SEASONAL FLUCTUATIONS OF *BELONOLAIMUS LONGICADATUS* IN BERMUDAGRASS[1]

P. Mc Groary[2]*, W. T. Crow[2], R. McSorley[2], R. M. Giblin-Davis[3], and J. L. Cisar[3]

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[2]Former Graduate Research Assistant, Associate Professor, and Professor, respectively. Entomology and Nematology Department, University of Florida, Gainesville, FL 32611, USA; [3]Professor, University of Florida-IFAS, Fort Lauderdale Research and Education Center, Davie, FL 33314, USA. *Corresponding author:pmcg@ufl.edu

ABSTRACT

Mc Groary, P. C., W. T. Crow, R. McSorley, R. M. Giblin-Davis, and J. L. Cisar. 2009. Seasonal fluctuations of *Belonolaimus longicaudatus* in bermudagrass. Nematropica 39:99-110.

Sting nematode (*Belonolaimus longicaudatus*) is an important pest of bermudagrass (*Cynodon dactylon)*, and other turfgrasses grown in the southeastern United States. On bermudagrass, *B. longicaudatus* causes severe damage to lateral roots, decreased water and nutrient uptake, and decreased rates of evapotranspiration leading to reduced turf quality, color, and density. Field experiments from January 2005 to March 2007 were conducted to monitor the seasonal dynamics of *B. longicaudatus* populations, bermudagrass root growth, and soil temperatures on four bermudagrass fairways in Florida in order to develop an empirical optimum time for nematicide application. Seasonal fluctuations in *B. longicaudatus* and root growth varied among locations and years, but similar trends were observed in all four trials for nematodes and root growth. Linear regression models relating root length to nematode population densities (0-15 cm depth) were significant ($P \leq 0.1$) at three of four sites. At the University of Florida Ft. Lauderdale Research and Education Center site, root length and nematode population were correlated ($P \leq 0.1$) in April and May. However at the Ironwood Golf Course site, root length was related to nematode population ($P \leq 0.1$) in June, September, and October. At the Sandpiper Golf Club site, root length and *B. longicaudatus* population densities were significantly related ($P < 0.1$) only in July. However, regression analysis did not provide consistent predictive models to characterize relationships between *B. longicaudatus* and root length.

Key words: Belonolaimus longicaudatus, bermudagrass, *Cynodon* sp., nematode, population fluctuations, root growth, soil temperature, sting nematode, turfgrass.

RESUMEN

Mc Groary, P. C., W. T. Crow, R. McSorley, R. M. Giblin-Davis, and J. L. Cisar. 2009. Fluctuaciones estacionales de *Belonolaimus longicaudatus* en pasto bermuda. Nematropica 39:99-110.

El nematodo *Belonolaimus longicaudatus* es una plaga importante del pasto bermuda (*Cynodon dactylon)* y de otros pastos en el sureste de los Estados Unidos. En pasto bermuda, *B. longicaudatus* ocasiona daños severos a las raíces laterales, causa reducción en la capacidad de toma de agua y nutrientes, y reduce la tasa de evapotranspiración, lo cual causa una reducción en la calidad, el color y la densidad del pasto. Se llevaron a cabo experimentos de campo entre enero 2005 y marzo 2007 para seguir la dinámica estacional de las poblaciones de *B. Longicaudatus,* el crecimiento del pasto bermuda, y las temperaturas del suelo, en cuatro campos de golf en Florida, con el fin de determinar el momento óptimo de aplicación de nematicidas. Se observaron variaciones en las fluctuaciones estacionales en las poblaciones del nematodo y el crecimiento de las raíces entre localidades y años, pero se observaron tendencias similares en los cuatro ensayos. Los modelos de regresión lineal que describen la relación entre el crecimiento de las raíces y las densidades de población del nematodo (0-15 cm de profundidad) fueron significativos ($P \leq 0.1$) para las cuatro localidades. En el sitio ubicado en University of Florida Ft. Lauderdale Research and Education Center, se observó correlación ($P \leq 0.1$) entre la longitud de las raíces y la población de los nemtodos en abril y mayo. Sin embargo, para el sitio ubicado en Ironwood Golf Course, la longitud de las raíces se relacionó con la población de nematodos ($P \leq 0.1$) en junio, septiembre y octubre. En el sitio ubicado en Sandpiper Golf Club, la longitud de las raíces y la desidad de población de *B. longicaudatus* se relacionaron significativamente ($P <$ 0.1) sólo en julio. El análisis de regresión no suministró ningún modelo predictivo consistente para caracterizar la relación entre *B. longicaudatus* y la longitud de las raíces.

