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Intercropping Sunflower Varieties with Bell Pepper: Effect on Populations of *Orius insidiosus* (Hemiptera: Anthocoridae) and Thrips

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ABSTRACT

Eight varieties (Bashful, Double Quick Orange, Pro Cut Bicolor, Pro Cut Lemon, Sundance Kid, Sunrich Lemon, Teddy Bear and Zebulon) of sunflower, Helianthus annuus L. (Asterales: Asteraceae), were evaluated for attractiveness to predators, mostly the minute pirate bug, *Orius insidiosus* (Say) (Hemiptera: Anthocoridae). In general, sunflower varieties bearing pollen were more attractive to both pests and predators. No other plant parameter (i.e., flower diameter, center diameter and plant height) measured affected insect densities. The variety Double Quick Orange was found to harbor the highest densities of *Orius*, but also the highest densities of thrips (Thysanoptera: Thripidae), mostly *Frankliniella tritici* (Fitch). Insect populations were monitored in bell pepper, *Capsicum annuum* L. (Solanales: Solanaceae) (var. Camelot) intercropped with Double Quick Orange, sunflower border and bell pepper monoculture. Densities of *Orius* and thrips were highest on the sunflower border, followed by the pepper monoculture and the bell pepper intercropped with sunflower. Over both seasons (2005 and 2006), the population of adult *Orius* sampled was comprised of 75.3% female and 24.8% male. About 55% of *Orius* sampled were nymphs. The thrips population was comprised of *F. tritici* (98.2%), with the remainder being *F. occidentalis* Pergande at 1.4%, and *F. bispinosa* (Morgan) at 0.4%. Most thrips sampled (58%) were in the immature stages. The sunflower variety most attractive to *Orius* was also most attractive to thrips. When intercropped with bell peppers, *Orius* remained in the sunflower which acted as a sink for both pests and predators. Sunflower may be more useful as a trap crop, rather than a source of predators, when used in multiple cropping systems.

Additional Key Words: trap crop, habitat manipulation, refuge crop, Frankliniella tritici, predator.

Conventional ecological theory holds that increased vegetational diversity reduces pest problems by enhancing the activity of natural enemies ("natural enemies" hypothesis) or by diluting the attractiveness of the crop to phytophagous pest insects ("resource concentration" hypothesis) (Root 1973). The use of intercrops to enhance the effectiveness of biological control agents thus comprised an intersection between biological and cultural control (Bugg and Pickett 1998). Numerous studies have demonstrated that carefully selected intercrops can serve to improve natural enemy activity by providing supplementary foods (e.g., alternate prey) or complementary food sources (e.g. nectar, pollen), or refuges with modified microclimate for overwintering or nesting (e.g. reviews in Pickett and Bugg 1998, Landis et al. 2000, Gurr et al. 2004, Altieri et al. 2006).

Although ample documentation exists to support the expectation of decreased pest populations (especially of specialized herbivores) (e.g., Landis 2000, Nicholls and Altieri 2004), an increasing body of literature demonstrates that increased vegetational diversity *per se* will not lead to reductions in pest infestations, and at times might actually exacerbate pest problems. Little or no benefit is derived from an intercrop if the natural enemies it attracts do not then migrate to the crop. The common knotweed (*Polygonum aviculare* L. [Polygonaceae]) harbors large populations of *Geocoris* spp. (Hemiptera: Lygaeidae). When used as an intercrop, the predator remained in the knotweed because of floral resources and alternate prey. Therefore, no increases in prey populations or predation rates were found in most crops tested (Bugg et al. 1987).

In this study, we first compared different varieties of sunflower, *Helianthus annuus* L. (Asterales: Asteraceae) for attractiveness to predators, mostly the minute pirate bug, *Orius insidiosus* (Say) (Hemiptera: Anthocoridae), as well as thrips. The sunflower variety most attractive to *Orius* was evaluated as an intercrop to enhance biological control in bell peppers. Bell peppers are an important crop in Florida which ranks first nationally in the value of bell pepper (>$183 million) in 2007 (USDA 2008). In Florida, thrips are a common pest, and *Orius* a common predator (Baez et al. 2004).

