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The Japanese beetle, *Popillia japonica* Newman, is among the worst pests of turfgrasses and woody landscape plants in the eastern United States. Adults feed on the foliage and flowers of nearly 300 host species. Research at the University of Georgia was conducted to determine the tolerance of seashore paspalum to Japanese beetle grubs in comparison to other warm-season turfgrass species and 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 290 projects at a cost of $25 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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Tolerance of Seashore Paspalum to Feeding by Japanese Beetle

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SUMMARY

Seashore paspalum, *Paspalum vaginatum* Swartz, is a highly salt tolerant, warm-season perennial grass found in tropical to warm temperate regions. Paspalums have been evaluated for potential resistance/tolerance to a variety of turfgrass pests and for compatibility with natural enemies. The objective of this project was to determine the tolerance of seashore paspalum to Japanese beetle grubs in comparison to other warm-season turfgrass species and cultivars.

- Ten cultivars of seashore paspalum were compared for their response to Japanese beetle larval root feeding. Cultivars of bermudagrass and zoysiagrass were also included for comparison. Turf grown in pots in the greenhouse was infested with second- and third-instar larvae in this two-year study.
- Grub survival and weight gain, foliar growth, and root loss were compared among turfgrass species and cultivars. Few species-related differences were identified.
- Differences in grub tolerance were observed to be a function of turfgrass cultivar. Some turf types demonstrating tolerance to grub feeding had rapid root growth and high root mass in control pots, but this was not consistent for all cultivars showing enhanced ability to maintain foliar growth despite grub feeding.
- The paspalum cultivars that appeared most tolerant of grub feeding were 561-79, 'Sea Isle 2000', 'Durban', 'HI-10', 'Kim-1', 'Sea Dwarf', and 'Sea Spray'.

The Japanese beetle, *Popillia japonica* Newman, is among the worst pests of turfgrasses and woody landscape plants in the eastern United States (10). Adults feed on the foliage and flowers of nearly 300 host species (13). Larvae feed on the roots of a variety of plants, including grasses. While Japanese beetles feed on all cool-season grasses (13), the range in susceptibility among warm-season turfgrasses is not known.

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Seashore paspalum, *Paspalum vaginatum* Swartz, is a highly salt tolerant, warm-season perennial grass found in tropical to warm temperate regions (9). Attributes of recently developed paspalum cultivars include low nitrogen and water requirements and superior salt tolerance, allowing them to tolerate most types of alternate water sources such as waste water, effluent, gray water, and brackish water.

Paspalums have been evaluated for potential resistance/tolerance to mole crickets, *Scapteriscus spp.* (1), twolined spittlebugs, *Prosapia bicincta* (Say), (12), and fall armyworms, *Spodoptera frugiperda* (J.E. Smith) (1, 2, 14). Extrinsic resistance characteristics, or the action of natural enemies as mediated by turfgrass with varying resistance levels, has also been documented for paspalum (2, 3, 4). Our objective was to determine the tolerance of seashore paspalum to Japanese beetle grubs in comparison to other warm-season turfgrass species and cultivars.

Experimental grasses included selections of seashore paspalum, bermudagrass, and zoysiagrass. Grasses were grown in a greenhouse in 15.2-cm diameter plastic pots in granular calcinated clay.

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Larvae of Japanese beetle, *Popillia japonica* Newman feed on the roots of a variety of plants, including grasses. While Japanese beetles feed on all cool-season grasses, the range in susceptibility among warm-season turfgrasses is not known.

Insects and Plants

Adult Japanese beetles were field collected from local residential landscapes using standard attractant traps. Adults were caged on 19-liter plastic pots planted with 'Kentucky 31' tall fescue to allow oviposition and grub development. Grubs were harvested for use in experiments as needed. Grubs were placed in soil in individual 32 ml plastic cups and held for 24 hours prior to infesting plants.

Experimental grasses included selections of seashore paspalum, bermudagrass, and zoysiagrass. Grasses were grown in a greenhouse in 15.2 cm diam plastic pots in granular calcinated clay. Before the experiment, pots were watered daily and fertilized once per week with a solution containing 250 ppm NPK (Peters 20-20-20). Grasses were transferred to native top soil in 2.8 L "Tall One" pots, 10 cm width X 36 cm height one month prior to infestation.

