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Field Responses of Bermudagrass and Seashore paspalum Cultivars to Sting and Spiral Nematodes

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Abstract: Belonolaimus longicaudatus and *Helicotylenchus* spp. are damaging nematode species on bermudagrass (*Cynodon* spp.) and seashore paspalum (*Paspalum vaginatum*) in sandy soils of the southeastern United States. Eight bermudagrass and three seashore paspalum cultivars were tested for responses to both nematode species in field plots for two years in Florida. Soil samples were taken every three months and nematode population densities in soil were quantified. Turfgrass aboveground health was evaluated throughout the growing season. Results showed that all bermudagrass cultivars, except TifSport, were good hosts for *B. longicaudatus,* and all seashore paspalum cultivars were good hosts for *H. pseudorobustus.* Overall, bermudagrass was a better host for *B. longicaudatus* while seashore paspalum was a better host for *H. pseudorobustus.* TifSport bermudagrass and SeaDwarf seashore paspalum cultivars supported the lowest population densities of *B. longicaudatus.* Seashore paspalum had a higher percent green cover than bermudagrass in the nematode-infested field. Nematode intolerant cultivars were identified.
Key words: Belonolaimus longicaudatus, bermudagrass, *Cynodon* spp., field, *Helicotylenchus* spp., *Paspalum vaginatum*, resistance, seashore paspalum, spiral nematodes, sting nematodes.

Bermudagrass (*Cynodon* spp.) is a warm-season turfgrass widely used on golf courses, sports fields, and home lawns in the warmer regions of the USA. Use of seashore paspalum (*Paspalum vaginatum* Swartz) has increased primarily in the coastal areas of the USA with the development of cultivars having finer leaf texture, high turf quality and excellent salinity tolerance (Dudeck and Peacock, 1985; Duncan, 1999a). However, a major limitation of planting turfgrasses in the sandy soils of the southeastern United States is the destruction of roots by plant-parasitic nematodes (Perry and Rhoades, 1982; Hixson et al., 2004). *Belonolaimus longicaudatus* Rau and *Helicotylenchus* spp. are found in the southeastern United States on turfgrasses and are prevalent in sandy soils (Holdeman, 1955; Christie, 1959; Robbins and Barker, 1974). *Belonolaimus longicaudatus* is the most damaging nematode species on turfgrasses in Florida (Crow, 2005). Feeding by *B. longicaudatus* can cause stunted root growth, decreased plant water and nutrient uptake, and decreased rates of plant evapotranspiration (Johnson, 1970; Perry and Rhoades, 1982; Busey et al., 1991; Giblin-Davis et al., 1992a; Busey et al., 1993; Luc et al., 2006). *Helicotylenchus* spp. has been found in turfgrasses on golf courses and home lawns in Canada and the United States (Yu et al., 1998; Hixson and Crow, 2004). Jordan and Mitkowski (2006) reported that *Helicotylenchus* spp. occurred in all 38 golf courses and 110 putting greens (98.2%) surveyed in New England. A survey of seashore paspalum golf courses and lawns found that 50% of golf courses and 40% of home lawns in Florida were infested with *B. longicaudatus*; while 88% of golf courses and 85% of home lawns were infested with *Helicotylenchus* spp. (Hixson and Crow, 2004). High densities of *Helicotylenchus* spp. (>500 nematodes/100 cm^3 soil) were often found associated with seashore paspalum in Florida (Hixson and Crow, 2004). *Belonolaimus longicaudatus* was the most common nematode found at damaging numbers in a survey of bermudagrass golf courses in Florida, present on 84% of golf courses, 60% of fairways, and 52% of greens in the golf courses surveyed (Crow, 2005). High population densities of *B. longicaudatus* that could cause damage to turfgrass were present on 60% of the golf courses, 25% of individual fairways, and 21% of individual greens surveyed (Crow, 2005). Feeding by *Helicotylenchus* spp. causes necrotic lesions and dieback of roots, which could further lead to the decline of the host plant (O'Bannon and Inserra, 1989).

Although several commercial bermudagrass cultivars and germplasm have been tested for their responses to *B. longicaudatus* or *Helicotylenchus* spp. under greenhouse conditions (Nign, 1963; Johnson, 1970; Giblin-Davis et al., 1992b; Pang et al., 2011a), information about their performance under field conditions is lacking. Davis et al. (2004) evaluated the host status of 15 commonly used forage grass species for *H. pseudorobustus* (Steiner, 1914) Golden, 1956 and found that tall fescue (*Festuca arundinacea* Schreb.), annual bluegrass (*Poa annua* L.), paspalum (*Paspalum* spp.), and perennial ryegrass (*Lolium perenne* L.) were all good hosts for *H. pseudorobustus* under controlled conditions. Mixed populations of *B. longicaudatus* and *Helicotylenchus* spp. in the field have been reported (Sasser et al., 1975; Lewis et al., 1993; Sikora, et al., 2001); however, little information is available about the responses of bermudagrass or seashore paspalum to both nematode species under field conditions. Therefore, the objectives of this study were to evaluate the responses of several commercial bermudagrass and seashore paspalum cultivars to *B. longicaudatus* and *H. pseudorobustus* under field conditions;

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and to evaluate the health of these cultivars grown in a nematode-infested environment.

