flower bug, *Orius insidiosus* (Say), is a natural enemy of thrips. Previous studies have shown variations in the success of *O. insidiosus* in regulating thrips populations. Funderburk et al. (2000) concluded that *O. insidiosus* was an effective predator of *Frankliniella occidentalis* (Pergande), *F. tritici* (Fitch), and *F. bispinosa* (Morgan) in the flowers of field-grown pepper. Van den Meiracker and Ramakers (1991) reported an almost complete elimination of *F. occidentalis* by *O. insidiosus* in sweet pepper. Ramachandran et al. (2001) reported a slightly different observation from their work on field pepper when they noted that although the adults of *F. occidentalis* and larval thrips were significantly suppressed by *O. insidiosus*, there was no significant suppression of the adults of *F. tritici* and *F. bispinosa*. The capacity of species of *Orius* to suppress populations of *F. occidentalis* has been reported by others as well (Chambers, et al., 1993; Higgins, 1992; Nicoli, 1997). Sabelis and van Rijn (1997) noted that *O. insidiosus* has the intrinsic ability to suppress a coherent population of *F. occidentalis* at a predator-to-prey ratio of 1:217 on plant species.

Greenhouse experiments have shown that successful biological control of *F. occidentalis* with *Orius* species is possible on chrysanthemum (Beekman et al., 1991) and on Canadian pepper and cucumber (Gilkeson et al., 1990; Tellier and Steiner, 1990). Tavella et al. (1996) concluded that anthocorid predators can be effective biological control agents of thrips in greenhouses. Mound and Teulon (1995) argued that there is little quantifiable information to indicate density-dependent regulation of thrips under natural conditions, and population attributes of rapid colonization and growth are still thought to possibly outstrip the capacity of natural enemies to regulate thrips population.

Biological control agents, such as predatory anthocorids (*Orius* spp.) can provide effective control of *F. occidentalis*, but are not successful on all crops or

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under all situations (Dissevelt et al., 1995; Jacobson, 1997; Jarosi et al., 1997). For example, Coll and Ridgway (1995) indicated that *O. insidiosus* searches less effectively for *F. occidentalis* on tomato plants than on bean and pepper plants. Reports about the success of *O. insidiosus* to suppress the population of *Frankliniella* species have been on crops other than cotton. In contrast to the above reported successes of anthocorid predators as agents for the control of the population of *Frankliniella* species, Parrella and Lewis (1997) concluded that natural enemies play an insignificant role in regulating thrips in field crops. Hulshof et al. (2003) noted that biological control of thrips is not easily achieved, and its success depends on the crop. Loomans et al. (1997) and Parrela and Lewis (1997) concluded that natural enemies must not be playing a major role. The objective of this study was to determine the effectiveness of *O. insidiosus* in regulating the population of *Frankliniella* thrips in field cotton.

MATERIALS AND METHODS

Research was conducted in 2006 and 2007 at two locations (approximately 65 km apart) at the North Florida Research and Education Center (NFREC) in Quincy (Gadsden Co.) and Marianna (Jackson Co.), FL. Cotton cultivar DPL-555 Bt/RR (Delta Pine and Land Co.; Scott, MS) was used and plots were maintained according to normal production practices recommended by the University of Florida Extension Services (Wright et al., 2007), unless otherwise stated. Each experiment at each location and year was four 18 m x 14.6 m blocks with between block distance of 4.6 m. Blocks consisted of 16 rows of plants, with a row spacing of 0.9 m. Planting was done after a broadcast application of 5-10-15 (N-P-K) fertilizer at 225 kg/ha three days prior to planting. No pesticides were applied throughout the study period in both years and locations.

Sampling of thrips and *O. insidiosus*. Sampling was done weekly starting at early bloom (when 50% of the plants have at least one bloom). Upland cotton produces white flowers on the first day of flower opening that turn pink after pollination the following day. In this study, only white, first-day flowers were used. On the day of sampling each week, a cotton square and a white flower from each of 40 plants (10 plants from each block) in each plot were randomly collected from different plant rows and put into 60-ml wide-mouth high-density polyethylene sample bottles containing 70% ethanol solution in water and taken to the laboratory for processing. Samples were kept at room temperature in the laboratory. The flowers were inverted (peduncle located at the opening of the bottle) in the sample bottles such that insects inhabiting them became dislodged and dropped to the bottom of the bottle. Sampling was done between 1100 and 1200 for eight consecutive weeks. Thrips were extracted and adult species identification and gender were determined based on taxonomic features (body color, antennae, pigmentation, and ornamentation) and counted under a stereomicroscope at 40x (Mound and Kibby, 1998). Larval thrips were recorded as a group. Adult and nymphal *O. insidiosus* were extracted using the same procedure. Flowers were randomly checked under the stereomicroscope to make sure all thrips and *O. insidiosus* were extracted.

