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Distributional patterns of fall armyworm parasitoids in a corn field and a pasture field in Florida

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HIGHLIGHTS

- The parasitoid endemic community does not discriminate between two strains of the host fall armyworm in corn crops.
- Differences in the composition and seasonal abundances of the parasitoids occurred in different habitats within the crop.
- Parasitoids distributions were affected by habitat complexity found in crop field edges adjacent to wood areas.
- Parasitoid distribution may exhibit behavior to minimize direct competition and avoid competitive exclusion.

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ABSTRACT

An assessment of parasitoids and their selective patterns among *Spodoptera frugiperda* corn and rice host strains was performed from August 2008 to August 2010 in a corn crop and a grass pasture in northern Florida under different seasonal conditions (spring and fall). Sentinel larvae from our laboratory were placed in both habitats. Results obtained in the corn crop differed from those in the pasture due to poor recovery rate of larvae in the pasture habitat. In corn fields, we found that the parasitoid community was composed of eight species of Hymenoptera and one Diptera species, which represented four families and two guilds. The more abundant parasitoid species in the corn field included *Aleiodes laphygmae*, *Meteorus autographae*, *Cotesia* sp., *Euplectrus platyhypenae* and *Ophion flavidus* while the Diptera species constituted the most abundant parasitoid in pastures. Among the parasitoid species collected in pastures were three Diptera species and four hymenoptera species.

Parasitoid species did not discriminate among fall armyworm host strains, however they varied among the different habitats in the corn field. The ectoparasitoid *Euplectrus platyhypenae* and an unknown ichneumonid species were found primarily at the edges of the crop (in areas adjacent to the woods); while the endoparasitoids *Cotesia* sp. and *Meteorus* sp. were recovered more often in the main corn crop. *Meteorus* and *Ophion* were more abundant in the spring while the unknown ichneumonid was more abundant in the fall. Predator species differ among corn and pasture, which might contribute to the dynamics of parasitoid species in these fields.

1. Introduction

Enhancing the natural enemies of insect pests has been promoted for many years as a valuable method for reducing the damage to agricultural crops caused by these pests (De Bach and Rosen, 1991; Elzen and King, 1999; Parella et al., 1992; Ridgway and Vinson, 1977; Hajek, 2004). It also provides a green alternative to the heavy use of insecticides in monocultures (Hladik et al., 2014). However, most of the success obtained by augmentative biological control programs has occurred in orchards and greenhouses, where climatic extremes are moderated or controlled (van Lenteren and Woets, 1988 and literature therein). Various abiotic factors may influence the population dynamics of parasitoid and predators, such as seasonal changes, temperature, humidity, agricultural cultivation, while biotic factors might include host stage of development, and competition. A thorough knowledge of

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all of these factors may help avoid the need for excessive human efforts and control the costs of maintaining a program of augmentative biological control.

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) inflicts damage on various agricultural crops, especially those of the family Poaceae [including corn (*Zea mays* L.), sorghum (*Sorghum* spp.), rice (*Oryza sativa* L.) and various pastures and grasses)]. This moth is composed of two host strains, individuals of the corn strain (CS) are found in annual tall grasses such as corn and sorghum while the rice strain (RS) are mostly found in short pasture grasses such as *Cynodon* spp. (Pashley, 1986, 1988; Pashley et al., 1985; Pashley and Martin, 1987; Lu et al., 1992, 1994; Lu and Adang, 1996; Nagoshi and Meagher, 2003). The use of molecular markers to distinguish different fall armyworm strains is an important tool for their identification, which is key to understanding the distributional patterns of fall armyworm strains in different habitats. McMichael and Prowell (1999) showed that there is a recurrent bias with respect to host strains' presence in corn fields. Despite the adaptation to rice and Bermuda grass [*Cynodon dactylon* (L.) Pers.] 18% of the rice strain larvae were collected in corn plants, suggesting that rice strain is less specific in their host plants preference than the corn strain larvae with only 2% of the individuals collected in pastures. Also, fall armyworm host strains differ in their physiology, chemistry and behavior. All these differences might complicate the management of the pest. For almost a century researchers have conducted fall armyworm parasitoids surveys and have provided important information regarding parasitoids in *corn* fields (Luginbill, 1928; Vickery, 1929; Pair et al., 1986; Molina-Ochoa et al., 2001, 2004), but very few in grasses (Allen, 1921; Dew, 1913; Reed, 1980; Enkerlin, 1975; Ashley et al., 1983; Braman et al., 2004) in the USA and Latin America. Most of these studies were generated by collecting larvae under field conditions and details for parasitoid preference of fall armyworm host strain-specificity have not been addressed before. Furthermore, the spatial patterns over which fall armyworm parasitoids' searches take place in the different habitats where they are found during the growing season have never been analyzed. This knowledge can be important for the implementation of seasonal releases of parasitoids in crops in different ecological systems.