Palabras clave: Belonolaimus longicaudatus, Cynodon sp., crecimiento de raíces, flutuaciones poblacionales, nematodo, pastos, pasto bermuda, temperatura del suelo.

INTRODUCTION

Belonolaimus longicaudatus Rau is an important pest of bermudagrass (*Cynodon dactylon* L.) and other turfgrasses grown in the southeastern United States. It is found predominately in soils with >80% sand content (Robbins and Barker, 1974). Feeding by *B. longicaudatus* can cause varying degrees of damage to root systems depending on plant type and age when the root system is first attacked. On bermudagrass, *B. longicaudatus* feeding typically causes severe damage to lateral roots that decrease water and nutrient uptake, but rarely kills the plant (Christie, 1959; Johnson, 1970). However, *B. longicaudatus* can predispose turfgrass to adverse conditions such as drought stress, heat stress, and malnutrition which could lead to a reduction in turf quality (Lucas, 1982).

Current strategies to reduce damage from this pest are limited to preplant or postplant nematicides (Bekal and Becker, 2003). However, options for chemical control have been reduced with the withdrawal of ethoprop and the voluntary cancellation of all product registrations of fenamiphos effective 31 May 2007 (Anonymous, 2002). The loss of these organophosphate nematicides has led to the development of new uses for existing nematicides. One of the most promising of these is 1, 3-dichloropropene (1,3-D) the active ingredient in Curfew® Soil Fumigant (Dow AgroSciences, Indianapolis, IN). Crow *et al.* (2003; 2005) reported that post-plant applications of 1,3-D at 55 kg a.i./ha significantly lowered populations of *B. longicaudatus* on bermudagrass. However, 1,3-D is typically limited to one application per year on golf courses due to its high application cost. Because 1,3-D has no residual activity, sting nematode numbers can rebound quickly following an application (Crow *et al.*, 2005).

In order to maximize the efficacy of a nematicide application, the nematicide should be applied when *B. longicaudatus* populations are expected to increase and/or when they are capable of doing the most damage to the grass roots. Therefore, the seasonal population dynamics of *B. longicaudatus* on bermudagrass must be determined to predict the optimal timing of a nematicide application. The objective of this study was to monitor the seasonal dynamics of *B. longicaudatus,* bermudagrass root growth, and soil temperatures on golf course fairways in Florida in order to develop a empirically optimum time for nematicide application. Validation of this theoretical model will be tested in later studies.

MATERIALS AND METHODS

Studies were conducted from January 2005 to March 2007 on four bermudagrass fairway sites naturally infested with *B. longi-*

caudatus along with, *Hoplolaimus galeatus* (Cobb Thorne) *Trichodorus* sp., *Hemicycliophora* sp., *Mesocriconema* sp., and *Meloidogyne* sp. Trial 1 (January 2005 to December 2006) was established at the University of Florida Ft. Lauderdale Research and Education Center (FLREC), Broward County, FL, and trial 2 (February 2005 to January 2006) at the Ironwood Golf Course (IW), Gainesville, FL. Trials 3 and 4 (March 2006-February 2007) were established at the Club Renaissance Golf Course (CR) and at the Sandpiper Golf Club (SP), both in Sun City, FL.

Experimental sites

In all trials, golf course fairways had stands of 'Tifway 419' bermudagrass. Soil in the experimental area at the FLREC was classified as Margate fine sand with a composition of 96% sand, 3% silt, 1% clay; with 7% organic matter and pH 7.1. Soil in the experimental area at IW was classified as Tavares fine sand with a composition of 93% sand, 3.7% silt, 3.3% clay; <1% organic matter and pH 6.5. Soil at CR and SP was classified as Fort Meade loamy fine sand. At CR the soil had a composition of 95% sand, 3.5% silt, 1.5% clay; <1% organic matter and pH 6.3. Soil at SP was 94% sand, 4.3% silt, 1.7% clay; 3% organic and pH 6.0. Experimental areas were maintained under golf course fairway conditions. Mowing, fertilization, and irrigation were provided by the maintenance staff at all sites. The fairways were mowed three times a week without grass catching baskets at a cutting height of 1.3 cm except when weather prevented. Overhead irrigation was applied using an overhead automatic irrigation system on an as-needed basis determined by the golf course superintendent. At all sites, soil temperatures were recorded at 15-cm depth throughout the experiment using temperature data recorders (StowAway Tidbit, Onset Computer Corp., Bourne, MA). Temperatures were recorded every hour and the mean was then calculated for each day, and for the entire month. To add to the aesthetics of the golf course for winter play fairways were overseeded with perennial ryegrass [*Lolium* L.] at 250kg seed/ha, in October of 2005 and 2006 at IW and CR. However, six weeks prior to the initiation of these trials, a selective herbicide Foramsulfuron (Revolver® Bayer Environmental Science, Triangle research Park, NC) was applied at 1 liter/ha to remove perennial ryegrass from the research plots. Through out the duration of the experiment no cultural practices were carried out on the experimental plots.

