Susceptibility of Zoysiagrasses to the Fall Armyworm (Lepidoptera: Noctuidae)[1]

S. Nair[3], S.K. Braman[2], and P. Raymer[4]

University of Georgia, Department of Entomology, 413 Biological Sciences Bldg., Athens, Georgia 30602 USA

J. Entomol. Sci. 56(1): 24–31 (January 2021)

Abstract Growth and developmental parameters of the fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), were evaluated on 41 new zoysiagrass taxa (*Zoysia* spp. Willd.), which belong to an increasingly popular group of warm-season turfgrasses, in comparison with 5 commercially available zoysiagrass taxa and 1 known susceptible *Paspalum* L. taxon. Results from two no-choice growth chamber trials indicated that the new *Zoysia japonica* Steud. taxa were unfavorable for the development of fall armyworm larvae in general compared with the susceptible *Paspalum* taxon. This was evidenced by significantly lower larval and pupal weights and survival and longer time to pupation and adult emergence, pointing to antibiosis in these zoysiagrass taxa. The new *Zoysia matrella* (L.) Merr., *Zoysia macrostachya* Franch. & Sav., and *Zoysia sinica* Hance taxa seemed more favorable than *Z. japonica* taxa, as evidenced by numerically higher larval and pupal weights and survival and shorter duration to pupation and adult emergence. Taxa that consistently showed low larval survival were identified for further testing.

Key Words zoysiagrass, fall armyworm, *Spodoptera frugiperda*, host plant resistance, antibiosis

Zoysiagrasses (*Zoysia* spp. Willd.) belong to an underused warm-season turf group that has been slowly increasing in use across the United States since its introduction (Patton 2009). These grasses are suited to diverse applications, including use on golf courses to create fairways and teeing areas and controlling erosion on slopes. They have many desirable characteristics, including uniformity, reduced mowing requirement during spring and fall, reduced need for fertilizer, and dormancy instead of death during drought and natural weed suppression (Patton 2009). However, despite their reliability and versatility, zoysiagrasses are not as popular as other warm-season turfgrasses (Diesburg 2001). Zoysiagrasses have some cold tolerance, but a relative lack of cold hardiness could be one of the limitations to their widespread use in the transition zone, especially compared to cool-season grasses. However, an expanded use of zoysiagrasses could play a

[1]Received 16 January 2020; accepted for publication 27 March 2020.
[2]Corresponding author (email: kbraman@uga.edu).
[3]University of Arizona, Maricopa Agricultural Center, 37860 W. Smith-Enke Rd., Maricopa, AZ 85138-3010 USA.
[4]University of Georgia, Department of Crop and Soil Sciences, 1109 Experiment St., Griffin, GA 30223 USA.

key role in making transition zone golf courses and lawns more environmentally friendly and sustainable (Patton and Reicher 2007).

Zoysiagrass breeding efforts are focused on cold, drought, shade, and salinity tolerance and resistance to various biotic stresses, including insects, mites, disease, and nematodes. The commercial release of zoysiagrasses with desirable characteristics was slow in the earlier years, with only 3 cultivars being released in the United States over 34 years from 1951 to 1985 (Patton et al. 2017). The increasing demand for low-maintenance turfgrasses suited to specific locations has spurred breeding research. Fifteen zoysiagrass cultivars have been released since 2000 (Patton 2009).

Fall armyworms, *Spodoptera frugiperda* (J. E. Smith) (Noctuidae: Lepidoptera), are important pests of turfgrasses, often causing severe damage in late summer or fall after migrating populations have increased during the season. The larvae attack a wide range of plants but feed preferentially on grasses and can cause significant economic losses in many crops including, corn *Zea mays* L., sorghum *Sorghum bicolor* (L.) Moench, forage grasses, turf grasses, cotton *Gossypium arboreum* L., and peanut *Arachis hypogaea* L. (Sparks 1979). They feed above the ground and mostly consume foliage and tender stems. In severe cases, the grasses are cut at the ground level, leaving bare, circular patches (Vance and App 1971). Polyphagy in the fall armyworm was previously thought to be due to lack of dietary specialization. However, it was later found that the fall armyworm has genetically differentiated strains, each exhibiting different host specificity (Pashley 1986; Nagoshi and Meagher 2004).