MATERIALS AND METHODS

2005 Sunflower Varieties. The sunflower, *Helianthus annuus*, varieties used in the experiment were planted on field plots at the USDA, ARS, CMAVE/FAMU Center for Biological Control in Tallahassee, FL (approx. 30.47 N -84.28W). Standard agronomic and management practices for the region were followed (Food and Rural Initiatives, Manitoba Agriculture 2005, Hochmuth and Hanlon 1998, Olson 2002). Fertilizer applications were made based on soil analysis test. White plastic mulch was used upon fumigation of the soil using methyl bromide at the rate of 225 kg/ha. Weeds were sprayed once during the season using Gramoxone Extra (paraquat dichloride) at the rate of 3.75 ml/ha. The field was irrigated as needed using plastic drip tape at the rate of 10 psi per hr. The experimental field measured 27 x 29.3 m. Twelve rows of 27 m with inter-row spacing of 0.9 m were set up with a roadway of 2.7 m every 4 rows. The field was divided into 48 plots (8 treatments x 6 replicates) in a randomized complete block design, each consisting of 2 rows of sunflower variety per replicate. Each block was 6.3 m with a buffer of 0.6 m between blocks.

Sunflower was direct-seeded on July 21, 2005. The eight different varieties of sunflower used were Bashful, Double Quick Orange, Pro Cut Bicolor, Pro Cut Lemon, Sundance Kid, Sunrich Lemon, Teddy Bear and Zebulon (Johnny's Selected Seeds, Albion, ME).

Sampling for *Orius insidiosus* and thrips consisted of randomly collecting five flowers per variety every week from September 16 to October 13, 2005. The flowers were placed in paper bags and returned to the laboratory. The flowers were then placed in Berlese funnels (30.5 cm wide x 60.9 cm height using 100 watt bulb) for 1 hour. Insects were collected into a masonry jar with 75% ethyl alcohol. The contents were then transferred to 118.3 ml plastic snap capped vials (Fisher Scientific, Pittsburgh, PA) for further processing. We recorded the numbers and species of adult and immature *O. insidious, Geocoris punctipes* (Say) *and Frankliniella* spp. (Thysanoptera: Thripidae) (*F. tritici* [Fitch], *F. occidentalis* Pergande, *F. bispinosa* [Morgan], and other thrips spp.). Plant measurements included the diameter of the flower, diameter of the flower center and plant height (cm).

2006 Bell Pepper Intercropped with Sunflower (Variety Double Quick Orange). The sunflower variety yielding the highest predator densities in the first season (Double quick orange) was used as an intercrop with bellpepper, *Capsicum annuum* L. (Solanales: Solanaceae) (var. Camelot). The field plots were located at the USDA, ARS, CMAVE/FAMU Center for Biological Control in Tallahassee, FL. Standard agronomic and management practices for the region were followed (Food and Rural Initiatives, Manitoba Agriculture 2005, Hochmuth and Hanlon 1998, Maynard et al. 2002, Olson 2002). Black plastic mulch was laid upon fumigation of the soil using methyl bromide at the rate of 225 kg/ha. Weeds were sprayed once using Gramoxone Extra (paraquat dicloride) at the rate of 3.75 ml/ha. The experimental field measured 27 x 56.7 m. Twenty rows of 27 m with inter-row spacing of 0.9 m were set up with a roadway of 6.3 m every 4 rows. The field was divided into 10 plots (1 treatment and control x 5 replicates) in a randomized complete block design, each consisting of 2 rows of bell pepper or sunflower measuring 6.6 m. The plants were spaced 0.3 m apart. The treatment consisted of bell pepper surrounded with sunflower border. The control consisted of bell pepper monoculture. Buffers consisted of a minimum of 5.4 m between blocks.

