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Researchers at Texas A&M University evaluated 46 cultivars and genotypes of Kentucky bluegrass (*Poa pratensis* L.) for their resistance or susceptibility to fall armyworm larvae in no-choice laboratory experiments. Results indicate 'Wabash', 'Adelphi', 'Eagelton', and 'Monopoly' present the greatest potential for transferring fall armyworm resistance in hybridization of future cultivars.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 450 projects at a cost of $31 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Fall Armyworm Susceptibility Among Kentucky Bluegrass Cultivars

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SUMMARY

The fall armyworm, [*Spodoptera frugiperda* (J. E. Smith)] (Lepidoptera: Noctuidae), feeds heavily on many species of cool- and warm-season turfgrass in the Americas and the Caribbean Basin. Severe outbreaks do not occur each year but rather every 2-3 years, and sometimes it may be up to 5 years between outbreak cycles. 2010 appears to be one of the severe outbreak years with damaging populations occurring across much of the U.S. Forty-six cultivars and genotypes of Kentucky bluegrass, (*Poa pratensis* L.), were characterized for their resistance or susceptibility to fall armyworm larvae in no-choice laboratory experiments. Results include:

- The majority of the Kentucky bluegrasses cultivars (32) provided 100% mortality before adult emergence. An additional seven cultivars provided greater than 90% mortality, and two more produced greater than 80% mortality.
- The most susceptible cultivars was 'Glade' with 8% mortality, followed by PTDF22B2 (25%), 'Kenblue' (29%), 'Connie' (58%), and H86-386 (67%).
- 'Reveille', a Texas bluegrass × Kentucky bluegrass (*Poa arachnifera* × *P. pratensis*) hybrid, was 100% resistant, characteristic of 'Huntsville' its Kentucky bluegrass parent, as opposed to 'Tejas', the Texas bluegrass parent.
- Analysis of the group of Kentucky bluegrass genotypes shows a gradation of resistance, with 'Wabash' killing 100% of larvae within 3 days feeding, an additional nine cultivars killing 100% within 9 days, and 22 additional cultivars killing 100% before the adult emerged.
- The data indicates 'Wabash', 'Adelphi', 'Eagelton', and 'Monopoly' (each producing greater than 92% mortality within 3 days feeding) present the greatest potential for transferring fall armyworm resistance in hybridization of future cultivars.

Genetic plant resistance to pests including insects, mites, nematodes, diseases, and weeds is an underutilized but very effective and economical means to manage these pests and should be a major component of every Integrated Pest Management program when resistant cultivars are available. Attention in turf breeding programs has usually been focused heavily on aesthetic traits rather than biotic and abiotic stresses. The continued development of improved cultivars with inherent resistance to primary turfgrass pests is a major need across the turfgrass industry, regardless of the turf utilization from production fields to installed landscapes, golf courses, or recreational fields. When pest resistant cultivars are used in the landscape, they help to reduce the need for pesticide input and indirectly reduce the potential for environmental contamination to help meet increasingly strict environmental quality and safety standards.

The fall armyworm [*Spodoptera frugiperda* (J. E. Smith)] (Lepidoptera: Noctuidae), is a destructive pest of over 50 species of plants (8) and it is known to feed on many species of both C_3 and C_4 (cool- and warm-season) turfgrasses (2, 14, 15, 16). Severe outbreaks do not occur every year but rather every 2-3 years and sometimes it may be up to 5 years between cycles. 2010 appears to be one of the more severe outbreak years with damaging populations occurring across much of the U.S.

Fall armyworm larvae feed on most warm- and cool-season turfgrasses. A mature larvae can consume about a hand full of grass per night during the last 5-7 days before pupation.

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Fall armyworm *(Spodoptera frugiperda*) adult. Larvae of this insect are a destructive pest of over 50 species of plants, and they are known to feed on many species of both cool- and warm-season turfgrasses.

Resistance to fall armyworm was first identified in genotypes of bermudagrass (7) and the high level of antibiosis and nonpreference in 'Tifton 292' and several other bermudagrass genotypes was confirmed by several other researchers (6, 9, 11). Many additional cultivars and breeding lines of bermudagrass have been evaluated for fall armyworm resistance, but no additional genotypes of bermudagrass have been identified (2, 18). A high level of resistance to fall armyworm was also recorded in 'Common' centipedegrass [*Eremochloa ophiuroides* (Munro.) Hack.] (5, 20) and resistance was high in tetraploid but lacking in diploid buffalograss, *Buchloe dactyloides* (Nutt.) Engelm (16).