Previous experiments have evaluated the preference of fall armyworms to different grasses (Chang et al. 1985), as well as the susceptibility of zoysiagrasses to various herbivores, such as fall armyworms, the tropical sod webworm *Herpetogramma phaeopteralis* (Guenée, 1854), *Eriophyes zoysiae* Baker, Kono, and O'Neill, the tawny mole cricket *Neoscapteriscus vicinus* (Scudder), western chinch bugs (*Blissus occiduus* Barber), and twolined spittle bugs (*Prosapia bicincta* Say) (Patton 2009). Information from these experiments supports and informs breeders in the development of turfgrasses adapted to different stresses. The identification and use of turfgrasses with resistance to the major turfgrass pests are important components of integrated pest management strategies in turf production. As new turfgrass varieties are developed, evaluation for pest resistance is warranted. The objective of the present project was to evaluate the growth and development of the fall armyworm on 41 experimental zoysiagrass taxa, in comparison with 5 commercially available zoysiagrasses, 1 *Paspalum* L. taxon, and artificial diet.

Materials and Methods

Plant material. Forty-six zoysiagrass taxa, including 41 experimental and 5 commercially available zoysiagrass taxa, were evaluated in 2 experiments. The susceptible *Paspalum* taxon (*P. vaginatum* Sw. 'UGA-22′) (Braman et al. 2014) and artificial insect diet (Benzon Research, Carlisle, PA) were used as positive controls. All test grasses were obtained from the University of Georgia Turfgrass Breeding and Genetics Research Program. The grasses were maintained in a greenhouse, in 6-inch plastic pots containing Metro Mix 300 (Sun Gro Horticulture Ltd. Vancouver, Canada). Plants were fertilized at transplanting with a controlled-release fertilizer (Osmocote 18-6-12; The Scotts Company, Marysville, OH) and regularly thereafter with a water-soluble general purpose fertilizer (Peter's 20-20-20; The Scotts Company, Marysville, OH).

Insects. Fall armyworm (corn/rice strain) eggs were obtained from a commercial supplier (Benzon Research) and were held at 27°C until eclosion. Fresh grass clippings (cut from potted grass plants within 1 h or less) were provided daily to the fall armyworm larvae during the course of the experiments until all larvae had pupated or died.

In each no-choice bioassay experiment, 32-ml clear plastic diet cups with snap-on plastic lids (Bio-Serv, Frenchtown, NJ) were arranged in plastic trays. One 2-cm filter paper disc was placed at the bottom of each cup and saturated with water. Fresh clippings of the desired grasses were placed on the moist filter paper disc. One set of cups received pieces of artificial diet (Benzon Research) as a second positive control. One neonate larva was transferred into each cup by using a camel-hair brush, and the lid was secured. The cups were arranged in a randomized complete block design, with the replication as the blocking factor. Two separate no-choice bioassay experiments were conducted, each with 48 treatments and 30 larvae per treatment (6 replications, with 5 larvae per replication).

The trays containing the cups were randomly stacked within an environmental chamber maintained at constant temperature (24°C) and photoperiod (15:9 h light:dark). Observations recorded included larval weight at 8 d and 15 d, pupal weight, and days to pupal stage and adult emergence.

Statistical analyses. Treatment means were subjected to analysis of variance by using the general linear model procedure, and means were separated with Fisher protected least significant difference (SAS Institute 2010).

Results

In both trials, growth and developmental parameters (larval and pupal weights, days to pupation and adult emergence, larval and pupal survival, and adult emergence) did not differ significantly among any of the tested zoysiagrasses. However, these parameters were significantly lower than those on the controls, that is, *P. vaginatum* 'UGA-22′ and the artificial diet (Table 1).