In the last decade, the use of Geographic Information Systems (GIS) and Remote Sensing – the mapping of features using imagery acquired either from an aircraft or a satellite – have become important tools for decision-making and the applied management of natural resources. These tools provide important information to help identify parameters of seasonal population dynamics of crop insect pests and the predators/parasitoids that feed on them, which are critical for developing an effective insect pest management program. We report the results of a two year study that employed GIS methods to examine the interaction between the fall armyworm host strains and its parasitoids and predators in a corn field and a pasture associated with its ecological habitat throughout the season.

2. Materials and methods

2.1. Study sites

2.1.1. Corn field

The experiment at the corn field was performed at the Dairy Research Unit (DRU), University of Florida, Hague, Alachua Co, Florida. The corn field was approximately 17.18 ha with an elevation up to 51 m. There were two habitat structures within the corn field. The main crop included areas completely surrounded by corn plants. The field edge included parts of the corn crop that were contiguous to a wooded border (ten rows of corn plants). The main corn crop and the field edge were divided into four plots each, for the split-plot analysis explained in the experimental section.

There were two corn growing seasons at the DRU, the beginning of each season depends on environmental conditions, such as freezing conditions or precipitation. In spring 2009, corn planting started in April, and in 2010 it started in May. The corn field was harvested in July. The second corn growing season began at the end of July and harvesting occurred at the end of October. For the analysis of the data we referred to the first growing season as the spring and the second growing season as the fall.

2.1.2. Pasture field

The experiment in the pasture field was conducted at Chiefland, Levy Co., Florida with approximately 9 ha. The field contained 'Tifton 85', which is a hybrid between the Bermuda grass 'Tifton 292' and the stargrass (*Cynodon nlemfuensis* var. *nlemfuensis*) 'Tifton 68' (Burton, 2001). At this site the habitat structure was similar to the corn field, the field was also contiguous to a wooded border and harvesting for forage occurred in the same months as in the corn field.

The experiment was performed from August to October 2008, June to October 2009 and May 2010.

2.2. Study organisms

The fall armyworm colonies used in this experiment were identified as corn and rice strain by molecular markers (Nagoshi et al., 2007; Nagoshi, 2010). The adults of the two host strains were reared separately in cylindrical screen cages [30 (h) × 20 (d)] with screen holes of 4 mm. The top of the cylinder was covered with a paper towel as an oviposition substrate, and the paper towel was held in place with a rubber band. The bottom of the cylinder was placed in a metal pie pan containing vermiculate.

Caterpillars were reared on pinto bean-based artificial diet (Guy et al., 1985) under laboratory conditions at 26 °C, 75% humidity and a 14:10 L:D photoperiod.

2.2.1. Larvae sentinel traps

A total of sixteen traps that consisted of PVC cylinders with dimensions 24 × 15 × 2 cm (Braman et al., 2004) were placed at different points within the field. Eight of these traps were placed in each habitat at random, (either the main crop or field edge). The coordinates of each trap location was determined using a Global Positioning System unit (Garmin eTrex HC series, Garmin International, Inc. Olathe, KS).

Each trap contained a pot (8.30 × 9.30 cm) with either five corn plants (15–17 cm height) used in the corn field or 'Florona' stargrass used in the pasture. The topsoil within the pot was covered with moist vermiculite to keep the plants alive during the experiment. Potted plants were buried to soil level and were surrounded by the traps, which were also buried 3 cm deep in a vertical orientation.

