Predatory Potential of *Geocoris* spp. and *Orius insidiosus* on Fall Armyworm in Resistant and Susceptible Turf

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ABSTRACT Predatory potential and performance of the predaceous heteropterans, *Geocoris punctipes* (Say), *G. uliginosus* (Say) (Geocoridae), and *Orius insidiosus* (Say) (Anthocoridae), were evaluated using fall armyworm, *Spodoptera frugiperda* (J. E. Smith), as prey on different turfgrass taxa (resistant zoysiagrasses, 'Cavalier' and 'Palisades'; moderately resistant Bermuda grass, 'TifSport'; and susceptible seashore paspalum, 'Sea Isle 1′) through laboratory and field studies. When background mortality was taken into account, in small arena trials in the laboratory, the greatest mortality by predators occurred on TifSport. The predator impact on TifSport by *O. insidiosus* was 92.6% above the mortality in the no-predator treatment on that grass. Predator induced mortality was rarely significant on the highly resistant zoysiagrass cultivar Cavalier because mortality, even in the absence of predators, was so high. Survival of larvae on TifSport Bermuda grass was significantly reduced by the addition of just two *O. insidiosus* per pot in laboratory pot trials. An increase in predator density to 4, 6, 8, or 10 further suppressed larval survival. *O. insidiosus* reduced larval survival on Sea Isle 1 at all densities. On Sea Isle 1, a density of two *O. insidiosus* resulted in >50% reduction in live fall armyworms compared with the no predator treatment in laboratory trials. However, addition of *O. insidiosus* did not significantly reduce survival of fall armyworm larvae on this cultivar in the field in the presence of alternative prey and predators. *O. insidiosus* densities of six or higher per 181.4 cm^2 did significantly reduce larval survival on TifSport Bermuda grass by as much as 80% during a 5-d trial period in the field. Predator-induced mortality among all trials was most consistent on a grass of intermediate resistance, TifSport Bermuda grass.

KEY WORDS *Geocoris uliginosus*, *Geocoris punctipes*, *Orius insidiosus*, turfgrass, *Spodoptera frugiperda*

Resistance among warm season grasses to a wide variety of pests has been identified (reviewed by Reinert et al. 2004). Furthermore, the influence of pest-resistant grasses on predators and parasitoids and the role of these grasses in mediating pest response to insecticides have been explored (Braman et al. 2003, 2004a, b). Bigeyed bugs, *Geocoris* spp. (Hemiptera: Geocoridae), are common generalist predators in the southern United States (Buschman et al. 1984, Cave and Gaylor 1988). *Geocoris uliginosus* (Say) frequently inhabits turfgrass systems (Reinert 1978, Braman et al. 2003). Bigeyed bugs feed on a wide range of prey, including insect eggs, spider mites, plant bugs, leafhoppers, aphids, chinch bugs, and various lepidopteran larvae (Dunbar 1971). Their predatory behavior contributes to suppression of various pest species, thereby playing a very important role in pest management in different ecosystems (Crocker and Whitcomb 1980).

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Although insidious flower bugs, *Orius insidiosus* (Say) (Hemiptera: Anthocoridae), are commonly collected from turfgrasses (Braman et al. 2003), no studies have evaluated their role in turfgrass systems. They are widely reported as common, generalist predators in various agro-ecosystems, such as vineyards, sunflower, cotton, soybean, corn, sorghum, alfalfa, crimson clover, apple, tomato, and tobacco (Jubb et al. 1979, McDaniel and Sterling 1979, Lynch and Garner 1980, Pfannenstiel and Yeargan 1998, Al-Deeb et al. 2001).

The fall armyworm, *S. frugiperda* (J. E. Smith), is considered a sporadic pest of turf in the southeastern United States (Sparks 1979). Moths migrate northward annually; often their larvae feed on the turfgrasses and cause severe damage (Potter and Braman 1991). Braman et al. (2000, 2002) showed varying degrees of resistance to fall armyworm larvae among turfgrass taxa, such as seashore paspalum, *Paspalum vaginatum* Swartz, Bermuda grass, *Cynodon dactylon* L. x *C. transvaalensis* (Burtt-Davy), and zoysiagrass, *Zoysia japonica* von Steudel and *Z. matrella* L. Merrill.

Zoysiagrasses resistant to the fall armyworm were also shown to be cross-resistant to twolined spittlebug, *Prosapia bicincta* (Say) (Shortman et al. 2002), zoysiagrass mite (Reinert et al. 1993), and hunting billbug, *Sphenophorus venatus vestitus* Chittenden (Reinert et al. 2004).