In order to track the densities of thrips and predators inhabiting the leaves and flowers, two leaves from the upper, middle, and lower canopies from each of 40 plants (10 plants from each block) were randomly collected into 1.9-L plastic containers containing 70% ethanol solution in water and processed as described above for thrips and *O. insidiosus*. Sampling of leaves began in the sixth week after the seedlings had emerged and continued for the subsequent eight weeks after first sample date**.** The data were subjected to analysis using SAS (8.2) General Linear Model procedure (SAS Institute, 2001) and ANOVA for randomized complete block of data pooled over date.. Predator-prey ratios were used to assess the effectiveness of the predator. These ratios were determined using densities of *O. insidiosus* and all the adult thrips species and larvae in the flowers on a per-plot basis for each sampling date for each location. Only densities of the predator and prey in the flowers were used for the determination of the predator-prey ratios because the flowers were host to the bulk of the insects. Pearson's correlation was used to determine the association between thrips and the predator (Sokal and Rohlf, 1987), using the weekly mean densities of the predator against that of adult and larval thrips combined per sampling date; these were done on year and location basis.

RESULTS

Cotton flowers served as host to most (> 95%) of *Frankliniella* species thrips recorded on the plant (data not shown). Other arthropods found inhabiting the flowers were mites, aphids, bugs, and ants. *Franklin-*

iella species found in the flowers in Quincy and Marianna were *F. bispinosa, F. fusca, F. occidentalis,* and *F. tritici. F. tritici* constituted > 98% of the adult population and it is reasonable to suggest that this species probably made up the bulk of the larvae too. In seven of the eight sampling weeks, the mean densities of the predator, *O. insidiosus*, were significantly higher in the flowers than on other plant parts.

Population fluctuations of the thrips species and the predators in the flowers are shown in Figures 1 and 2. In 2006, *F. tritici* reached its peak density per flower a week or two after the peak population of the predator. However, in 2007 both *F. tritici* and *O. insidiosus* attained peak densities of 18.3 and 0.1 per flower, respectively, in the sixth week. By the eighth week, *F. tritici* density declined to 3.2 per flower, whereas that of the predator was negligible. In Marianna, *F. tritici* reached its highest mean density per flower of 33.7 before that of *O. insidiosus* (0.1 per flower) in 2006. However, there were simultaneous peak densities of 24.2 and 0.1 per flower of *F. tritici* and the predator, respectively, in the fourth week in 2007. The mean densities of the adults of the other *Frankliniella* species were < 1 per flower throughout the study.

The mean densities of the predator and the thrips species across years are shown in Table 1. The ratio of the nymphal *O. insidiosus* to adult ranged from 1:2.5 to 1:4 in Quincy, and 1:3 to 1:5 in Marianna. The ratio of male to female *F. tritici* ranged from 1:1 to 1:2 in Quincy and was approximately 1:1 in Marianna. The predator-prey ratio did not show any consistent improvement over time in either location.

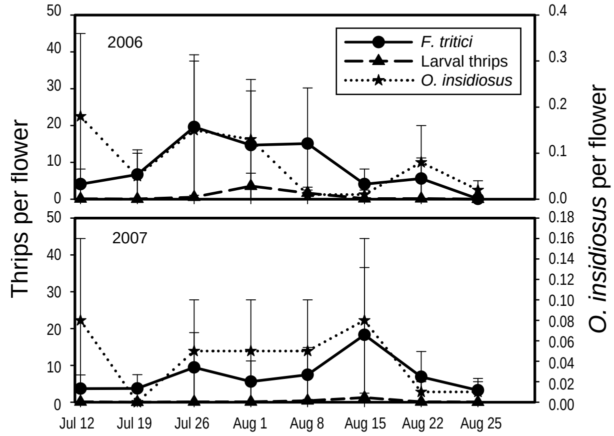

Figure 1. Mean densities (±SEM) of *Frankliniella* thrips and *O. insidiosus* in cotton flowers from 12 July through 25 August in 2006 and 2007 in Quincy, FL.

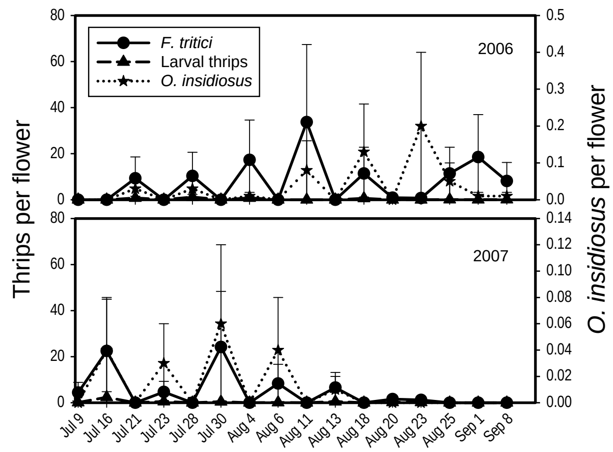

Figure 2. Mean densities (±SEM) of *Frankliniella* thrips and *O. insidiosus* in cotton flowers from 9 July through 23 August in 2006, and 21 July through 8 September in 2007 in Marianna, FL.