Six caterpillars were placed in each trap, three first or second instar and three third or fourth instar. At each coordinate point we set two traps, one containing corn strain larvae, and the other containing rice strain larvae. The traps were placed 2 m apart. After six days of exposure, the pots and soil within the traps (4 cm depth) were brought back to the lab in Tupperware containers with dimensions 30 × 30 × 10 cm for further treatment. Cohorts of 96 caterpillars at two different stages of development (48 per instar) were used as sentinel larvae twice per month. Fall armyworm larvae, pupae and other insects were collected by sieving soil samples through a set of stainless steel mesh ranging in size from 12.5 to 1.00 mm.

2.3. Parasitoid rearing

Larvae and pupae recovered at the beginning of the study (fall 2008) were reared on an artificial diet in individual 1 oz SOLO cups at 26 °C, 75% humidity and 14:10 photoperiod. The individuals were checked daily for stage of development, parasitoid or moth emergence, and disease status. We experienced high mortality of parasitoid larvae, when the hosts were fed an artificial diet. Therefore, the following season (spring 2009 and 2010) we fed the hosts their natural host plants.

Parasitoids that emerged were preserved in 85% ethanol and sent for identification to the Systematic Laboratory at the Smithsonian Institution in Washington, DC. Voucher specimens of all the species are held in our collections at the USDA, ARS, CMAVE Behavior and Biocontrol Unit, Gainesville, FL. Some of the parasitoids were kept alive and we established parasitoid colonies for future experiments.

2.4. Experimental analysis

The program, ArcGIS V. 5, was used to determine the spatial distribution of parasitoids. The percentage of larval recovery and the percentage of parasitism of initial numbers of larvae and of recovered larvae were transformed, before statistical analysis using arcsine [square root (X)]. The transformed data was analyzed using a split-plot ANOVA design, with habitat (main crop vs. field edge) as the main plot, and host strain (corn vs. rice strain) as secondary plot, and seasons as factors. We used the Tukey multiple comparison test for interaction contrast. A contingency table *chi-square* test was performed to determine effects of season and habitat preference on parasitoid abundance. The program SAS (SAS Institute, 2002–2010) was used to perform the statistical analysis.

3. Results

3.1. Corn field

3.1.1. Parasitoid species

Eight parasitoid species were collected at Hague, FL which corresponds to two parasitoid guilds attacking *S. frugiperda* at different developmental stages (Table 1). The larval guild was represented by the braconids *Cotesia* sp. [probably *marginiventris* (Cresson) however the genus is under review, R. Kula, personal communication], *Aleiodes laphygmae* (Viereck) and *Meteorus autographae* Muesebeck. The family Ichneumonidae was represented by *Ophion flavidus* Brullé and a second species that we were unable to identify because it never reached adulthood (Unknown). The family Eulophidae was represented by the ectoparasitoids *Euplectrus platyhypenae* Howard and *Horismenus* sp. nr. *ignotus* Burks. The larval-pupae guild was represented by the tachinid *Lespesia archippivora* Riley.

3.1.2. Parasitoid recovery rate

No significant variations were observed for larval recovery among host strains ($F_{1,120} = 0.04$, $p > 0.05$), or different habitats, ($F_{1,6.75} = 0.36$, $p > 0.05$), or for parasitoid recovery among host strain ($F_{1,120} = 0.07$, $p > 0.05$), or different habitats ($F_{1,7.29} = 0.05$, $p > 0.05$) (Table 2). However, larval recovery varied among different collecting periods ($F_{3,\ 103} = 2.8$, $p < 0.05$). Pairwise comparisons showed that larval recovery was significantly greater in the fall 2008 and the spring 2009 compared to the spring 2010 (Fig. 1).

3.1.3. Parasitoid dynamics

None of the most abundant parasitoids species discriminated among fall armyworm host strains ($X^2 = 7.69$, df = 7, $p > 0.05$). However, parasitoid abundance varied by seasons ($X^2 = 47.6$, df = 7, $p < 0.001$). *Aleiodes*, *Euplectrus* and *Cotesia* were all collected in both corn planting seasons (Table 3, for *Euplectrus* see Fig. 2 and for *Cotesia* Fig. 3). However, *Meteorus*, ($X^2 = 17.23$, df = 1, $p < 0.001$)

Table 1
Parasitoid species collected in the corn and pasture fields, during 2008–2010.

