RESPONSE OF NEMATODE POPULATIONS AND GROWTH OF FAIRWAY MANAGED BERMUDAGRASS TO APPLICATION OF FERTILIZER AND FENAMIPHOS[1]

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ABSTRACT

Giblin-Davis, R. M., J. L. Cisar, and F. G. Bilz. 1988. Response of nematode populations and growth of fairway managed bermudagrass to application of fertilizer and fenamiphos. Nematrópica 18: 117–127.

The effects of fertilizer application on the efficacy of the 10G formulation of fenamiphos (13.5 kg a.i./ha broadcast) against phytoparasitic nematodes in 'Tifgreen' bermudagrass *(Cynadon dactylon* × *C. transvaalensis)* were examined at three locations on Margate fine sand with different soil-amendment histories. The soils were unamended, colloidal phosphate, or composted-sewage amended 2 yr prior prior to the study. Turfgrass quality ratios at 28 and 56 days after nematicide application showed a significant (P = 0.05) nematicide response at the two locations without sewage amendment. A significant fertilizer effect (P = 0.01) was observed as early as 7 days following fertilizer application and lasted at least 35 days at the two amended sites. Root biomass increased significantly (P = 0.01) in nematicide treated plots 56 days following application at the unamended location. There were significant (P = 0.05) decreases due to fenamiphos in the Pm/Pi ratios for *Belonolaimus longicaudatus* at the unamended and colloidal phosphate amended locations. Also, significant (P = 0.05) decreases due to fenamiphos were observed in the Pm/Pi ratios for *Meloidogyne* spp. at the amended locations. No significant fertilizer or fenamiphos responses were observed for population estimates or ratios of either *Hoplolaimus galeatus* or *Criconemella ornata.*

Key words: Belonolaimus longicaudatus, bermudagrass, *Criconemella ornata, Cynodon dactylon,* fenamiphos, *Hoplolaimus galeatus, Meloidogyne* spp.

RESUMEN

Giblin-Davis, R. M., J. L. Cisar, and F. G. Bilz, 1988. Respuesta de poblaciones de nematodos y crecimiento de pasto de Bermuda mantenido en pistas de golf a la aplicación de abono y fenámifos. Nematrópica 18: 117–127.

Se examinaron los efectos de la aplicación de abono sobre la eficacia de la formulación 10G de fenámifos (13.5 kg i.a./ha sembrada al voleo) contra los nematodos fitoparasítos en pasto de Bermuda 'Tifgreen' (*Cynadon dactylon* × *C. transvaalensis*) en trés localidades de arena fina de typo "Margate" con diferentes historias de enmiendamiento de suelo. Los suelos fueron sin enmienda, o enmendido 2 años antes del estudio o con fosfato coloidal o con aguas de albañal estercoladas. Las razones de la calidad del los pastos 28 y 56 días despues de la aplicación del nematicida mostraron respuestas del nematicida significativamente (P = 0.05) en las dos localidades sin enmienda de los suelos. Se observó un efecto del abono significante (P = 0.05) hasta 7 días despues de la aplicación de los abonos, y este efecto duró por lo menos por 35 días en los dos sitios enmendados. En la localidad enmendada la biomasa de los raices se aumentó significativamente ($P = 0.01$) en las parcelas tratados con nematicida 56 días despues de la aplicación. En las localidades enmendadas con fosfato coloidal y las sin enmienda hubieron rebajadas significantes ($P = 0.05$) en razones de Pm/Pi de *Belonolaimus longicaudatus* debido a fenámifos. También, en las localidades enmendadas se observaron rebajas significantes ($P = 0.05$) debidas a fenámifos en las razones de Pm/Pi de *Meloidogyne spp.* No se observaron respuestas significantes de ni abonos ni fenámifos por estimados de las poblaciones o razones de *Hoplolaimus galeatus* o *Criconemella ornata.*

Palabras claves: Belonolaimus longicaudatus, Criconemella ornata, Cynodon dactylon, fenámiphos, *Hoplolaimus galeatus, Meloidogyne* spp., pasto de Bermuda.