Bell pepper seedlings were transplanted on March 20, 2006. To assure sunflower availability in the early and late part of the season, sunflower planting dates were staggered on different dates. Additional sunflower seedlings were transplanted in the field on March 22 and 28, 2006. The plots were covered with a screen net (1.9 cm mesh; 2.1 m x 2.1 m, Gemplers, Madison, WI) after planting to prevent bird damage.

Sampling of bell pepper and sunflower for *O. insidiosus* and thrips consisted of collecting 10 pepper flowers and 2 sunflowers per replicate twice a week from April 25 to June 1, 2006. The sunflowers were placed in paper bags and returned to the laboratory for processing. The insects from sunflower were collected using a Berlese funnel and kept in mason jars with 75% ethyl alcohol for further processing. The bell pepper flowers collected from the field were placed directly on to 118.3 ml snap cap plastic vials filled halfway with 75% ethyl alcohol until further processing. We recorded the numbers and species of adult and immature *O. insidiosus, G. punctipes*, and *Frankliniella* spp. (*F. tritici, F. occidentalis, F. bispinosa,* other thrips spp.). The diameter of the bell pepper and sunflower (cm) were recorded.

Statistical Analyses. Data were analyzed using Systat 11 (Systat Statistical Software, San Jose, CA). Insect counts were standardized by using counts per square centimeter of plant area. Density of *O. insidiosus* and thrips in the two field season experiments were analyzed using 2-way ANOVA. The plant parameters (flower diameter, center diameter and plant height) of sunflower varieties with pollen and those without or scant pollen were analyzed using t-test.

RESULTS

2005 Sunflower Varieties. Density of *O. insidiosus* per sq cm was significantly affected by sampling period and species of sunflower (2-way ANOVA; F = 8.947; df = 33, 162; P < 0.001; R^2 = 0.65). Both sampling period (F = 18.884; df = 4, 191; P < 0.001; R^2 = 0.28) and sunflower species (F = 4.258; df = 7, 188; P < 0.001; R^2 = 0.14) significantly affect insect densities. *Orius* densities were highest on variety Double Quick Orange, followed by those on Pro Cut Lemon, Zebulon and Teddy Bear, and lowest on the remaining varieties (Fig. 1; Tukey HSD, P =

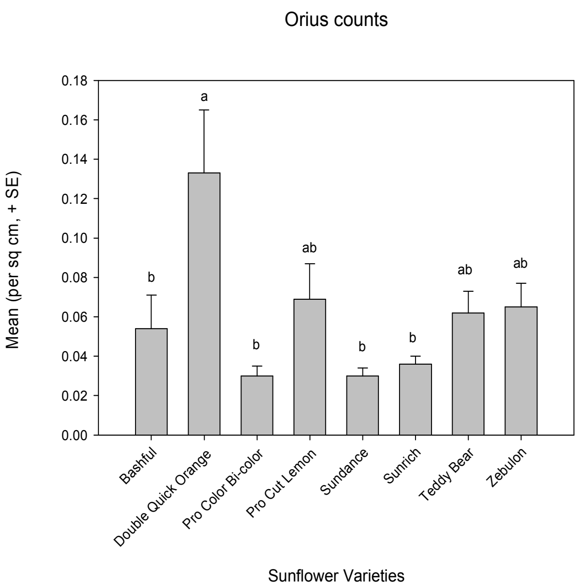

Fig. 1. Mean density (per sq cm ±SE) of adult and immature *Orius insidiosus* on different sunflower varieties.

