Journal of Nematology 39(1):62–66. 2007.

Effects of *Belonolaimus longicaudatus* Management and Nitrogen Fertility on Turf Quality of Golf Course Fairways

J. E. Luc,[1] W. T. Crow,[1] J. L. Stimac,[1] J. B. Sartain,[2] R. M. Giblin-Davis[3]

Abstract: Field experiments evaluated the effects of nematicide and fertility on performance of 'Tifway 419' bermudagrass parasitized by the sting nematode (*Belonolaimus longicaudatus*). Plot treatments were nontreated or nematicide (1,3-dichloropropene) treated combined with different nitrogen (N) fertilizer levels. Effects of treatments on numbers of *B. longicaudatus* and turf performance were compared. Nematicide consistently reduced numbers of *B. longicaudatus*, but fertilizer level had no effect on *B. longicaudatus*. Turf performance of nematicide-treated plots was improved compared with nontreated plots during both experiments. Increasing N fertilizer level improved turf performance in nematicide-treated plots in some cases, but had no effect on turf performance in nontreated plots in either experiment. Results suggest that increasing N fertilizer levels may not improve turf performance at sites infested with *B. longicaudatus* unless nematode management tactics are effective in reducing nematode densities.
Key words: *Belonolaimus longicaudatus*, bermudagrass, *Cynodon dactylon*, fertilizer, nitrogen, sting nematode, turfgrass, management, turf quality.

Belonolaimus longicaudatus, the sting nematode, was initially found in Florida on several crops including bermudagrass (*Cynodon dactylon*) (Rau, 1958). The sting nematode has an extensive host range and has been recognized as a parasite of many agronomic, horticultural and ornamental crops (Abu-Gharbieh and Perry, 1970). While it can be devastating to a wide range of crops, *B. longicaudatus* is found predominately in sandy coastal areas of the southeastern United States where soils consist of >80% sand and <10% clay with minimal organic matter (Robbins and Barker, 1974; Rhoades, 1980).

Belonolaimus longicaudatus is considered to be the most damaging plant-parasitic nematode on bermudagrass in Florida (Crow et al., 2003b, 2005). 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. Damage caused by *B. longicaudatus* to bermudagrass root systems can decrease water and nutrient uptake and reduce plant growth, but rarely does nematode feeding alone kill a plant (Christie, 1959; Johnson, 1970). Typically, nematode feeding will predispose turf to other stresses such as drought, heat, malnutrition, arthropods, pathogens and weeds, which can reduce turf quality by affecting color and density (Lucas, 1982).

Damage to turf by plant-parasitic nematodes is increasingly recognized by the turf industry as a growing problem due to the limited number of effective post-plant nematicides currently available. If nematode management is not effective, a typical response to decreasing turf performance by golf course managers is to increase water and nitrogen (N) fertilizer levels. When fertilizers are applied to well drained soils, substantial leaching may occur. Reductions of the turfgrass root system by *B. longicaudatus* may increase nitrate leaching and minimize the positive effects of N fertilizer (Luc et al., 2006). The purpose of this study was to define the relationships between nematode management, nitrogen fertilizer and turf performance on golf course fairways.

Materials and Methods

Two field trials were conducted in west central Florida on golf course fairways infested with *B. longicaudatus*. Experiment 1 was conducted in Citrus County, FL, in 2002, and experiment 2 was conducted in Pasco County, FL, in 2003. Plant-parasitic nematodes present at the Citrus County site included *B. longicaudatus*, *Hopolaimus galeatus*, *Helicotylenchus* sp., *Peltamigratus* sp., *Trichodorus* sp., *Paratrichodorus* sp., *Hemicycliophora* sp., *Hemicriconemoides* sp. and *Mesocriconema* sp. Plant-parasitic nematodes present at the Pasco County site included *B. longicaudatus*, *H. galeatus*, *Helicotylenchus* sp., *Trichodorus* sp. and *Mesocriconema* sp. At both sites, *B. longicaudatus* was the only plant-parasitic nematode present at levels considered damaging based on thresholds used by the University of Florida Nematode Assay Lab (Crow et al., 2003b).