Materials and Methods

Field study: A field experiment was conducted from May 2008 to June 2010 at the IFAS Agronomy Forage Research Unit (29°48.0' North, 82°25.1' West) in Hague, Florida. The soil type was a flatwood soil (2% clay, 6% slit, and 92% sand) with 5% organic matter and a pH value of 5.9. The field selected for this experiment was naturally infested with *B. longicaudatus* and *H. pseudorobustus*, along with low numbers of *Meloidogyne* sp., *Paratrichodorus* sp., *Mesocriconema ornatum, Hemicycliophora* sp., *Hemicriconemoides* sp., *Pratylenchus* sp., and *Tylenchorhynchus* sp. Fifty-five 1.5-m × 1.5-m square plots were laid out, with 0.3-m-wide non-planted border areas. Treatments consisted of the following 11 turfgrass cultivars: five dwarf bermudagrass cultivars 'Tifgreen', 'Champion', 'MiniVerde', 'TifEagle', and 'Floradwarf'; three non-dwarf cultivars 'Tifway', 'Celebration', and 'TifSport'; and three seashore paspalum cultivars 'Aloha', 'Sea Isle 1', and 'SeaDwarf'. The experiment was a randomized complete block design with five replications and lasted for two years.

Turfgrasses were propagated by planting nematode free aerial stolons into 15-cm-diam. clay plots in a greenhouse at the University of Florida under a temperature range of 24°C to 34°C with natural daylight. Grasses were fertilized once a week using 24-8-16 (N-P_2O_5-K_2O) at a rate of 0.5 kg N/100 m^2 per growing month. Turfgrass was watered by overhead irrigation for 6 min every day and clipped once a week. Ten pots were maintained for each cultivar. Well-established nematode-free grasses were transplanted from the greenhouse to the field plots on May 26, 2008. For planting, each pot was divided in half to provide four plugs for each plot. Plugs were planted into 0.6-m × 0.6-m squares in the plot centers. Grasses were watered for 15 min three times a day for the first 20 days, and irrigated as needed thereafter. Fertilizer 10-10-10 (N-P_2O_5-K_2O) was applied biweekly at a rate of 0.5 kg N/100 m^2 per growing month from May to October.

Nematode population densities in each plot were assayed just prior to planting. Nine soil cores (2.5-cm-diam. × 10-cm-deep) were randomly collected using a 2.5-cm-diam. cone-shaped sampler to form a representative sample for each plot. Sample holes were then refilled with air-dried natural field soil from the same field. The soil in each sample was well mixed and nematodes were extracted from 100-cm^3 sub-sample of soil using a modified centrifugal-flotation technique (Jenkins, 1964). The plant-parasitic nematodes were identified to genus and counted under an inverted light microscope at ×32 magnification. Nematode population densities were assayed similarly every three months throughout the study. Grasses were mowed at 2.5 cm with a reel mower, and gramineous weeds were hand picked when needed. Pesticide applications included 2,4-D and dicamba mixture (Outlaw™, Helena Chemical Company, Collierville, TN) at a rate of 1.8 L/ha to control weeds, azoxystrobin (Heritage®, Syngenta, Wilmington, DE) at a rate of 0.6 kg/ha to prevent fungal disease, *Bacillus thuringiensis,* subsp. *kurstaki* (DiPel®, Valent BioSciences, Libertyville, IL) at a rate of 1.1 kg/ha and fipronil (TopChoice®, Bayer CropScience, Research Triangle Park, NC) at a rate of 5.6 kg/ha to control caterpillar (order Lepidoptera) and mole crickets (*Scapteriscus* spp.) when needed.

Turfgrass health was determined by evaluating root lengths and percent green cover every three months throughout the growing season. Digital images of each plot were analyzed using the SigmaScan Pro software (SPSS, Inc., Chicago, IL) to determine the percentage of green pixels in the image (PGC) (Karcher and Richardson, 2005). Turfgrasses were dormant during March of both years; therefore, these images were not included in the analysis. Root samples were collected from two soil cores (4-cm-diam. × 15-cm-deep) taken randomly in each plot to form a representative sample and the holes were then filled with air-dried natural field soil from the same field. Samples were stored in a cooler until processing. Roots were collected by removing the shoots and thatch, and washing them free of soil on an 853-μm sieve. The roots were then placed into a 50-ml plastic tube and submerged with water. Finer roots were further separated from soil and collected into the plastic tube by submerging and shaking the 853-μm sieve in tap water. Roots were digitally scanned using WinRhizo root scanning equipment and software (Regent Instruments, Ottawa, Ontario, and CA). Total root length of each sample was quantified.