Parasitoid species	Guilds	Instar	Behavior & traits
Corn field			
Braconidae			
Cotesia sp.	Larval	1st, 2nd	Endoparasitoid, solitary
Aleiodes laphygmae (Viereck)	Larval	1st, 2nd	Endoparasitoid, solitary
Meteorus autographae Muesebeck	Larval	≠ Instars	Endoparasitoid, solitary
Ichneumonidae			
Ophion flavidus Brullé	Larval	4rd, 5th	Endoparasitoid, solitary
Unknown	Larval	3rd, 5th	Endoparasitoid, solitary
Eulophidae			
Euplectrus platyhypenae Howard	Larval	3rd, 4th	Ectoparasitoid, gregarious
Horismenus sp. nr. *ignotus* Burks	Larval	3rd, 4th	Ectoparasitoid, gregarious
Tachinidae			
Lespesia archippivora Riley	Larval-Pupal		Endoparasitoid, gregarious
Pasture field			
Braconidae			
Aleiodes laphygmae (Viereck)	Larval	1st, 2nd	Endoparasitoid, solitary
Aleiodes sp.*	Larval	1st, 2nd	Endoparasitoid, solitary
Ichneumonidae			
Ophion flavidus Brullé	Larval	4rd, 5th	Endoparasitoid, solitary
Ophion sp.	Larval	4rd, 5th	Endoparasitoid, solitary
Tachinidae			
Lespesia archippivora Riley	Larval-Pupal		Endoparasitoid, gregarious
Lespesia aletiae Riley	Larval-Pupal		Endoparasitoid, gregarious
Eucelatoria rubentis Coquillett	Larval-Pupal		Endoparasitoid, gregarious

* The adults were collected in the field and parasitized FAW under laboratory conditions.

Table 2
Fall armyworm recovered and parasitized in the corn field at Hague, Alachua Co., FL during the fall and spring corn growing season 2008–2010.

Season	Field edge						Main crop					
	Tested larvae		Recovered		Parasitized		Recovered		Parasitized		Total Recov.	Total Paras.
	CS	RS	CS	RS	CS	RS	CS	RS	CS	RS		
Spring	432	432	46	51	16	18	55	59	31	20	211	85
Fall	277	288	33	45	15	22	36	35	6	12	149	55

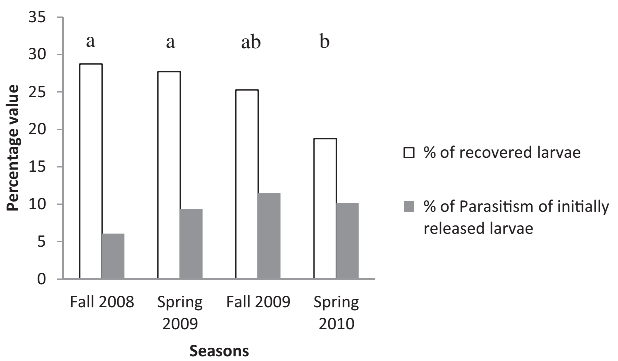

Fig. 1. Percentage of larvae recovered and parasitism of initially released larvae during fall and spring 2008–2010.

and *Ophion* ($X^2 = 19.41$, df = 1, $p < 0.001$) were significantly more abundant in the spring, in May (Table 3, for *Meteorus* see Fig. 4), and the Unknown parasitoid was more abundant in the fall ($X^2 = 5.82$, df = 1, $p < 0.02$) (Table 3).