Both sites were mature stands (15 to 20-yr-old) of 'Tifway 419' bermudagrass (*Cynodon dactylon* × *C. transvaalensis*) and had histories of nematode damage. Weather permitting, the turf was mowed to a height of 1.3 cm 3 times/week during both trials. Cultural practices such as aeration, slicing and vertical mowing were suspended during these experiments.

Soil texture to a depth of 10 to 15 cm was analyzed using the hydrometer method (Bouyoucos, 1936). Soil

Received for publication October 27, 2006
[1] Graduate Student, Associate Professor and Professor, Entomology and Nematology Department, and [2]Professor, Soil and Water Science Department, University of Florida, Gainesville, FL 32611.
[3] Professor, University of Florida-IFAS, Fort Lauderdale Research and Education Center, 3205 College Ave., Davie, FL 33314.
A portion of the Master of Science thesis by the first author. This study was supported by grants from the Florida Golf Course Superintendent Association and the Golf Course Superintendents Association of America and contributions from Dow AgroSciences LLC. The authors would like to thank the staff at Sugarmill Woods Country Club and Meadow Oaks Golf and Country Club for their assistance and for allowing us to conduct this research at their facilities. Utilization of products in a study is not an endorsement by the University of Florida.
E-mail: turfman@ufl.edu
This paper was edited by Steve Koenning.

at the Citrus County site was Tavares fine sand (92% sand, 4.5% silt, 3.5% clay; <1% organic matter; pH 5.8). Soil at the Pasco County site was Millhopper-Candler Variant soil (97% sand, 0% silt, 3% clay; <1% organic matter; pH 6.0).

Experiment 1: The experiment was arranged in a split-plot 3 × 4 (nematicide × fertilizer) factorial design with four replications. Whole plots were nematicide treatments, and subplots were fertilizer rates. Nematicide treatments were applied on 4 May 2002 and consisted of 1,3-dichloropropene (1,3-D) at 55 kg a.i./ha (46.76 formulated liters/ha) (Crow et al.,2003a), a mechanical slit treatment with no chemical applied, and nontreated. Fertilizer treatments were potassium nitrate 14-0-46 (N-P_2O_5-K_2O) at levels of 0, 18, 37 and 55 kg N/ha applied with a drop spreader every 2 wk starting 19 April 2002 and continuing until the end of the study. Nematicide was applied with a nitrogen gas-pressurized application rig (Southern Soils Turf Management, Lake Mary, FL). The application rig had straight coulters placed on 30.5 cm centers, followed by a chisel with a metal drip line attached, that placed the 1,3-D at a depth of 13 to 17 cm. A steel roller wheel followed each chisel to close the soil. Approximately 1.25 cm of water was applied immediately after application, which assisted in holding the 1,3-D in the soil. Plots were 3.7-m-wide and 15.2-m-long, with subplots being 0.9-m-wide and 15.2-m-long. Plots were separated by border areas 1.5 m on the sides and 3.0 m at each end, while subplots were directly adjacent to one another. The turf was irrigated with 0.6 cm of water as needed.

Nematode populations in each plot were assayed twice prior to nematicide treatment (6 wk prior to and 1 d prior to nematicide treatment) and at 2-wk intervals following nematicide application. Twelve 2.5 cm-diam. × 10.2 cm-deep cores were collected randomly to form a representative composite sample from each plot. Nematodes were extracted from a 100 cm^3 subsample using a centrifugal flotation technique (Jenkins, 1964), and numbers of all plant-parasitic nematodes were identified to the genus or species level and quantified. However, only numbers of *B. longicaudatus* are reported. Plots were assigned to blocks according to *B. longicaudatus* population counts obtained 6 wk prior to nematicide treatment so that initial populations within blocks were similar. Treatments were randomized within each block. Every 2 wk, beginning with the first fertilizer treatment, turf was visually evaluated for overall quality on a 1 to 9 scale (1 poor, 6.5 acceptable, and 9 excellent) (Morris,2002). This measurement included both color and density factors.