Statistical analysis: Percent green cover, total root length, and nematode population densities at each sample date were subjected to analysis of variance (ANOVA), and the differences among cultivars were compared using Fisher's protected least significant difference (LSD) test at $P \leq 0.05$. Statistical analysis was conducted by using the SAS software (SAS Institute, Cary, NC). Data for bermudagrass dwarf cultivars, non-dwarf cultivars, and seashore paspalum cultivars were analyzed separately. Nematode population density changes across sample date were analyzed too. Interaction relationship between *B. longicaudatus* and *H. pseudorobustus* on all turfgrass cultivars was determined by correlation analyses. Linear regression analyses were conducted to determine the relationship between: 1) the soil population densities of *B. longicaudatus* or *H. pseudorobustus* and turfgrass total root length; 2) and the population densities of *B. longicaudatus* or *H. pseudorobustus* and percent green cover in each individual cultivar.

Results

Bermudagrass cultivars: For both dwarf and non-dwarf bermudagrass cultivars, nematode population densities

TABLE 1. Population densities of *Belonolaimus longicaudatus* on eight bermudagrass cultivars of a two-year long field study at Hague, FL.

Cultivar	Nematode population density[a]								
	May 2008	Sep 2008	Dec 2008	Mar 2009	Jun 2009	Sep 2009	Dec 2009	Mar 2010	Jun 2010
					Dwarf cultivars				
Champion	86[b]	66	276	355	178	20	40	116	118
Floradwarf	98	49	327	310	170	14	31	101	67
Tifgreen	113	92	301	273	162	33	85	225	109
MiniVerde	94	78	327	255	137	13	68	70	132
TifEagle	96	76	248	248	186	7	30	84	79
Mean	97	72	296	288	167	17	51	119	101
					Non-dwarf cultivars				
Tifway	80	43	206 a	197	61 a	8	21	44	54
Celebration	96	26	144 ab	73	69 a	5	26	25	70
TifSport	102	46	71 b	40	26 b	3	20	17	7
Mean	93	38	140	103	52	5	22	29	44

[a] Values represent numbers of nematodes recovered from 100 cm^3 of soil.
[b] Data are means of five replications; and for each cultivar type, means within a column followed by the same letter or no letter are not different ($P \leq 0.05$), Fishers protected least significant difference test.

changed significantly through time with the highest density of *B. longicaudatus* in December of 2008 and March 2009 and the lowest in September of 2009 ($P <$ 0.0001). There was no difference in the population densities of *B. longicaudatus* among all dwarf cultivars throughout the two year study (Table 1). By the end of the study, population densities of *B. longicaudatus* increased on Champion and MiniVerde, and decreased on Floradwarf, Tifgreen, TifEagle compared to their respective initial population densities in May 2008. In December 2008, the population density of *B. longicaudatus* was the highest ($P \leq 0.05$) for Tifway and lowest ($P \leq 0.05$) for TifSport, and in June 2009, the nematode population density associated with TifSport was significantly lower ($P \leq 0.05$) than observed on Tifway and Celebration cultivars (Table 1). Mean population densities of *B. longicaudatus* were not different between the dwarf and non-dwarf cultivars.

As oppose to *B. longicaudatus*, populations of *H. pseudorobustus* kept growing from the lowest of May 2008 to the highest in June of 2010 on bermudagrass ($P < 0.0001$). Densities of *H. pseudorobustus* were not different among the dwarf cultivars but increased on non-dwarf bermudagrass cultivars from 6 to 270 nematodes/100 cm^3 of soil for the duration of the study (Table 2). In June and December 2009 and June 2010, population densities in the non-dwarf cultivars of *H. pseudorobustus* were significantly higher ($P \leq 0.05$) in TifSport than the other two cultivars. Over the course of this experiment, population density increased from 6 to 744 *H. pseudorobustus*/100 cm^3 (124 fold) on TifSport. Mean population densities of *H. pseudorobustus* were not different between the dwarf and non-dwarf cultivars.

Root lengths were not different among the dwarf bermudagrass cultivars in this study (Table 3). In September 2009, the root length of non-dwarf cultivar Celebration was significantly greater ($P \leq 0.05$) than both Tifway and TifSport. Differences were not identified among the non-dwarf cultivars for the remaining root length sampling dates. There was no difference in percent green cover

TABLE 2. Population densities of *Helicotylenchus pseudorobustus* on eight bermudagrass cultivars for the two-year field study at Hague, FL.

