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Authors: Kalsi, M., Seal, D. R., Nuessly, G. S., Capinera, J. L., and Martin, C. G.

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SEASONAL TIMING, ABUNDANCE, AND PREDATORY STATUS OF ARTHROPODS ASSOCIATED WITH CORN INFESTED BY PICTURE-WINGED FLIES (DIPTERA: ULIDIIDAE) IN SOUTH FLORIDA

M. Kalsi[1], D. R. Seal[1]*, G. S. Nuessly[2], J. L. Capinera[3] and C. G. Martin[1]
[1]University of Florida, Tropical Research and Education Center (TREC), 18905 SW 280th Street, Homestead, FL 33031, USA

[2]University of Florida, Everglades Research and Education Center, 3200 E. Palm Beach Rd., Belle Glade, FL 33430, USA

[3]University of Florida, Department of Entomology and Nematology, Bldg. 970, Natural Area Drive, Gainesville, FL 32611, USA

*Corresponding author; E-mail: dseal3@ufl.edu

Abstract

Since the 1960s, the USA has led all other countries in the production of sweet corn (*Zea mays* L.), and Florida has often led the nation, such as from 2004 to 2009. Picture-winged flies, or corn silk flies, including *Euxesta stigmatias* Loew, *E. eluta* Loew, *E. annonae* F., and *Chaetopsis massyla* Walker (Diptera: Ulidiidae), are serious pests of field and sweet corn in southern Florida. Control has focused on the use of chemical insecticides, but efforts have begun to explore other control methods, such as using predatory arthropods. We studied the timing, abundance, identification, and predatory status of ulidiids and other arthropod species associated with corn ears growing in the field in the spring, summer, and fall of 2010. Predators of ulidiids included *Orius insidiosus* Say (Hemiptera: Anthocoridae), *Anotylus insignitus* (Gravenhorst) (Coleoptera: Staphylinidae), *Chrysoperla carnea* Smith (Neuroptera: Chrysopidae), *Zelus longipes* (L.) (Hemiptera: Reduviidae), and potentially other arthropod species. Larvae of *A. insignitus, C. carnea,* and nymphs and adults of *O. insidiosus* consumed eggs and larvae of ulidiids in laboratory no-choice tests. Other than ulidiid eggs and/or larvae, *O. insidiosus* was the most abundant arthropod species in the silking (R1) stage of corn in all 3 seasons. Sap beetle larvae or adults (Coleoptera: Nitidulidae) were the most abundant arthropod groups in the spring blister stage (R2) and in milk stages (R3) of the spring and fall. The most abundant groups in the summer R2 and R3 stages included *A. insignitus* larvae and sap beetle larvae and adults, and in the summer R2, also *O. insidiosus*. The most abundant groups in the fall R2 were *O. insidiosus,* sap beetle adults, *Thrips* sp. (Thysanoptera: Thripidae), and mites. *Chrysoperla carnea* was found only in the summer, and *Z. longipes* only in the fall. In all 3 seasons, ulidiid eggs were more abundant than larvae in the R1 stage, but larvae usually outnumbered eggs in the R2 and R3 stages. Each of the groups, *O. insidiosus* and eggs and larvae of ulidiids, were most abundant in the summer followed by the fall and least abundant in the spring. These findings may help in determining spatial distributions and functional responses of these predators to further evaluate their potential to control ulidiid flies.

Key Words: *Orius, Anotylus*, *Chrysoperla, Euxesta*

Resumen

Desde los 1960s, los Estados-Unidos ha excedido todos los otros paises en la producción de maiz dulce (*Zea mays* L.), y Florida ha excedido el resto del paiz, por ejemplo, durante 2004 a 2009. Moscas moscas con alas pintadas, o moscas de la seda del maiz, incluyendo *Euxesta stigmatias* Loew, *E. eluta* Loew, *E. annonae* F., y *Chaetopsis massyla* Walker (Diptera: Ulidiidae), son plagas muy serias del maiz de campo y maiz dulce en el sur de la Florida. Su manejo ha enfocado en el uso de insecticidas chemicas, pero ya les han comenzado pruebas con otros métodos de control tales como usando depredadores. Estudiamos la sincronización, abundancia, identificación, y estatus de predación de ulidiids y otras especias artrópodos associados con espigas de maiz en el campo en la primavera, verano, y otoño de 2010. Depredadores de ulidiides incluyeron *Orius insidiosus* Say (Hemiptera: Anthocoridae), *Anotylus insignitus* (Gravenhorst) (Coleoptera: Staphylinidae), *Chrysoperla carnea* Smith (Neuroptera: Chrysopidae), *Zelus longipes* (L.) (Hemiptera:

Reduviidae), y potencialmente otras especias de artrópodos. Larvas de *A. insignitus, C. carnea,* y nymphos y adultos de *O. insidiosus* comieron huevos y larvas de ulidiides en las pruebas de no opciónes del laboratorio. Excluyendo huevos y larvas de ulidiides, *O. insidiosus* fué la especie de artrópodo mas abundante en la etapa de seda (R1) del maiz en toda las tres temporadas. Larvas y adultos de escarabajos de la savia (Coleoptera: Nitidulidae) fueron los grupos mas abundantes de artrópodos en la etapa ampolla de primavera (R2) y en las etapas de leche (R3) de la primavera y del otoño. Los grupos mas abundantes en las etapas R2 y R3 de verano fueron larvas de *A. insignitus* y larvas y adultos de escarabajos savias, y en el R2 de verano, también *O. insidiosus*. Los grupos mas abundantes del R2 de otoño fueron *O. insidiosus,* adultos de escarabajos savias, *Thrips* sp. (Thysanoptera: Thripidae), y acaros. *Chrysoperla carnea* fué coleccionaba solamente en el verano y *Z. longipes* solamente en el otoño. En toda las tres temporadas en la etapa R1, huevos de ulidiides fueron mas abundante que larvas, pero en las etapas R2 y R3, larvas fueron usualmente mas abundantes que huevos. Huevos y larvas de ulidiides y *O. insidiosus* cada fueron mas abundante en el verano, seguido por el otoño, y menos abundante en la primavera. Estas conclusiones puede ayudar en determinar la distribución espacial y respuestas functionales de estas depredadores para evaluar sus capacidades de controlar moscas ulidiides.