Twenty experimental zoysiagrasses consistently showed 20% or less larval survival percentages in both trials, and they were *Z. japonica* Steud. 324184, *Z. japonica* 338565, *Z. japonica* 338566, *Z. japonica* 338568, *Z. japonica* 338571, *Z. japonica* 338573, *Z. japonica* 338574, *Z. japonica* 338575, *Z. japonica* 338580, *Z. japonica* 338581, *Z. japonica* 338582, *Z. japonica* 553016, *Z. japonica* 553018, *Z. japonica* 648263, *Z. japonica* 648264, *Z. japonica* 648265, *Z. japonica* 648269, *Z. japonica* 660545, *Z.* sp. 337602, and *Z.* sp. 16471 (Fig. 1).

Discussion

Antibiosis as a mechanism of resistance in zoysiagrass against fall armyworm has been recorded in earlier studies (Chang et al. 1985). The commercially available zoysiagrasses included in the trials ('Cavalier', 'Zeon', 'Meyer', 'Pali-

Table 1. Developmental parameters of *S. frugiperda* on zoysiagrass taxa in growth chamber studies.[1]

Species[2]	Taxon Number / Name	Mean Larval Weight at 8 d (mg)	Mean Larval Weight at 15 d (mg)	Mean Pupal Weight (mg)	Mean Days to Pupation	Mean Days to Adult Emergence	% Survival to 8 Days	% Survival to Pupation	% Adult Emergence
Z. j.	231389	1.36 c	11.00 c	–[3]	–	–	18.33 e–j	0.00 f	0.00 f
Z. j.	235334	5.13 c	38.56 c	102.13 b	30.25 d–g	41.29 d–h	26.67 c–g	13.33 de	11.67 de
Z. j.	324184	9.86 bc	44.17 c	108.00 b	28.75 d–g	40.75 d–h	11.67 g–j	6.67 d–f	6.67 d–f
Z. j.	324185	6.00 c	18.00 c	99.00 b	32.75 a–d	44.50 a–d	26.67 c–g	6.67 d–f	6.67 d–f
Z. j.	338563	4.85 c	47.50 c	87.00 b	31.25 c–e	41.50 d–h	21.67 e–i	6.67 d–f	6.67 d–f
Z. j.	338564	3.38 c	25.60 c	100.67 b	33.00 a–d	44.00 a–f	35.00 c–e	5.00 ef	5.00 ef
Z. j.	338565	2.13 c	16.33 c	94.00 b	37.00 a	–	13.33 f–j	1.67 f	0.00 f
Z. j.	338566	3.00 c	–	–	–	–	3.33 j	0.00 f	0.00 f
Z. j.	338567	1.62 c	5.00 c	–	–	–	21.67 e–i	0.00 f	0.00 f
Z. j.	338568	1.00 c	–	–	–	–	5.00 ij	0.00 f	0.00 f
Z. j.	338569	5.79 c	29.00 c	117.25 b	30.33 d–g	39.67 d–h	23.33 d–h	6.67 d–f	5.00 ef
Z. j.	338570	1.64 c	37.00 c	91.00 b	33.00 a–d	–	18.33 e–j	1.67 f	0.00 f
Z. j.	338571	4.00 c	42.50 c	95.00 b	30.00 d–g	–	10.00 g–j	1.67 f	0.00 f
Z. j.	338572	2.30 c	10.00 c	–	–	–	16.67 f–j	0.00 f	0.00 f
Z. j.	338573	1.25 c	–	–	–	–	6.67 h–j	0.00 f	0.00 f
Z. j.	338574	2.71 c	38.00 c	101.67 b	32.33 b–e	44.33 a–e	11.67 g–j	5.00 ef	5.00 ef
Z. j.	338575	2.25 c	–	–	–	–	6.67 h–j	0.00 f	0.00 f
Z. j.	338578	1.70 c	7.00 c	–	–	–	16.67 f–j	0.00 f	0.00 f

Table 1. Continued.