Turfgrass attributes, including those that impart plant resistance, may directly or indirectly affect the occurrence and predatory efficiency of heteropteran predators in managed turf (Braman et al. 2000, 2003). Fifth-instar bigeyed bugs significantly reduced fall armyworm numbers in susceptible grass and in resistant grasses (Braman et al. 2003), but nothing is known about the ability of *O. insidiosus* to reduce fall armyworm in turf. Anthocorids were well represented in different turfgrasses in residential turf and abundant in St. Augustine grass (Joseph 2006). The purpose of our study was to advance the understanding of predatory behavior of heteropterans such as *O. insidiosus, G. uliginosus,* and *G. punctipes* to help provide decision-making criteria for pest management in turfgrass. Specifically, we sought to determine how predation by *O. insidiosus, G. uliginosus,* and *G. punctipes* differs among grasses with different levels of resistance to fall armyworm.

Materials and Methods

Insect and Plant Source. Bigeyed bugs were field collected from turf that included the weeds white clover, *Trifolium repens* L., and crimson clover, *Trifolium incarnatum* L., in Spalding Co., GA, during June, July, and August 2005. Sweep nets (Ward's, Rochester, NY) and a Vortis vacuum sampler (Burkhard Manufacturing, Herefordshire, United Kingdom) were used to collect insects from the field. Male and female bigeyed bug pairs [*G. uliginosus* and *G. punctipes* (Say)] were individually sorted and held in plastic petri dishes (11 cm diameter and 2.2 cm height; Pioneer Plastics, Dixon, KY) in the laboratory at 24°C and 14:10-h (L:D) photoperiod and provided with frozen lepidopteran eggs of *Ephestia kuehniella* Zeller (Beneficial Insectary, Redding, CA) and *S. frugiperda* (USDA, Tifton, GA), sections of green bean, *Phaseolus vulgaris* L., a moist paper towel, and a small section of cheese cloth as an oviposition site. Insidious flower bugs, *O. insidiosus,* were obtained as 'Oriline' (Syngenta Bioline, Little Clacton, Essex, United Kingdom). The fall armyworm colony was initiated with eggs of the corn strain, obtained from the USD–ARS Crop Protection and Management Research Unit (Tifton, GA).

Grass taxa were the resistant turf cultivars Cavalier (zoysiagrass) and Palisades (zoysiagrass), intermediately resistant TifSport (Bermuda grass), and susceptible Sea Isle 1 (seashore paspalum). Grass plugs were grown in granular calcinated clay (Turface; Applied Industrial Materials, Deerfield, IL) in 15-cm-diameter pots in a greenhouse. Pots were watered daily and fertilized once per week with a solution containing 250 ppm N–P–K (Peters 20–20-20; Scotts-Sierra Horticultural Products, Maryville, OH). Grasses were sheared weekly and maintained at 8 cm height.

Predators in Small Arenas. All small arena experiments were conducted using a completely randomized design with 11 replications per grass taxon. An experimental unit consisted of a 32-ml plastic cup (Jetware; Jet Plastica Industries, Hotfield, PA) containing a single species of predator (bigeyed bug or insidious flower bug), five 1-d-old fall armyworm larvae, and a small quantity (≈15 leaves) of one of the turfgrasses under study. The fall armyworm larvae and insidious flower bug were transferred using a paint brush, whereas the bigeyed bugs were transferred using an aspirator. After introduction of predators and prey, cups were maintained at 27°C, 80% RH, and 14:10-h (L:D) photoperiod in a growth chamber (Percival Environmental Chambers; Percival Scientific, Perry, IA) for 24 h. Separate experiments were conducted with males and females of *G. uliginosus* and *G. punctipes,* nymphs (third to fifth instars), and one group of 11 adult *G. punctipes* that were not sorted by sex. *O. insidiosus* were not sorted by sex, but a subsample of the shipment determined that the sex ratio was 1:1. After 24 h, the number of total live fall armyworm larvae was quantified. Percent larval mortality was calculated as the difference between one and the ratio of average live fall armyworm and total fall armyworm released multiplied by 100. The adjusted mortality is the difference between percent mortality of fall armyworm in each trial and mortality of fall armyworm larvae in no-predator controls.

