Turfgrass Species and Cultivar Influences on Survival and Parasitism of Fall Armyworm

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ABSTRACT Interactions between host plant resistance and biological control may benefit or hinder pest management efforts. Turfgrass cultivars have rarely been tested for extrinsic resistance characteristics such as occurrence and performance of beneficial arthropods on plant genotypes with resistance to known turf pests. Parasitism of fall armyworm, *Spodoptera frugiperda* (J.E. Smith), among six turfgrass genotypes was evaluated. The six grasses tested [Sea Isle-1 and 561-79 seashore paspalum, *Paspalum vaginatum* Swartz; TifSport and TifEagle hybrid Bermuda grass, *Cynodon dactylon* (L.) × *C. transvaalensis* (Burtt-Davy); and Cavalier and Palisades zoysiagrass, *Zoysia japonica* von Steudel and *Z. matrella* (L.) Merrill, respectively] represented a range in resistance to *S. frugiperda*. Differential recovery of larvae released as first instars reflected this gradient in resistance of Cavalier ≥ Palisades ≥ TifSport = TifEagle ≥ 561- = Sea Isle-1 Larval recovery (percentage of initial number released) was greatest in May, less in July and August, and least in October, probably reflecting the increase in activity of on-site predators and disease pressure. Parasitism of the fall armyworm by the braconid *Aleiodes laphygmae* Viereck varied among turfgrass genotypes. Parasitism was greatest during July. In total, 20,400 first instars were placed in the field; 2,368 were recovered; 468 parasitoids were subsequently reared; 92.2% were *A. laphygmae*. In the field, the greatest percentage of reduction in *S. frugiperda* larvae by *A. laphygmae* occurred on the armyworm-susceptible seashore paspalums (51.9% on Sea Isle-1 in July). *Cotesia marginiventris* Cresson and *Meteorus* sp. also were reared from collected larvae. No parasitoids were reared from larvae collected from resistant Cavalier zoysiagrass. *A. laphygmae* and *C. marginiventris* were reared from larvae collected from the other five grass cultivars. No parasitoids of older larvae or pupae were observed.

KEY WORDS turfgrass, host plant resistance, *Aleiodes laphygmae*, *Cotesia marginiventris*, biological control

Sustainable pest management requires understanding of interactions between inherent plant defenses, natural enemies, and other components of agricultural systems (Lewis et al. 1997). Resistance among warm-season turfgrasses to a variety of phytophagous pest species has been reported previously (Reinert 1982; Quisenberry 1990; Braman et al. 1994, 2000a, b; Shortman et al. 2002; Reinert et al. 2004). Despite the intuitive impression that host plant resistance and biological control should be compatible strategies, the interactions between these tactics may benefit, or in some cases hinder pest management efforts (van Emden 1991). Partial host plant resistance and natural enemies often act synergistically to suppress pest insects (van Emden 1999). Price (1986) pointed out the need to understand the biology of each trophic level before the complex interactions between host plant resistance and natural enemies can be understood. Inability to predict the direction and degree of potential interactions contributes to the delay in implementation of integrated pest management plans for turfgrass.

Spodoptera frugiperda (J.E. Smith), the fall armyworm, is one of the most serious pests of corn, *Zea mays* L., and grasses throughout the Americas (Ashley et al. 1989). Although Luginbill (1928) lists >60 host plants, corn; sorghum, *Sorghum bicolor* L.; and grasses such as common bermudagrass, *Cynodon dactylon* (L.), are preferred. Ashley (1979) listed 53 species of fall armyworm parasitoids from 43 genera and 10 families. More recently, Molina-Ochoa et al. (2003) reported ≈150 species of parasitoids and parasites from 14 families in the Americas and Caribbean basin. Ashley (1986) reported that the highest levels of parasitism occurred in corn and that *Chelonus insularis* Cresson (Hymenoptera: Braconidae) was the predominant

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parasitoid. Gross and Pair (1986) reported that the dominant, endemic parasitoids of the fall armyworm in the southern United States include the tachinid *Archytas marmoratus* (Townsend), the braconids *Cotesia marginiventris* (Cresson) and *Chelonus insularis* Cresson, and the ichneumonids *Campoletis* spp. The genus *Rogas* =*Aleiodes* reportedly has the least impact on fall armyworm populations (Ashley 1986), although the highest parasitization rates by this genus occurred in forage grasses. Similarly, Molina-Ochoa et al. (2001) found that *Aleiodes laphygmae* Viereck was the only parasitoid that was only collected one time among 251 parasitoids representing 11 species from three families reared from *S. frugiperda* collected from corn or sorghum in Mexico.