Species[2]	Taxon Number / Name	Mean Larval Weight at 8 d (mg)	Mean Larval Weight at 15 d (mg)	Mean Pupal Weight (mg)	Mean Days to Pupation	Mean Days to Adult Emergence	% Survival to 8 Days	% Survival to Pupation	% Adult Emergence
Z. j.	338580	2.22 c	21.00 c	–	–	–	15.00 f–j	0.00 f	0.00 f
Z. j.	338581	1.25 c	11.00 c	–	–	–	13.33 f–j	0.00 f	0.00 f
Z. j.	338582	2.33 c	12.00 c	86.00 b	30.00 d–g	39.00 e–h	10.00 g–j	1.67 f	1.67 ef
Z. j.	553016	2.09 c	4.00 c	65.00 b	37.00 a	47.00 a–c	18.33 e–j	1.67 f	1.67 ef
Z. j.	553018	2.00 c	–	–	–	–	10.00 g–j	0.00 f	0.00 f
Z. j.	648261	1.75 c	–	–	–	–	13.33 f–j	0.00 f	0.00 f
Z. j.	648262	3.10 c	–	–	–	–	16.67 f–j	0.00 f	0.00 f
Z. j.	648263	2.00 c	–	–	–	–	3.33 j	0.00 f	0.00 f
Z. j.	648264	2.00 c	30.00 c	71.00 b	31.00 c–e	42.00 c–g	11.67 g–j	1.67 f	1.67 ef
Z. j.	648265	2.71 c	27.40 c	100.33 b	36.33 ab	43.00 b–g	11.67 g–j	5.00 ef	3.33 ef
Z. j.	648266	2.67 c	–	–	–	–	15.00 f–j	0.00 f	0.00 f
Z. j.	648267	2.00 c	12.50 c	108.50 b	33.00 a–d	43.00 b–g	15.00 f–j	3.33 ef	3.33 ef
Z. j.	648268	2.71 c	21.33 c	97.33 b	32.33 b–e	43.50 a–f	23.33 d–h	5.00 ef	3.33 ef
Z. j.	648269	2.21 c	22.50 c	81.50 b	32.00 b–e	43.00 b–g	15.00 f–j	3.33 ef	3.33 ef
Z. j.	660545	1.40 c	–	–	–	–	8.33 h–j	0.00 f	0.00 f
Z. mac.	553020	3.21 c	31.08 c	114.20 b	29.90 d–g	40.80 d–h	40.00 cd	16.67 d	16.67 cd
Z. mat.	264343	5.50 c	124.80 bc	108.28 b	26.11 f–h	36.50 hi	43.33 c	30.00 c	26.67 c
Z. mat.	231146	2.85 c	72.47 bc	97.06 b	29.17 d–g	39.71 d–h	65.00 b	30.00 c	23.33 c

Table 1. Continued.