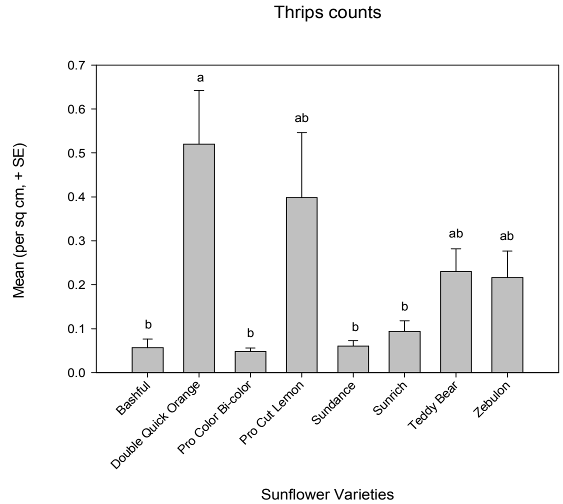

Fig. 2. Mean density (per sq cm ±SE) of adult and immature thrips (*Frankliniella tritici*, *F. occidentalis*, *F. bispinosa*, other thrips spp.) on different sunflower varieties.

0.05).

Densities of thrips showed seasonal patterns similar to those of *Orius* (Fig. 2). Densities of thrips were significantly affected by sampling date and species of sunflower (2-way ANOVA; F = 8.126; df = 33, 162; P < 0.001; R^2 = 0.62). As in *Orius* spp., both sampling period (F = 10.378; df = 4, 191; P < 0.001; R^2 = 0.18) and sunflower species (F = 5.41; df = 7, 188; P < 0.001; R^2 = 0.17) affected densities of thrips. As in the case of *Orius*, densities of thrips on sunflower species were found in three groups: highest on Double-Quick Orange, followed by Pro Cut Lemon, Teddy Bear and Zebulon, and lowest on the remaining varieties (Fig. 2; Tukey HSD; P = 0.05). Therefore, those species of sunflower that harbored the highest numbers of *Orius* predators were also attractive to the pest thrips.

The plant parameters (flower diameter, center diameter and plant height) had no significant effects on the densities of *Orius* predators or thrips (Table 1). However, varieties that were pollen-free (or had scant pollen) were Bashful, Pro Cut Bicolor, Pro Cut Lemon, and Sunrich Lemon (Johnny's Selected Seeds Catalogue). The other varieties (Double Quick Orange, Sundance Kid, Teddy Bear, and Zebulon) produced pollen. The pollen-producing varieties had higher mean densities of total *Orius* (aggregate counts of males, females and immatures per sq cm) than varieties with scant or no pollen (with pollen: mean = 0.076 ± 0.011, N = 99; without pollen: mean = 0.047 ± 0.006, N = 97) (t = 2.268; df = 194; P = 0.024). However, counts of thrips were also higher on the varieties with pollen (with pollen: mean = 0.273 ±