Year 1

Turfgrass cultivars used during year 1 were paspalum cultivars 'Durban', Sea Isle 1', 'Sea Isle 2000, 'Sea Dwarf', 'Salam', 'Sea Spray, 'Asul', 'Sea Isle Supreme', 'HI 10', and an Argentine selection 561-79. Zoysiagrass cultivars were 'Cavalier' and 'Palisades', while bermudagrasses were 'TifSport' and 'TifEagle'. Japanese beetle second- and third-instar grubs were harvested from the grub "nursery" and weighed prior to infestation of pots on August 26, 2003. Prior to infestation, grasses were trimmed to a height of 6 cm. Three grubs per pot were introduced to the soil and observed to insure that they had successfully burrowed in. Any grubs that had not entered the soil within one hour were replaced.

Foliar growth was clipped to a height of 6 cm on November 4, placed in paper bags, oven dried at 30^{o} C for 7 days and weighed. On December 9, pots were destructively sampled, grubs counted and weighed. Roots were separated from shoots at the soil line, washed, oven-dried and weighed. Foliage was also dried and weighed as before. The design was a randomized complete block with 8 replications. There were also 8 uninfested pots of each grass type maintained and

Grass Species and Cultivar	Year 1			Year 2		
	Grubs recovered	Grub weight	Weight gain	Grubs recovered	Grub weight	Weight gain
Paspalum						
561-79	1.1 abc	227.2 ab	60.4 ab	---	---	---
'Durban'	1.1 abc	212.2 ab	68.7 ab	1.6 abc	183.5 a	-40.7 a
'Sea Isle 2000'	1.5 ab	218.3 ab	5.0 ab	1.9 abc	227.3 a	7.3 a
'Sea Isle 1'	1.7 a	215.3 ab	66.3 ab	1.5 bc	248.8 a	22.2 a
'Sea Dwarf'	0.6 c	188.7 b	52.9 ab	1.9 abc	199.0 a	-23.9 a
'Salam'	1.2 abc	215.4 ab	53.8 ab	2.6 ab	216.1 a	2.3 a
'HI-10'	0.9 bc	211.7 ab	32.4 b			
'Sea Spray'	1.4 abc	194.2 b	36.0 b	2.1 abc	200.6 a	-13.4 a
'Asul'	1.0 abc	214.0 ab	66.1 ab	2.3 abc	214.0 a	-14.3 a
'Sea Isle Supreme'	1.0 abc	208.3 ab	66.1 ab	1.1 c	245.5 a	26.1 a
'Kim-1'	---	---	---	1.4 c	246.2 a	39.5 a
Forage type Q	---	---	---	1.2 c	201.6 a	-48.4 a
Zoysia						
'Cavalier'	1.5 ab	195.1 ab	63.4 ab	2.7 a	210.6 a	-8.5a
'Palisades'	0.9 bc	223.6 ab	30.6 b	---	---	---
Bermudagrass						
'TifSport'	1.4 abc	233.7 a	92.7 a	2.0 abc	240.2 a	32.4 a
'TifEagle'	1.1 abc	196.2 ab	87.6 a	---	---	---

Table 1. Mean Japanese beetle *Popillia japonica*, grubs recovered, weight and weight gain (mg) on greenhouse-grown turfgrass species and cultivars

sampled identically to infested pots for comparison to determine root and foliage loss due to grub feeding.

Year 2

Turfgrass cultivars used during year 2 were paspalum cultivars 'Durban', Sea Isle 1', 'Sea Isle 2000, 'Sea Dwarf', 'Salam', 'Sea Spray, 'Asul', 'Sea Isle Supreme', Forage Type Q, and 'Kim-1'. Zoysiagrass and bermudagrass cultivars were 'Cavalier' and 'TifSport'. During year 2 procedures were similar to those used for year 1 except that 6 grubs per pot were used to infest grasses on September 24, 2004. Design, replication, uninfested controls and type of data collected were identical to year 1.

Results

Year 1

Survival of grubs was influenced by cultivar (Table 1). Average survival ranged from 90% on ‘Cavalier’ zoysiagrass to 20% on ‘Sea Dwarf’ paspalum. Weight of grubs at the termination of the trial varied with cultivar and ranged from 184 to 249 mg on average. Weight of grubs initially assigned to pots did not differ. Average weight gain did vary with cultivar. Weight gain of larvae feeding on the roots of the two bermudagrasses exceeded that which occurred on ‘Palisades’ zoysiagrass and ‘HI-10’ and’ Sea Spray’ paspalums by about 40%.