Table 1. Mean densities (±SEM) of *Frankliniella* thrips and *O. insidiosus* per cotton flower across 2006 and 2007 at Quincy and Marianna, FL

	Quincy		Marianna	
	2006	**2007**	**2006**	**2007**
***F. tritici* female**	**6.26 ± 0.36**	**4.11 ± 0.22**	**7.97 ± 0.38**	**5.42 ± 0.34**
***F. tritici* male**	**2.64 ±0.17**	**3.83 ± 0.36**	**8.18 ± 0.43**	**4.39 ± 0.37**
***F. occidentalis* female**	**0.01 ± 0.01**	**0.03 ± 0.01**	**0.29 ± 0.07**	**0**
***F. occidentalis* male**	**0.01 ± 0.01**	**0**	**0.18 ± 0.07**	**0**
***F. fusca* female**	**0.01 ± 0.01**	**0**	**0.01 ± 0.01**	**0**
***F. fusca* male**	**0**	**0**	**0**	**0**
***F. bispinosa* female**	**0**	**0.01 ± 0.01**	**0**	**0**
***F. bispinosa* male**	**0**	**0**	**0**	**0**
Larval thrips	**0.76 ± 0.10**	**0.28 ± 0.05**	**0.06 ± 0.08**	**0.58 ± 0.09**
***Orius* sp. adult**	**0.05 ± 0.01**	**0.05 ± 0.01**	**0.05 ± 0.01**	**0.03 ± 0.01**
***Orius* sp. nymph**	**0.02 ± 0.01**	**0.03 ± 0.01**	**0.01 ± 0.01**	**0.01 ± 0.00**

In 2006, the lowest predator-prey ratio was 1:1170 and highest 1:5 in Quincy, and lowest 1:1900 and highest 1:92 in Marianna. In 2007, the lowest ratio was 1:700 and highest 1:49 in Quincy, and lowest 1:1620 and highest 1:170 in Marianna (Table 2). The high predator-prey ratios obtained towards the end of the sampling period in 2006 were possibly due to the low number of thrips in the flowers during that period as there were few flowers available on the plants. This situation probably caused migration of thrips to peanut and cotton fields in the vicinity that were in peak bloom, so the low thrips numbers possibly were not a direct result of predation by *O. insidiosus*. Generally, thrips numbers were comparatively higher in 2006 than 2007. No correlation was obtained between thrips and *O. insidiosus* and between the predator and the larval thrips (Table 3).

DISCUSSION

Cotton flowers appear to be a good host for *F. tritici*; the gradual decline in the population of other *Frankliniella* species as summer approaches adds to its success during this period in the Southeast. The ability of a predator to effectively regulate the population of the prey depends on several factors including the initial populations of the predator and prey, their fecundity, and the host plant architecture. Previous studies (Chambers et al., 1993; Funderburk et al., 2000; Higgins, 1992; Nicoli, 1997; Ramachandran et al., 2001) documented the ability of *O. insidiosus* to effectively suppress *Frankliniella* thrips on crops other than cotton and mostly in greenhouse studies.

In these studies, the predator consistently reduced the thrips population over time. The effectiveness of *O. insidiosus* to suppress *Frankliniella* thrips has been variable and depended on the species involved. Most successes were reported with *F. occidentalis* rather than *F. tritici* and *F. bispinosa*; among these three species, *F. occidentalis* is the least mobile. Tommasini and Nicoli (1993) reported that the predator had the capacity to consume 12.5 individuals of *F. occidentalis* per day, and in their study the population of the prey was less than this predation rate, which allowed effective control of this species of *Frankliniella* thrips. In this study, the most abundant species was *F. tritici*, for which the predator has little success in controlling due to the evasive nature of this species. *F. tritici* are significantly more active than *F. occidentalis* (Reitz et al., 2003). There was no consistent suppression of *F. tritici* populations over time, with a characteristic "dip and rise" pattern in the predator-prey ratio in most cases. Predator-prey ratios in many of the

Table 2. Weekly ratios of *O. insidiosus* to *Frankliniella* thrips inhabiting cotton flowers in Quincy and Marianna, FL