INTRODUCTION

There are at least eight genera of phytoparasitic nematodes associated with warm-season turfgrasses in Florida, and several of these are serious pests (2,6,8,11–13,18). Turfgrass is typically comprised of a perennial plant community that is intensively managed for many years, e.g. golf courses. The most successful forms of nematode control in annual crops, such as crop rotation with nonsusceptible hosts, fallowing, and preplant fumigation, are not practical options for the golf course superintendent (10,14). Several nonfumigant nematicides have been tested and are currently labeled for post-plant usage on turfgrass (1–3,8). However, control is inconsistent and depends upon the nematode species, timing, rates, soil types, and cultural management practices (2). In southern Florida, turfgrasses are grown mostly on sandy soils which are low in native fertility and water holding capacity. Soil amendation is often recommended to improve physical, chemical, and biological properties (10,16). Addition of clay or clay-like amendments, e.g. colloidal phosphate, will improve the water holding and cation exchange capacity of sand (10). Organic soil amendments are suppressive to phytoparasitic nematodes in turfgrass, although the cause of such suppression is not fully understood (4,9). Suppression may be due to increased nitrogen cycling and threshold titers of toxic metabolites, and/or increased antagonism from other organisms (4,9,15).

Nutritionally deficient grass may not respond to the temporary suppression of nematode populations resulting from a nematicide application (2). Thus, the application of fertilizer prior to and during a nematicide treatment may be critical for improved plant performance. The objective of this study was to examine the effects of fenamiphos in 'Tifgreen' bermudagrass (*Cynodon dactylon* (L.) Pers. × *C. transvaalensis* J. B. Davy).

MATERIALS AND METHODS

This study was conducted at the Fort Lauderdale Research and Education Center, Broward Co., Florida. Soil was classified as a Margate fine sand (siliceous, hyperthermic Mollic psammaquent) with a pH of 7.1. The mineral contribution to the surface horizon (upper cm) was 96% sand, 1% clay, and 3% silt and the organic contribution was 3% by weight. The saturated hydraulic conductivity at the site was 35.5 cm hr^{-1} and field capacity was 0.08 cm^3 cm^{-3} (17).

In the spring of 1985 following a glyphosate treatment and removal of all grass, the native soil was amended in two areas with either composted-sewage sludge or colloidal phosphate or left unamended in one area. Each amended area was 10 × 20 m. Composted municipal waste (C:N ratio = 30:1) was obtained from Earthlife Sales Co. (354 N. Main St., Doylestown, PA 18901) and mixed into the native soil to a depth of 15 cm at a rate of ca. 25% by volume (4.71 m^3/93 m^2) with a rototiller. Colloidal phosphate (60% clay residue from super phosphate mining) was obtained from Howard's Fertilizer Inc., Orlando 32803 and incorporated into the soil to a depth of 15 cm at a rate of ca. 5% by volume (0.75 m^3/93 m^2). All areas were sprigged with 'Tifgreen' (Tifton-328) bermudagrass following methyl bromide fumigation at a rate of 486 kg/ha. The three areas were used in 1987 for 2 × 2 factorial experiments concerning the effects of fenamiphos and fertilizer on fairway managed bermudagrass.

The 'Tifgreen' bermudagrass was maintained under golf course fairway conditions. Fertilization of the plots was discontinued 3 mo prior to the test in order to starve the grass to emphasize treatment differences. Turfgrass was mowed every other day at a 1.3-cm mowing height, and all clippings were removed. Four treatments were replicated four times in a completely randomized design in each of the three locations having the previously mentioned amendment histories. The treatment plot dimensions were 1.9 × 1.9 m. Treatments consisted of the following: nematicide only (the 10G formulation of fenamiphos applied at the rate of 13.5 kg a.i./ha broadcast) which was applied on 27 May 1987; fertilizer only (Par Ex custom formulated fertilizer, Estech Branded Fertilizers, Inc., Fairview Heights, IL 62208) which was applied at the rate of 4.9 g N/m^2, 0.6 g P/m^2, and 2.0 g K/m^2 per application on 20 May and 17 June 1987; nematicide and fertilizer using the combined fenamiphos and fertilizer treatments from above; and a control which received no fertilizer or nematicide. The nematicide and/or fertilizer was preweighed and applied with a shaker can in three directions over each plot to achieve a uniform distribution. Treatments were applied between 0900 and 1000 hr and the plot was watered within 20 min of application with 1.3 cm of water. Plots were irrigated with approximately 7.2 mm of water every other day to avoid drought stress. Cumulative rainfall over the course of the experiment was 157 mm.