Palabras Claves: *Orius, Anotylus*, *Chrysoperla, Euxesta*

Since the 1960s, the USA has led all other countries in tonnage of annual production of sweet corn (*Zea mays* L.) (Hansen & Brester 2012). In 2009 fresh-market corn was valued at $836 million and processed (frozen and canned) corn was valued at $336 million (ERS 2010). From 2004 to 2009, Florida led the nation in fresh-market sweet corn production with 19-27% of the total national crop value each year (Mossler 2008; ERS 2010). Several species of picture-winged or corn silk flies have become serious pests of sweet corn in the United States. They include *Euxesta stigmatias* (Loew), *E. eluta* (Loew), *E. annonae* F., and *Chaetopsis massyla* (Walker) (Diptera: Ulidiidae) in Florida (Van Zwaluwenburg 1917; Barber 1939; Hayslip 1951; Seal & Jansson 1989; Nuessly & Hentz 2004; Goyal et al. 2010). The larvae have 3 instars that feed on corn silk, kernels, and the remainder of the cob (Seal et al. 1996, Nuessly & Capinera 2010). They oviposit in bundles of silk strands, or stigmas and styles of corn flowers. After severing the silk and disrupting pollination by feeding (Bailey 1940), larvae enter kernels through the soft pericarp and feed on the cob (App 1938; Seal & Jansson 1989; Nuessly et al. 2007). If larval infestation causes any damage to corn kernels, the sweet corn ears are unmarketable.

According to Bean (2010), the developmental stages of corn are 1) R1 or silking stage at 8-9 weeks after planting, 2) R2 or blister stage at 10-14 days after first silk, and 3) R3 or milk stage at 18-22 days after first silk when the corn silk begins to senesce or turn brown. Corn-infesting ulidiids typically start to cause economic losses in the R1 stage with maximum emergence of larvae from eggs in R2, and the kernels have maximum damage from larval feeding with thick, pasty endosperm in R3 (Seal & Jansson 1989, 1993).

Chemical insecticides are currently the only effective management tactic to control ulidiid flies. Sweet corn fields in the R1 through R3 stages are often sprayed daily with insecticides (Goyal 2010) that are effective at killing adult flies while other life stages remain protected inside corn ears (eggs and larvae) or soil (pupae) (Nuessly & Capinera 2010). In the northeastern United States, the primary predators of sweet corn pests are *Coleomegilla maculata* (DeGeer), *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae), and minute pirate bugs *Orius insidiosus* (Say) (Hemiptera: Anthocoridae) (Andow & Risch 1985; Coll & Bottrell 1992; Coderre et al. 1995; Wheeler & Stoops 1996; Hoffmann et al. 1997; Musser et al. 2004). In the corn fields of Spain, Albajes et al. (2003) found that common foliage predators included beetles (Carabidae, Staphylinidae, and Coccinellidae), bugs (Heteroptera), and spiders (Araneae), and in pitfall traps, beetles (Carabidae), earwigs (Dermaptera), and spiders (Araneae). Asin & Pons (1999) found additional cornfield predators including lacewings (Chrysopidae) and syrphid flies (Syrphidae) that specialized on aphids. In Germany, Eckert et al. (2006) found *O. insidiosus*, predatory lacewings, and parasitic Hymenoptera on corn silk and husks. Eckert et al. (2006) reported that sampling corn ears is a good method for finding changes in the abundance of different arthropod species. Biological control agents may be of great value if they control adults and hidden developmental stages of ulidiids, but information on biocontrol of ulidiids is lacking.

Objectives of the present study were to determine the identification, abundance, and predatory status of arthropod species found in corn ears growing in the field in south Florida. This will help in further studies to determine spatial distributions of predators and ulidiid prey and predatory functional responses indicating their potential effectiveness in controlling eggs, larvae, and adults of ulidiids.

Materials and Methods

The study was conducted at the University of Florida, Tropical Research and Education Center (TREC), Homestead, Florida, from Feb through Dec 2010. Samples were also taken from a commercial field (Super 6 Farms, Kendall, Florida).

Environmental Conditions

During the 11-mo study period, temperature, humidity, and rainfall were recorded 60 cm above ground by the Florida Automated Weather Network (FAWN), Homestead. Mean monthly temperatures for Feb through Dec 2010 ranged from 27.9 °C in Jun to 14.2 °C in Dec with maximums of 35 °C in Jun, Jul and Aug, and a minimum of -1 °C in Dec (FAWN 2010). Relative humidity ranged from a mean monthly maximum of 85% in Aug and Sep to 76% in Dec, and rainfall ranged from 28 cm (11.0") in Aug to 2 cm (0.7") in Dec (FAWN 2010).

Seasonal Abundance and Diversity of Arthropods

Field Preparation. There were 3 field tests in the spring, summer, and fall of 2010 with one test per season. At each location (Kendall and Homestead), one field was used for all field data collection. Field tests were conducted in Krome gravelly loam soil (loamy-skeletal, carbonatic, hypothermic, lithic, udorthents) that was well drained, had a pH of 7.4-8.4, was 34-76% limestone pebbles (≥ 2 mm diam), and had low organic matter (< 2%) (Nobel et al. 1996; Li 2001). Each test field (0.4 ha) was divided into 40 equal 0.01-ha plots that were each 2 rows wide by 27.5 m long. At Homestead, 'Obsession' sweet corn (Seminis Vegetable Seeds, Oxnard, California) was planted in rows with a garden seeder (Model 1001-B, Earthway® Products, Bristol, Indiana) on 15 Feb, 2 Jun, and 1 Oct for the spring, summer, and fall tests, respectively. Field corn instead of sweet corn was planted at Kendall. Planting sites were spaced 0.3 m apart in rows separated by 0.9 m. Three to 5 seeds were planted per planting site to assure at least 1 seed germinated, but seedlings were thinned to 1 plant per site upon emergence. Granular fertilizer (N-P-K: 8-16-16, Diamond R fertilizers, Fort Pierce, Florida) was applied at 1,347 kg/ha at planting in parallel bands spaced 0.1 m from the seed rows. In addition, liquid fertilizer (N-P-K: 4-0-8, Diamond R fertilizers, Fort Pierce, Florida) was applied twice as a foliar spray 21 and 35 d after planting (DAP) to provide 2.8 kg of N/ha/d. To control weeds, the pre-emergence herbicide, trifluralin (Treflan™ 4EC, Dow AgroSciences, Indianapolis, Indiana), was applied at 0.09 kg/ha at planting, and plants were irrigated as needed by drip irrigation.