Cultivar	Nematode population density[a]								
	May 2008	Sep 2008	Dec 2008	Mar 2009	Jun 2009	Sep 2009	Dec 2009	Mar 2010	Jun 2010
					Dwarf cultivars				
Champion	5[b]	5	13	6	20	13	76	74	100
Floradwarf	11	7	15	5	11	61	65	84	117
Tifgreen	11	16	20	25	30	84	175	137	187
MiniVerde	4	6	4	4	10	22	14	25	48
TifEagle	22	17	17	31	19	7	66	64	120
Mean	11	10	14	14	18	37	79	77	114
					Non-dwarf cultivars				
Tifway	9	4	5	3	3 b	5	8 b	10	47 b
Celebration	2	4	2	2	3 b	40	23 b	114	20 b
TifSport	6	16	130	227	262 a	198	592 a	333	744 a
Mean	6	8	46	77	89	81	208	152	270

[a] Values represent numbers of nematodes recovered from 100 cm^3 of soil.
[b] Data are means of five replications; and for each cultivar type, means within a column followed by the same letter or no letter are not different ($P \leq 0.05$), Fishers protected least significant difference test.

TABLE 3. Total root length of eight bermudagrass cultivars in nematode infested field plots of a two-year long field study at Hague, FL.

Cultivar	Total root length (cm)					
	Mar 2009	Jun 2009	Sep 2009	Dec 2009	Mar 2010	Jun 2010
			Dwarf cultivars			
Champion	540[a]	405	473	539	436	337
Floradwarf	498	486	447	732	402	438
Tifgreen	634	707	801	842	671	583
MiniVerde	553	328	357	370	540	273
TifEagle	619	539	611	710	493	465
Mean	569	493	538	639	508	419
			Non-dwarf cultivars			
Tifway	659	723	566 b	831	808	739
Celebration	572	558	1054 a	1042	895	1003
TifSport	528	620	605 b	748	809	848
Mean	586	634	742	874	837	863

[a] Data are means of five replications; and for each cultivar type, means within a column followed by the same letter or no letter are not different ($P \leq 0.05$), Fishers protected least significant difference test.

among the dwarf cultivars from June 2009 to June 2010 except for December 2009 (Table 4). In December 2009, the PGC of Tifgreen was significantly higher ($P \leq 0.05$) than that of Floradwarf, TifEagle and MiniVerde; and Champion had greater PGC than MiniVerde. No other dates provided significant differences for PGC among the dwarf cultivars nor were differences found (at any dates) between the non-dwarf cultivars. The mean root lengths or percent green cover of dwarf cultivars were not different from the non-dwarf cultivars throughout the study.

Both root length (Fig. 1A) and PGC (Fig. 1B) had a weak, negative linear correlation with the population density of *B. longicaudatus* in Celebration bermudagrass cultivar (r^2=0.3 and 0.24, respectively). Regression analysis showed that for each *B. longicaudatus* in 100 cm^3 of soil, there was a corresponding reduction of 5 cm in total root length and 0.14% in PGC of Celebration cultivar. A negative linear relationship between the population densities of *H. pseudorobustus* and the total root length (Fig. 2A) or PGC (Fig. 2B) in Floradwarf bermudagrass cultivar was observed. For each *H. pseudorobustus* nematode in 100 cm^3 of soil, there was a corresponding reduction of 1 cm in total root length and 0.20% in PGC in Floradwarf.

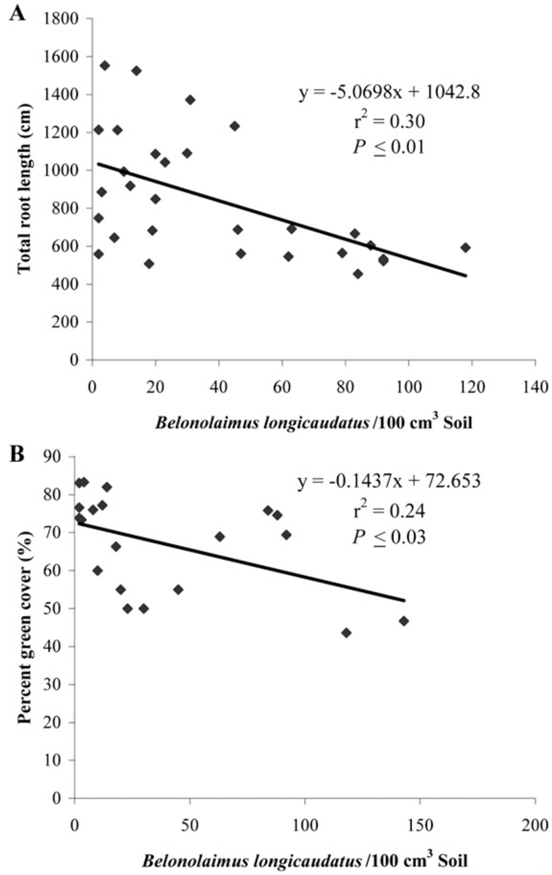

FIG. 1. Regression relationship between the total root length (A) or percent green cover (B) of 'Celebration' bermudagrass and population densities of *Belonolaimus longicaudatus* of a two-year long field study at Hague, Florida.