Soil samples for estimating nematode densities for each plot were taken at just prior to, 28, and 56 days after nematicide application. Each sample contained 10 random cores taken to a 10-cm depth with a cone-shaped sampling tube (2.5-cm orifice). Samples were processed within 72 hr of collection. Each sample was mixed thoroughly, and a 100-cm^3 subsample was taken for extraction of plant-parasitic nematodes using a modified sugar-flotation-centrifugation method (3,5). The nematodes surveyed in this study were *Belonolaimus longicaudatus* Rau, *Hoplolaimus galeatus* (Cobb) Thorne, *Criconemella ornata* (Raski) Luc and Raski, and *Meloidogyne* spp. The levels of *Meloidogyne* spp. (*M. graminis* (Sledge and Golden) Whitehead and *M. javanica* (Treub) Chitwood were based upon counts of second-stage juveniles and males from the soil. The preliminary population densities (Pi) of these nematodes were pooled for each of the three differently amended areas and compared with analysis of variance (ANOVA) and a Waller-Duncan *k*-ratio *t*-test ($P < 0.05$; $k = 100$) (Table 1).

Turfgrass visual rating scores were taken just prior to, 28, and 56 days after nematicide treatment with a scale of 1–10 where: 1 = bare ground; 6 = acceptable golf course fairway grass; and 10 = excellent quality turfgrass. Observations for phytotoxicity were made biweekly. Root dry weight yields for each plot were determined at the end of the experiment. Six cores were taken to a 10-cm depth with a soil probe (1.9-cm orifice) and processed as described previously (3). Data were analyzed for each location by factorial ANOVA to determine significant ($P < 0.05$) main effects (nematicide and fertilizer) and the nematicide × fertilizer interaction.

Table 1. Preliminary population densities (Pi) of *Belonolaimus longicaudatus, Hoplolaimus galeatus, Criconemella ornata,* and *Meloidogyne* spp. per 100 cm^3 of soil for each of the three different study areas.

	Location[y]		
Nematode	Unamended	Colloidal phosphate amended	Sewage amended
B. longicaudatus	97 ± 38 ab[z]	106 ± 53 a	70 ± 21 b
H. galeatus	247 ± 122 a	27 ± 29 c	118 ± 140 b
C. ornata	60 ± 48 c	507 ± 198 a	309 ± 156 b
Meloidogyne spp.	70 ± 53 b	115 ± 83 b	303 ± 182 a

[y]All plots were pooled (n = 16) for preliminary population estimates at each of the three locations with different soil amendment histories. See materials and methods section for details on the soil amendment history of the different locations.
[z]Mean ± standard deviation; means followed by different letters in a row are significantly different according to a Waller-Duncan *k*-ratio *t*-test ($P < 0.05$; $k = 100$).

RESULTS AND DISCUSSION

No phytoxicity (leaf burn) was observed in any of the treatments throughout the experiment. A significant ($P < 0.01$) fertilizer response was observed as early as 7 days following fertilizer application (VRi) and lasted at least 35 days (VRf) at the two amended areas only (Table 2). The quick fertilizer response is a logical consequence of depriving the grass of fertilizer for 3 mo and then fertilizing 7 days prior to the nematicide treatment and visual evaluation date. The lack of rapid and sustained fertilizer response in the unamended area suggests that the grass was too stressed to respond efficiently (Table 2). Previous work concerning bermudagrass response to fertilizer applied under Florida

Table 2. Analysis of variance of data from a 2 × 2 factorial experiment to evaluate the effects of the 10G formulation of fenamiphos and/or fertilizer applications on 'Tifgreen' bermudagrass visual ratings and root growth at 0, 28, and 56 days (VRi, VRm, and VRf, respectively) after fenamiphos application.