In an evaluation of the incidence of fall armyworm parasitoids on resistant and susceptible corn genotypes, where *C. marginiventris* was the most prevalent parasitoid early in the season, genotype-related differences in parasitism were demonstrated on only one date during the 1990 growing season (Riggin et al. 1992). In that study, during 1991, when *A. marmoratus* was the most abundant parasitoid, fall armyworm collected from one of two susceptible corn genotypes were parasitized less frequently than those collected from a second susceptible and a resistant corn genotype. Percentage of parasitization under greenhouse conditions by *C. marginiventris* of larvae previously parasitized by *C. insularis* was two-fold higher in corn compared with sorghum and more than four-fold higher compared with bermudagrass (Rajapakse et al. 1991). Limited studies have examined the action of beneficial insects as mediated by turfgrass species and cultivars varying in resistance to common pests (Braman et al. 2002b, 2003). This study was undertaken to determine what type and degree of parasitism can be expected for fall armyworm in turfgrass in the southeastern United States, and the influence of turfgrass species and cultivars that represent a gradient in resistance to the pest.

Materials and Methods

Insects Used in Experiments. *S. frugiperda* were from a colony maintained on commercial diet (Bioserv, Inc., Frenchtown, NJ). The fall armyworm colony (corn strain) was initiated with eggs obtained from the USDA–ARS Crop Protection and Management Research Unit (Tifton, GA) in 1994 and is supplemented annually with new material from the USDA colony.

Field Plot Establishment. Turfgass species and cultivars representing a range of resistance to fall armyworms (Braman et al. 2000b, 2002a) were established in the field during May 2000. Cultivars evaluated were Palisades and Cavalier zoysiagrasses, *Zoysia japonica* von Steudel and *Z. matrella* (L.) Merrill; TifSport and TifEagle bermudagrasses, *Cynodon dactylon* (L.) × *C. transvaalensis* (Burtt-Davy); and 561-79 and Sea Isle-1 paspalum grasses, *Paspalum vaginatum* Swartz. Six replications of each of the six grasses were arranged in a randomized complete block design. Plots (36 total, each 5 by 5 m) were located at the Research and Education Garden of the Georgia Station in Griffin. Plots were irrigated as necessary to prevent wilt symptoms. Irrigation was supplied using Toro 700 pop up nozzles on 10-m spacing activated with a Toro Greensmaster controller (Toro Co., Bloomington, MN). Plots were fertilized according to University of Georgia recommendations (Landry 2000). Four and one-half kilograms of 12–4-8 per 1000 square feet was applied in early spring. Four and one-half more kilograms was applied in midsummer and again in late summer for a total of 1.6 kg of nitrogen. Mowing height was 10 cm. Herbicides that were applied to control broadleaf and grass weeds were glyphosate at 4 kg (AI)/ha to maintain alleys between plots and for spot weed control and granular oxadiazon at 4.5 kg (AI)/ha. No insecticides were applied.

Field Evaluation of Relationship between Turfgrass Genotype and Parasitism of Fall Armyworm. Four trials evaluating the relative parasitism of first and second instars of fall armyworm among the various turfgrass cultivars were conducted. Two hundred first instars of *S. frugiperda* were exposed collectively to parasitism within open 15.2-cm-diameter, 24-cm-high polyvinyl chloride (PVC) pipe cages inserted 5 cm into the soil in each turf plot 23–27 May and 30 July–4 August 2003. Fifty and 150 larvae were exposed in open cages during the time periods 7–13 August and 8–15 October, respectively. No neonates were observed attempting to crawl out of cages.