Results from the regression analysis also showed that *H. pseudorobustus* reduced the root length of Tifgreen bermudagrass cultivar. For each *H. pseudorobustus* nematode in 100 cm^3 of soil, there was a corresponding reduction of 0.6 cm in total root length for Tifgreen (Fig. 3). In addition, Fig. 4 shows that the PGC of TifEagle cultivar was reduced by 0.26% for each *H. pseudorobustus*/100 cm^3 of soil.

Seashore Paspalum cultivars: Population densities of *B. longicaudatus* significantly reduced ($P \leq 0.001$) in all seashore paspalum cultivars by the end of the study compared with the initial population densities of May 2008 (Table 5). Similarly to bermudagrass, *B. longicaudatus* populations significantly fluctuated throughout the two years of the field study, reaching the highest and lowest densities at the beginning and end of the

TABLE 4. Percent of aboveground green cover of eight bermudagrass cultivars in nematode infested field plots of a two-year long field study at Hague, FL.

Cultivar	Percent green cover (%)			
	Jun 2009	Sep 2009	Dec 2009	Jun 2010
		Dwarf cultivars		
Champion	61[a]	76	34 ab	57
Floradwarf	70	73	28 bc	39
Tifgreen	65	75	44 a	59
MiniVerde	72	68	22 c	33
TifEagle	73	55	26 bc	28
Mean	68	69	31	43
		Non-dwarf cultivars		
Tifway	69	79	47	64
Celebration	71	80	54	63
TifSport	72	76	57	61
Mean	71	78	53	63

[a] Data are means of five replications; and for each cultivar type, means within a column followed by the same letter or no letter are not different ($P \leq 0.05$), Fishers protected least significant difference test.

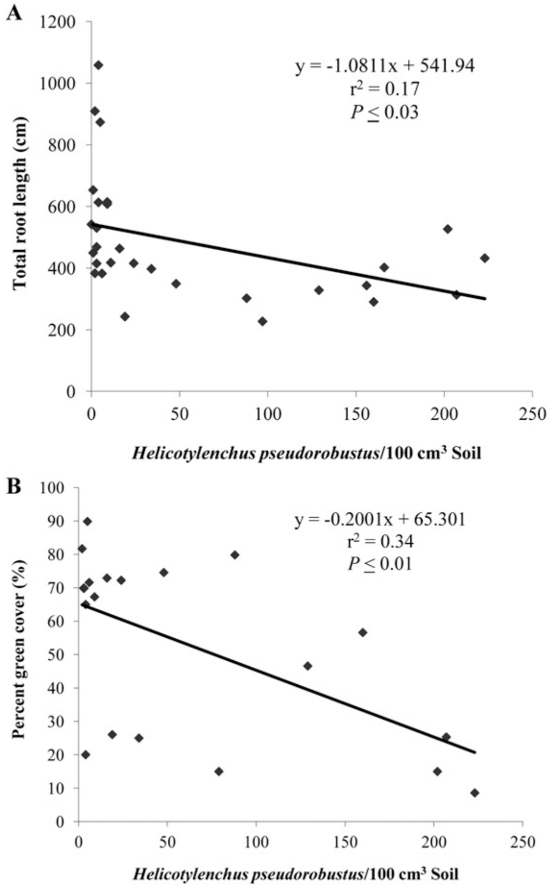

FIG. 2. Regression relationships between the total root length (A) or percent green cover (B) of 'Floradwarf' bermudagrass and population densities of *Helicotylenchus pseudorobustus* of a two-year long field study at Hague, Florida.

study, respectively ($P < 0.0001$). Population densities of *B. longicaudatus* were the highest in SeaIsle 1 and lowest in SeaDwarf cultivars in December of 2008 and June 2009, respectively. However, there were no treatment differences at other dates.

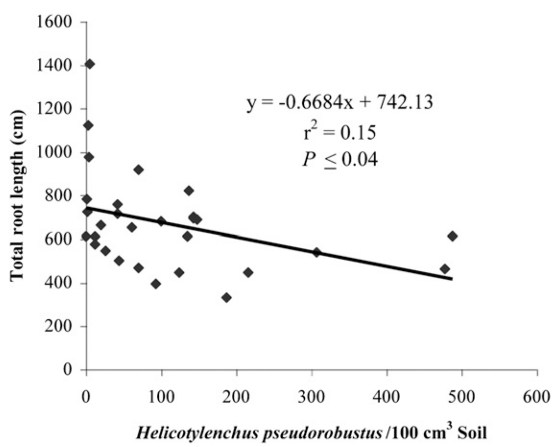

FIG. 3. Regression relationships between the total root length of 'Tifgreen' bermudagrass and the population densities of *Helicotylenchus pseudorobustus* of a two-year long field study at Hague, Florida.