Experimental design

Eight weeks prior to the first sampling date 30 plots, 2-m^2 with 0.5-m borders between plots were arranged in a grid at each site and nematode samples were collected from each plot. Nematode samples consisted of nine soil cores 1.9-cm-diam. × 7.5-cm-deep from each plot combined to make a single sample. Nematodes were extracted from a 100-cm^3 subsample using a modified sugar flotation with centrifugation and counted using an inverted light microscope at 40X magnification. Based on *B. longicaudatus* population densities of the plots, only twelve plots at the FLREC and IW sites and four plots at the CR and SP sites were considered acceptable to be used in the study.

Sampling and evaluation

After the initial nematode sampling to select plots, the protocol was modified so that both nematode and root samples could be extracted from the same cores. Three cores from each plot were removed arbitrarily using T-samplers. At FLREC and IW, the cores were 5-cm-diam. × 15-cm-deep, with a total volume of 300 cm^3. At CR and SP cores were 2.5-cm-diam. × 15-cm-deep, with a total volume of 75 cm^3. Samples were taken at monthly intervals throughout the duration of the trials. Nematodes were extracted from each individual core using centrifugal flotation. For ease of comparison among sites, nematode numbers and root lengths were converted and reported per 300 cm^3 volume.

Root samples were obtained from the same cores that were used to determine plant- parasitic nematode populations. Roots were caught on an 18 mesh (1000 µm) kitchen sieve and placed into 50-ml plastic centrifuge tubes. Five drops (0.25 ml) of 1% methylene blue mixture was added to 30 ml of tap water to stain the roots. After a minimum of 24 hours in solution, the roots were removed, placed on a 75-µm-pore sieve, and washed free of excess dye. Stained roots were placed into a glass bottom tray and scanned on a flat bed scanner (Epson Perfection 4990 Photo) to create a bitmap image of the roots. The bitmap images were imported into the WinRhizo (Regent Instruments, Chemin Sainre-Foy, Quebec) software program to measure root lengths from the scanned images.

Data analysis

Linear regression models were used to relate nematode population densities with root growth and monthly mean soil temperature using SAS (SAS Institute, Carry, NC) software. Empirical observations were used to detect seasonal trends in nematode population and root length increases and declines.

RESULTS

Seasonal fluctuations in *B. longicaudatus* populations and root lengths were different for each location (Figs. 1, 2, 3, and 4). At the FLREC site, initial populations of *B. longicaudatus* were 91/300 cm^3 of soil in January 2005 (Fig. 1). The *B. longicaudatus* populations declined in February before increasing in March. In April, *B. longicaudatus* populations reached a season high with a mean of 118 *B. longicaudatus*/300 cm^3 of soil (Fig. 1). This was followed with a decrease in *B. longicaudatus* population in May and June to means of 91 and 30 *B. longicaudatus*/300 cm^3 of soil, respectively (Fig. 1). Populations of *B. longicaudatus* then increased in July before declining through the rest of the year. *Belonolaimus longicaudatus* populations reached a season low in December with a mean of 10 *B. longicaudatus*/300 cm^3 of soil (Fig. 1).

Root lengths at the FLREC site followed a similar trend as the *B. longicaudatus* populations from February through December. Root length increased from 611 to 696 mm/300 cm^3 of soil before reaching a season high of 1189 mm/300 cm^3 of soil (Fig. 1). Root length declined in May and June before increasing to a mean of 1080 mm/300 cm^3 of soil in July. In August root length declined again to a mean of 716 mm/300 cm^3 of soil (Fig. 1). Root length remained constant for the next two months. Root length declined in November before reaching a season low of 251 mm/300 cm^3 of soil in December (Fig. 1).