Also, parasitoid abundance varied by habitat ($X^2 = 29.9$, df = 7, $p < 0.001$). Parasitism by *E. platyhypenae* occurred more frequently near the field edge ($X^2 = 6.34$, df = 1, $p < 0.01$) (Table 4 and Fig. 2). This species had a fast reproductive rate producing 20–60 offspring per parasitized larvae with a developmental time of only two weeks. Also, at the field edge, an unidentified Ichneumonid ($X^2 = 5.82$, df = 1, $p < 0.02$) was abundant. Lastly, the parasitoid wasp *Cotesia* sp. ($X^2 = 7.1$, df = 1, $p = 0.007$), and *Meteorus* ($X^2 = 5.88$, df = 1, $p < 0.02$) were significantly more active in the main crop (Table 4, Figs. 3 and 4 respectively). The ichneumonid *Ophion* sp. and *Aleiodes* were found in both habitats (Table 4).

In May 2010, we observed multiparasitism on two occasions. These involved the ectoparasitoid *Euplectrus* and *Chelonus* (an egg-larval parasitoid). Although the endoparasitoids left their hosts, the larvae were unable to pupate and all died. Also, a case of hyperparasitism occurred where an ichneumonid wasp emerged from the host but was unable to pupate. Host dissection uncovered an encapsulated unknown hyperparasitoid within the larvae.

3.1.4. Climatic conditions at the Dairy Research Unit

The temperature and humidity in which parasitoids and moths were present ranged from 22 to 26 °C and 76% to 80% respectively for the years 2009 and 2010 (Fig. 5).

3.1.5. Predators found in the corn field during the study years

A major predator of fall armyworm larvae was the earwigs *Labidura riparia* and *Doru taeniatum* in September and October 2008 and 2009. Other predator species included various spider species, and Chilopoda all of which were recovered from the PVC traps. However, we also recovered various Coleoptera (Staphylinidae, Elateridae, Scarabaeidae), some of which are known as corn plant pests.

3.2. Pasture field

The recovery rate of sentinel larvae in pastures was poor (Table 5) compared to the rate in corn (Table 2). A possible contributing factor was a lower survival rate due to the large numbers of predators present in the field, often found in our traps, or in the soil sample. The most abundant predators found were fire ants (*Solenopsis invicta*), wasps (*Polistes* sp.), the hemiptera (*Orius* sp.), a diversity of spider species (wolf spiders and jumping spiders), predator mites, chilopoda, and nematodes. Also, vertebrate predators were observed during the two years of study i.e. egrets, and other birds associated with cattle. Despite the poor recovery numbers of both larvae and parasitoids, we did collect some parasitoids that were not found in the corn fields, including the Diptera (*Eucelatoria rubentis* and *Lespesia aletiae*) and *Ophion* sp. and *Aleiodes* sp. (Table 1).

4. Discussion

The results of this study showed that fall armyworm parasitoids did not discriminate between host strains in the corn field. In a previous study (Hay-Roe et al., 2013) we observed that *Euplectrus platyhypenae*, for example, will wait for the rice strain larvae (which has a slower larval developmental time, as compared to the corn strain) to reach the right size, before parasitizing it. Another important result was the observation of different

Table 3
Parasitoid abundance throughout the spring and fall corn growing season 2008–2010 at Alachua, FL. Different letters indicate significant differences.

	Parasitoid species								
	Aleiodes	*Cotesia*	*Euplectrus*	*Meteorus*	*Ophion*	Unknown	*Lespesia*	*Horismenus*	Total
Apr	0	0	0	0	1	2	0	0	3
May	13	16	14	17	11	0	2	1	74
Jun	0	1	7	0	2	0	0	0	10
Spring total	13[a]	17[a]	21[a]	17[a]	14[a]	2[a]	2[a]	1[a]	87
Aug	9	0	2	0	0	5	0	0	16
Sep	3	1	5	0	0	4	0	0	13
Oct	11	7	4	1	0	1	0	0	24
Fall total	23[a]	8[a]	11[a]	1[b]	0[b]	10[b]	0[a]	0[a]	53

Fig. 2. GIS spatial dynamics of *Euplectrus platyhypenae* at Hague, FL. Color dots indicate the location of one or more specimens. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

parasitoids species in corn and pasture fields. It is well known that carnivorous arthropods exploit herbivore-induced plant volatiles (HIPV) to find their host (Turlings et al., 1990, 1993; Vet and Dicke, 1992). Several studies have demonstrated that parasitoids can discriminate between plants infested with different herbivores (for a review see Dicke, 1999). The results of our studies together with the knowledge that grasses from *Cynodon* sp. contain cyanide-releasing compounds—cyanogenic glycosides (Hay-Roe et al., 2011), lead us to believe that HIPV's in corn and pasture field may play a role in the attraction of different parasitoid species. However, more research in relation to the role of HIPV should be done in pasture ecosystems.