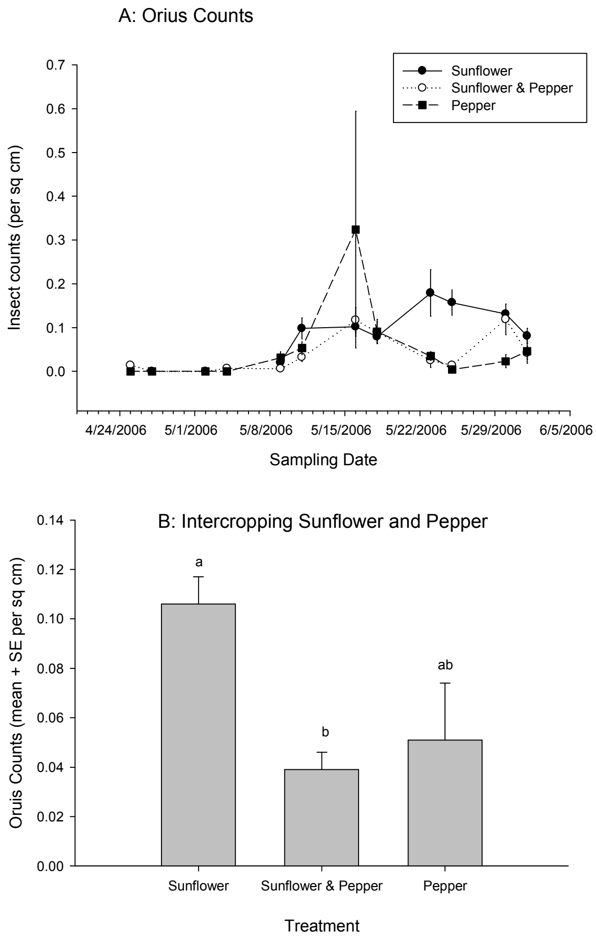

Fig. 3. (A) Mean density (per sq cm ±SE) of adult and immature *Orius insidiosus* on each sampling date in the sunflower border, pepper intercropped with sunflower and pepper monoculture. (B) Mean density (per sq cm ±SE) of adult and immature *Orius insidiosus* in the sunflower border, pepper intercropped with sunflower and pepper monoculture.

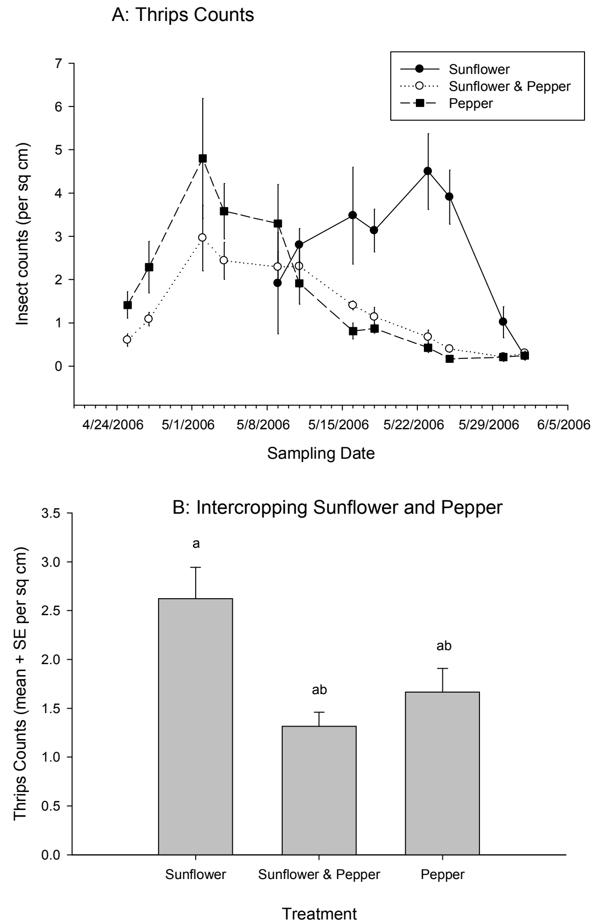

Fig. 4 (A) Mean density (per sq cm ±SE) of adult and immature thrips (*Frankliniella tritici*, *F. occidentalis*, *F. bispinosa*, other thrips spp.) on each sampling date in the sunflower border, pepper intercropped with sunflower and pepper monoculture. (B) Mean density (per sq cm ±SE) of adult and immature thrips (*Frankliniella tritici*, *F. occidentalis*, *F. bispinosa*, other thrips spp.) in the sunflower border, pepper intercropped with sunflower and pepper monoculture.

0.044, N = 99; without pollen mean = 0.149 ± 0.040, N = 97) (t = 2.089; df = 192.0; P = 0.038).

2006 Bell Pepper Intercropped with Sunflower (Double Quick Orange). When bell pepper was intercropped with sunflower, both time and planting treatment significantly affected predator density (2-way ANOVA; F = 1.884; df = 31, 128; $P < 0.01$; R^2 = 0.31). Densities of *Orius* were highest on the sunflower border, followed by the bell pepper monoculture, then the bell pepper intercropped with sunflower (Fig. 3A) (F = 3.934; df = 2, 157; $P < 0.05$; R^2 = 0.05; Fig. 3B; Tukey HSD; P = 0.05).