At IW, *B. longicaudatus* population density was greatest in February with a mean of 130/300 cm^3 of soil (Fig. 2). *Belonolaimus longicaudatus* populations declined from March through May, with means of 91, 80, and 62/300 cm^3, respectively. In June, *B. longicaudatus* populations increased slightly to 75/300 cm^3 of soil before declining in July to 14 *B. longicaudatus*/300 cm^3 of soil (Fig. 2). Populations of *B. longicaudatus* increased again in August and September before declining in October. In November and December *B. longicaudatus* population

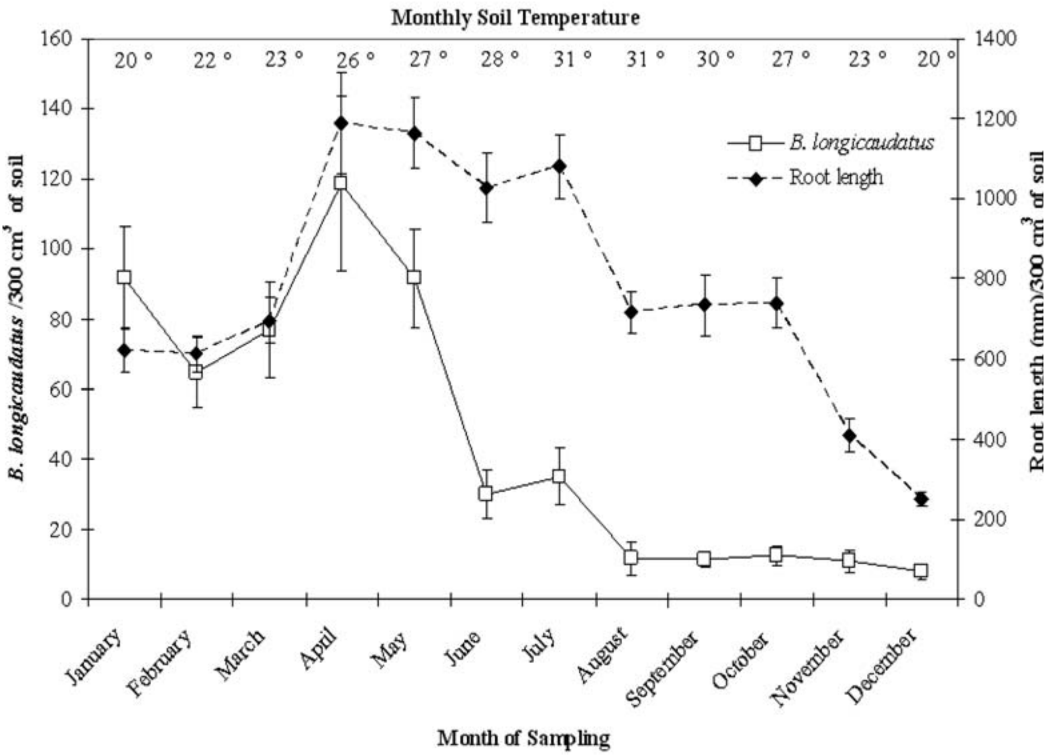

Fig. 1. Population densities of *Belonolaimus longicaudatus* and root lengths from 300 cm^3 of soil from bermudagrass and soil temperatures at the Ft. Lauderdale Research and Education Center, Ft. Lauderdale, FL (January 2005-December 2005). Data are means ± standard error.

densities remained unchanged before reaching a season low in January with a mean of 9 *B. longicaudatus*/300 cm^3 of soil (Fig. 2). Root lengths at IW followed similar trends to that of *B. longicaudatus* population from March through December. Root lengths declined from March to May and increased in June to a mean root length of 246 mm/300 cm^3 of soil (Fig. 2). In September root lengths reached a season high with a mean length of 327 mm/300 cm^3 of soil (Fig. 2). Root length declined from October through December with root lengths of 300, 235, and 185 mm/300 cm^3 of soil (Fig. 2). In January root length increased to 207 mm/300 cm^3 of soil (Fig. 2).