Our results also show that habitat structure plays a role in the distributional patterns of certain parasitoids within the corn field environment. Various studies have demonstrated that habitat structure is an important determinant of host-parasitoid dynamics (Roland and Taylor, 1995; Hassell and May, 1988; Kareiva, 1990) especially in agro ecosystems (Marino and Landis, 1996; Menalled et al., 1999). In corn fields parasitoid abundance was correlated with the structure of the habitat at different periods in time. The two eulophid species and the unidentified Ichmeumonid were all collected more frequently at the edge of the corn field near the woodlots, and *Cotesia* and *Meteorus* were more frequently found at the center of the crop. There was a tendency for the parasitoid populations to be more abundant during the spring, during this period competing interactions, such as multi- or hyperparasitism occurred. The chances for a species to survive multiparasitism are rare, because it involves physiological suppression and aggressive encounters, which confer competitive superiority to one species over another (Miller, 1982; Vinson, 1981). So, the general rule for successful coexistence in intraguild interaction is competitive exclusion (Salt, 1961). The ability to disperse within the different habitats and to find other, unoccupied habitats, to avoid competition is a good strategy used by parasitoids that have higher dispersal capabilities. For example, *Cotesia* and *Meteorus* are fast fliers and have a higher dispersal rate within the crop, as compared to *Euplectrus* species, which remains within a narrow home range (Parkman and Shepard, 1982). *Euplectrus* males patrolled for

Fig. 3. GIS spatial dynamics of *Cotesia* sp. at Hague, FL. Color dots indicate the location of one or more specimens. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

female emergence from the pupal stage and mated with their siblings (Hay-Roe, pers. observations). On the other hand, *Ophion* sp. coexisted with other ichneumonids, both within the main crop, as well as at the edge of the crop, due to its preference for later instar fall armyworm larvae.

Complex habitat structure such as the field edge not only provides a broad range of resources to biological control agents, such as protective cover from environmental extremes, (Langellotto and Denno, 2004), wildflowers nectar, grass pollen (Marino and Landis, 1996) which are nutrients used by the genus *Euplectrus* (Hay-Roe, pers. obs.), but it also can serve to reduce encounter rates with conspecifics, thus favoring coexistence.

We noticed that our recovery rates for larval-pupal parasitoids, such as most dipterous parasitoids, were low. In general late instar fall armyworm larvae buried themselves in the ground making them difficult to recover. These results are in agreement with those from Marino and Landis (1996) and Menalled et al. (1999).

Our poor recovery rates in the pasture may indicate strong selective pressures by predators, especially fire ants, wasps and spiders, which are known to be a predator force in pastures (Finke and Denno, 2002). In addition, during the rainy season 90% of the recovered specimens died from pathogens (i.e. viruses, fungi and other pathogens). During our long term study we constantly checked for naturally occurring fall armyworm larvae in the pasture fields, but we did not find any, except during the months of August and September 2008, when we collected a few larvae after Tropical Storm Fay. Another Noctuidae moth (*Mocis* sp.) was abundant in the pasture field and we frequently found this species in September and October in all the years that we sampled in this ecosystem.