During the 105-day greenhouse study, turf in some of the pots wilted and died despite a consistent watering schedule. Foliar weights of infested grass during the first sampling period demonstrated cultivar-related differences (Table 2). There

Grass Species and Cultivar	Year 1 Sample 1 Infested Wt.	Sample 1 Unifested Wt.	Sample 1 Growth Difference	Sample 2 Infested Wt.	Sample 2 Unifested Wt.	Sample 2 Growth Difference
Paspalum						
561-79	378 e	1,246 def	868 cd	113 d	175 g	63 d
'Durban'	276 e	761 f	485 d	86 d	170 g	84 cd
'Sea Isle 2000'	522 de	935 def	413 d	186 d	480 fg	259 bcd
'Sea Isle 1'	1,554 abc	3,350 ab	1,796 cde	336 abcd	1,193 ab	856 a
'Sea Dwarf'	619 de	1,200 def	581 d	193 d	423 fg	233 bcd
'Salam'	435 e	728 f	293 d	223 d	548 ef	378 bcd
'HI-10'	223 e	896 ef	790 cd	110 e	447 fg	369 bcd
'Sea Spray'	770 cde	2,045 cde	1,275 abcd	246 bcd	843 cde	596 ab
'Asul'	1,633 ab	4,041 a	2,408 a	560 a	1,383 a	823 a
'Sea Isle Supreme'	1,326 abcd	2,484 bc	1,158 bcd	451 abc	943 bcd	491 ab
Zoysia						
'Cavalier'	1,282 abcd	1,953 cde	671 cd	459 abc	923 bcd	463 abc
'Palisades'	1,341 abc	3,414 ab	2,073 ab	568 a	938 bcd	370 bcd
Bermudagrass						
'TifSport'	1,781 a	3,578 a	1,797 abc	478 ab	1,008 bc	530 ab
'TifEagle'	878 bcde	2,114 cd	1,236 abcd	266 bcd	645 def	379 bcd

Grass Species and Cultivar	Year 2 Sample 1 Infested Wt.	Sample 1 Unifested Wt.	Sample 1 Growth Difference	Sample 2 Infested Wt.	Sample 2 Unifested Wt.	Sample 2 Growth Difference
Paspalum						
'Kim-1'	814 cde	436 d	222 cd	54 bcd	93 bcd	39 ab
'Durban'	1,408 bc	163 ab	205 abc	81 bc	136 bcd	55 ab
'Sea Isle 2000'	1,696 ab	1,489 abc	-208 bcd	56 bcd	129 bcd	73 a
'Sea Isle 1'	628 de	1,338 abc	710 ab	50 bcd	106 bcd	56 ab
'Sea Dwarf'	1,061 bcd	1,268 abc	206 abc	86 bc	154 b	68 ab
'Salam'	581 de	1,031 bcd	450 abc	25 d	105 bcd	80 a
Forage Type Q	850 cde	1,960 a	1,110 a	60 bcd	149 bc	89 a
'Sea Spray'	2,181 a	978 bcd	-1,204 d	58 bcd	141 bcd	84 a
'Asul'	251 e	736 bcd	485 abc	19 d	89 cd	70 ab
'Sea Isle Supreme'	651 de	118 bcd	524 abc	44cd	114 bcd	70 ab
Zoysia						
'Cavalier'	1,383 bc	1,678 ab	295 abc	150 a	248 a	98 a
Bermudagrass						
'TifSport'	1,415 bc	1,091 bcd	-324 bcd	91 b	85 d	-6 b

Table 2. Mean foliar growth dry weight (mg) of greenhouse-grown turfgrass species and cultivars infested by Japanese beetle, *Popillia japonica*, grubs

Grass Species and Cultivar	Year 1			Year 2		
	Infested Wt.	Unifested Wt.	Growth Difference	Infested Wt.	Unifested Wt.	Growth Difference
Paspalum						
'Kim-1'	----------	----------	----------	393 fg	563 f	145 bc
561-79	1,480 efg	2,950 de	1,470 bed	----------	----------	----------
'Durban'	974 fg	1,867 de	1,177 cd	1,295 de	1,731 cdef	253 bc
'Sea Isle 2000'	1,538 efg	2,038 de	500 d	1,090 def	2,462 bcd	1,222 ab
'Sea Isle 1'	2,890 cdefg	4,135 cd	1,245 cd	1,170 de	1,955 bcde	857 abc
'Sea Dwarf'	2,049 defg	6,208 bc	4,159 ab	1,804 cd	3,127 b	1,428 ab
'Salam'	1,180 efg	2,003 de	893 d	296 g	835 ef	580 abc
'HI-10'	281g	918 e	636 d	----------	----------	----------
'Forage Type Q'	----------	----------	----------	655 efg	2,440 bcd	1,738 a
'Sea Spray'	1,785 defg	970 de	1,185 cd	1,959 c	2,123 bcde	68 bc
'Asul'	3,975 bcd	9,625 bc	2,350 abcd	191 g	933 ef	760 abc
'Sea Isle Supreme'	2,776 def	3,933 cd	1,156 cd	614 efg	1,233 def	587 abc
Zoysia						
'Cavalier'	5,021 bc	9,150 a	4,129 ab	4,756 abcd	5,857 a	693 abc
'Palisades'	6,058 ab	9,953 a	3,895 abc	----------	----------	----------
Bermudagrass						
'TifSport'	7,285 a	9,240 a	1,955 abcd	2,678 b	2,703 bc	-203 c
'TifEagle'	3,288 cde	7,815 ab	4,528 a	---------	----------	----------