Analysis of variance (ANOVA) was performed to compare turf quality and counts of *B. longicaudatus* among treatments at individual sampling dates. Linear contrasts were performed at individual N fertilizer levels to compare between treatments. Analysis of variance and contrasts were performed using SAS (SAS Institute, Cary, NC).

Experiment 2: The experiment was arranged in a randomized complete block 2 × 4 (nematicide × fertilizer) factorial design with four replications. Nematicide treatments were applied on 3 May 2003 and consisted of 1,3-D at 55 kg a.i./ha (46.76 formulated liters/ha) and nontreated. Fertilizer treatments involved a sulfur-coated blend of slow release fertilizer 14-14–14 (N-P_2O_5-K_2O) at levels of 0, 18, 37 and 55 kg N/ha applied with a hand-held rotary spreader every 2 wk starting 4 April 2002 and continuing until the end of the study. Fertilizer consisted of sulfur-coated urea, sulfur-coated ammonium phosphate, sulfur-coated sulfate of potash, iron oxide and manganese sucrate. An unscheduled fertilizer application occurred during wk 11 with a slow-release blend of 21-0-18 (N-P_2O_5-K_2O) at 71 kg N/ha (broadcast), which was evenly applied to the entire research site. Plots were 3.7-m-long and 3.7-m-wide and separated by nontreated border areas 1.5-m-wide on all sides. The randomized complete block design was used rather than a split-plot to reduce the possibility of fertilizer runoff from one subplot into another. A mechanical slit treatment where no nematicide was applied was not included in this experiment because no differences ($P \leq 0.05$) were observed between the mechanical slit treatment and control plots in experiment 1 and other experiments (Crow et al., 2005). The turf was irrigated as needed with 0.6 cm of water except wk 3 and 9 when the irrigation system failed, causing the turf to go without watering for 3 to 4 d.

Nematode populations were assayed and reported as in trial one. Every 2 wk, beginning with the first N fertilizer treatment, turf was visually evaluated for overall quality except for wk 6. Each plot was divided into four quadrants, and each quadrant was rated independently, rendering four measurements per plot which were then averaged.

Analysis of variance was performed to compare turf quality and counts of *B. longicaudatus* among treatments at individual sampling dates. Due to interactions between nematicide treatment and N fertilizer, linear contrasts were performed at individual N fertilizer levels to compare treatments. Analysis of variance and linear contrasts were performed using SAS (SAS Institute, Cary, NC).

Results

Numbers of *B. longicaudatus* in both experiments were lower ($P \leq 0.05$) in plots treated with 1,3-D than in nontreated plots. However, no differences ($P > 0.05$) in numbers of *B. longicaudatus* were observed later than 6 wk after nematicide application (Fig. 1A,B). Fertilizer had no effect ($P > 0.05$) on numbers of *B. longicaudatus* in either experiment (data not shown).