At the SP site sting nematode populations were more stable, increasing from March to May with means of 134, 243, and 283 sting nematodes/300 cm^3 of soil, respectively (Fig. 3). In June, sting nematode populations declined before reaching their highest in July with a mean of 315/300 cm^3 of soil. Populations rapidly declined in August, to a mean of 129 sting nematodes/300 cm^3 of soil (Fig. 3). However, in September sting nematode populations increased to a mean of 197/300 cm^3 of soil. In October sting nematode population densities declined, reaching their lowest with a mean of 71 sting nematodes/300 cm^3 of soil. However, sting nematode populations increased again in December to a

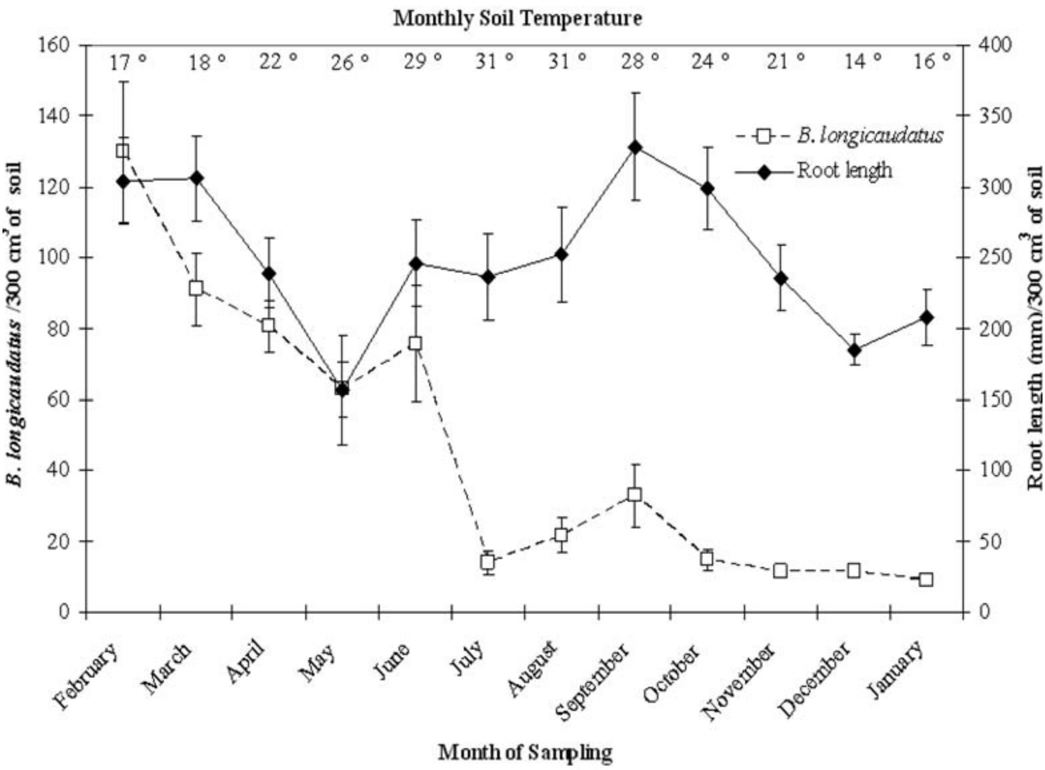

Fig. 2. Population densities of *Belonolaimus longicaudatus* and root lengths from 300 cm^3 of soil from bermudagrass and soil temperatures at Ironwood Golf Course, Gainesville, FL (February 2005-January 2006). Data are means ± standard error.

mean of 155 sting nematodes/300 cm^3 of soil. Populations declined again in January to a mean of 116 sting nematodes/300 cm^3 of soil before increasing again in February to a mean of 145 sting nematodes/300 cm^3 of soil. Root length at the SP site decreased from March to May with means of 1052, 756, and 476 mm/300 cm^3 of soil, respectively (Fig. 3). In June, July and August root length increased with means of 672, 897 and 1388 mm/300 cm^3 of soil. In September root lengths were greatest with 3416 mm/300 cm^3 of soil (Fig. 3). Thereafter, root lengths declined to 1060 mm, 947, and 772 mm/300 cm^3 of soil in November, December, and January, respectively. In February, root length increased to a mean of 905 mm/300 cm^3.