Data Collection. The sweet corn fields were sampled once during each of the 3 corn development stages described by Bean (2010). The first sample was during the silking (R1) stage and 4 days after first silk; the second sample was 5 days after the beginning of the blister (R2) stage, and the final sample was during the first week of the milk (R3) stage. For the spring and fall, the first, second, and third samples were 49, 63, and 70 DAP for the R1, R2, and R3 stages, respectively, and for the summer they were 56, 70, and 77 DAP, respectively. Two corn ears, 1 per plant, were randomly collected from each plot per sample date resulting in 80 ears per sample date. Each ear was separately placed in a 17 × 22 cm self-sealing plastic bag, and samples that could not be immediately processed were stored at 26 ± 5 °C until processing. Each corn ear was removed from storage, cut in half at mid-point, and placed in a 100-mL beaker filled with 75% ethanol for 5 min to collect arthropods, then carefully removed with forceps and discarded. The corn husk, silk, and pieces of corn cob were also rinsed in alcohol to dislodge arthropods. Alcohol rinses were filtered through a 25-µm mesh (USA Standard Testing Sieve, W. S. Tyler Co., Mentor, Ohio) to collect arthropods, which were then saved in 70% ethanol for identification. In the commercial field corn site at Kendall, only the top 5 cm of ear sheath (excluding the cob but including leaf tips and silk) were collected and handled as described for sweet corn. Arthropods were counted with a 10X microscope and identified to species where possible. Unidentified arthropods were sent for identification and voucher specimens submitted to the Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville, Florida.

Laboratory Evaluation of Arthropod Species for Predatory Status

Ulidiid Colonies. Colonies of *E. stigmatias*, *E. eluta,* and *E. annonae* each originated with 100 adults collected from corn fields in Summer 2010. Each *Euxesta* sp. was reared in a separate cage (31 × 31 × 31 cm) that was maintained at 30 ± 5 °C and 75 ± 10% relative humidity; rearing methods were the same for each fly species. Colonies were fed a beet armyworm artificial diet (BAW, Southland Co., Lake Village, Arkansas) using methods described by Seal & Jansson (1989), and adult flies were supplied with fresh water and 1% honey solution. Diet mixture was attached to the bottoms inside plastic 28-g vials (BioServe™, Beltsville, Maryland, USA) that were affixed upside-down to cage ceilings with the tops facing down to encourage adult oviposition. Eggs were collected from oviposition vials every 24 h, then transferred to fresh BAW diet for larval emergence in the same environmental conditions as adults. Freshly eclosed first instars were removed from the vials every 24 h, transferred into plastic 28-g vials with BAW diet, and allowed to complete development into pupae. Vials with diet and larvae were checked every 4 h to remove pupae, which were rinsed gently with tap water to remove dietary residue and to reduce fungal infection. Pupae were air-dried, then placed into Petri dishes each with a moist paper disk (5 cm-diam) to prevent desiccation. Petri dishes containing pupae were placed in cages (31 × 31 × 31 cm) to allow adult emergence and checked every 2 h to collect newly emerged adults.

Collection of Arthropods for the Predatory Status Test. The study was conducted in the summer and fall using 150 ears per season. The source was mainly sweet corn from the foregoing Homestead field, but field corn from the Kendall field was also used. Nymphs and adults of *O. insidiosus* and third instar larvae of *A. insignitus* and *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) were each evaluated for predation on different ulidiid life stages. The species and developmental stage of each arthropod was determined by its size and color. To preserve corn ears (including arthropods) and to prevent the escape of arthropods until their use in tests, 10 ears were placed per self-sealing plastic bag (17 × 22 cm) with bags temporarily stored at 26 ± 5 °C and 30 ± 5 °C for the summer and fall tests, respectively. After 1 h, corn ear tips were excised 10 cm from the top by a knife and inspected using a 10X microscope. For each species, individuals of a similar developmental stage were collected using a fine paint brush to transfer immatures and adults from corn ears to Petri dishes (10.5 cm diam). One predator of a given taxon and stage was initially placed in a Petri dish along with water and honey as food, but it was deprived of water and food for 24 h before being offered ulidiid prey in a no-choice test. There were 3 sets of petri dishes for each predator of a given taxon and stage. In one set, the predator was provided with 20 eggs (1-day old) of one of the 3 species (*E. stigmatias*, *E. eluta,* and *E. annonae*) from the foregoing laboratory colonies. In a second set of Petri dishes, the predator was provided with 20 one-day-old, first, second, and third instar larvae of an *Euxesta* sp., and in a third set, the predator was provided with twenty 1-day-old adults of an *Euxesta* sp. Each Petri dish thus contained one predator of a given taxon and age and 1 *Euxesta* sp. and was 1 of 4 replications. Petri dishes were checked at 24-h intervals to record numbers of ulidiid eggs and larvae. Dead (evidenced by deflation) or missing eggs and larvae were assumed to have been consumed by predators, which were often seen deflating eggs as they fed in an environment too moist to allow desiccation. The study was conducted in a growth chamber at 28 ± 0.5 °C and 75% RH.

Statistical Analyses.

Data for counts of ulidiid eggs and larvae and abundances of other arthropod species were transformed using square-root transformations for statistical analyses, however, non-transformed means and standard errors of means are reported in the figures. Treatments were then compared using one-way ANOVAs or non-paired *T*-tests as appropriate (SAS Institute 2003). Within each corn stage, abundances of ulidiid eggs and larvae were compared by non-paired *T*-tests. However, comparisons of numbers of arthropods other than ulidiids found in corn ears and cumulative seasonal abundances of *Euxesta* spp. eggs, larvae, and *O. insidiosus* were analyzed by one-way ANOVAs (PROC GLM, SAS Institute 2003). Differences among means were evaluated for statistical difference by Tukey-Kramer HSD tests ($P < 0.05$).