Third and fourth instars were placed in the field 13–16 May (50 larvae) and 18–21 August (30 larvae). Fall armyworm pupae were placed in open 10-cm-diameter petri dishes (four pupae per dish) and inserted into the thatch layer in each turf plot by cutting an opening with an adz (flat-bladed pickaxe). Pupae were exposed in the field 16–23 September 2003.

At the end of each exposure period, turf plugs inside PVC cylinders were pulled up, placed in large plastic bags, and returned to the laboratory. Each turf plug was destructively sampled; all larvae were counted and transferred to 32-ml plastic cups containing fall armyworm diet. Cups containing diet and individual fall armyworms were placed in environmental chambers at 24°C and a photoperiod of 15:9 (L:D) h and monitored for parasitoid pupal formation. Parasitoids emerging from larvae collected from the field were identified and recorded. All fall armyworm larvae were kept until parasitoid emergence, adult armyworm emergence, or death of the larva. Percentage of larval recovery and percentage of parasitism were compared among the six cultivars for individual cultivar effects. Percentage of larval or pupal recovery from the experimental plots and percentage of parasitism of initial number of larvae and of recovered larvae were transformed before analysis by arcsine [square root $(X + 0.5)$] and then subjected to analysis of variance (ANOVA) by using the GLM procedure of SAS (SAS Institute 1985). Mean separation was by least significant difference. Percentage of larval recovery and parasitism also were compared among the three turfgrass genera in a similar manner.

Table 1. Mean ± SE recovery and parasitism by the braconid *A. laphygmae* of *S. frugiperda* first and second instars caged in turfgrass field plots during May–October 2003

Turf genotype	May		July		Aug.		Oct.	
	% recovery of larvae	% parasitism by *A. laphygmae*	% recovery of larvae	% parasitism by *A. laphygmae*	% recovery of larvae	% parasitism by *A. laphygmae*	% recovery of larvae	% parasitism by *A. laphygmae*
Paspalum								
561-79	nd	nd	27.7 ± 7.6a***	42.7 ± 7.6ab*	11.2 ± 6.6ab**	8.4 ± 5.6abc*	nd	nd
Sea Isle-1	35.2 ± 9.5a***	6.4 ± 2.5a*	25.6 ± 10.6ab	51.9 ± 24.2a	16.0 ± 3.1a	35.1 ± 12.9ab	5.5 ± 1.7a**	35.9 ± 13.9a
Cynodon								
TifSport	28.3 ± 6.0a	1.7 ± 1.1ab	2.8 ± 1.7c	8.2 ± 6.2bc	11.0 ± 4.2ab	38.5 ± 14.1a	3.1 ± 0.1ab	27.3 ± 10.3a
TifEagle	27.8 ± 6.5a	5.2 ± 2.7ab	10.1 ± 4.2bc	26.1 ± 12.7abc	9.7 ± 3.9ab	2.8 ± 2.8bc	nd	nd
Zoysia								
Cavalier	2.2 ± 1.3b	0b	0c	0c	1.3 ± 0.9b	0c	nd	nd
Palisades	6.3 ± 1.0b	1.2 ± 1.2ab	0.2 ± 0.1c	16.6 ± 16.6abc	0.2 ± 0.1b	16.7 ± 16.7abc	0.3 ± 0.2b	16.7 ± 16.7a

Mean separation by least significant difference. Means within a column with different letters are significantly different (*$P < 0.10$, **$P < 0.05$, ***$P < 0.001$). nd, no data available for these plots.

Results

Turfgrass Genus and Cultivar Effects on Larval and Pupal Recovery. First and second instar recovery from field plots varied significantly ($P < 0.05$) among both cultivar and turfgrass genera for all four trials (Table 1; Fig. 1; May: $F = 17.6$; df = 2, 10; $P = 0.001$; July: $F = 8.1$; df = 2, 10; $P = 0.002$; August: $F = 7.8$; df = 2, 10; $P = 0.002$; October: $F = 5.2$; df = 2, 10; $P = 0.03$). Recovery of caged larvae was least among zoysiagrasses, especially Cavalier zoysiagrass, and greatest for the paspalums, especially Sea Isle-1. Percentage of recovery of larvae decreased as the season progressed, perhaps reflecting increasing predation observed in earlier studies (Braman et al. 2003) and/or disease pressure that was occasionally observed in the field.