Levels of resistance were also identified in several genotypes of seashore paspalum, *Paspalum vaginatum* Swartz (2). High levels of antibiosis has been documented in 'Cavalier' (*Zoysia matrella* L.) and in several other genotypes of zoysiagrass (2, 12, 16). 'Cavalier' was subsequently introduced as a new cultivar for its resistance to several environmental stresses including its resistance to the fall armyworm, four other chewing insects, and several diseases. Resistance to selected *Poa spp.* has also been characterized (17). A summary of the research studies conducted up to 2004 to identify host resistance to insects and mites in both cool- and warm-season turfgrass was prepared by Reinert et al. (13). This summary emphasized the considerable lack of known information on host response to insects and mites for many cultivars that are used throughout the turfgrass industry.

Kentucky bluegrass (*Poa pratensis* L.) is a cool-season grass introduced from Europe and used extensively across the upper half of the United States as a turfgrass on golf courses, lawns, and all aspects of recreational turf. Although there are over 10 species of *Poa* used for turf, Kentucky bluegrass is the most widely used with more than 100 cultivars in cultivation (1, 3, 4, 10) and potentially more than 15 new cultivars arriving on the market every five years after testing in the National Turfgrass Evaluation Program (10). The purpose of this research was to characterize the cultivars of Kentucky bluegrass for their resistance or susceptibility to the fall armyworm.

Grasses were cultured in the greenhouse. Clippings were taken from several pots and thoroughly mixed before samples were fed to larvae.

Materials and Methods

Forty-six cultivars of Kentucky bluegrass, 'Laser,' (*P. trivialis*), 'Tejas' (*P. arachnifera*), and 'Reveille' (*P. arachnifera* × *P. pratensis*) were evaluated for their response to fall armyworm feeding. Plants (Table 1) were maintained in the greenhouse and cultured in 15.2-cm top diam., 12.7-cm bottom diam. by 17.7-cm tall plastic pots. Clippings from these plants were used to feed the fall armyworm larvae in a no-choice feeding study. The experiment was set up in the laboratory using 9-cm diam. x 20-mm deep plastic petri dishes as larvae feeding chambers. Each dish was provided with two water-saturated 7.5-cm filter paper discs. Water was added as needed throughout the experiment to keep the filter paper saturated and to maintain the grass clippings. Each feeding chamber was individually labeled and provided with a small amount of fresh leaf tissue (approximately 3 g) of the respective *Poa* genotype. Grass was added or replaced throughout the experiment so that turgid fresh grass was always available to the developing larvae.

Three randomly selected 4-day-old larvae that had been allowed to develop on 'Laser' (an excellent developmental host for the fall armyworm larvae) were placed on the grass in each feeding chamber in a randomized complete block design with 8 replications and maintained in the rearing room. Larvae were separated into individual dishes when they were 9-days-old, since they become highly cannibalistic shortly after that age. Grass was added or replaced throughout the experiment so that turgid, fresh grass was always available to the developing larvae.

Survivorship was evaluated when the larvae were 7- and 12-days-old, at pupation, and at adult emergence. All surviving larvae were weighed when 12-days-old, which was well before any pupation, and each pupae was weighed within 1 day after pupation. Days-to-pupation and days-to-adult emergence were monitored for all surviving larva. Data were analyzed using analy-