At the CR site sting nematode populations were more variable, rapidly declining from March to April with means of 828 and 557 sting nematodes/300 cm^3 of soil. Sting nematodes population continued to gradual decline in May, June, and July, with means of 536, 506, and 439 sting nematodes/300 cm^3 of soil, respectively (Fig. 4). In August sting nematode populations increased to a mean of 662 sting nematodes/300 cm^3 of soil before rapidly declining to 238 sting nematodes/300 cm^3. From October to November nematode population increased with means of 385, and 417/

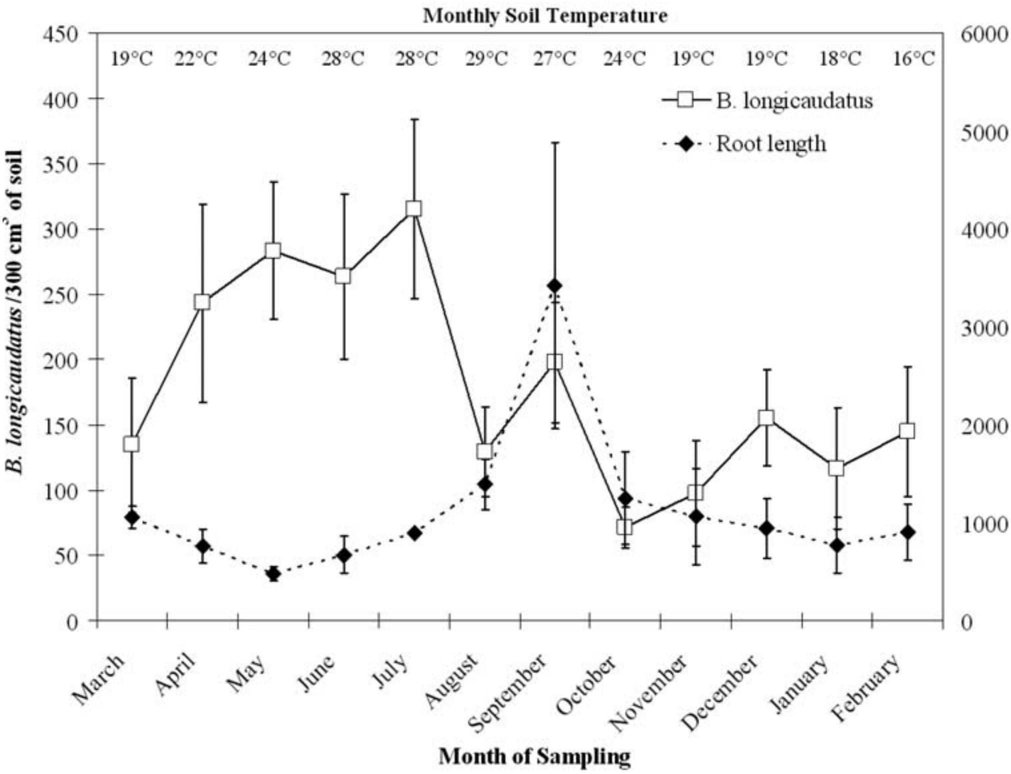

Fig. 3. Population densities of *Belonolaimus longicaudatus* and root lengths from 300 cm^3 of soil from bermudagrass and soil temperatures at Sandpiper Golf Course, Sun City, FL (March 2006-February 2007). Data are means ± standard error.

300 cm^3 of soil. However, in December nematode population declined to a mean of 359 sting nematodes/300 cm^3 (Fig. 4). In January and February sting nematode populations increased to 405, and 408 sting nematodes/300 cm^3.

From March to April at CR, root lengths declined from a mean of 1108 to 1057 mm/300 cm^3 of soil In May root lengths reached a season high of 1204 mm/300 cm^3 of soil (Fig. 4). From June to July root lengths declined by 429 mm reaching a season low of soil 434 mm/300 cm^3 before increasing again in August. Root length continued to decline in September to a mean of 619 mm/300 cm^3. In October and November root length increased before declining in December to a root length mean of 610 mm/300 cm^3 of soil (Fig. 4). In January and February root lengths increased to root length means of 747 and 795 mm/300 cm^3 of soil, respectively.

Linear regression models relating mean root length to nematode population densities (0 - 15 cm depth) were significant ($P \leq 0.10$) on some sampling dates at FLREC, IW, and SP (Table 1). However at CR, no significant ($P \geq 0.10$) relationships between mean root lengths and nematode population densities models were observed (Table 1). At the FLREC site, linear regression models were significant ($P \leq 0.10$) in April and May; at IW they were significant