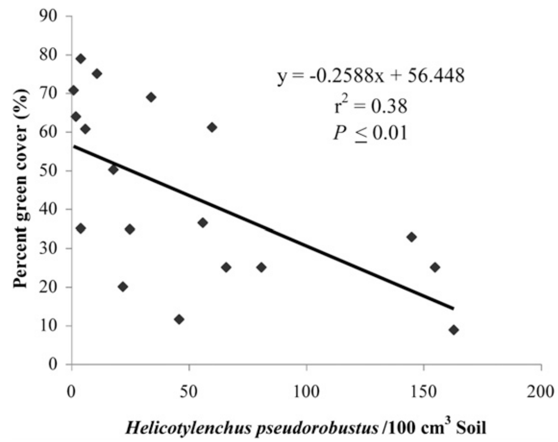

FIG. 4. Regression relationships between percent green cover in 'TifEagle' bermudagrass and the population density of *Helicotylenchus pseudorobustus* of a two-year long field study at Hague, Florida.

All of the seashore paspalum cultivars were good hosts to *H. pseudorobustus* and their densities had been continuously increasing from the lowest of May 2008 to the highest in June of 2010 ($P < 0.0001$). Population densities of *H. pseudorobustus* increased from less than 13 to as high as 1414 nematodes/100 cm^3 of soil during the study (Table 6); however, there was no difference in the population density increase among the three cultivars throughout the two years.

The total root lengths of the three cultivars varied from 373 to 993 cm, but were not different throughout the study (Table 7). No association was found between the population densities of *B. longicaudatus* or *H. pseudorobustus* and the root length of seashore paspalum. Percent green cover varied between cultivars for most dates. In June and September 2009 and June 2010, PGC of SeaDwarf cultivar was significantly higher than Aloha and SeaIsle 1 cultivars (Table 8). A negative linear relationship ($r^2 = 0.39$, $P \leq 0.01$) was found between the PGC of Aloha and the population density of *B. longicaudatus* (Fig. 5). The PGC of Aloha cultivar was reduced by 0.94% for each *B. longicaudatus* in 100 cm^3 of soil (Fig. 5).

When all bermudagrass cultivars were compared as a group to the seashore paspalum cultivars, significant

TABLE 5. Population density of *Belonolaimus longicaudatus* on three seashore paspalum cultivars of a two-year long field study at Hague, FL.

	Nematode population density[a]								
Cultivar	May 2008	Sep 2008	Dec 2008	Mar 2009	Jun 2009	Sep 2009	Dec 2009	Mar 2010	Jun 2010
Aloha	87[b]	54	104 ab	116	28 ab	7	24	23	17
SeaDwarf	134	33	75 b	115	25 b	6	21	10	6
SeaIsle 1	105	51	130 a	128	39 a	8	16	26	15

[a] Values represent numbers of nematodes recovered from 100 cm^3 of soil.
[b] Data are means of five replications; and means within a column followed by the same letter or no letter are not different ($P \leq 0.05$), Fishers protected least significant difference test.

TABLE 6. Population densities of *Helicotylenchus pseudorobustus* on three seashore paspalum cultivars of a two-year long field study at Hague, FL.

	Nematode population density[a]								
Cultivar	May 2008	Sep 2008	Dec 2008	Mar 2009	Jun 2009	Sep 2009	Dec 2009	Mar 2010	Jun 2010
Aloha	8[b]	10	162	282	611	1029	1066	1045	1414
SeaDwarf	13	33	161	254	451	585	939	515	1377
SeaIsle 1	5	15	84	226	482	564	1282	894	1070

[a] Numbers represent numbers of nematodes recovered from 100 cm^3 of soil.
[b] Data are means of five replications, and data within a column followed by no letter are not statistically different ($P \leq 0.05$).

TABLE 8. Percent of aboveground green cover of three seashore paspalum cultivars in nematode infested field plots of a two-year long field study at Hague, FL.