Poa Cultivar [1]	% Mortality at stage of development [2] 7-days-old	12-days-old	Pupation	Adult	Weight [3] 12-day-old larvae (mg)	Days [3] to pupation
Wabash	100 a [5, 6]	100 a	100 a	100 a	- - [7]	- -
Adelphi	95.83 ab	100 a	100 a	100 a	- -	- -
Eagleton	95.83 ab	100 a	100 a	100 a	- -	- -
Monopoly	91.67 abc	100 a	100 a	100 a	- -	- -
American	83.33 abc	100 a	100 a	100 a	- -	- -
CS CT 1	77.08 a d	100 a	100 a	100 a	- -	- -
H86 712	70.83 b e	100 a	100 a	100 a	- -	- -
Georgetown	66.67 c g	100 a	100 a	100 a	- -	- -
CS CT 2	50.00 d l	100 a	100 a	100 a	- -	- -
CS CT RW	25.00 f j	100 a	100 a	100 a	- -	- -
Challenger	75.00 a d	95.83 ab	100 a	100 a	44.20 a e	- -
4Aces	70.83 b f	95.83 ab	100 a	100 a	38.60 a e	- -
Norfolk	66.67 c g	95.83 ab	100 a	100 a	7.30 a	- -
Blacksburg	62.50 c h	95.83 ab	100 a	100 a	16.70 ab	- -
Delwood Fine	41.67 d j	95.83 ab	100 a	100 a	12.90 ab	- -
A84 747	33.33 e j	95.83 ab	100 a	100 a	21.70 abc	- -
Dawn	33.33 e j	95.83 ab	100 a	100 a	9.60 a	- -
KY Classic	20.83 hij	87.50 abc	100 a	100 a	27.55 a d	- -
NuBlue	20.83 hij	87.50 abc	100 a	100 a	14.93 ab	- -
Bronco	25.00 g j	79.17 a d	100 a	100 a	22.50 a d	- -
Suffolk	25.00 g j	79.17 a d	100 a	100 a	6.43 a	- -
PTDF26	12.50 ij	79.17 a d	100 a	100 a	31.48 a d	- -
CS CT 3	8.33 ij	79.17 a d	100 a	100 a	18.84 abc	- -
Nugget	8.33 ij	79.17 a d	100 a	100 a	38.76 a e	- -
Huntsville	16.67 ij	70.83 a e	100 a	100 a	19.05 abc	- -
Nustar	16.67 ij	66.67 a e	100 a	100 a	17.51 ab	- -
CS CT 4	12.50 ij	66.67 a e	100 a	100 a	24.02 a d	- -
Baron	8.33 ij	66.67 a e	100 a	100 a	22.50 a d	- -
H86 683	4.17 ij	45.83 d g	100 a	100 a	39.76 a e	- -
Nottingham	8.33 ij	41.67 d g	100 a	100 a	48.17 a e	- -
Fairfax	4.17 ij	4.17 g	87.50 ab	100 a	72.54 a f	22.50 b f
Washington	0 j	4.17 g	87.50 ab	100 a	50.27 a e	22.00 c f
Apex	16.67 ij	54.17 d g	95.83 ab	95.83 a	42.59 a e	23.00 b f
Ram 1	0 j	29.17 efg	95.83 ab	95.83 a	68.25 a f	24.00 b e
Fylking	0 j	8.33 g	95.83 ab	95.83 a	80.15 b f	27.00 abc
Limousine	4.17 ij	45.83 c g	91.67 ab	95.83 a	30.69 a d	28.50 ab
Absolute	0 j	16.67 fg	87.50 ab	95.83 a	65.21 a f	22.67 b f
Mystic	8.33 ij	58.33 b f	91.67 ab	91.67 a	35.50 a d	25.00 bcd
Nassau	0 j	8.33 g	91.67 ab	91.67 a	71.64 a f	20.50 def
HBG J86	4.17 ij	16.67 fg	79.17 bc	87.50 a	69.29 a f	23.38 b f
Explorer	8.33 ij	45.83 d g	79.17 bc	83.33 a	37.85 a d	23.50 b f
H86 386	0 j	8.33 g	58.33 cd	66.67 b	107.15 efg	20.93 c f
Connie	0 j	0 g	37.50 de	58.33 bc	86.70 c h	22.77 b f
Kenblue	0 j	0 g	20.83 e	29.17 de	126.77 fg	18.69 ef
PTDF22B2	0 j	0 g	0 e	25.00 de	154.16 gh	18.63 ef
Glade	0 j	0 g	4.17 e	8.33 e	90.72 d h	20.06 def
Reveille[1]	20.83 hij	50.00 c g	95.83 ab	100 a	41.32 a e	32.00 a
Tejas[1]	0 j	4.17 g	20.83 e	45.83 bcd	54.03 a e	22.88 b f
Laser[1]	0 j	0 g	12.50 e	33.33 cde	207.99 h	17.58 f

1 'Laser' rough bluegrass (*Poa trivialis*) and 'Tejas' Texas bluegrass (*P. arachnifera*) included as susceptible hosts. Hybrid bluegrass (*P. arachnifera* × *P. pratensis* 'Reveille') included as a resistant grass. All other cultivars are Kentucky bluegrass (*P. pratensis*).

2 Mean % larvae mortality at days after egg hatch, % mortality at pupation, and % mortality at adult emergence.

3 Mean weight of surviving larvae at 12 days after egg hatch (fed 8 days on each genotype).

4 Mean number of days from egg hatch to pupation for larvae fed on each genotype.

5 Analysis was made on arc sine transformation of the percent mortality data: Percent mortality is presented.

6 Means in columns not followed by same letters are significantly different (Tukey's Range Test.) (P = 0.05).

7 All larvae were dead on this cultivar.

Table 1. Resistance among Kentucky bluegrass cultivars to fall armyworm; assayed as mortality of life stages, 12-day-old larvae weight, and days-to-pupation for 4-day-old larvae in laboratory no-choice studies (8 reps).

sis of variance procedures, and mean were separated by Tukey's studentized range test (P= 0.05) (19). Mortality data were transformed to arcsine before each analysis of variance was performed, but the actual percentage of mortality is presented.