Week	Quincy		Marianna	
	2006	2007	2006	2007
1	1:23	1:49	1:190	–
2	1:140	–	1:380	1:1620
3	1:130	1:190	1:180	1:170
4	1:140	1:110	1:420	1:410
5	1:1170	1:160	1:92	1:210
6	1:420	1:240	1:230	1:700
7	1:71	1:700	1:1900	–
8	1:5	1:330	1:830	–

Table 3. Covariation of *Frankliniella tritici* and *O. insidiosus* in Quincy and Marianna, FL

		Association	Correlation (*r*)*	*P*-value
Quincy	2006	None	0.11	0.43
Quincy	2007	None	0.28	0.17
Marianna	2006	None	0.06	0.56
Marianna	2007	Positive	0.71	0.008

*Determined from eight data points.

sampling weeks were far lower than 1:217 for which Sabelis and van Rijn (1997) cited as the critical capacity ratio for *O. insidiosus* to effectively suppress populations of *F. occidentalis*. Ramachandran et al. (2001) reported significant suppression by *O. insidiosus* of adult *F. occidentalis* and larval thrips but not for *F. tritici* and *F. bispinosa*.

Generally, initial (first week of sampling) mean densities of *O. insidiosus* in the flowers were low (< 0.1 per flower) and continued to remain low until about the third or fourth week before increasing to > 0.1 per flower and then began to decline again. This was in direct contrast to that of *F. tritici*, for which densities increased rapidly in the flowers after the first week. The rapid build-up of the population or colonization of *F. tritici* in the flowers and the low densities of *O. insidiosus* in the flowers in the first and the subsequent two or three weeks may account for their unsuccessful suppression of population of adult *F. tritici* in this study. These results agree with Mound and Teulon (1995) that population attributes of rapid colonization and growth of thrips possibly outstrip the capacity of *O. insidiosus* to effectively control thrips populations. The predator seems to prefer the larvae, appearing more vulnerable to predation than the adults because they are less mobile (Funderburk et al., 2000). The apparent preference and consumption of the larvae by the predator as was shown by the low numbers of larvae recorded is consistent with Ramachandran et al. (2001) and Reitz et al. (2006). The adults are more active and therefore are more likely to evade predation than the larvae.

If the predator-prey ratio observed over time can serve as a reliable predictor of predator effectiveness, then the ratios obtained in this study suggest that *O. insidiosus* may not be effective in suppressing populations of *F. tritici* in cotton. This is especially so when thrips numbers are so high that they overwhelm the ability of *O. insidiosus* to suppress them. *O. insidiosus* may have been more effective in this instance if the most abundant thrips species recorded had been the less active *F. occidentalis*. The functional response to prey density by the predator was not determined in this study but it may be affected by the searching ability of the predator and the evasive nature of the prey. Montserrat et al. (2000) studied the functional response of heteropteran predators preying on greenhouse whiteflies and flower thrips. They showed that *O. laevigatus* (Fieber) did not have a significant increase in consumption of whiteflies as prey density increased. Riudavets (1995) had, however, reported that anthocorid bugs showed higher prey consumption than mirid bugs at low thrips densities. Coll and Ridgway (1995) reported that *O. insidiosus* searches less effectively for *F. occidentalis* on tomato plants than on bean and pepper plants. This demonstrates that the effectiveness of *O. insidiosus* on *F. occidentalis* varies with the crop, and may be based on the prey's occurrence in the preferred habitat of the predator (Cloutier and Johnson, 1993), or vulnerability of the prey (Lang and Gsodl, 2001). The architecture of plants seems to play an important role in the determination of the success of the predator, as this may restrict its access to preferred microhabitat of thrips species (Loomans et al., 1997). Relatively smaller species of thrips may be able to hide in places inaccessible to the predator and that would affect the success of the predator, supporting the idea that *O. insidiosus* may not be effective in suppressing populations of all thrips species on all crops and in all instances. Predatory insects like *O. insidiosus* seem to do better as insect population regulators in greenhouses (Beekman et al., 1991; Tavella et al., 1996). Environmental factors and microhabitat conditions within plants in the greenhouse are different than field conditions and impact the behavior of both predators and prey.

It appears the association between *O. insidiosus* and *Frankliniella* thrips in cotton is weak, demonstrated by no correlation between the two in Quincy. Mailhot et al. (2007) reported a similar association when their data were aggregated by location, but they showed that correlation between the two was as high as 0.5 when their data were separated by location and year, and this was similar to the 0.71 obtained in Marianna in 2007 in this study. The association between *O. insidiosus* and *Frankliniella* thrips seems to vary and depended on the location and year, suggesting that environmental conditions impacting reproduction and behavior of both insects may be a factor. In conclusion, the ability of *O. insidiosus* to suppress populations of *Frankliniella* thrips depends on the host crop and the *Frankliniella* species involved, and it was not effective in suppressing the population of *F. tritici* in cotton in this study.

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