Predators Caged on Turf Pots. Two trials on potted turfgrasses were conducted with Cavalier zoysiagrass, TifSport Bermuda grass, and Sea Isle 1 seashore paspalum. Uniform grass density was maintained in 15-cm-diameter pots (exposure area, 176.62 cm^2). Twenty 1-d-old fall armyworms were transferred onto the turf in each pot using a small paint brush. *O. insidiosus* were released at 0, 2, 4, 6, 8, or 10 individuals per pot, immediately after infestation with larvae, and pots were quickly covered with 32-mesh nylon screen. A subsample of the shipment determined that the sex ratio was 1:1. For each trial, pots were arranged in a randomized complete block design with four replications for each density per turfgrass taxon and maintained for 4 d under laboratory conditions (24°C and 14:10-h [L:D] photoperiod). During the first trial, Cavalier and Sea Isle 1 were used, and TifSport was added in the second trial. After the 4-d period, all live fall armyworms were counted using visual inspection of potted plants.

Predators in Field Cages. Cavalier, Palisades, TifSport, and Sea Isle 1 were planted as plugs at the Georgia Station Research and Education Garden in Griffin on a sandy clay loam soil in the spring of 2000. The area used for our experiment was maintained with no insecticide application, was regularly hand weeded, and was mowed weekly. Thatch accumulation was minimal. The study was conducted from 10 to 15 August, 2005. Average high and low temperatures during this time period were 31.8 and 21.1°C, respectively. Average precipitation was 1.1 cm, and the average daylength was 13.2 h (UGA, Griffin Campus, weather station). Plots measured 25 m^2 (5 by 5 m) and were arranged in a randomized complete block design with six replications. Cages were 15.2-cm-diameter, 30-cm-long PVC pipe, with 144 cages (5,440.9 cm^3; exposure area, 181.4 cm^2) in all. These cages were pushed 15 cm into the turf in each plot to prevent escape of introduced predators. No attempts were made to remove any naturally occurring potential predators or prey. This experiment attempted to measure any increase in predation in the presence of alternative prey and predators that were known to commonly inhabit turf in this location (Braman et al. 2003). One-day-old fall armyworm larvae (20 per cage) were released into six cages per grass taxon per predator density. *O. insidiosus* were introduced (0, 2, 4, 6, 8, or 10 per cage) at the same time as the armyworms. Cages were covered with nylon mesh within 1 min after the insects were introduced into the cylinders. After 5 d, cages with turf plugs were removed from the field intact, taken from the field, and were intensively examined in the laboratory for remaining live larvae.

Statistical Analysis. The number of surviving fall armyworms was the response variable in each experiment. Separate analyses were conducted for each small arena experiment. In addition, overall survival of fall armyworms was again analyzed for each turfgrass taxon when they were exposed to different predator species or sexes. Similarly, both pot trials and field trial data of live fall armyworm were independently analyzed against turfgrass taxon and predator density. Variances were homogenous, and therefore, data were not transformed. Data were subjected to analysis of variance (ANOVA) using the PROC GLM procedure in SAS (SAS Institute 2003); mean separation was accomplished using the Fisher protected least significant difference (LSD) test.

Results

Predators in Small Arenas. Fall armyworm larval mortality in the absence of predators was statistically similar on Sea Isle 1 paspalum grass (15%) and TifSport Bermuda grass (4%), but significantly greater on Cavalier zoysiagrass (46%), even within the single 24-h trial period (Table 1). Live predator recovery after 24 h was 95% from all grasses combined. Fall armyworm larval survival was significantly reduced by the addition of predators on all grasses except for both bigeyed bug species males on Cavalier. However, turfgrass taxon had few effects on predator potential when not corrected for mortality caused by cultivar alone. Within a predator category, for example, grass effects were significant only for *O. insidiosus* and *G. punctipes* males (Table 1). When *O. insidiosus* were introduced, larval mortality was lowest on the susceptible Sea Isle 1 paspalum, averaging 47% [1 – (2.27/4.27)] of that in no-predator controls for that grass taxon. Mortality of larvae, when *O. insidiosus* was the predator, on TifSport and Cavalier was similar, averaging 96 and 84% of no-predator controls for those grasses, respectively. In contrast, when *G. punctipes* males were introduced,

Table 1. Mean ± SE and ANOVA of live fall armyworm larvae recovered when five 1-d-old larvae were exposed for 24 h to the predators, *O. insidiosus*, *G. uliginosus*, and *G. punctipes* on different turfgrass taxon in small arenas