Species[2]	Taxon Number / Name	Mean Larval Weight at 8 d (mg)	Mean Larval Weight at 15 d (mg)	Mean Pupal Weight (mg)	Mean Days to Pupation	Mean Days to Adult Emergence	% Survival to 8 Days	% Survival to Pupation	% Adult Emergence
Z. s.	553019	2.79 c	18.67 c	100.00 b	32.00 b–e	44.00 a–f	23.33 d–h	1.67 f	1.67 ef
Zoysia sp.	337602	1.80 c	37.33 c	99.67 b	30.67 c–f	38.00 gh	8.33 h–j	5.00 ef	3.33 ef
Zoysia sp.	16485	1.22 c	6.00 c	–	–	–	15.00 f–j	0.00 f	0.00 f
Zoysia sp.	16471	3.00 c	18.67 c	121.00 b	36.00 ab	48.50 a	11.67 g–j	3.33 ef	3.33 ef
Zoysia sp.	16461	2.61 c	32.00 c	106.00 b	30.00 d–g	39.50 d–h	30.00 c–f	3.33 ef	3.33 ef
Z. mat.	Zeon	1.67 c	9.25 c	98.00 b	36.00 ab	48.00 ab	15.00 f–j	6.67 d–f	6.67 d–f
Z. j.	Meyer	4.17 c	57.40 c	115.13 b	27.88 e–g	38.71 f–h	40.00 cd	13.33 de	11.67 de
Z. j. X Z. p.	Emerald	1.75 c	28.00 c	83.00 b	35.00 a–c	44.00 a–f	13.33 f–j	1.67 f	1.67 ef
Z. mat.	Cavalier	1.81 c	3.00 c	85.00 b	26.00 gh	38.00 gh	26.67 c–g	1.67 f	1.67 ef
Z. j.	Palisades	1.73 c	–	–	–	–	18.33 e–j	0.00 f	0.00 f
P. v.	UGA-22	35.60 b	192.57 ab	117.50 b	21.72 hi	32.12 ij	100.00 a	96.67 a	85.00 a
Artificial diet	None	107.95 a	270.42 a	192.07 a	17.61 i	30.87 j	100.00 a	68.33 b	50.00 b
F		13.08	7.51	8.28	30.37	17.02	9.68	18.28	14.00
P value		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Overall model		$F = 15.45$; df $= 53, 577$; $P < 0.0001$	$F = 12.43$; df $= 42, 237$; $P < 0.0001$	$F = 8.17$; df $= 35, 177$; $P < 0.0001$	$F = 34.14$; df $= 35, 176$; $P < 0.0001$	$F = 17.94$; df $= 32, 147$; $P < 0.0001$	$F = 17.88$; df $= 53, 522$; $P < 0.0001$	$F = 18.31$; df $= 53, 522$; $P < 0.0001$	$F = 14.54$; df $= 53, 522$; $P < 0.0001$

[1] Results are averages over two studies. Means in the same column bearing different letters are significantly different ($\alpha = 0.05$).
[2] *Z. j.*, *Zoysia japonica; Z. mac.*, *Zoysia macrostachya*; *Z. mat.*, *Zoysia matrella*; *Z. s.*, *Zoysia sinica*; *P. v.*, *Paspalum vaginatum.*
[3] –, No individuals survived for measurement.

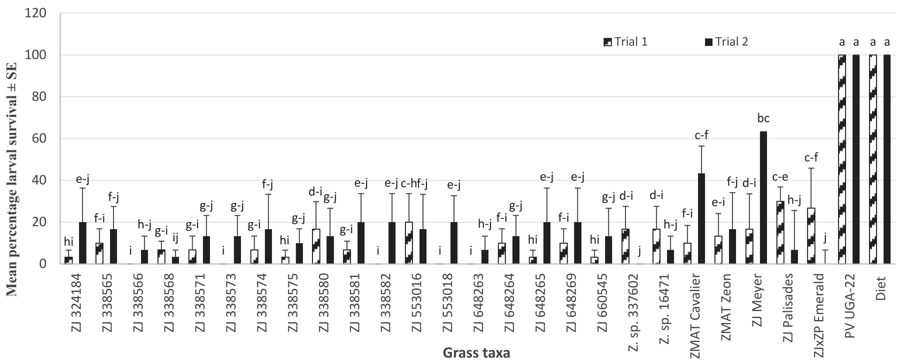

Fig. 1. New zoysiagrasses showing 20% or lesser larval survival of *Spodoptera frugiperda* at 8 d, in comparison with commercially available *Zoysia* taxa and controls. Bars of the same fill pattern bearing different letters are significantly different ($\alpha = 0.05$).

sades', and 'Emerald') were not favorable for larval growth and development, which is consistent with results of earlier reports (Braman et al. 2000, Reinert and Engelke 2010). This was indicated by low numerical larval and pupal weights, larval and pupal survival, and adult emergence and longer duration to pupation and adult emergence. However, these levels were not different from those of the least favorable experimental zoysiagrass taxa listed above.