Third and fourth instar recovery was similar among grass genera in both trials (trial 1: $F = 1.56$; df = 5, 10; $P = 0.23$; trial 2: $F = 1.84$; df = 5, 10; $P = 0.18$). Average larval recovery of the initial 50 larvae exposed as third or fourth instars per plot in trial 1 was paspalum,35.8%; zoysiagrass, 25.8%; and bermudagrass, 24.2%. Average larval recovery of the initial 30 larvae exposed as third or fourth instars per plot in trial 2 was paspalum, 13.0%; zoysiagrass, 5.6%; and bermudagrass, 10.8%. Recovery was similar among cultivars for the earlier (May) trial ($F = 0.71$; df = 5, 25; $P = 0.62$) but varied during the second (August) trial ($F = 2.65$; df = 5, 25, $P = 0.048$) from 1.7% in Cavalier zoysiagrass to 17.3% in TifSport bermudagrass. As indicated above, no parasitoids were reared from the 549 larvae that were returned to the laboratory from the initial 2,650 third instars that were released into field plots.

Pupal recovery varied among the three genera of turfgrasses ($F = 2.74$; df = 5, 25; $P = 0.08$), averaging 68.7% in zoysiagrass, 37.5% in paspalum, and 31.2% in Bermuda grass. Among cultivars, although average recovery ranged from 83.3% in Palisades zoysiagrass to 25.0% in TifEagle bermudagrass, these differences were not significant ($F = 1.4$; df = 5, 25; $P = 0.26$).

Parasitoids Recovered. Parasitoids were reared from fall armyworms in each of the four trials where larvae were exposed as first or second instars. In total, 20,400 first or second instars were placed in the field; 2,368 were recovered from the field; and 486 parasitoids were reared with 448 (92.2%) being *A. laphygmae.* No parasitoids were recovered in either of the

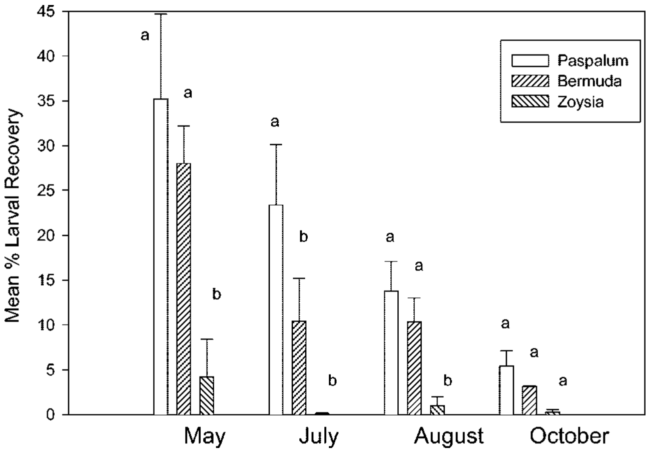

Fig. 1. Mean ± SE (%) recapture of fall armyworms after 4–7-d exposure in turfgrass field plots after release as first instars. Columns with the same letter within each month are not significantly different ($P > 0.05$).

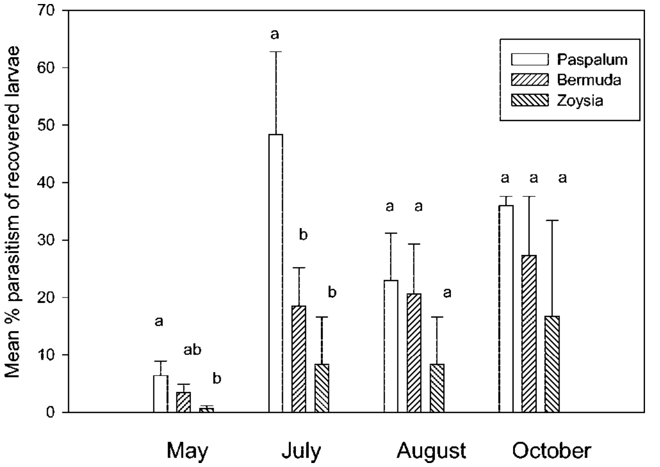

Fig. 2. Mean ± SE (%) parasitism by the braconid *A. laphygmae* of fall armyworm larvae recovered from turfgrass field plots after 4–7-d exposure after release as first instars. Columns with the same letter within each month are not significantly different ($P > 0.05$).