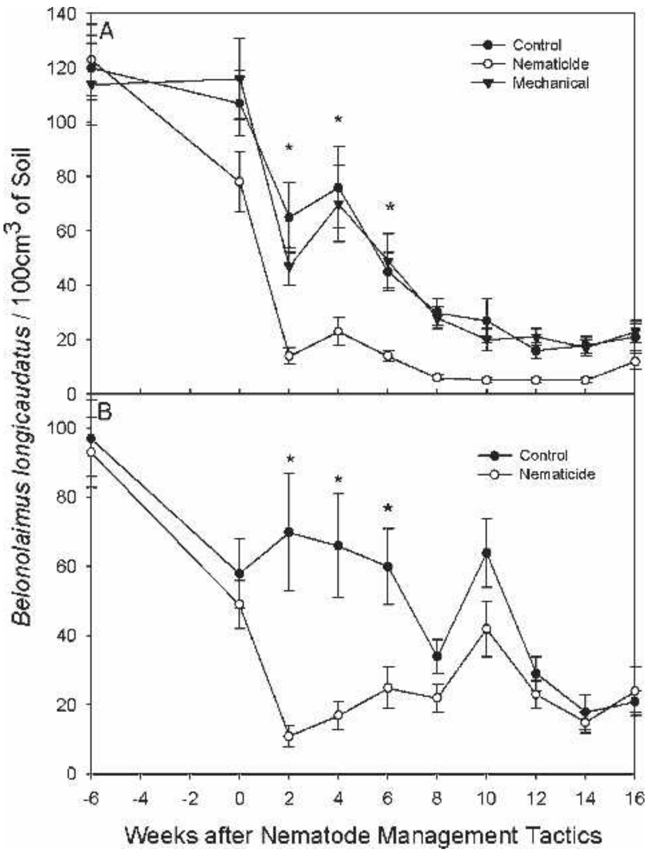

FIG. 1. Mean numbers of *B. longicaudatus* per 100 cm^3 of soil assayed from 6 wk before to 16 wk after nematicide treatment during experiment 1 (A) and experiment 2 (B), respectively. Error bars indicate standard error of individual population means. Nontreated = no added soil disturbance or nematicide treatment; Mechanical = soil disturbance without nematicide; Nematicide = injection of 1,3-D at a rate of 55 kg a.i./ha (46.76 liters/ha) at 13 to 17 cm of soil depth. * Nematicide-treated different from nontreated ($P \leq 0.05$).

In experiment 1, the mechanical treatment had no effect on turf quality (data not shown) or counts of *B. longicaudatus* (Fig. 1A). Turf quality was higher in plots treated with 1,3-D than in nontreated plots at individual N fertilizer levels at 2, 8, 10 and 12 wk after treatment during experiment 1 and 2, 4, 8, 10, 12, 14 and 16 wk after treatment during experiment 2 (Figs. 2,3). Turf quality improved ($P \leq 0.05$) with increasing fertilization in plots treated with 1,3-D only at 2 wk after nematicide application in experiment 1. Conversely, turf quality was reduced in nontreated plots at 8, 10 and 12 wk in experiment 1. Turf quality improved ($P \leq 0.05$) in experiment 2 with increasing fertilization in plots treated with 1,3-D throughout the first 14 wk after nematicide application, whereas turf quality did not improve ($P > 0.05$) in response to fertilization in the nontreated plots for any observation in either experiment.