Table 3. Mean root growth dry weight (mg) of greenhouse-grown turfgrass species and cultivars infested by Japanese beetle, *Popillia japonica*, grubs

were, however, also significant cultivar-related differences in top growth of uninfested plants. The difference between top growth of infested plants and their uninfested controls was significant by cultivar with 'Salam', 'Sea Dwarf', 'Sea Isle 2000' and 'Durban' paspalums displaying the least grub-inflicted reductions in top growth during the first sampling period.

Foliar dry weights during the second sampling period were influenced by cultivar for infested grasses, uninfested controls, and for the difference between infested and uninfested, with 561-79 and 'Durban' paspalums demonstrating the least effect on top growth after 105 days in the greenhouse, although 'Durban' was not significantly different from seven other selections evaluated (Table 2).

Root dry weights (Table 3) similarly showed cultivar-related effects for infested turf, uninfested controls, and the difference between the two. Cultivars demonstrating the least root loss were 'Sea Isle 2000', 'HI-10', and 'Salam' paspalums.

While grub survival and final weights varied among cultivars, it was similar among the three grass genera (Table 4). However, weight gain was greatest on zoysia . Foliar growth dry weights from infested grasses were least for paspalum during the first and second samples (Table 5). Uninfested weights were least for paspalum during the first sample, but were similar for the second sample. The growth differences during the first and second samples were also similar among species. Root dry weights among species during year 1 (Table 6) were always least for Paspalum compared with bermudagrass and zoysiagrass for infested, uninfested and the growth difference.

Year 2

Survival of grubs was influenced by cultivar. Average survival ranged from 45% on

Grass Genus	Year 1			Year 2		
	Grubs recovered	Grub weight	Weight gain	Grubs recovered	Grub weight	Weight gain
Paspalum	1.2 a	212 a	55 b	1.8 a	219 a	-3.4 a
Zoysia	1.2 a	215 a	90 a	2.8 a	211 a	-8.5 a
Cynodon	1.2 a	206 a	51 b	2.0 a	240 a	32.4 a

Table 4. Mean Japanese beetle, P*opillia japonica*, grubs recovered, weight, and weight gain (mg) on greenhouse-grown turfgrass species

'Cavalier' zoysiagrass to 18% on 'Sea Isle Supreme' paspalum. Weight of grubs at the termination of this trial was similar among cultivars. Average weight difference did not vary with cultivar. Foliar weights of infested grass during the first sampling period demonstrated cultivar-related differences (Table 2). There were, also again significant cultivar related differences in top growth of uninfested plants. The difference between top growth of infested plants and their uninfested controls was significant by cultivar with 'Kim-1', 'Sea Isle 2000', 'Sea Spray', and 'TifSport' actually demonstrating an increase in topgrowth compared with uninfested control plants during the first sampling period.

Foliar dry weights during the second sampling period were again influenced by cultivar for infested grasses, uninfested controls, and for the difference between infested and uninfested, with 'TifSport' bermudagrass demonstrating the best top growth at the end of the infestation period.

Root dry weights (Table 3) similarly showed cultivar related effects for infested turf, uninfested controls, and the difference between the. Cultivars demonstrating the least root loss were 'TifSport' bermudagrass and 'Sea Spray' and 'Kim-1' paspalums.

During year 2, grub survival, final weights, and weight differences were similar among the three grass genera (Table 4). Foliar growth dry weights from infested grasses were least for paspalum and bermudagrass during the second sample (Table 5). Uninfested weights were least for bermudagrass and paspalum during the second sample only. The growth differences during the second sample were least for the bermudagrass. Root dry weights among species during year 2 (Table 6) were least for paspalum compared with bermudagrass and zoysiagrass for infested and uninfested root dry weights, but were similar for the growth difference.