Results

Seasonal Abundance and Diversity of Arthropods

In corn ears, 5 species of arthropods other than ulidiids were found in the spring, 11 species in the summer, and 8 species in the fall of 2010 (Table 1). Nymphs and adults of *O. insidiosus* occurred throughout the survey season as did larvae and adults of *Lobiopa insularis* Castelnau and *Carpophilus lugubris* Murray (Coleoptera: Nitudilidae) and an unidentified mite species (Acari) (Table 1; Figs. 1a and b, 2). Larvae of *Anotylus insignitus* (Gravenhorst) (Coleoptera: Staphylinidae) were found only during the spring and summer blister (R2) and summer milk (R3) stages (Table 1, Figs. 1c and 2). Other multiple-season finds included an unidentified *Thrips* sp. (Thysanoptera: Thripidae) and an unidentified muscoid fly (Diptera: Muscidae) each in the summer and fall (Table 1, Fig. 2). Single-season finds in the summer included larvae of *C. carnea,* and in field corn, an unidentified species of an ant (Hymenoptera: Formicidae), an earwig (Dermaptera: Forficulidae), and a booklouse (Psocoptera) (Table 1, Fig. 1d). Single-season finds in the fall included an unidentified roach species (Blattaria) and *Zelus longipes* (L.) (Hemiptera: Reduviidae) (Table 1). When stages of corn were combined for each season, mean numbers of ulidiid eggs and larvae and of *O. insidiosus* (nymphs and adults combined) were each significantly greater in the summer than in the fall or spring, when they were least abundant (Figs. 3 and 4).

Spring 2010. The only arthropods found in the spring R1 stage that may have preyed upon ulidiids were *O. insidiosus* (Figs. 1a and b; 2). In R2, the arthropods included *O. insidiosus*, *Thrips* sp., larvae and adults of *L. insularis* and *C. lugubris*,

TABLE 1. ARTHROPODS OTHER THAN ULIDIIDS FOUND ON CORN EARS (INCLUDING HUSK AND SILK) IN SOUTHERN FLORIDA IN 2010.

Arthropod taxon	(Order: Family), (Order), or [Subclass]	Corn type[1]	Spr.[2]	Smr.[2]	Fall[2]	Pred. status[3]	Pred. stage[4]	Ulid. Stage[5]
Orius insidiosus	(Hemiptera: Anthocoridae)	S, F	X	X	X	Yes	N, A	E, L
Lobiopa insularis	(Coleoptera: Nitidulidae)	S, F	X	X	X	No	—	—
Carpophilus lugubris	(Coleoptera: Nitidulidae)	S, F	X	X	X	No	—	—
Anotylus insignitus	(Coleoptera: Staphylinidae)	S, F	X	X	—	Yes	L	E, L
Thrips sp.	(Thysanoptera: Thripidae)	S?	—	X	X	Unk	—	—
—	[Acari]	S, F	X	X	X	Unk	—	—
—	(Diptera: Muscidae)	S, F	—	X	X	No	—	—
Chrysoperla carnea	(Neuroptera: Chrysopidae)	S, F	—	X	—	Yes	L	L, A
Zelus longipes	(Hemiptera: Reduviidae)	S, F	—	—	X	Yes	N, A	L, A
—	(Blattaria)	S	—	—	X	Unk	—	—
—	(Hymenoptera: Formicidae)	F	—	X	—	Unk	—	—
—	(Dermaptera: Forficulidae)	F	—	X	—	Unk	—	—
—	(Psocoptera)	F	—	X	—	No	—	—

[1]Type of corn: S (sweet corn, TREC, Homestead) or F (field corn, Super 6 Farms, Kendall).
[2]Spr. (Spring), Smr. (Summer), or Fall.
[3]Predator (pred.) status: Yes (feeds on), No (does not feed on), or Unk (unknown if it feeds on) *Euxesta* spp.
[4]Predator stage: N (nymph), L (larva), or A (adult).
[5]Stage of ulidiid (ulid.) prey: E (egg), L (larva), or A (adult).

and *A. insignitus* larvae (Figs. 1a, b, c and 2). There were significant differences among arthropod taxa in numbers found in the R2 stage with the mean number of larval *L. insularis* and *C. lugubris* the highest (F = 10.19; df = 5, 39; P < 0.0005). During R3, arthropods included *O. insidiosus*, unidentified mites, and adults of *L. insularis* and *C. lugubris* (Figs. 1a, b and 2) with the latter group significantly more abundant than the other taxa (F = 17.49; df = 5, 39; P < 0.0001). The mean number of ulidiid eggs was significantly greater than larvae during R1 (t = 10.89; df = 1,39; P < 0.002), but larvae significantly outnumbered eggs during R2 (t = 61.69; df = 1, 39; P < 0.001) and R3 (t = 48.2; df = 1, 39; P < 0.0001) (Fig. 3a).

Summer 2010. Significant differences occurred in numbers of arthropods among taxa found in corn ears during the summer R1 (F = 21.67; df = 5, 39; P < 0.0001) (Fig. 2). The mean number of *O. insidiosus* was significantly greater than the other groups, which included *Thrips* sp., unidentified mites, and adults of *L. insularis* and *C. lugubris*. All four of these groups were also found during R2 and R3 stages along with larvae of *L. insularis, C. lugubris,* and *A. insignitus* (Figs. 1a, b, c and 2). A muscoid fly species and larvae of *C. carnea* were also found at the study sites (Table 1, Fig. 1d). At the Kendall site in field corn, unidentified species of an ant, an earwig, and a booklouse were also found (Table 1). There were significant differences in numbers of arthropods found in summer R2 (F = 61.13; df = 5, 39; P < 0.0001) with mean numbers of larval *L. insularis, C. lugubris,* and *A. insignitus* significantly greater than *Thrips* sp. or mites (Figs. 1c and 2). Significant differences also occurred in numbers of arthropods in summer R3 (F = 69.11; df = 5, 39; P < 0.0001) with mean numbers of larval and adult *L. insularis* and *C. lugubris* and larvae of *A. insignitus* significantly greater than *O. insidiosus, Thrips* sp., or mites (Figs. 1a, b, c, and 2). *Anotylus insignitus* larvae were found only during the R2 stages of spring and summer and the summer R3 stage; *C. carnea* larvae were found only during the summer (Table 1; Figs. 1c and d, 2). The other summer arthropods included unidentified species of a muscoid fly, an ant, an earwig, and a booklouse (Table 1). As in the spring, mean numbers of ulidiid eggs were significantly greater than numbers of larvae in the R1 stage (t = 53.17; df = 1, 39; P < 0.0015), but mean numbers of larvae were significantly greater than numbers of eggs in the R2 and R3 stages (t = 69.66; df = 1, 39; P < 0.0001, and t = 72.9, df = 1, P < 0.002, respectively; Fig. 3b).