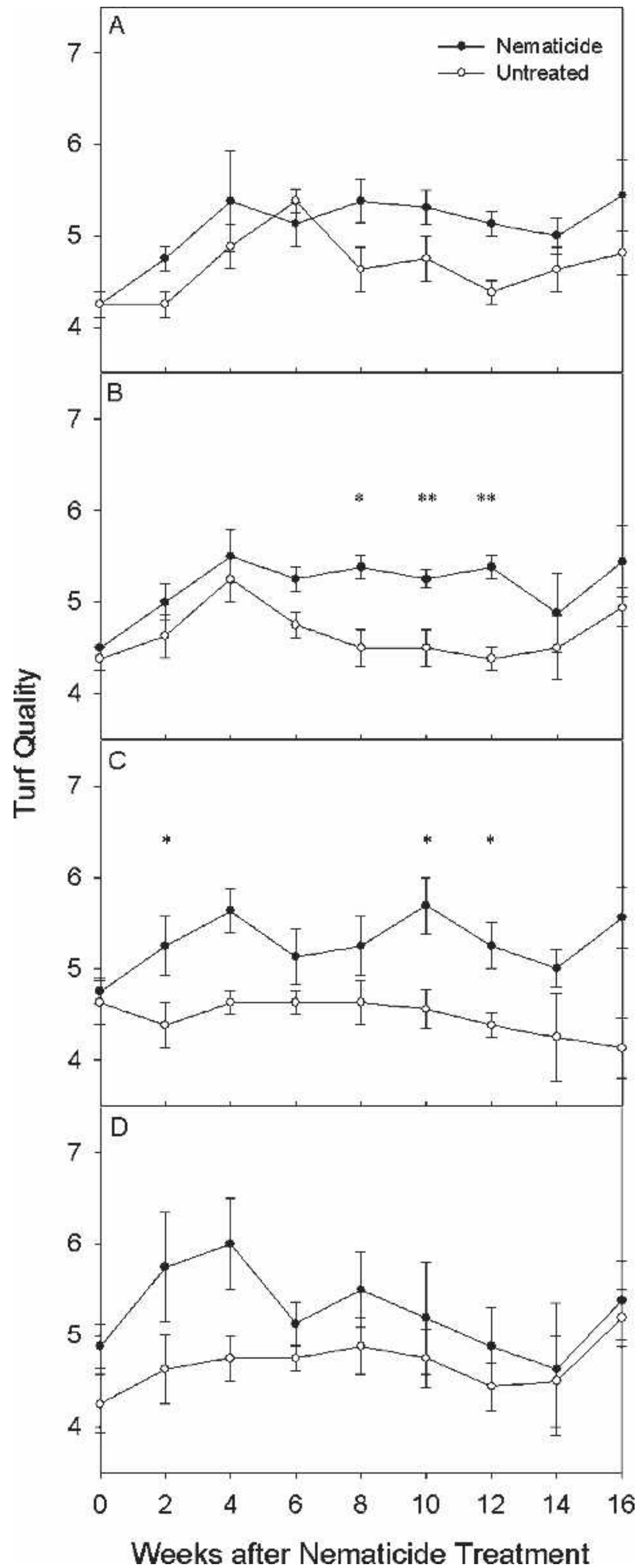

FIG. 2. Effects of treatment with 1,3-D on quality of 'Tifway 419' bermudagrass infested with *B. longicaudatus* at N fertilizer levels of 0 (A), 18 (B), 37 (C) and 55 (D) kg N/ha at 0 to 16 wk after treatment during experiment 1. Turf quality was rated on a subjective 1 to 9 scale, with 1 as completely dead turf, 9 as maximum turf quality. Data are means and mean standard error of four replications. *, **, *** Nematicide-treated different from nontreated ($P \leq 0.05, 0.01, 0.001$).

DISCUSSION

Reduced *B. longicaudatus* counts following application of 1,3-D in both experiments indicate adequate