Results and Discussion

'Wabash' (100%), 'Adelphi' (96%), and 'Eagleton' (96%), and 'Monopoly' (92%) were the most resistant to 7-day-old larvae (after only 3 days of feeding). When larvae were 12-days-old (8 days of feeding), 10 cultivars produced 100% mortality with an additional seven cultivars providing 96% mortality. Of the 46 cultivars of Kentucky bluegrass evaluated, 30 cultivars (or 65% of cultivars tested) provided 100% mortality, and an additional nine cultivars provided greater than 87% mortality before the larvae pupated. Only two more cultivars produced 100% mortality by adult emergence, but 89% of the cultivars provided greater than 80% mortality.

For the cultivars with larvae surviving to pupation, most produced an additional level of mortality before the adults emerged. 'Glade' (8% mortality) was the most susceptible Kentucky bluegrass evaluated. 'Kenblue' and PTDF22B2 were also highly susceptible with only 29% and 25% larval mortality, respectively. 'Connie' and H86-386 with 58% and 67% larval mortality, respectively, only had a moderate level of resistance.

By comparison, 'Laser' (*P. trivialis*) produced 33% mortality of the larvae, and it has consistently been one of the most susceptible hosts evaluated (usually mortality less than 20%). 'Tejas' Texas bluegrass provided 46% mortality, but it has provided much higher mortality in several other experiments. The hybrid, 'Reveille' [a hybrid between TBPC20-11 (3-88) Texas bluegrass × 'Huntsville' Kentucky bluegrass] provided 100% mortality with similar levels of mortality at each growth stage to its resistant parent 'Huntsville'.

For the surviving larvae at 12 days, weights were greatest for the five most susceptible Kentucky bluegrass cultivars and 'Laser' rough bluegrass. The mean weight of 12-day-old larvae that survived on the five susceptible cultivars of Kentucky bluegrass ('Glade', PTDF22B2, 'Kenblue', 'Connie', and H86-386) was 113 mg and these larvae were significantly heavier (mean = 36 mg) than larvae that survived on the 31 resistant cultivars. Larvae that survived on 'Laser' only required 18 days to pupate. By comparison, larvae that survived on 'Reveille', 'Limousine', and 'Fylking' took significantly longer to develop before pupation (32, 29, and 27 days, respectively), than larvae surviving on the other Kentucky bluegrass cultivars (23 days, mean of nine cultivars).

Conclusions

Results of this study indicate that as a species, Kentucky bluegrass exhibits a strong level of resistance to the fall armyworms. Even though only 46 of the more than 250-300 cultivars were evaluated, the percentage of highly resistant cultivars (89%) is very high. The level of susceptibility at various growth stages varied considerably among the cultivars that were tested. In a previous study with two of the cultivars evaluated in this experiment, 'Delwood Fine' and 'Baron' each provided 100% mortality of the confined larvae before they could pupate (16). These results are very similar to the current results. Most cultivars of Kentucky bluegrass should serve as good parents for future hybridization to produce progeny with fall armyworm resistance. Care must be taken not to use any of the five or seven susceptible cultivars that were identified in this test.

High larval mortality or antibiosis was observed as the primary mechanism of resistance in the *P. pratensis* genotypes. Larvae feeding on these cultivars would develop normally to either the second or third instar (growth stage), when they would begin swelling during molting and then appeared to freeze in a bloated state. They were unable to complete the molt or shedding of the old larval skin. This antibiosis could most likely be due to some toxin associated with these

Kentucky bluegrass cultivars. Additional feeding studies with fall armyworms larvae on Kentucky bluegrass are needed to determine the true nature of this mechanism of resistance.

Another consideration is the potential cross-resistance to other armyworm species. With the high level of resistance to fall armyworms expressed in most of these cultivars, the question arises, could these same cultivars also express resistance to other species of *Spodoptera*, including the African armyworm, *S. exempta* (Walker), which causes damage around much of the world? Additionally, could this mechanism of resistance also provide protection against the lawn armyworm, *S. mauritia* (Boisduval), and yellowstriped armyworm, *S. ornithogalli* (Guenée) which also cause considerable turf damage in the U.S? The resistance may even be beneficial against the true armyworm, *Pseudaletia unipuncta* (Haworth). These resistances have yet to be tested.

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