Grass Species and Cultivar	Year 1					
	Sample 1			Sample 2		
	Infested Wt.	Unifested Wt.	Growth Difference	Infested Wt.	Unifested Wt.	Growth Difference
Paspalum	781 b	1,768 b	1,010 a	256 b	661 a	423 a
Zoysia	1,330 a	2,846 a	1,516 a	372 ab	826 a	454 a
Bermudagrass	1,311 a	2,683 ab	1,372 a	513 a	930 a	417 a
Grass Species and Cultivar	**Year 2**					
	Sample 1			**Sample 2**		
	Infested Wt.	Unifested Wt.	Growth Difference	Infested Wt.	Unifested Wt.	Growth Difference
Paspalum	1,012 a	1,202 a	190 a	53 b	1,215 b	68 a
Zoysia	1,383 a	678 a	295 a	150 a	248 a	98 a
Bermudagrass	1,415 a	1,091 a	-324 a	91 b	85 b	-6.2 b

Table 5. Mean foliar growth dry weight (mg) of greenhouse-grown turfgrass species infested by Japanese beetle, *Popillia japonica*, grubs

Grass Genus	Year 1			Year 2		
	Infested Wt.	Unifested Wt.	Growth Difference	Infested Wt.	Unifested Wt.	Growth Difference
Paspalum	1,914 b	3,408 b	1,500 b	947 c	1,739 b	764 a
Zoysia	5,286 a	8,528 a	3,241 a	4,756 a	5,857 a	693 a
Bermudagrass	5,539 a	9,551 a	4,012 a	2,678 b	2,703 b	20 a

Table 6. Mean root growth dry weight (mg) of greenhouse-grown turfgrass species infested by Japanese beetle, *Popillia japonica*, grubs

Discussion

Among the paspalums evaluated, those demonstrating improved ability to tolerate grub feeding measured as reduced impact on foliar growth were 561-79, 'Sea Isle 2000', 'Durban', 'HI-10', 'Kim-1', 'Sea Dwarf' and 'Sea Spray'. We expected turf types with the largest root mass to be the most tolerant of grub injury. Among paspalums, the cultivar with the largest root mass was 'Sea Dwarf'. However, this turf type also had the largest root loss among the paspalums. Among all turf types tested, 'Cavalier' and 'Palisades zoysiagrasses and 'TifSport' bermudagrass had the greatest uninfested root weights. Cultivars within the paspalums that lost the least root mass, 'Sea Isle 2000', 'HI-10', and 'Salam' during year 1 and 'Sea Spray' during year 2, were among those demonstrating the best top growth despite grub feeding. Grubs gained the most weight and consumed the most roots on 'TifEagle' bermudagrass. Grub survival varied considerably between years.

Paspalums vary in their response to other important pests impacting turfgrass in the southeastern United States. Paspalums have been shown to be relatively susceptible to fall armyworms (2, 5) among other warm-season grasses and in comparison with the cool-season grass, tall fescue. Parasitism of the fall armyworm by *Aleiodes laphygmae* Viereck was highest in the field on paspalum versus that which occurred on bermudagrass or zoysiagrass cultivars (4). Predation by big eyed bugs, *Geocoris uliginosus* Say in laboratory evaluations was greatest on zoysiagrass, but in the field, mortality of fall armyworms due to big eyed bugs was greatest on paspalums (3).

Survival of two lined spittlebugs in greenhouse studies was greatest on centipedegrass followed by bermudagrass, seashore paspalum, and zoysiagrass (12). Development times were extended when spittlebugs were feeding on paspalums. In field trials, 'SeaIsle 2000' was among four paspalums that demonstrated the best regrowth potential following spittlebug infestation. In greenhouse, laboratory, and field evaluations for mole cricket tolerance, none of the tested genotypes was highly resistant to mole cricket injury, but 'TifSport' bermudagrass and 561-79 paspalum were the most tolerant (1).

The gradients in response among paspalums to grub-induced injury mirror the previously observed variation in response to other turf pests. Those turf selections that demonstrated greater ability in the greenhouse to tolerate Japanese beetle larval feeding require further evaluation under low maintenance conditions in the field. It is possible that predation or parasitism by natural enemies of grubs could be similarly influenced by turf type. Tiger beetles, *Megacephala carolina carolina* L. were most abundant in 561-79 paspalum and 'TifEagle 'bermudagrass plots in the field (3). The activity of predaceous adults overlaps with larval Japanese beetles upon which the adult beetles have been observed to feed. Extrinsic resistance or the action of natural enemies as influenced by turf types offers opportunities for pest management and conservation biological control that merit further research.

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