Additionally, the poor recovery rates in the pasture may have been affected by the 'Florona' stargrass we were using in this study. We had demonstrated in a previous study (Hay-Roe et al., 2011) that *Cynodon* species have a gradient of toxicity from cyanide

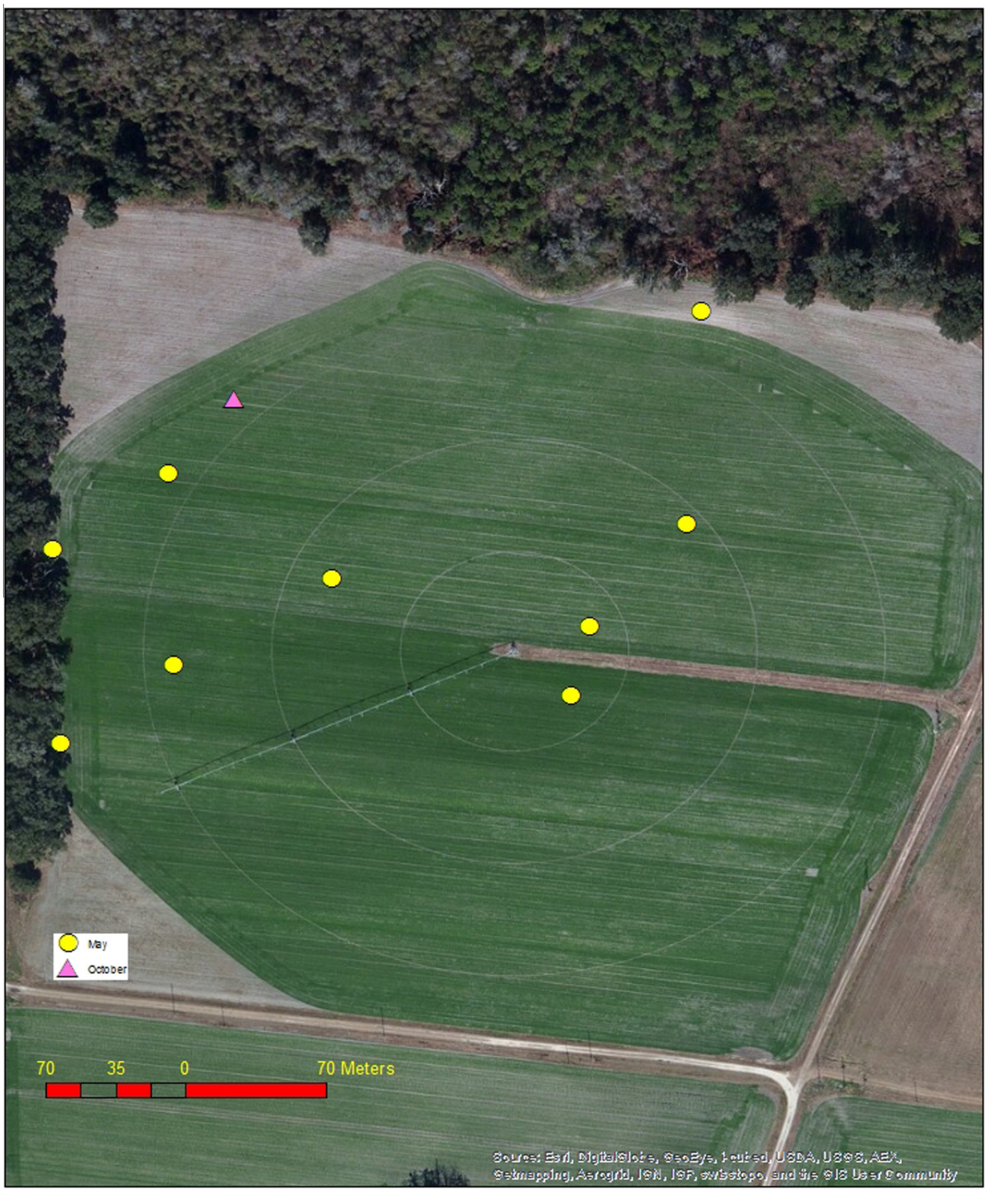

Fig. 4. GIS spatial dynamics of *Meteorus autographae* at Hague, FL. Color dots indicate the location of one or more specimens. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 4
Parasitoid abundance in different habitats of the corn field during the year 2008–2010. Different letters indicate significant differences.