Heteroptera	Sea Isle 1 seashore paspalum	% mortality	% adjusted mortality[a]	TifSport bermudagrass	% mortality	% adjusted mortality	Cavalier zoysiagrass	% mortality	% adjusted mortality	df	F	P
Orius unk sex	2.3 ± 0.5 aB	54.6	40.0	0.2 ± 0.1 bDE	96.4	92.6	0.5 ± 0.3 bC	91.0	45.4	2	11.7	0.0002
G. uliginosus ♂	1.6 ± 0.5 aBC	67.4	52.8	1.5 ± 0.5 aC	71.0	67.2	1.5 ± 0.5 aABC	71.0	25.4	2	0.0	0.9577
G. uliginosus ♀	1.6 ± 0.5 aBC	67.6	53.0	1.1 ± 0.7 aCDE	77.4	73.6	0.3 ± 0.3 aC	95.0	49.4	2	2.0	0.1574
G. punctipes Nymphs	1.8 ± 0.6 aBC	63.8	49.2	1.2 ± 0.4 aCD	76.4	72.6	0.9 ± 0.5 aC	82.0	36.4	2	0.8	0.4603
G. punctipes ♂	0.7 ± 0.3 bCD	85.6	71.0	0.91 ± 0.48 bCDE	81.8	78.0	2.5 ± 0.6 aAB	51.0	5.4	2	4.1	0.0250
G. punctipes ♀	0 ± 0 aD	100	85.4	0 ± 0 aE	100	96.2	0.7 ± 0.4 aC	85.6	40.0	2	2.9	0.0716
G. punctipes unk sex	1.1 ± 0.4 aBCD	78.2	64.0	2.9 ± 0.6 aB	42.0	38.2	1.4 ± 0.6 aBC	72.8	27.2	2	3.1	0.0598
Control	4.3 ± 0.2 aA	14.6	0	4.8 ± 0.1 aA	3.8	0	2.7 ± 0.5 bA	45.6	0	2	10.8	0.0003
df	7			7			7					
F	8.9			15.1			3.4					
P	0.0001[a]			0.0001			0.003					

Means within each row followed by the same lowercase letter are not significantly different ($P > 0.05$). Means within a column followed by the same upper case letter are not significantly different ($P > 0.05$). Mean separation by Fisher's protected least significant difference test.

[a] Adjusted mortality = percent mortality − control mortality.

Table 2. ANOVA among different turfgrass taxon and different *O. insidiosus* densities when provided 20 neonates of fall armyworms in laboratory and field trials

Category	Turf Pot experiment: 1			Turf Pot experiment: 2			Field cage experiment		
	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*
Grass taxon	1	48.52	<0.0001	2	29.07	<0.0001	3	14.24	<0.0001
Orius density	5	12.30	<0.0001	5	45.23	<0.0001	5	2.81	0.0196
Replication	3	0.25	0.8638	3	1.27	0.2950	5	1.59	0.1683
Grass taxon × *Orius* density	5	7.33	0.0001	10	12.50	<0.0001	15	1.33	0.3370
Orius density on different turfgrass taxon									
Cavalier zoysiagrass	5	13.31	<0.0001	5	1.00	0.4509	5	1.00	0.4381
TifSport bermudagrass	—	—	—	5	46.67	<0.0001	5	2.33	0.0719
Sea Isle 1 seashore paspalum	5	9.10	0.0004	5	17.80	<0.0001	5	0.66	0.6545
Palisades zoysiagrass	—	—	—	—	—	—	5	0.68	0.6438

mortality was lowest on Cavalier, averaging 10% of the larval survival recorded for no-predator controls. Larval mortality on Sea Isle 1 and TifSport were similar and averaged 83 and 81% of the no-predator controls when *G. punctipes* males were the predators. However, for *O. insidiosus,* 45.6% of the larval mortality on Cavalier zoysiagrass could be attributed to antibiosis from this fall armyworm-resistant taxon as indicated by the no-predator controls. The remaining mortality, 45.4%, would be the predator effect. This predator effect was very similar to that on Sea Isle 1, 40% above the natural mortality observed in 24 h for the no-predator treatment on that susceptible grass. The predator impact on TifSport by *O. insidiosus* was 92.6% above the mortality in the no-predator treatment on that grass. When background mortality is taken into account, the greatest mortality by predators occurred on TifSport in this trial, except for the *G. punctipes* unknown sex group, where the greatest mortality occurred on Sea Isle 1.