		F^v					
Effect	df	VRi	VRm	VRf	VRm/VRi	VRf/VRi	DWT(mg)[w]
		Unamended location[x]					
Fenamiphos (N)[y]	1	1.59	28.88**	16.07**	10.67**	4.87*	11.57**
Fertilizer (F)[z]	1	0.18	5.12*	1.55	3.54	1.01	0.27
N × F	1	1.59	5.12*	1.55	0.81	0.03	0.43
MS Error	12	0.35	0.78	0.82	0.06	0.07	160.08
		Colloidal phosphate amended location					
Fenamiphos (N)	1	0.00	16.62**	12.39**	9.48**	8.75**	3.15
Fertilizer (F)	1	13.71**	37.38**	12.39**	4.51	1.92	0.02
N × F	1	0.86	0.00	1.74	0.70	0.28	2.28
MS Error	12	0.07	0.14	0.32	0.01	0.01	821.83
		Sewage amended location					
Fenamiphos (N)	1	0.87	2.45	0.93	3.71	3.33	1.51
Fertilizer (F)	1	27.97**	33.00**	17.48**	0.52	1.13	0.08
N × F	1	0.87	0.27	0.93	0.83	0.02	0.08
MS Error	12	0.16	0.23	0.15	0.01	0.01	281.87

[v]*F* value; *$P < 0.05$; ** $P < 0.01$.

[w]Roots were harvested from six random cores 1.9 × 10 cm; ash dry weight.

[x]Each combination of treatments were replicated four times in three locations with different soil amendment histories. See materials and methods section for details on the soil amendment history of the different locations.

[y]10G formulation of fenamiphos was applied at the rate of 13.5 kg a.i./ha broadcast on 27 May 1987.

[z]Fertilizer was applied at 4.9 gm N/m² in a 16-4-8 formulation on 20 May and 17 June 1987.

soil conditions has suggested that nitrogen is rapidly leached (16). For the purpose of discussion, the fertilizer effects were removed from the pretreatment means of VRi as described by Little and Hills (7) and the pooled means for the three different locations compared (n = 16 for each location). The mean ± standard deviation for the corrected VRi for the unamended, colloidal phosphate, and composted-sewage amended areas were 4.6 ± 0.4, 5.7 ± 0.1, and 6.5 ± 0.4, respectively. All three means were different from each other after analysis by ANOVA and a Waller-Duncan *k*-ratio *t*-test ($P < 0.05$; $k = 100$). These data suggest that even after 2 yr the soil amendments improved the performance of low maintenance bermudagrass when compared to unamended native soil.

There were significant ($P < 0.01$) nematicide responses at the unamended and colloidal phosphate amended locations for the visual rating scores 28 (VRm) and 56 days (VRf) after nematicide application (Table 2). Visual scores 28 or 56 days after nematicide application were compared with initial visual scores and used to determine rating performance ratios of VRm/VRi or VRf/VRi. There were significant ($P < 0.05$) increases in performance due to the nematicide application for the 28-day and 56-day ratio at the colloidal phosphate amended and unamended locations (Fig. 1 and Table 2). The lack of response to fenamiphos in the composted-sewage amended area may have been due to an interaction between the nematicide and the increased organic matter present.

Mean VRi values for composted-sewage amended plots were 1.9 and 0.8 visual rating points above the unamended and colloidal phosphate amended soils, respectively. Thus, if the potential for improvement in turfgrass visual ratings is nonlinear the chances for improvement or improvement detection in sewage amended soils may be less than for the other soil areas. Similarly, Nutter and Christie (9) reported that activated sewage sludge-treated bermudagrass looked better prior to DBCP treatment than inorganic nitrogen source-treated grass. However, the activated sewage sludge-treated grass responded less to the nematicide treatment.