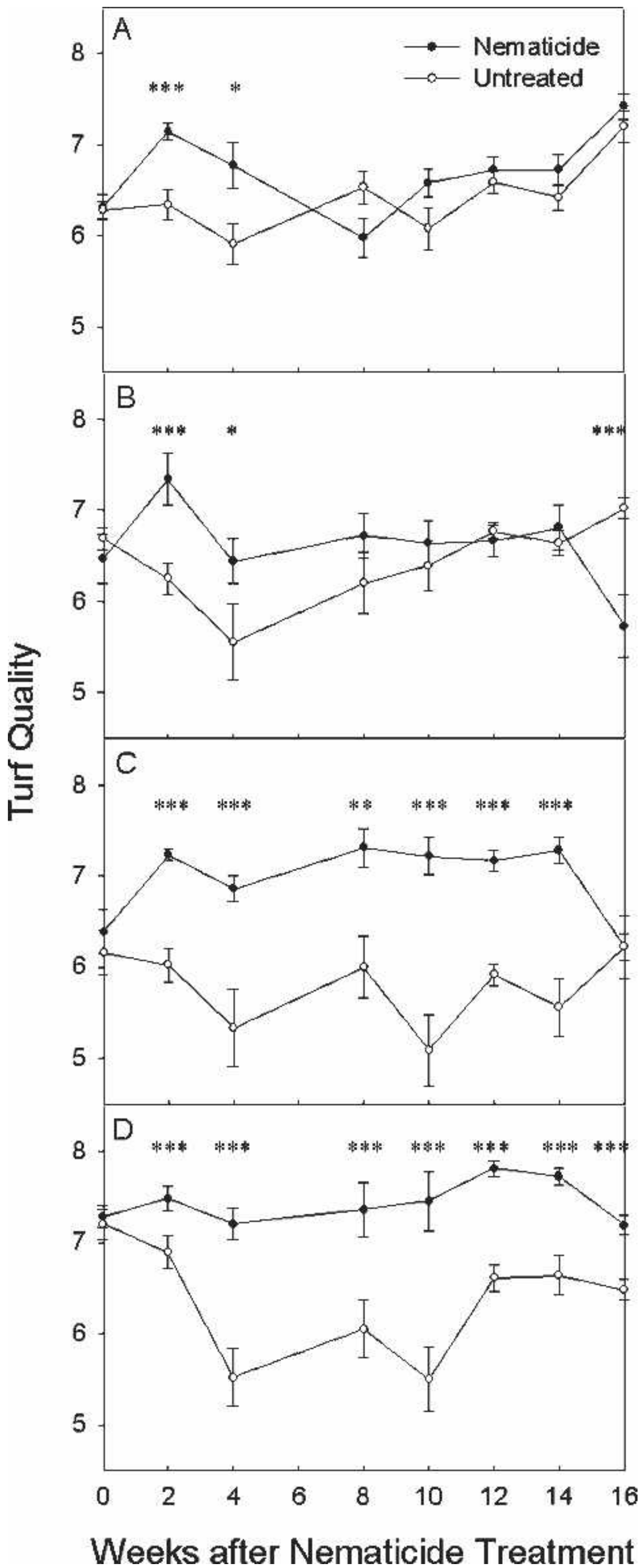

FIG. 3. Effects of treatment with 1,3-D on quality of 'Tifway 419' bermudagrass infested with *B. longicaudatus* at N fertilizer levels of 0 (A), 18 (B), 37 (C) and 55 (D) kg N/ha at 0 to 16 wk after treatment during experiment 2. Turf quality was rated on a subjective 1 to 9 scale, with 1 as completely dead turf, 9 as maximum turf quality. Data are means and mean standard error of four replications. *, **, *** Nematicide-treated different from nontreated ($P \leq 0.05$, 0.01, 0.001).

coverage and rates of nematicide treatments for management of *B. longicaudatus*. A general decline in nematode populations over time was observed in nontreated plots during experiments 1 and 2 (Fig. 1A,B). This may indicate a seasonal reduction of nematode populations from March through August. This is contrary to the seasonal population dynamics reported for *B. longicaudatus* in California, where populations increased during the same time of year (Bekal and Becker, 2000). Further studies of *B. longicaudatus* population dynamics may be warranted to determine when best to apply nematicide treatments for a maximum benefit to turf stands in Florida.

Improvement in turf performance was observed in 1,3-D-treated plots across or within individual N fertilizer levels at some dates during both experiments (Figs. 2,3). Improvement in turf quality was most pronounced in experiment 2 when a slow-release nitrogen source was used rather than potassium nitrate. The irregular turf quality response to nematicide application and increased N fertilizer during experiment 1 may have been caused by salt-induced phytotoxicity from high rates of potassium nitrate that were not properly irrigated following application. The irrigation system at that site did not apply water equally to all plots, and phytotoxicity was observed that clearly followed irrigation patterns.

During experiment 2, improvement was observed in turf quality that corresponded with reduced *B. longicaudatus* population counts. Reduced parasitism by *B. longicaudatus* may have allowed more water and nutrients to reach leaf tissue, leading to increased production, storage and use of photosynthates that could be used for plant development or maintenance during times of drought stress. This reduced parasitism coupled with possible increased reserves of photosynthates may explain differences in turf quality that were observed between nontreated and nematicide-treated plots following each of the irrigation system failures. Whereas reduced turf quality was observed in both the nontreated and nematicide-treated plots following irrigation system failures, turf quality losses were minimized in nematicide-treated plots. Upon reviewing turf quality following the first irrigation failure at three weeks after treatment, the drop in turf quality was greatest in nontreated plots at the two highest N fertilizer levels. The drought damage continued to hinder turf quality in nontreated plots at the high N fertilizer levels for several weeks and was reinforced during week 9 with a second irrigation failure. This situation illustrates that increased irrigation frequency and N fertilizer can maintain turf quality in the short term. However, if stresses such as drought, heat or improper mowing occur on turf stands suffering from nematode parasitism, then turf quality can be reduced for an extended period of time (Lucas, 1982).

The positive relationship between turf quality and N fertilizer indicates that fertilizer was having a positive affect when *B. longicaudatus* was managed. However, the data had so much variability that the r^2 values were extremely low. Therefore, these regressions were not useful as predictive models for turf performance at a given fertility level.