Predators Caged on Turf Pots. In the first pot trial, fall armyworm larval survival was significantly influenced by turfgrass taxon (Table 2). Survival of larvae was significantly less on Cavalier zoysiagrass (Fig. 1). Addition of predators on Sea Isle 1 and Cavalier significantly reduced larval survival. Suppression was statistically similar, however, among all *O. insidiosus* densities: from 2 to 10 adults per pot (Fig. 1).

In the second pot experiment, fall armyworm larval survival, in the absence of predators, was statistically similar on Sea Isle 1 paspalum and TifSport Bermuda grass and significantly reduced on Cavalier zoysiagrass (Fig. 2). The addition of *O. insidiosus* on Cavalier did not statistically reduce larval survival, although the only larvae recovered were in the no-predator controls. Survival of larvae on TifSport Bermuda grass was significantly reduced by the addition of just two *O. insidiosus* per pot. An increase in predator density to 4, 6, 8, or 10 further suppressed larval survival. *O. insidiosus* reduced larval survival on Sea Isle 1 at all densities. On Sea Isle 1, a density of two *O. insidiosus* resulted in >50% reduction in live fall armyworms compared with the no predator treatment (Fig. 2). When *O. insidiosus* densities reached 8 and 10 per pot, no fall armyworms survived on any of the turfgrasses.

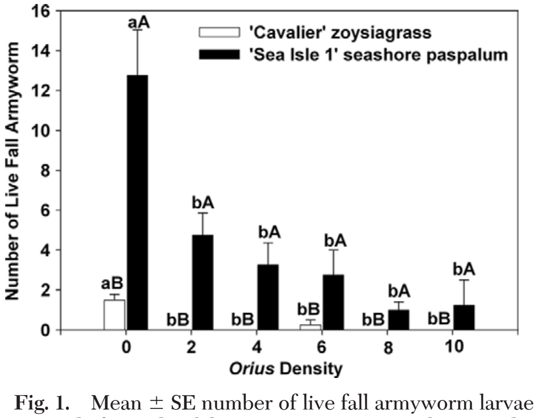

Fig. 1. Mean ± SE number of live fall armyworm larvae recovered after 4 d in laboratory experiments where predaceous *O. insidiosus* were introduced on different turfgrass taxa in pots. Letters in caps denote differences in mean survival of fall armyworm larvae between turfgrass taxa. Letters in lowercase denote differences in mean survival of fall armyworm among *O. insidiosus* densities within a grass taxon. Values followed by the same letter are not significantly different according to Fisher protected LSD ($P > 0.05$).

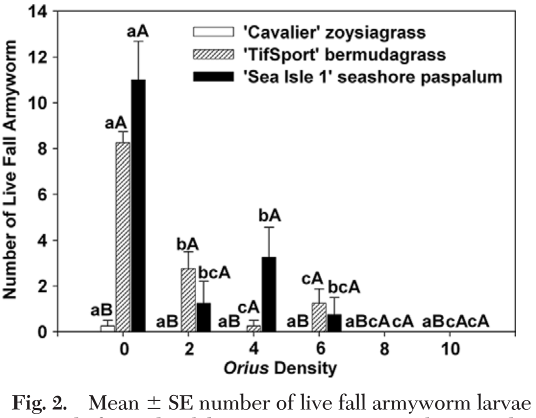

Fig. 2. Mean ± SE number of live fall armyworm larvae recovered after 4 d in laboratory experiments where predaceous *O. insidiosus* were introduced on different turfgrass taxa in pots. Letters in caps denote differences in mean survival of fall armyworm larvae among turfgrass taxa. Letters in lowercase denote differences in mean survival of fall armyworm among *O. insidiosus* densities within a grass cultivar. Values followed by the same letter are not significantly different according to Fisher protected LSD ($P > 0.05$).

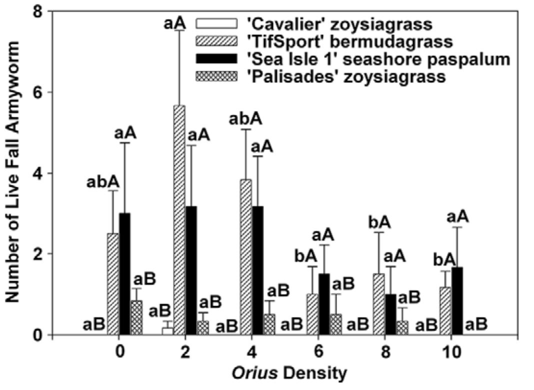

Fig. 3. Mean ± SE number of live fall armyworm larvae recovered after 5 d in experiments where predaceous *O. insidiosus* were introduced on different turfgrass taxa in field plots. Letters in caps denote differences in mean survival of fall armyworm larvae among turfgrass taxa. Letters in lowercase denote differences in mean survival of fall armyworm among *O. insidiosus* densities within a grass taxon. Values followed by the same letter are not significantly different according to Fisher protected LSD ($P > 0.05$).