	Percent green cover (%)			
Cultivar	Jun 2009	Sep 2009	Dec 2009	Jun 2010
Aloha	69 b	92 b	76[a]	44 b
SeaDwarf	71 a	96 a	82	64 a
SeaIsle 1	64 b	91 b	75	44 b

[a] Data are means of five replications; and means within a column followed by the same letter or no letter are not different ($P \leq 0.05$), Fishers protected least significant difference test.

differences in responses to *B. longicaudatus* and *H. pseudorobustus* were found. Throughout both years, densities of *B. longicaudatus* declined on average of 25% on bermudagrass, and 88% on seashore paspalum. In contrast, population densities of *H. pseudorobustus* increased by 1,822% on bermudagrass, and 14,200% on seashore paspalum (Table 9). Throughout the study, population densities of *B. longicaudatus* varied from 2 to 5.5 times higher in bermudagrass than in seashore paspalum, suggesting that bermudagrass is a better host to *B. longicaudatus* than seashore paspalum (Table 9). However, population densities of *H. pseudorobustus* in seashore paspalum were 2 to 13 times higher than in bermudagrass, suggesting that seashore paspalum might be a better host to *H. pseudorobustus* than bermudagrass (Table 9). Negative correlation relationships were discovered between *B. longicaudatus* and *H. pseudorobustus*, which could indicate a competition when they were together in soil. Weak relationship between *B. longicaudatus* and *H. pseudorobustus* was found in Celebration, Mini Verde, TifEagle, and TifSport bermudagrass cultivars ($-0.4 < r < -0.3$, $P < 0.05$), and stronger relationship was in all seashore paspalum cultivars ($-0.7 < r < -0.6$, $P < 0.0001$). The root lengths of bermudagrass and seashore paspalum were not different throughout the study (Table 10). However, PGC ($P \leq 0.05$) was different between the two species for two of four sampling dates (Table 10).

DISCUSSION

All bermudagrass cultivars except TifSport were good hosts for *B. longicaudatus*. During the two-year field study, population densities of *B. longicaudatus* exhibited seasonal fluctuations, but at the end of the study densities increased on Champion and MiniVerde, slightly dropped in Tifgreen, TifEagle, and Celebration cultivars, and dropped by 32%, 33%, and 93% respectively in Floradwarf, Tifway and TifSport cultivars. Population densities of *B. longicaudatus* on TifSport continuously declined and remained the lowest among the cultivars evaluated, indicating that TifSport might have some level of resistance to *B. longicaudatus.* Earlier greenhouse studies of bermudagrass response to *B. longicaudatus* indicated that TifSport suffered less root damage from *B. longicaudatus* than other bermudagrass cultivars evaluated (Pang et al., 2011a). Conversely, TifSport was a good host for *H. pseudorobustus*, and supported a 124-fold increase in population density. Therefore, among bermudagrasses, TifSport cultivar was the poorest host to *B. longicaudatus* and yet the best host to *H. pseudorobustus*. This differential response of TifSport to two nematode species might be of great significance to consider when selecting a turfgrass for use or when designing a breeding program for improving nematode responses. It could be practical for turfgrass users to test soil samples for presence and densities of nematode species before selecting a cultivar. If *B. longicaudatus* is the major nematode species causing high damage, then using

TABLE 7. Total root length of three seashore paspalum cultivars in nematode infested field plots of a two-year long field study at Hague, FL.

	Total root length (cm)					
Cultivar	Mar 2009	Jun 2009	Sep 2009	Dec 2009	Mar 2010	Jun 2010
Aloha	506[a]	438	413	647	457	373
SeaDwarf	622	651	558	807	760	768
SeaIsle 1	552	365	577	993	514	572

[a] Data are means of five replications, and data within a column followed by no letter are not statistically different ($P \leq 0.05$).

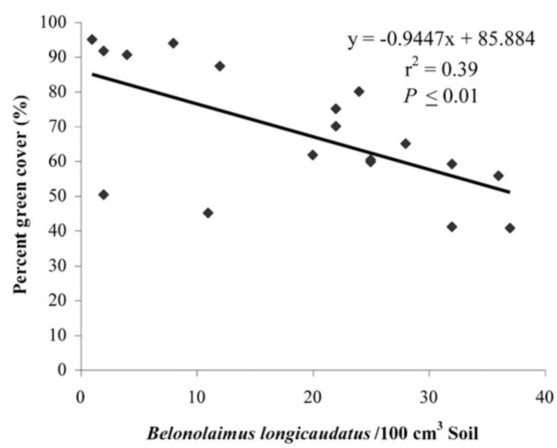

FIG. 5. Regression relationships between the percent green cover in 'Aloha' seashore paspalum and the population densities of *Belonolaimus longicaudatus* of a two-year long field study at Hague, Florida.

TABLE 9. Population densities of *Belonolaimus longicaudatus* and *Helicotylenchus pseudorobustus* on bermudagrass and seashore paspalum of a two-year long field study at Hague, FL.