two trials where larvae were exposed in the field as third or fourth instars. No parasitoids were recovered from pupae. In addition to *A. laphygmae*, parasitoids reared from larvae exposed in the field as first or second instars were the hymenopterans *C. marginiventris, Meteorus* sp., and two tachinids. The braconid, *A. laphygmae*, the most numerous parasitoid collected, parasitized 18.1% of larvae recovered over all among all grasses in all four first or second instar trials. *C. marginiventris* emerged from 1.0% of the larvae collected among all grasses in the same trials. The remaining parasitoids accounted for <1% parasitism.

Turfgrass Genus and Cultivar Effects on Parasitism. Parasitism by *A. laphygmae* peaked during July on the paspalums, especially Sea Isle-1 at 51.9% of recovered larvae (Table 1). No parasitoids were recovered from larvae exposed in the highly resistant Cavalier zoysiagrass. Cultivar-related differences in percentage of parasitism by *A. laphygmae* within a grass genus were observed during August (Table 1). Significant differences in parasitism among turfgrass genera by *A. laphygmae* were evident during May and July measured as percentage of parasitism of recovered larvae (Fig. 2; May: $F = 3.4$; df = 2, 10; $P = 0.05$; July: $F = 5.1$; df = 2, 10; $P = 0.01$). In general, parasitism was highest in paspalum, lower on bermudagrass, and least for larvae recovered from zoysiagrass.

No differences in parasitism were observed during August and October (August: $F = 1.1$; df = 2, 10; $P = 0.36$; October: $F = 0.51$; df = 2, 10; $P = 0.62$). When parasitism was measured as percentage of initial release, indicating degree of impact or overall mortality attributable to *A. laphygmae,* the same plant taxon-related differences in parasitism were observed (Fig. 3; May: $F = 4.88$; df = 2, 10; $P = 0.02$; July: $F =$

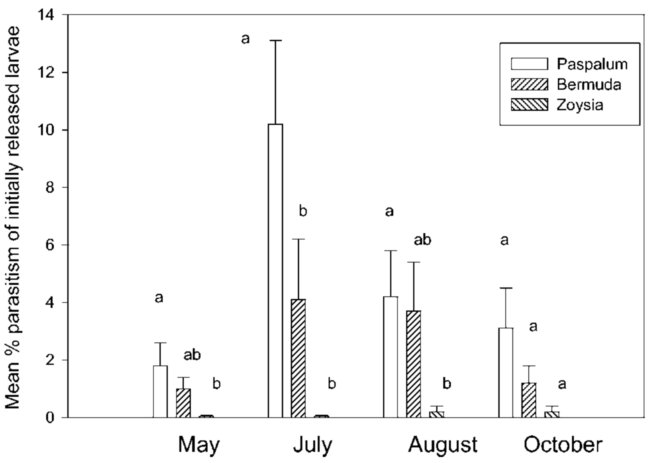

Fig. 3. Mean ± SE (%) parasitism by the braconid *A. laphygmae* of fall armyworm larvae based on initial number of first instars released into turfgrass field plots and exposed for 4–7 d. Columns with the same letter within each month are not significantly different ($P > 0.05$).

6.58; df = 2, 10; P = 0.005; August: F = 2.70; df = 2, 10; P = 0.08. October: F = 2.47; df = 2, 10; P = 0.13).

A low percentage (0.4–5.0% depending on cultivar) of larvae were parasitized by *C. marginiventris* during May, July, and October. No larvae were parasitized by *C. marginiventris* during August. There were no significant differences among turfgrass cultivars or genera with respect to parasitism by *C. marginiventris.* This parasitoid was reared from larvae collected from all cultivars except Cavalier zoysiagrass.