	Parasitoid species							
	Aleiodes	*Cotesia*	*Euplectrus*	*Meteorus*	*Ophion*	Unknown	*Lespesia*	*Horismenus*
Main Crop	16[a]	19[a]	9[a]	14[a]	8[a]	2[a]	0[a]	0[a]
Field edge	20[a]	6[b]	23[b]	4[b]	6[a]	10[b]	2[a]	1[a]
Total	36	25	32	18	14	12	2	1

releasing compounds that could affect fall armyworm larvae differently. Stargrasses have a higher degree of toxicity than 'Tifton 85' followed by Bermuda grass. Braman et al. (2004) postulated that differences in host plant resistance might be related to the occurrence and performance of beneficial insects; these could explain the absence of *Cotesia* sp., *Meteorus* sp. and *Aleiodes laphygmae* from 'Tifton85' fields which are slightly more cyanogenic than Bermuda grass and less toxic than stargrass. As mentioned earlier few studies performed in Bermuda grass listed similar tachinid parasitoids (Ashley et al., 1983; Reed, 1980; Braman et al., 2004) but in contrast to Ashley et al. (1983), we did not collect *Cotesia marginiventris* in 'Tifton 85'.

It was of interest that *E. platyhypenae*, which was abundant in the corn field, was never found in the pasture field. A reference review by Molina-Ochoa et al. (2003) showed absence of this species in Bermuda grass, too. Previous choice and no-choice experiments under laboratory conditions showed that this species will parasitize corn and rice strain larvae fed corn plants producing

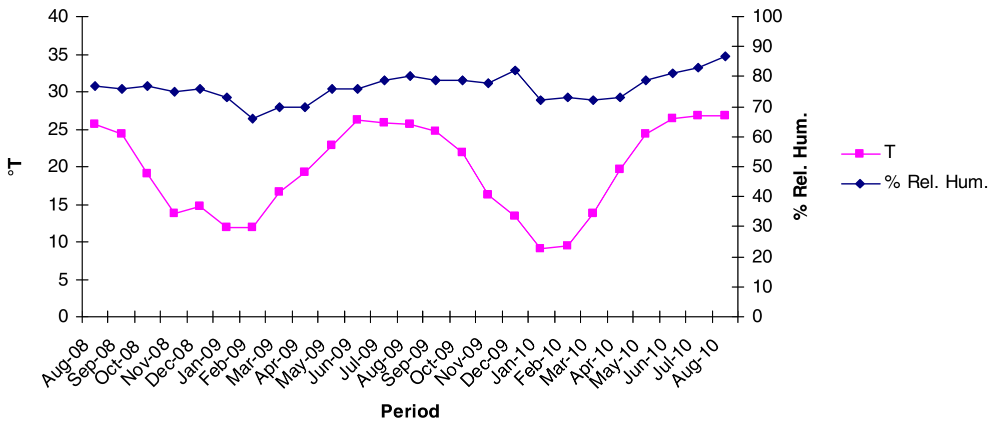

Fig. 5. Meteorological factors showing patterns of humidity and temperature during the first corn crop season (dark squares) and second corn crop season (light squares) where parasitoids and FAW dynamics peaks throughout the years 2008–2010.

Table 5
Fall armyworm recovered and parasitized in the pasture field at Chiefland, Levy Co., FL during the fall and spring 2008 and 2010.

Season	Field edge						Main crop			
	Tested larvae		Recovered		Parasitized		Recovered		Parasitized	
	CS	RS	CS	RS	CS	RS	CS	RS	CS	RS
Spring	144	144	5	6	1	0	4	7	3	0
Fall	432	432	36	44	11	8	38	47	9	9

more and bigger offspring compared with fall armyworm host strain larvae fed stargrass, which causes wasp juvenile mortality (Hay-Roe et al., 2013).

In corn fields we observed the strong seasonality of the predator *Doru* in September-October, wherein eggs and small larvae were predated by this species. *Doru* were found in soil, whorls, and leaves; the environmental conditions were favorable for this species.

In addition, parasitoid dynamics were also linked with certain conditions of temperature and humidity within the range of 22–26 °C and 76–80% humidity.

In summary, parasitoid species are separated by the habitats structure and were more active during certain periods during each season, possibly an indication of adaptations that have result in the reduction of occurrences of competitive interactions. This knowledge provides a basis for future applied research for mass-production and delivery of species for conservation biological control to reduce the use of chemicals in an integrated pest management approach.

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