Densities of thrips declined more rapidly in the bell pepper monoculture and bell pepper intercropped with sunflower treatments than in the sunflower border (Fig. 4A). As in the case of *Orius*, densities of thrips were significantly affected by sampling period and planting treatment (2-way ANOVA; F = 6.473; df = 31, 128; $P < 0.001$; R^2 = 0.61). Thrips densities were highest on the sunflower border, followed by the bell pepper monoculture and the bell pepper intercropped with sunflower (Fig. 4B) (F = 7.422; df = 2, 157; P = 0.001; R^2 = 0.09; Tukey HSD; P = 0.05).

2005 and 2006 Insect Population Counts. In this study, insect counts for both predators and thrips over both seasons are summarized in Table 2. The population of adult *Orius* sampled was 75.3% female (3054/4060) and 24.8% male (1006/4060). About 55%

Table 1. Statistical analysis of effects of plant parameters of densities of *Orius* spp. and thrips.

Dependent factors	Independent factor	*F*-value	df	*P*	R^2
Orius density	Diameter	0.128	1, 30	0.723	0.004
	Flower center	0.084	1, 30	0.774	0.003
	Height	0.020	1, 22	0.889	0.001
Thrips density	Diameter	1.027	1, 30	0.319	0.033
	Flower center	0.071	1, 30	0.791	0.002
	Height	1.026	1, 22	0.322	0.045

of *Orius* sampled were nymphs (4980/9040). The thrips population sampled (40,754) was dominated by *F. tritici* at 99% (40347), with the remainder comprised of *F. occidentalis* at 1.4% (234), and *F. bispinosa* at 0.4%. Most thrips sampled (58%) were in the immature stages (57670/99474). Numbers of *Geocoris* were too low to analyze statistically in both seasons.

Table 2. Cumulative *Orius* and thrips counts for 2005 (on sunflower only) and 2006 (sunflower – bell pepper intercrop) cropping seasons.

Insects	2005	2006
Orius females	2107	947
Orius males	625	381
Orius nymphs	3530	1450
Geocoris	180	137
Frankliniella occidentalis	3	231
Frankliniella tritici	2917	37430
Frankliniella bispinosa	55	118
thrips larvae	21,239	36431
Other thrips species	348	702

DISCUSSION

In this study, we chose sunflowers as the intercrop because they are known to attract beneficial insects such as pollinators or natural enemies, including *Orius* spp. (Bottenberg et al. 2000; Chyzik et al. 1995; Jones and Gillett 2005, Lynch and Garner 1980, Royer and Walgenbach 1991). Beneficial insects with small mouthparts such as small parasitic wasps can easily extract nectar from sunflowers with small, shallow flowers (Dufour 2000). Jones and Gillett (2005) found that a sunflower intercrop yielded higher numbers of beneficial insects such as *Geocoris* spp., honeybees (*Apis mellifera* L. [Hymenoptera: Apidae]), spiders (*Peucetia viridans* (Hentz) (Arachnida: Oxyopidae), ants (Hymenoptera: Formicidae) and sphecid (Hymenoptera: Sphecidae) wasps compared to control plots. Moreover, densities of beneficial insects were similar to those in sunflower for adjacent crops (<1 m distant) compared to those farther from the sunflower (>10 m distant). Pest densities were similar or higher in sunflower compared to the crops.