Analysis of the final root dry weights showed a significant nematicide response in the unamended location only (Table 2). The final root dry weights for the different treatments and locations are depicted in Figure 1. There was a trend for increased root dry weight yields after nematicide application at all three locations (Fig. 1). Only the final root dry weights from the unamended soil showed a significant positive correlation with the final visual ratings (VRf) ($r = 0.51$, $P = 0.043$). These root dry weight data, although highly variable, demonstrate that increased root biomass was attributable to nematicide treatment and not to fertilizer treatment. The lack of fertilizer response may have been

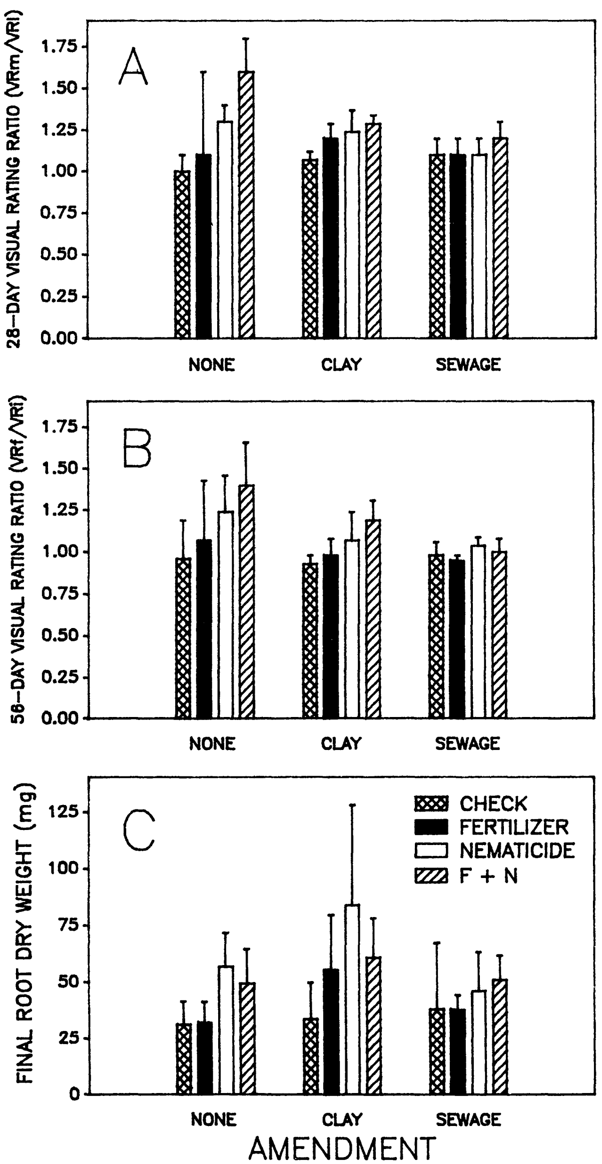

Fig. 1. Evaluation of 'Tifgreen' bermudagrass 28- and 56-day performance ratios and final root dry weight relative to different fertilizer and/or nematicide treatments and locations. A) 28-day turfgrass performance ratio (VRm/VRi). B) 56-day turfgrass performance ratio (VRf/VRi). C) Final root dry weight per six 1.9 × 10 cm soil cores. Treatments: Nematicide (N) = 10G formulation of fenamiphos broadcast at the rate of 13.5 kg a.i./ha on 27 May 1987; Fertilizer (F) = 4.9 g N m^{-2} in a 16-4-8 forumlation per application was applied on 20 May and 17 June 1987; N + F = the combined fenamiphos and fertilizer treatments; Check = no treatment. See materials and methods section for details of amendment histories: NONE = unamended soil; CLAY = soil amended with colloidal phosphate; and SEWAGE = soil amended with composted-sewage sludge. Error bar = up only.

due to the short-lived nature of fertilizer in soil, the starved condition of the grass in conjunction with a short pulse of fertilizer, and/or shoot growth as a primary sink for nutrient flow. The initial primary sink allocation after application of a high nitrogen fertilizer is for shoot production. Increased shoot growth could explain the low root dry weight of plants in fertilized plots and good visual performance ratings.