Predators in Field Cages. Grass taxon influenced recovery of live fall armyworm larvae in the field, with more larvae found on Sea Isle 1 paspalum and TifSport Bermuda grass than on Cavalier and Palisades zoysiagrass when *O. insidiosus* were released into cages at different densities (Table 2; Fig. 3). Larval mortality was not influenced when different densities of *O. insidiosus* were released on Cavalier zoysiagrass because very few fall armyworms survived when caged on that taxon. Larvae were recovered in similar numbers on Palisades, a slightly less resistant grass, regardless of *O. insidiosus* density. Addition of *O. insidiosus* did not significantly reduce survival of fall armyworm larvae on the most susceptible cultivar 'Sea Isle' in this field trial. *O. insidiosus* densities of six or higher per 181.4 cm^2 significantly reduced larval survival on TifSport Bermuda grass by as much as 80% during this 5-d trial period (Table 2; Fig. 3).

Discussion

This study suggested that common heteropteran predators may be important in reducing survival of fall armyworm larvae on seashore paspalum and Bermuda grass taxa or cultivars. Predator induced mortality was rarely significant on the highly resistant zoysiagrass Cavalier, because mortality, even in the absence of predators, was so high. In an earlier study comparing growth and survival of fall armyworm among 65 turfgrass genotypes, fall armyworm larval survival averaged 10% on Cavalier, 17% on Palisades, 32% on TifSport, and 78% on Sea Isle 1 compared with 85% on artificial diet. Duration of development to the pupal stage in that study averaged 37.1 d on Cavalier, 38.7 d on Palisades, 23.9 d on TifSport, and 20.5 d on Sea Isle 1 compared with 20.5 d on artificial diet. Larval weights on day 10 averaged 4.7 mg on Cavalier, 4.2 mg on Palisades, 28.9 mg on TifSport, and 68.4 mg on Sea Isle 1 compared with 105.8 on artificial diet (Braman et al. 2002). These data show the spectrum of resistance among the taxa used in this study to the fall armyworm. In small arena trials, in this study, two species of bigeyed bugs showed an ability to successfully prey on fall armyworm larvae on all grasses, consistent with previous studies (Braman et al. 2003).

Bigeyed bugs are not currently available for commercial purchase, although *G. punctipes* was in production in the recent past. *O. insidiosus*, which is readily available commercially and is a commonly occurring predator in turfgrass, showed significant predation on fall armyworm larvae in both laboratory and field studies. This predator had the greatest impact on fall armyworm when the turfgrass host was TifSport Bermuda grass, a grass that has shown an intermediate level of resistance to the fall armyworm. The level of resistance exhibited by TifSport Bermuda grass may affect the behavior of fall armyworm larvae, making them more susceptible to predation. Furthermore, the longer time required for fall armyworms to complete development on even moderately resistant cultivars (Braman et al. 2002) may increase the likelihood of predation of larvae on these compared with more susceptible cultivars such as Sea Isle 1. Differences in architecture such as leaf density, size, shape, or orientation among turfgrass taxa may also influence predation in turfgrass systems. Morphological differences among turfgrasses and variation in intrinsic resistance characteristics such as antibiosis make it difficult to predict the outcome of potential interactions on a broad scale, appearing rather to require separate case by case assessment.

Geocoris and *Orius* spp. feed to some extent on plants, enabling their survival when prey density is low. It is possible that factors in zoysiagrass imparting resistance to fall armyworms may also have had negative affects directly on predators through plant feeding. However, in separate studies evaluating plant-mediated effects of insecticides on predator survival (Joseph 2006), *Geocoris* spp. that were confined on Cavalier, TifSport, and Sea Isle 1 turfgrasses in the absence of prey in controls receiving no insecticides experienced identical survival rates, suggesting a lack of direct mortality effects from plant feeding. In this study, field cages did not exclude naturally occurring predators and prey, better reflecting tritrophic interactions of *O. insidiosus* in natural turfgrass settings. Additional studies to better define the potential of *O. insidiosus* and other heteropteran predators as natural enemies and candidates for conservation biocontrol in the turfgrass system are needed.

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