Fall 2010. In the R1 stage, there were significant differences in numbers of arthropod taxa found on corn ears (F = 20.29; df = 5, 39; P < 0.0001). The mean number of *O. insidiosus* was significantly greater than *Thrips* sp., the only other arthropod taxon found other than ulidiids (Figs. 1a, b and 2). In the R2 stage, there were also significant differences among arthropod taxa (F = 23.37; df = 5, 39; P < 0.003). Although mean numbers of *O. insidiosus* were numerically the greatest, they were not statistically higher than other arthropods present. The other taxa found in R2 were *L. insularis* and *C. lugubris* adults, *Thrips* sp., and mites (Fig. 2). In R3, there were also significant differences among arthropod taxa (F = 48.2; df = 5, 39; P < 0.005) with

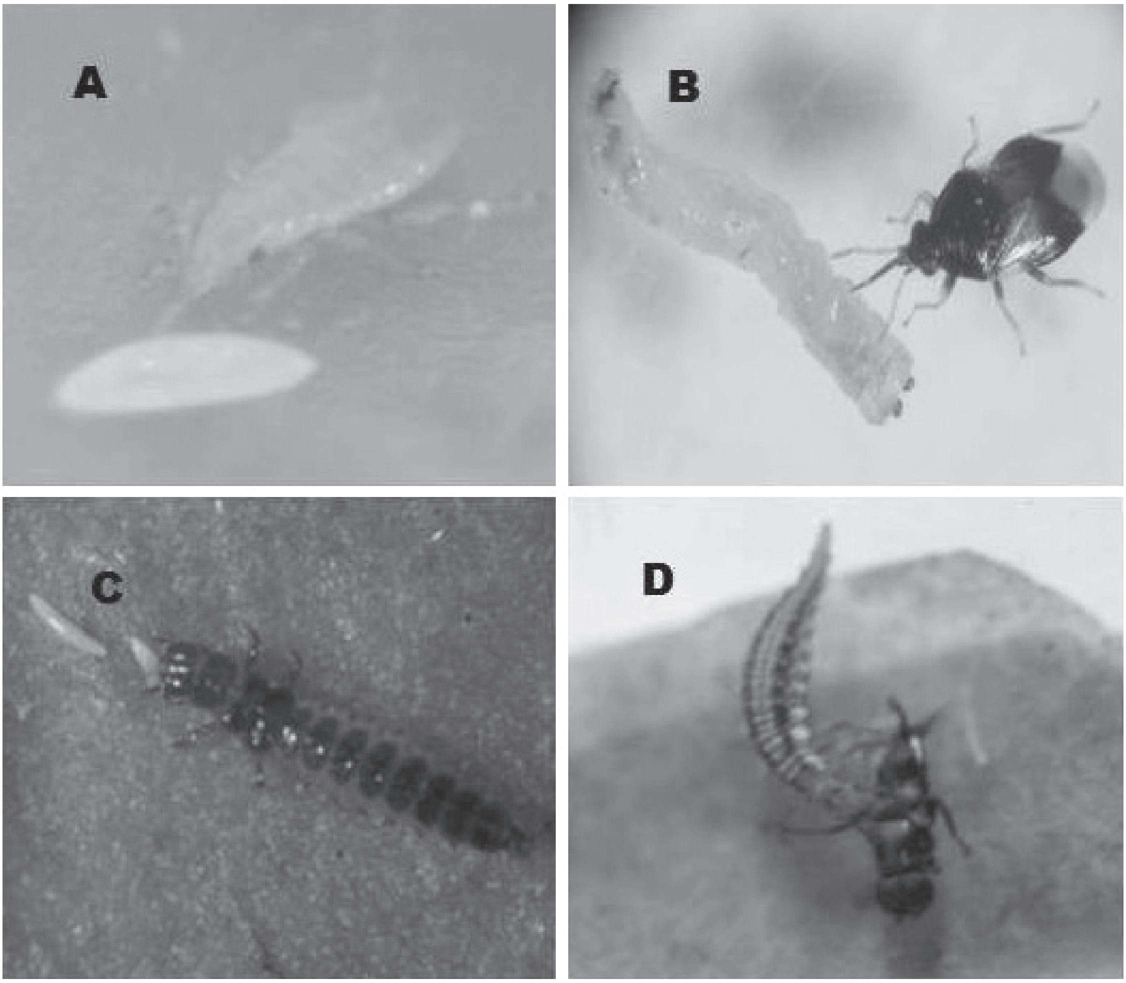

Fig. 1. Predators of *Euxesta* spp. (A) First instar nymph of *Orius insidiosus* feeding on a *Euxesta* sp. egg. (B) Adult of *O. insidiosus* feeding on a third instar larva of *E. stigmatias*. (C) *Anotylus insignitus* larva feeding on *Euxesta* sp. eggs. (D) Larva of *Chrysoperla carnea* feeding on an adult *Euxesta* sp. fly.

mean numbers of adult *L. insularis* and *C. lugubris* significantly greater than *O. insidiosus* or *Thrips* sp., the only other non-ulidiids found (Figs. 1a, b and 2). In R1, the mean number of ulidiid eggs was significantly higher than larvae ($t = 10.98$; df = 1, 39; $P < 0.0015$), while in R3, ulidiid larvae significantly outnumbered eggs ($t = 53.11$; df = 1, 39; $P < 0.0002$). However in R2, there were no significant differences between ulidiid eggs and larvae (Fig. 3c). Arthropods collected in the fall also included unidentified species of a roach and a muscoid fly and *Z. longipes* (Table 1).