Discussion

Cultivar and genera-related differences in recovery of fall armyworm larvae reflect the spectrum of resistance to this insect observed in previous studies with these particular grasses (Braman et al. 2000b, 2002a, 2003). Previous and present studies demonstrated a gradient in resistance to fall armyworm when exposed to grasses as neonates where, in general, Cavalier ≥ Palisades ≥ TifSport = TifEagle ≥ 561-79 = Sea Isle-1. Larger larvae and pupae demonstrated fewer differences in cultivar related survival in the field. Percentage of parasitism of *S. frugiperda* by *A. laphygmae,* measured in the present field study, was least in Cavalier zoysiagrass and greatest in Sea Isle-1 paspalum.

To account for differential mortality of fall armyworm among host plants unrelated to parasitism, percentage of parasitism reported here was based on either the number of recovered larvae (Fig. 2) or the number of initial larvae released into field plots (Fig. 3). The relative influence of turfgrass genera on larval parasitism regardless of other mortality factors (Fig. 2) is similar to that observed when evaluated in the context of total mortality (Fig. 3). Parasitism observed here would be indicative of that which would occur when an egg mass hatches in the field and ≈50–300 larvae disperse in the grass. The increase in percent parasitism in grasses that are more susceptible to fall armyworm may reflect a density response on the part of the parasitoid to a greater number of surviving caterpillar hosts within the same area over the 4–7-d trial periods. Alternatively, it may indicate an increased abundance of parasitoids especially in the paspalums, increased attraction to herbivore-damaged grass (De Moraes et al. 1998), more favorable plant architecture for host location in susceptible grasses, or a possible deterrent to host location or parasitism in zoysiagrass. In addition, parasitoids may experience greater mortality in hosts feeding on the more resistant grasses, which would be expressed as a reduction in percentage of parasitism. Parasitoid abundance independent of the lepidopteran host was not measured during this trial. In a previous report (Braman et al. 2003), however, no differences among these same turfgrass cultivars or genera were determined for parasitic Hymenoptera as a group when measured by vacuum samples. Distinct turfgrass cultivar and species-related differences in predator fauna were noted in that earlier study, e.g., higher densities of predatory Heteroptera in the paspalums and increased abundance of spiders in the zoysiagrasses (Braman et al. 2003).

In a previous experiment (Braman et al. 2003), an increase in predation by the big eyed bug, *Geocoris uliginosus* (Say), on *S. frugiperda* neonates was observed on resistant Cavalier zoysiagrass compared with Bermuda grass or paspalum in the laboratory. That increase in predation was explained by the lengthened developmental time of larvae feeding on resistant zoysiagrass; the larvae remained in an acceptable prey size range longer on the resistant grass. Release of the same predator species in the same grasses in the field, however, resulted in additional significant reductions in larval survival in paspalums in plots receiving the big eyed bugs. Percentage of parasitism of *S. frugiperda* in the present field study decreased with increasing resistance levels to the host insect. However, substantial parasitism on TifSport, a cultivar of Bermuda grass demonstrating intermediate levels of resistance to fall armyworm, suggests a promising potential synergy between modest levels of host resistance and pest suppression by natural enemies. High levels of parasitism and predation in paspalums suggest potential candidates for conservation biological control targeting specific beneficials that occur in abundance in these grasses. Future work also will examine the potential mechanisms responsible for the observed differences in parasitism.

The predominance of parasitism by *A. laphygmae* in each of four trials, resulting in 92% of the parasitoids collected is in stark contrast with the much lower proportion of total parasitoids of fall armyworm represented by this species in agricultural crops (Ashley 1986, Gross and Pair 1986, Riggin et al. 1992, Molina-Ochoa et al. 2001). Further investigation of parasitoid species of importance in managed turfgrasses is warranted.

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References Cited

Ashley, T. R. 1979. Classification and distribution of fall armyworm parasites. Fla. Entomol. 62: 114–123.

Ashley, T. R. 1986. Geographical distributions and parasitization levels for parasitoids of the fall armyworm, *Spodoptera frugiperda.* Fla. Entomol. 69: 516–524.

Ashley, B. R. Wiseman, F. M. Davis, and K. L. Andrews. 1989. The fall armyworm: a bibliography. Fla. Entomol. 72: 152–202.

Braman, S. K., A. F. Pendley, R. N. Carrow, and M. C. Engelke. 1994. Potential resistance in zoysiagrasses to tawny mole crickets (Orthoptera: Gryllotalpidae). Fla. Entomol. 77: 302–305.