Cultivar	May 2008	Sep 2008	Dec 2008	Mar 2009	Jun 2009	Sep 2009	Dec 2009	Mar 2010	Jun 2010
				Population density of *Belonolaimus longicaudatus*					
Bermudagrass	96[ab]	60	237 a	219 a	124 a	13	40	85	72 a
Seashore paspalum	109	46	103 b	119 b	31 b	7	20	20	13 b
				Population density of *Helicotylenchus pseudorobustus*					
Bermudagrass	9	9 b	26 b	38 b	45 b	54 b	127 b	105 b	173 b
Seashore paspalum	9	20 a	136 a	254 a	515 a	726 a	1096 a	818 a	1287 a

[a] Numbers of nematodes recovered from 100 cm^3 of soil.
[b] Data are means of five replications; and means within a column followed by the same letter or no letter are not different ($P \leq 0.05$), Fishers protected least significant difference test.

TifSport cultivar instead will minimize nematode damage; however, if *H. pseudorobustus* is predominate in the soil, TifSport would not be a good choice.

In contrast to most bermudagrass cultivars, the population densities of *B. longicaudatus* in seashore paspalum declined from 109 to13 nematodes/100 cm^3 soil over the two year field experiment. Potential explanations for this decline include: 1) Seashore paspalum might be a non-host to *B. longicaudatus* under field conditions, although this would contradict the results of greenhouse experiments and general field observations (Hixson et al., 2005; Pang et al., 2011b); 2) Seashore paspalum might be intolerant to *B. longicaudatus* and have a low carrying capacity, agreeing with observations by Hixson et al. (2005); or 3) Field interactions between *B. longicaudatus* and *H. pseudorobustus* may affect the reproduction rate of *B. longicaudatus*.

Throughout the study, differences in PGC among the bermudagrass dwarf cultivars were observed only in December 2009, which are likely related to a given cultivar's ability to retain color during periods of cooler temperatures and not related to nematode response. For nondwarf cultivars, however, a negative linear relationship between the population densities of *B. longicaudatus* and total root length or aboveground PGC was observed for Celebration bermudagrass. Greenhouse studies (Pang et al., 2011a) had shown that *B. longicaudatus* caused significant root length reductions in Celebration cultivar, confirming that it was not a tolerant cultivar for *B. longicaudatus*. The negative relationships between nematode population density and turfgrass growth parameters could indicate that Floradwarf, Tifgreen, and TifEagle cultivars may not be a tolerant cultivar for *H. pseudorobustus*. A negative linear relationship between the population densities of *B. longicaudatus* and aboveground PGC of Aloha seashore paspalum was observed. Considering these field results and the fact that its root length was reduced in a controlled greenhouse trial (Pang et al., 2011b), it appears that Aloha may not be a tolerant cultivar for *B. longicaudatus*. Based on the ability to maintain greater root lengths and PGC in nematode infested soil, SeaDwarf might be a relatively tolerant cultivar to *B. longicaudatus* feeding (Tables 7, 8). A previous greenhouse study also indicated that SeaDwarf was tolerant to *B. longicaudatus* feeding (Pang et al., 2011b). Although the relationships between nematode population densities and turfgrass plant growth parameters are significant, these weak relationships have limited practical predictive value. Compared with greenhouse studies, field studies more closely approximated a real-life situation where multiple nematode species or pathogens coexist. In the future, these cultivars could be tested under pressure from different populations or isolates of *B. longicaudatus* and *H. pseudorobustus*.

In summary, bermudagrass was a better host for *B. longicaudatus* and seashore paspalum was a better host for *H. pseudorobustus*. *Belonolaimus longicaudatus* is more damaging than *H. pseudorobustus* to bermudagrass with the exception of TifSport cultivar, which was relatively resistant to *B. longicaudatus*, but an excellent host for *H.*

TABLE 10. Total root length and aboveground percent green cover of bermudagrass and seashore paspalum in nematode infested field plots of a two-year long field study at Hague, FL.

Cultivar	Mar 2009	Jun 2009	Sep 2009	Dec 2009	Mar 2010	Jun 2010
			Total root length (cm)			
Bermudagrass	576[a]	546	614	727	632	586
Seashore paspalum	560	484	516	815	577	571
			Percent green cover (%)			
Bermudagrass	——	69	73 b	39 b	51	——
Seashore paspalum	——	65	93 a	78 a	51	——

[a] Data are means of five replications; and means within a column followed by the same letter or no letter are not different ($P \leq 0.05$), Fishers protected least significant difference test.
——Data were not collected.

pseudorobustus. The seashore paspalum cultivars evaluated were all good hosts for *H. pseudorobustus*, and this nematode species appeared more damaging than *B. longicaudatus* to seashore paspalum. Seashore paspalum had higher PGC than bermudagrass in the nematode-infested field studies. TifSport bermudagrass might be a good choice for tees and fairways infested with *B. longicaudatus*. SeaDwarf might be a good seashore paspalum cultivar to use on greens infested with *B. longicaudatus*.

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