Laboratory Evaluation of Arthropod Species for Predatory Status

In the laboratory, nymphs and adults of *O. insidiosus* fed on eggs and larvae of *E. stigmatias, E. eluta, and E. annonae* (Table 1, Figs. 1a and b). *Anotylus insignitus* larvae also consumed eggs and larvae of *Euxesta* spp. (Table 1, Fig. 1c), and larvae of *C. carnea* fed on larvae and adults of *Euxesta* spp. (Table 1, Fig. 1d). Hence, at least 3 predatory species in the present study consumed ulidiid flies (Table 1, Fig. 1).

Discussion

In the spring, the mean number of ulidiid eggs was numerically larger in R1 than in R2 or R3 reproductive stages of corn ears, but in the summer and fall, eggs numbers appeared to increase from R1 to R3, although this was not verified statistically. This may have been caused by larger populations of adult ulidiids and overlapping generations once populations were established.

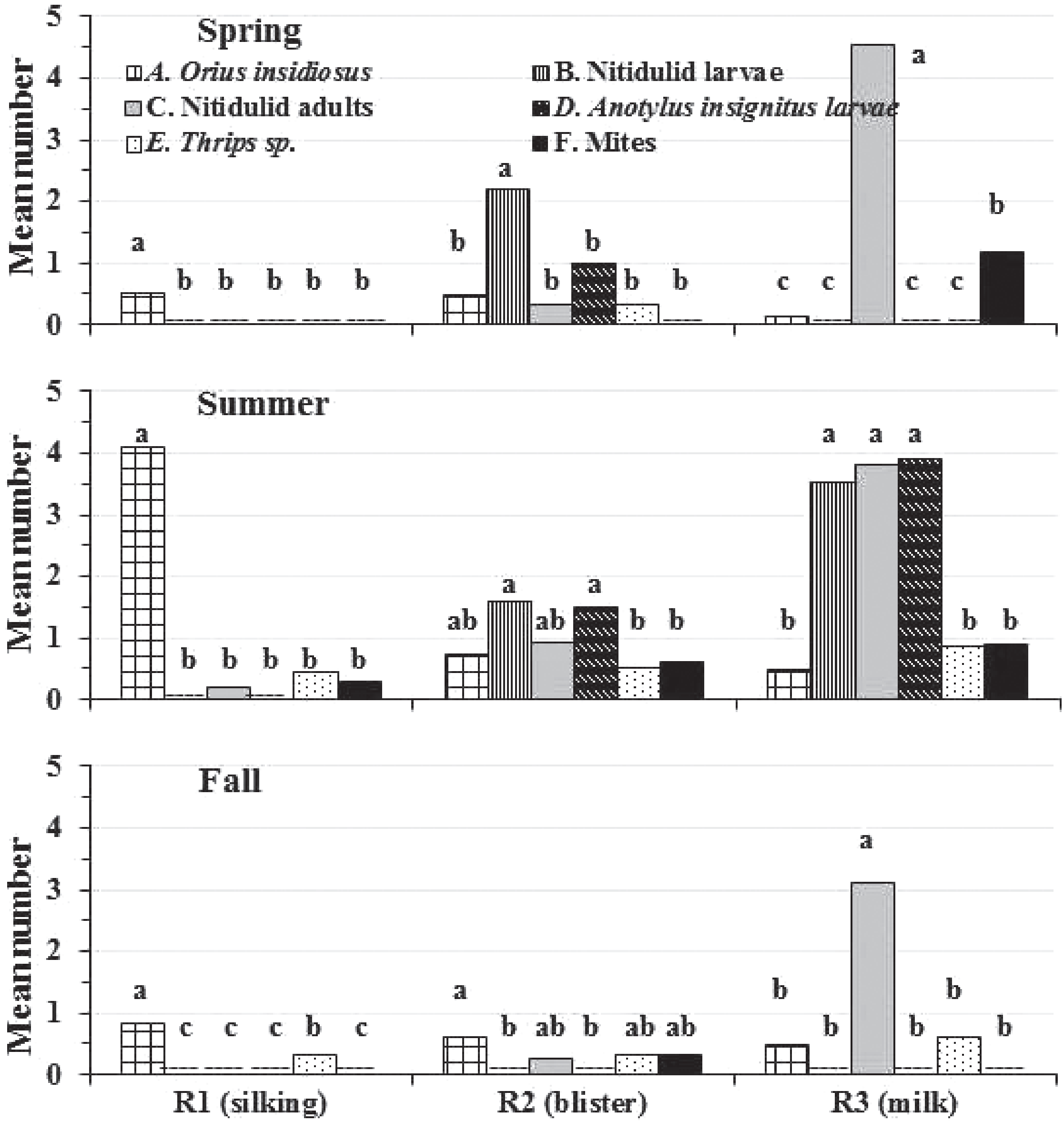

Fig. 2. Mean numbers of arthropods other than ulidiids found in corn ears at different reproductive stages of corn in 2010. A) *Orius insidiosus.* B) Nitidulid larvae: sum of *Lobiopa insularis* and *Carpophilus lugubris*. C) Nitidulid adults: sum of *L. insularis* and *C. lugubris*. D) *Anotylus insignitus* larvae. E) *Thrips* sp. F) Mites (unidentified). Different letters within each corn stage and season denote significant differences in mean numbers among arthropod groups based on ANOVAs followed by Tukey HSD tests ($\alpha = 0.05$).