Overall, the experimental *Z. japonica* taxa were unfavorable for the development of fall armyworm larvae. The new *Z. matrella* (L.) Merr. (231146 and 264343) and *Z. macrostachya* Franch. & Sav. (553020) taxa, supported larval growth and development better than the *Z. japonica* taxa, as evidenced by numerically high larval and pupal weights and survival and shorter duration to pupation and adult emergence. However, these differences were not statistically significant.

Mechanisms of resistance to herbivory in zoysiagrasses should be further investigated. Earlier studies have shown that lignin concentration and leaf tensile strength in 'Cavalier' and 'Emerald' were positively correlated with host resistance (Hale et al. 2009). Further evaluation of zoysiagrasses and other taxa should consider the effects of strain-specific development and dietary conditioning on the level of resistance to fall armyworms. Future research (no-choice and choice) should focus on a field assessment of taxa showing potential resistance identified in the studies reported here. Taxa providing multiple pest resistance should be identified and popularized for extensive use in new and restored landscapes.

Acknowledgment

The technical support provided by Jim Quick is greatly appreciated.

References Cited

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

Braman, S.K., P.L. Raymer, M. Harrison-Dunn and S. Nair. 2014. Antibiosis among selected *Paspalum* taxa to the fall armyworm (Lepidoptera: Noctuidae). J. Entomol. Sci. 49: 11–20.

Chang, N.T., B.R. Wiseman, R.E. Lynch and D.H. Habeck. 1985. Fall armyworm: expressions of antibiosis in selected grasses. J. Entomol. Sci. 20: 179–188.

Diesburg, K.L. 2001. Improvements in zoysiagrass: From Kansas to D.C., the grass is becoming more common. Golf Course Manage. 69: 72–77.

Hale, T.C., J.A. Reinert and R.H. White. 2009. Resistance of zoysiagrasses (*Zoysia* spp.) to fall armyworm (Lepidoptera: Noctuidae): I. Leaf tensile strength and cell wall components. Int. Turfgrass Soc. Res. J. 11: 639–648.

Nagoshi, R.N. and R.L. Meagher. 2004. Behavior and distribution of the two fall armyworm host strains in Florida. Florida Entomol. 87: 440–449.

Pashley, D.P. 1986. Host-associated genetic differentiation in fall armyworm (Lepidoptera: Noctuidae): a sibling species complex? Ann. Entomol. Soc. Am. 79: 898–904.

Patton, A.J. 2009. Selecting zoysiagrass cultivars: Turfgrass quality, growth, pest and environmental stress tolerance. Appl. Turfgrass Sci. doi:10.1094/ATS-2009-1019-01-MG.

Patton, A.J., B.M. Schwartz and K.E. Kenworthy. 2017. Zoysiagrass (*Zoysia* spp.) history, utilization, and improvement in the United States: A review. Crop Sci. 57: S-37–S-72. doi: 10.2135/cropsci2017.02.0074.

Patton, A.J. and Z.J. Reicher. 2007. Zoysiagrass species and genotypes differ in their winter injury and freeze tolerance. Crop Sci. 47: 1619–1627.

Reinert, J.A. and M.C. Engelke. 2010. Resistance in zoysiagrass (*Zoysia* spp.) to the fall armyworm (*Spodoptera frugiperda*) (Lepidoptera: Noctuidae). Florida Entomol. 93: 254–259.

SAS Institute. 2010. SAS® system (version 9.3) for Windows. SAS Institute, Cary, NC.

Sparks, A.N. 1979. A review of the biology of the fall armyworm. Florida Entomol. 62: 82–87.

Vance, A.M. and B.A. App. 1971. Lawn insects: How to control them. U.S. Dept. Agric. Home and Garden Bull. No. 53.