In summary, management of *B. longicaudatus* can improve turf performance, especially when turf is stressed by other factors. Turf performance improved only when an effective management tactic for *B. longicaudatus* was used. Conversely, fertilizer had no effect on numbers of *B. longicaudatus* in either experiment. Positive responses to N fertilizer also occurred only in the nematicide-treated plots. However, these experiments did not demonstrate consistent increases in turf quality in response to increasing N fertilizer with nematicide treatment. Golf courses in Florida use an estimated 16 million kg of nitrogen annually (Haydu et al., 1997). A recent field survey of golf courses in four regions of Florida found damaging numbers of *B. longicaudatus* on 60% of golf courses surveyed (Crow, 2005). Use of effective tactics for management of *B. longicaudatus* should reduce losses of N and potentially improve water quality by reducing the amounts of nitrates leaching into the aquifer. This emphasizes the importance and need for new management tools for plant-parasitic nematodes on golf course turf.

Literature Cited

Abu-Gharbieh, W. I., and Perry, V. G. 1970. Host differences among Florida populations of *Belonolaimus longicaudatus*. Journal of Nematology 2:209–216.

Bekal, S., and Becker, J. O. 2000. Population dynamics of the sting nematode in California turfgrass. Plant Disease 84:1081–1084.

Bouyoucos, G. J. 1936. Directions for making mechanical analyses of soils by the hydrometer method. Soil Science 42:225–229.

Christie, J. R. 1959. Plant nematodes: Their bionomics and control. Jacksonville, FL: H. and W. B. Drew.

Crow, W. T. 2005. How bad are nematode problems on Florida's golf courses? Florida Turf Digest 22(1):10–12.

Crow, W. T., Giblin-Davis, R. M., and Lickfeldt, D. W. 2003a. Slit injection of 1,3-dichloropropene for management of *Belonolaimus longicaudatus* on established bermudagrass. Journal of Nematology 35: 302–305.

Crow, W. T., Lickfeldt, D. W., and Unruh, J. B. 2005. Management of sting nematode (*Belonolaimus longicaudatus*) on bermudagrass putting greens with 1,3-dichloropropene. International Turfgrass Society Research Journal 10(2):734–741.

Crow, W. T., Noling, J. W., Kinloch, R. A., Rich, J. R., and Dunn, R. A. 2003b. Florida Nematode Management Guide. Gainesville, FL: University of Florida.

Haydu, J. J., Hodges, A. W., van Blokland, P. J., and Cisar, J. L. 1997. Economic and environmental adaptations in Florida's golf course industry. International Turfgrass Society Research Society Journal 8: 1109–1116.

Jenkins, W. R. 1964. A rapid centrifugal-floatation technique for separating nematodes from soil. Plant Disease Reporter 48:692.

Johnson, A. W. 1970. Pathogenicity and interaction of three nematode species on six bermudagrasses. Journal of Nematology 2:36–41.

Luc, J. E., Crow W. T., Stimac J. L., Sartain J. B., and Giblin-Davis R. M. 2006. Influence of *Belonolaimus longicaudatus* on nitrate leaching in turf. Journal of Nematology 38:461–465.

Lucas, L. T. 1982. Population dynamics of *Belonolaimus longicaudatus* and *Criconemella ornata* and growth response of bermudagrass and overseeded grasses on golf greens following treatments with nematicides. Journal of Nematology 14:358–363.

Morris, K. N. 2002. A Guide to NTEP Turfgrass Ratings. The National Turfgrass Evaluation Program (NTEP). http://www.ntep.org/reports/ratings.htm.

Rau, G. J. 1958. A new species of sting nematode. Proceedings of the Helminthological Society 25:95–98.

Rhoades, H. L. 1980. Reproduction of *Belonolaimus longicaudatus* in treated and untreated muck soil. Nematropica 10:139–140.

Robbins, R. T., and Barker, K. R. 1974. The effects of soil type, particle size, temperature, and moisture on reproduction of *Belonolaimus longicaudatus*. Journal of Nematology 6:1–6.