During the R1 stage in all 3 seasons, mean numbers of ulidiid eggs were greater than larvae, but during R2 and R3, the trend was reversed with mean numbers of larvae greater than eggs except for the fall R2, when the numbers of eggs and larvae were similar. Hence, oviposition appeared to be more prominent in the R1 than the R2 or R3 stages. This is supported by the preference of ulidiids for fresh corn silk for oviposition (Barber 1936; Seal & Jansson 1993; Nuessly & Capinera 2010). Ulidiid flies may have lower populations as corn matures to the R3 stage because the silk becomes dry and brown (Knutson & Gilstrap 1989), and oviposition on other plant parts such as corn leaves can increase egg mortality (Nuessly & Capinera 2010).

Arthropods other than ulidiids found in sweet corn ears included nymphs and adults of *O. in-*

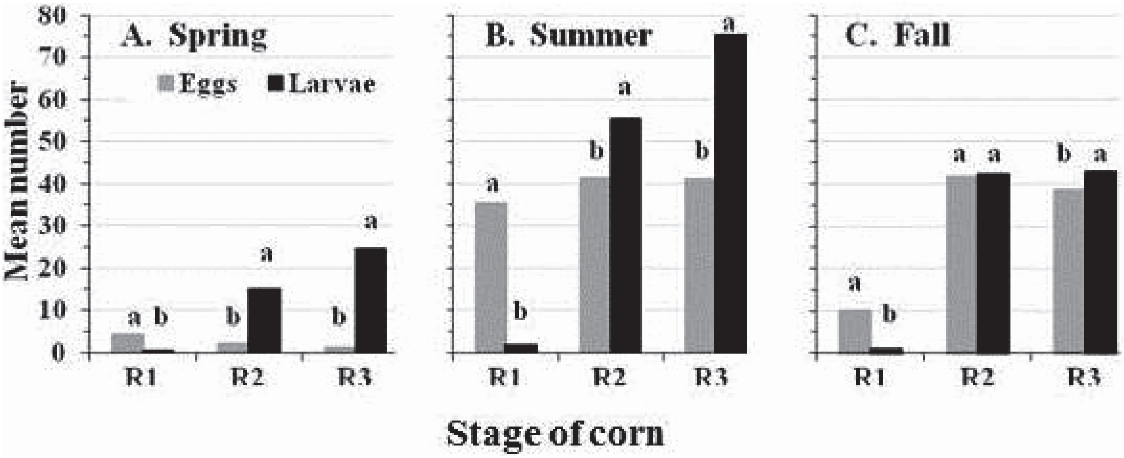

Fig. 3. Abundances of ulidiid eggs and larvae (2010). Different letters indicate significant differences in mean numbers of eggs or larvae at each corn stage and season based on a *T*-test.

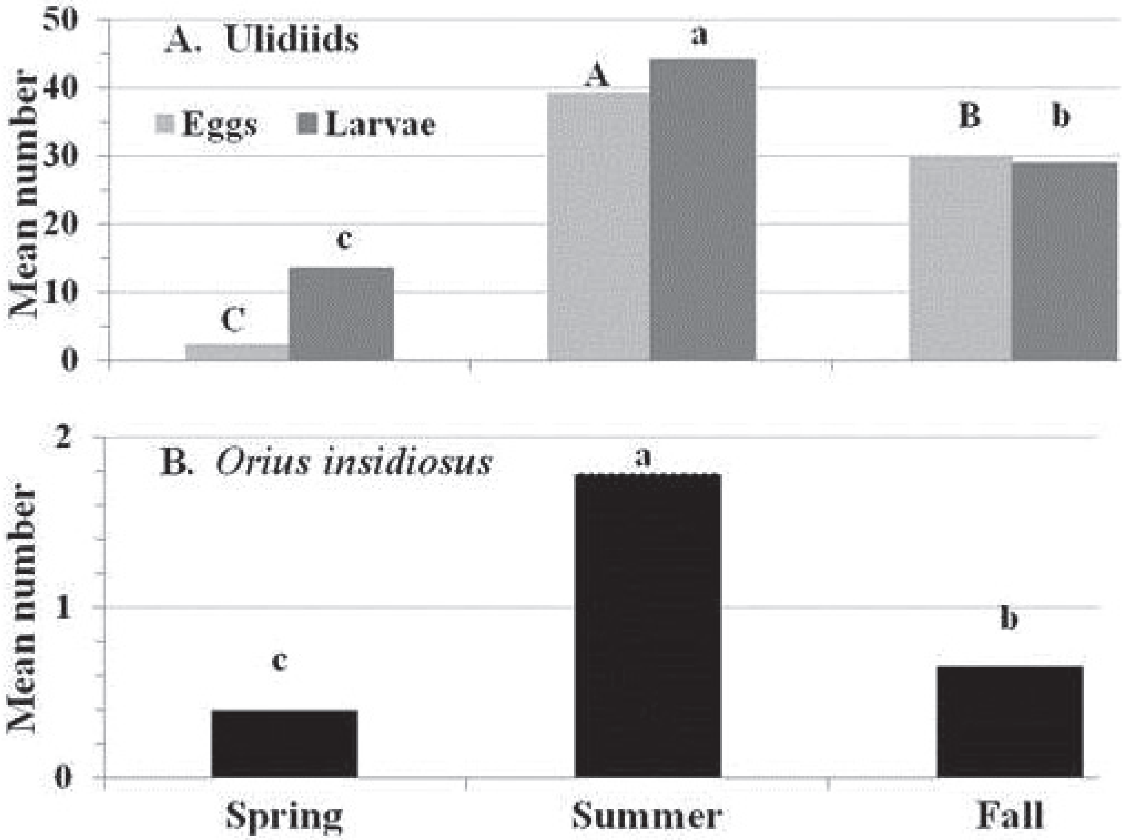

Fig. 4. Cumulative seasonal abundance of *Euxesta* spp. eggs, larvae, and *Orius insidiosus* collected from corn plants in 2010. Different lower case letters (a, b, and c) indicate significant differences in mean numbers of ulidiid larvae or *O. insidiosus,* and different upper case letters (A, B and C) indicate significant differences in mean numbers of ulidiid eggs based on ANOVAs followed by Tukey HSD tests ($\alpha = 0.05$).