Orius insidiosus has been recovered from buckwheat (*Fagopyrum esculentum* Moench) and sunflower cover crops in Canadian fruit orchards (Hagley 1996). In northern California, sunflower and buckwheat were used as cover crops in vineyards. The resulting floral diversity increased the numbers of natural enemies such as spiders, *Nabis* sp., *Orius* sp., *Geocoris*, coccinellids and *Chrysoperla*, while reducing numbers of western grape leafhoppers (*Erythroneura elegantula* Osborn [Homoptera: Cicadellidae]) and *F. occidentalis* compared to monocultures (Altieri et al. 2006, Nicholls and Altieri 2004). Sunflower provided an alternate host (*Aphis helianthi* [Monell] [Homoptera: Aphididae]), leading to increased parasitism in *Schizaphis graminum* [Rondani] [Homoptera: Aphidae]) on nearby sorghum

(Eikenbary and Rogers 1974) (cited by Coll 1998). In Finland, sunflower was one of several trap crops used in a mixture to suppress the damage by the blossom beetle, *Meligethes aeneus* F. (Coleoptera: Nitidulidae), on cauliflower (Hokkanen 1989 cited by Muniappan et al. 2004). Not all results have been positive. Sunflower was found to be less effective as a refuge crop for predatory beetles, bugs and lacewings against *Helicoverpa* spp. compared to lucerne (*Medicago sativa* L. [Fabaceae]) in Australian cotton fields (Mensah 1999).

Therefore, intercrops do not always enhance the benefits from natural enemies and may, in some cases, actually exacerbate pest problems. Coll (1998) includes the following examples:

1. Providing a favorable harbor for the development of the pest – e.g., intercropping maize with cotton increases infestation by *Heliothis armigera* (Hübner) (Lepidoptera: Noctuidae) which multiplies in maize, then migrates to cotton
2. Obscuring host-finding cues of the natural enemy – e.g., ability to find sawfly larvae hosts in *Bessa harveyi* (Townsend) (Diptera: Tachinidae) is impaired by the forest understory species (Monteith 1960 as cited by Coll 1998).
3. Acting as trap plants to natural enemies – e.g., glandular exudates of petunia prevented *Lysiphlebus testaceipes* (Cresson) (Hymenoptera: Aphidiidae) from moving to okra to parasitize cotton aphid (*Aphis gossypii* [Glover] [Homoptera: Aphidae]) (Marcovitch 1935 as cited by Coll 1998)

Intercrops that attract beneficial insects or pest species can also act as either “sources” (when the insect migrates from the intercrop into the main crop) or “sinks” (when the insect is attracted to the intercrop but does not leave). Whereas, the ideal intercrop might function as either a sink of the pest, a source of natural enemies or both, experimental data often yield mixed results (Corbett 1998). Simulation studies have shown that the interplay of a few factors (e.g., insect mobility, time of insect colonization relative to crop germination), can affect the role of the intercrop, either as a source or sink of natural enemies (Corbett 1998).

We found that different varieties of sunflower harbored significantly different densities of *Orius* spp. Those varieties that were attractive to *Orius* were also attractive to pest thrips. Pollen production appears to be an important factor in the attractiveness of a sunflower variety to both the predator and thrips because of higher insect densities on pollen-producing varieties. Plant height, flower diameter and diameter of flower center did not significantly affect densities of *Orius* spp. or thrips. The sunflower variety, Double Quick Orange, harbored the most thrips and *Orius* species. Intercropping Double Quick Orange sunflower with bell peppers was studied with the expectation that the *Orius* spp. populations would migrate to the bell pepper, thereby reducing thrips populations in the latter. Results showed that population densities of *Orius* spp. and thrips were higher on the sunflower border, but there were no significant differences in predator and thrips densities between the bell pepper intercropped with sunflower and the bell pepper monoculture. In other words, sunflower appeared to act more as a sink of both pest and predator, rather than the intended source of predators, suggesting possible utility of sunflower as a trap crop. Michaud and Grant (2005) also suggest that sunflower may be more effective as a trap crop rather than a refuge crop or source of nutrition when intercropped with soybean, *Glycine max* L. (Merr.), because it is the nutritionally superior preferred host plant for the longhorned beetle, *Dectes texanus* LeConte (Coleoptera: Cerambycidae).

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