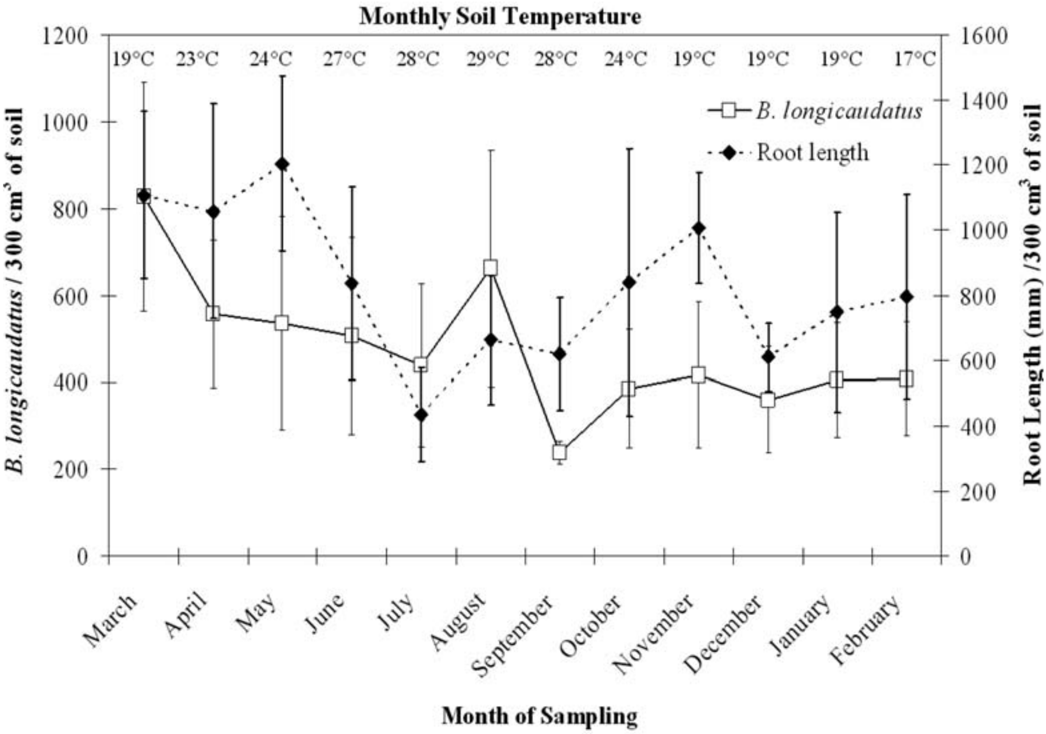

Fig. 4. Population densities of *Belonolaimus longicaudatus* and root lengths from 300 cm^3 of soil from bermudagrass and soil temperatures at Club Renaissance Golf Course, Sun City, FL (March 2006-February 2007). Data are means ± standard error.

in June, September, and October: and at SP, they were significant in July (Table 1). At all sites, linear regression models relating temperature and *B. longicaudatus* densities were not significant ($P \geq 0.10$). Average monthly high and low temperatures at FLREC and IW ranged from 20 to 31°C and 14 to 31°C. At CR and SP, average monthly high and low temperatures ranged from 17 to 29°C and 16 to 29°C.

DISCUSSION

Correlations between root length and *B. longicaudatus* were observed infrequent at FLREC, IW, and SP. Regression analysis did not provide conclusive, predictive models to characterize relationships between *B. longicaudatus* and root length. At most, significant relationships occurred at only 3 of the 4 sites at any one month (e.g., FLREC in April, May; IW in June, September, and October and SP in July). This suggests that root length had an effect on population densities of *B. longicaudatus,* but other environmental factors also may have been affecting root growth (Robbins and Barker, 1974; Huang and Becker, 1999). Furthermore, root lengths could also have been adversely affected by root pathogens (Elliott, 1995), or by insects (Potter, 1998).

Populations of *B. longicaudatus* fluctuated greatly at each site. These fluctuations may have been influenced by a combination of food, soil moisture, vertical movement, and temperature. Temperature,

Table 1. Linear regression number of *Belonolaimus longicaudatus*/300 cm^3 of soil (Y) on root length 300 cm^3 of soil (x) from four golf course fairways in Florida sampled monthly.