sidiosus, larvae and adults of *L. insularis* and *C. lugubris,* larvae of *A. insignitus* and *C. carnea*, *Thrips* sp., mites, muscoid flies, roaches*,* and nymphs and adults of *Z. longipes.* In field corn, unidentified species of an ant, an earwig, and a booklouse were also found. Predatory species included *O. insidiosus*, *A. insignitus*, *C. carnea*, and *Z. longipes*. *Chrysoperla carnea* was found only in the summer, and *Z. longipes* only in the fall. Kalsi (2011) studied *Z. longipes* in the same fields and same year as in the present study (2010) and found that although not tested statistically, *Z. longipes* generally increased considerably in numbers from the R1 to R3 stages. Not only did nymphs and male and female adults of *Z. longipes* feed on ulidiids, but within-plant distributions of ulidiids and *Z. longipes* were generally similar (Kalsi 2011). Distribution patterns were consistently aggregated between ulidiids and *Z. longipes* in the R2 and R3, but not the R1 stages (Kalsi 2011). Nymphs and adults of *Z. longipes* each fed on larvae and adults of *Euxesta* spp. (Kalsi 2011). Based on the combined findings of the present study and the study of *Z. longipes* in (Kalsi 2011), at least 4 predatory species preyed on ulidiid flies (Table 1, Fig. 1).

Orius insidiosus populations consist mainly of fertilized females during the spring after most males have died the preceding winter from cold (Saulich & Musolin 2009). Once the growing season begins, Eckert et al. (2006) reported that *Orius* spp. were the most abundant predators on corn ears. Similarly, in the present study, populations of *O. insidiosus* were larger in the summer than in the spring or fall as were populations of ulidiid eggs and larvae. Unlike in R2 or R3, *O. insidiosus* was the most abundant arthropod species other than ulidiids in the R1 of each season. For this earliest corn flowering stage, the results appear consistent with other surveys of cornfield arthropods, such as Knutson & Gilstrap (1989), who found *O. insidiosus* was the most abundant arthropod predator on corn accounting for 80% of all predators. Knutson & Gilstrap (1989) found that mean numbers of *O. insidiosus* were greatest during anthesis but declined as corn silk became dried and brown during milk stage (R3). This may have resulted from a lack of fresh corn silk causing breeding conditions to be unfavorable for the predators in R2 and R3 (Barber 1936). Flowering corn plants have been reported to harbor abundant prey during silking and tasseling, thus strongly attracting *O. insidiosus* (Isenhour & Marston 1981; Elkassabany et al. 1996; Saulich & Musolin 2009). The relatively large populations of *O. insidiosus* during R1 of each season suggested that they were among the first predators to colonize corn silk. *Orius insidiosus* may have reproduced soon after colonizing corn fields, which is supported by Ritchie & Hanway (1984). Knutson & Gilstrap (1989) and Barber (1936) also observed that *O. insidiosus* was the first predator to colonize corn ears with the nymphs abundant during silking stage (R1). *Orius insidiosus* would first appear between leaves and stalks of corn plants and later become more common on young tassels (male inflorescences) (Barber 1936). Shortly after first silk, *O. insidiosus* would travel to silk strands, which provided a substrate for oviposition (Barber 1936). *Orius* spp. are common generalist predators and biological control agents in agricultural systems (Isenhour & Marston 1981; Isenhour & Yeargan 1981; Isenhour et al. 1990; Reid 1991; Bush et al. 1993). Báez et al. (2010) found *Orius* spp. in Sinaloa, Mexico feeding on different stages of *E. stigmatias*. *Orius insidiosus* adults are commercially available in Europe and the U.S.A., therefore, further research is needed to understand relationships between these predators and their prey such as ulidiid eggs and larvae.

In Florida, farmers treat sweet corn fields with broad-spectrum, synthetic insecticides more than once a week. These include pyrethroids, organophosphates, and carbamates, which threaten non-target arthropods and natural enemies and may reduce *O. insidiosus* populations considerably (Kazmer & Brewer 2009). Therefore, assessing the compatibilities of the pesticides to the survival of natural enemies such as *O. insidiosus* is also warranted.

Another predatory species found as larvae in corn ears was *A. insignitus*. Along with *C. lugubris* and *L. insularis* larvae and/or adults, *A. insignitus* was statistically one of the most common taxa other than ulidiids during the spring R2 and the summer R2 and R3 stages with most occurring in the summer R3 stage. Although not tested statistically, *A. insignitus* larvae seemed to be more common with more persistent populations in the summer than in the spring, and most were found in dry corn silk. According to Frank & Thomas (1981), *A. insignitus* is primarily found in bovine dung, but has also been found under rotting breadfruit in Costa Rica. It is believed to be a non-predatory dung feeder, though many dung-inhabiting staphylinid species do consume fly larvae, but they are generally in a different subfamily (Staphylinae) (Frank & Thomas 1981; J. H. Frank, pers. comm. 2013). Hence, the present study represents the first known report of *A. insignitus* consuming fly larvae. Perhaps *A. insignitus* is a facultative predator that can survive in cow dung when corn silk flies or other prey are not available. Cow dung may have been occasionally used to fertilize corn, thus encouraging the transition of *A. insignitus* to corn silk fly larvae when available. Everly (1938) found 6 species of staphylinids in surveys of Ohio corn fields including *Leptolinus rubripennis* Lec., *Atheta* sp., *Barydoma* sp., *Mycetoporus* sp., *Philonthus* sp., and *Coproporus* sp., which were collected from corn plants or on nearby ground. Adults of the staphylinid *Stenus flavicornis* Erichson fed on egg masses of the European corn borer *Ostrinia nubilalis* Hübner (Lepidoptera: Crambidae) in corn fields (Andow 1990). Thus, several staphylinid species are predaceous and potential biocontrol agents of agricultural pests (Cividanes et al. 2009). However, staphylinids have been used infrequently in IPM programs because of the lack of knowledge on their feeding preferences, ecology, and taxonomy (Balog & Marko 2008; Balog et al. 2008 a, b, c, 2010).

Results of the present study could help in finding spatial distributions of ulidiid eggs, larvae, and predators in addition to functional responses of predators to eggs, larvae, and adult ulidiids. This would permit the further identification and evaluation of potential for many predatory arthropods to biologically control all ulidiid life stages.

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