Braman, S. K., R. R. Duncan, and M. C. Engelke. 2000b. Evaluation of turfgrasses for resistance to fall armyworms (Lepidoptera: Noctuidae). HortScience 35: 1268–1270.

Braman, S. K., R. R. Duncan, W. W. Hanna, and W. G. Hudson. 2000a. Evaluation of turfgrasses for resistance to mole crickets (Orthoptera: Gryllotalpidae). HortScience 35: 665–668.

Braman, S. K., R. R. Duncan, M. C. Engelke, W. W. Hanna, K. Hignight, and D. Rush. 2002a. Grass species and endophyte effects on survival and development of fall armyworm. J. Econ. Entomol. 95: 487–492.

Braman, S. K., A. F. Pendley, and W. Corley. 2002b. Influences of commercially available wildflower mixes on beneficial arthropod abundance and predation in turfgrass. Environ. Entomol. 31: 564–572.

Braman, S. K., R. R. Duncan, W. W. Hanna, and M. C. Engelke. 2003. Predator occurrence and performance of *Geocoris uliginosus* (Say) on pest-resistant and susceptible turfgrasses. Environ. Entomol. 32: 907–914.

De Moraes, C. M., W. J. Lewis, P. W. Paré, H. T. Alborn, and J. H. Tumlinson. 1998. Herbivore-infested plants selectively attract parasitoids. Nature (Lond.) 393: 570–573.

Gross, H. R., Jr., and S. D. Pair. 1986. The fall armyworm: status and expectations of biological control with parasitoids and predators. Fla. Entomol. 69: 502–515.

Landry, G. 2000. Lawns in Georgia. University of Georgia, CES pub. B773.

Lewis, W. J., J. C. van Lenteren, S. C. Phatak, and J. H. Tumlinson. 1997. A total system approach to sustainable pest management. Proc. Natl. Acad. Sci. U.S.A. 94: 12243–12248.

Luginbill, P. 1928. The fall armyworm. USDA Tech. Bull. 34.

Molina-Ochoa, J., J. E. Carpenter, E. A. Heinrichs, and J. E. Foster. 2003. Parasitoids and parasites of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas and Caribbean basin: an inventory. Fla. Entomol. 86: 254–289.

Price, P. W. 1986. Ecological aspects of host plant resistance and biological control: interactions among three trophic levels, pp. 11–30. *In* D. J. Boethel and R. D. Eikenbary [eds.], Interactions of plant resistance and parasitoids and predators of insects. Wiley, New York.

Quisenberry, S. S. 1990. Plant resistance to insects and mites in forage and turf grasses. Fla. Entomol. 73: 411–421.

Rajapakse, R.H.S., T. R. Ashley, and V. H. Waddill. 1991. Interspecific competition between parasitoids of the fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae). Insect Sci. Appl. 12: 473–480.

Reinert, J. A. 1982. A review of host resistance in turfgrasses to insects and acarines with emphasis on the southern chinch bug, pp. 3–12. *In* H. D. Niemczyk and B. G. Joyner [eds.], Advances in turfgrass entomology. Hammer Graphics, Inc. Piqua, OH.

Reinert, J. A., M. C. Engelke, and J. C. Read. 2004. Host resistance to insects and mites - a major IPM strategy in turfgrass culture. Acta Hortic. (in press).

Riggin, T. M., B. R. Wiseman, D. J. Isenhour, and K. E. Espelie. 1992. Incidence of fall armyworm (Lepidoptera: Noctuidae) parasitoids on resistant and susceptible corn genotypes. Environ. Entomol. 21: 888–895.

SAS Institute. 1985. SAS users guide: statistics, 5th ed. SAS Institute, Cary, NC.

Shortman, S. L., S. K. Braman, R. R. Duncan, W. W. Hanna, and M. C. Engelke. 2002. Evaluation of turfgrass species and cultivars for potential resistance to twolined spittlebug, *Prosapia bicincta* (Say) (Homoptera:Cercopidae). J. Econ. Entomol. 95: 478–486.

van Emden, H. F. 1999. Transgenic host plant resistance to insects - some reservations. Ann. Entomol. Soc. Am. 92: 788–797.

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