Month[a]	Y =	r^2	P
Ft. Lauderdale Research Center			
January	ns	0.0032	0.7429
February	ns	0.0054	0.6715
March	ns	0.0031	0.7483
April	203.2 - 0.0712x	0.1500	0.0192
May	141.2 - 0.0423x	0.0820	0.0791
June	ns	0.0122	0.5205
July	ns	0.0507	0.1868
August	ns	0.0047	0.6910
September	ns	0.0061	0.6513
October	ns	0.0008	0.8760
November	ns	0.0048	0.6869
December	ns	0.0145	0.4838
Ironwood Golf Course			
February	ns	0.0704	0.1177
March	ns	0.0088	0.5858
April	ns	0.0154	0.4708
May	ns	0.0092	0.5775
June	114.6 - 0.1587x	0.1800	0.0081
July	ns	0.0500	0.1129
August	ns	0.0001	0.9512
September	62.15 - 0.0888x	0.1212	0.0349
October	25.41 - 0.0355x	0.1121	0.0486
November	ns	0.0006	0.8866
December	ns	0.0049	0.6887
January	ns	0.0192	0.4710
Club Renaissance			
March	ns	0.1012	0.3134
April	ns	0.1078	0.2975
May	ns	0.2150	0.1289
June	ns	0.1859	0.1855
July	ns	0.0226	0.6419
August	ns	0.0344	0.5639
September	ns	0.0177	0.6799
October	ns	0.0070	0.4054

[a]Month of Sampling.
[b]ns = not significant, df = 11.

Table 1. (Continued) Linear regression number of *Belonolaimus longicaudatus*/300 cm^3 of soil (Y) on root length 300 cm^3 of soil (x) from four golf course fairways in Florida sampled monthly.

Month[a]	Y =	r^2	P
November	ns	0.1842	0.1639
December	ns	0.1251	0.2451
January	ns	0.0211	0.3211
February	ns	0.0121	0.1144
Sandpiper Golf Course			
March	ns	0.0500	0.4819
April	ns	0.1724	0.1795
May	ns	0.0001	0.9794
June	ns	0.2294	0.1613
July	118.4 - 0.1474x	0.3015	0.0802
August	ns	0.0648	0.4245
September	ns	0.1311	0.2475
October	ns	0.0044	0.8376
November	ns	0.0414	0.5260
December	ns	0.0125	0.2111
January	ns	0.1121	0.8541
February	ns	0.1521	0.5482

[a]Month of Sampling.
[b]ns = not significant, df = 11.

moisture, and vertical movement have great affect on *B. longicaudatus* population densities (Boyd and Perry, 1970; McSorley and Dickson, 1990; Robbins and Barker, 1974). Furthermore, Crow *et al.* (1997) attributed a decline in *B. longicaudatus* populations in cotton to quality or absence of a food source. However, little work has been done quantifying the effects of each of these factors in controlled experiments. Further research examining the combinations of these factors may help in predicting *B. longicaudatus* population dynamics in the future.

Differences in *B. longicaudatus* behavior among sites could also be attributed to differences in ecotypes. Han *et al.* (2006) reported that the life cycle duration of *B. longicaudatus* collected from citrus in Lake Alfred, FL was three days longer at 28°C than that of *B. longicaudatus* collected from bermudagrass in Gainesville, FL. This evidence may suggest that *B. longicaudatus* populations within Florida may react differently to environmental conditions, which could account for some variation in the population dynamics. Gozel *et al.* (2006) has recently shown that several distinct genotypes comprise the polymorphic grouping that is currently considered a single species, i.e., *B. longicaudatus.* This genetic variability supports the suggestion of different ecotypes or even different cryptic species with differing population dynamics and life history traits.

Root length fluctuations were highly variable among sites. A combination of environmental conditions and maintenance practices may have influenced these seasonal fluctuations (Duble, 1996). At IW, pine trees in close proximity to the research site reduced solar irradiance to the plots in June, July, and August. Reduction in irradiance can cause bermudagrass to thin and lose turf coverage (Bunnell *et al.,* 2005), leading to a decline in root growth. These conditions were observed at the IW site. Once the plots thinned and lost turfgrass coverage, the plots never recuperated throughout the duration of the experiment. Temperature differences between sites also could have influenced root fluctuations at each location (DiPaola *et al.*, 1982). Soil temperatures at the FLREC, SP and CR site were optimum for root growth for three months longer than that at IW. Soil temperatures were never low enough to cause root growth to completely cease at FLREC, SP, and CR. However, at IW, temperatures did fall below the root growth base temperature of 10°C (DiPaola *et al.*, 1982), which could probably influenced root growth.

In conclusion, *B. longicaudatus* and root growth were highly variable among sites. However, both *B. longicaudatus* populations and root lengths generally increased during the spring months, especially from March to May. Significant correlations between root growth and *B. longicaudatus* also were observed at some point during the spring at most sites. These results suggest that, depending on location in the state and seasonal differences, March through May might be the optimum time to apply nematicides to turf in Florida, USA. Future research in a controlled environment may be more effective in examining the effects of root growth and temperature on *B. longicaudatus* populations.

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