The mean population density estimates at just prior to, 28, and 56 days after nematicide application (Pi, Pm, and Pf) and ratios of Pm/Pi and Pf/Pi for *B. longicaudatus* are presented in Table 3. There were significant ($P < 0.05$) decreases due to fenamiphos in the Pm/Pi ratios of *B. longicaudatus* at the unamended (df = 12, MSE = 0.16, F = 4.90). Also, significant ($P = 0.05$) decreases due to fenamiphos were observed in the Pm/Pi ratios for *Meloidogyne* spp. at the sewage amended (df = 12, MSE = 0.76, F = 14.10) and the colloidal phosphate amended

Table 3. Mean densities of *Belonolaimus longicaudatus* per 100 cm^3 of soil at 0, 28, and 56 days (Pi, Pm, and Pf, respectively) after fenamiphos application on 'Tifgreen' bermudagrass.

Treatment[u]	Pi	Pm	Pf	Pm/Pi	Pf/Pi
			Unamended location[v]		
Fenamiphos (N)[w]	105 ± 52[x]	99 ± 68	74 ± 17	0.93 ± 0.39	0.81 ± 0.32
Fertilizer (F)[y]	109 ± 43	129 ± 39	55 ± 14	1.27 ± 0.35	0.57 ± 0.24
N + F	101 ± 19	59 ± 32	107 ± 55	0.59 ± 0.31	1.04 ± 0.45
Check[z]	73 ± 32	90 ± 67	50 ± 18	1.23 ± 0.54	0.82 ± 0.50
			Colloidal phosphate amended location		
N	103 ± 48	57 ± 26	88 ± 46	0.59 ± 0.26	0.96 ± 0.66
F	89 ± 93	105 ± 30	51 ± 13	1.21 ± 0.40	0.59 ± 0.20
N + F	105 ± 74	31 ± 12	73 ± 30	0.37 ± 0.22	0.94 ± 0.65
Check	129 ± 72	118 ± 21	111 ± 43	1.44 ± 1.43	1.08 ± 0.53
			Sewage amended location		
N	79 ± 22	36 ± 18	29 ± 22	0.47 ± 0.23	0.39 ± 0.26
F	61 ± 25	44 ± 39	49 ± 35	0.65 ± 0.32	0.83 ± 0.80
N + F	84 ± 9	38 ± 17	51 ± 68	0.46 ± 0.21	0.61 ± 0.80
Check	54 ± 16	50 ± 40	30 ± 19	1.02 ± 0.96	0.59 ± 0.48

[u]Each combination of treatments was replicated four times for each location.

[v]See materials and methods section for details on the soil amendment history of the different locations.

[w]10G formulation of fenamiphos was applied broadcast at the rate of 13.5 kg a.i./ha on 27 May 1987.

[x]Mean ± standard deviation.

[y]Fertilizer was applied at 4.9 gm N/m^2 in a 16-4-8 formulation on 20 May and 17 June 1987.

[z]No nematicide or fertilizer treatments were applied.

location (df = 12, MSE = 0.21, F = 5.65). No significant fertilizer or fenamiphos responses were observed for population estimates or ratios of *H. galeatus* or *C. ornata*. These results are similar to those we reported earlier (3). In that study, only *B. longicaudatus* levels were affected significantly 42 days after fenamiphos applications of 13.5 kg a.i./ha applied broadcast. Visual ratings were affected by nematicide for at least 56 days (Table 2, Fig. 1), while nematicide effects on *B. longicaudatus* lasted less than 56 days. The residual nematicide effect on root biomass at 56 days suggests that the increases in levels of *B. longicaudatus* from between 28–56 days after fenamiphos application were not evident in the performance of the grass.

Correlations were done on pooled data from all three amendment locations. Initial population densities of *B. longicaudatus* and *H. galeatus* were negatively correlated with VRi (r = –0.16 and –0.43, and P = 0.29 and 0.0024, respectively) whereas Pi values for *C. ornata* and *Meloidogyne* spp. were positively correlated with VRi (r = 0.40 and 0.65, and P = 0.0047 and 0.0001, respectively. At 28 days, the Pm of *B. longicaudatus* and *H. galeatus* were negatively correlated with VRm (r = –0.39 and –0.67, and P = 0.007 and 0.0001 respectively), where *C. ornata* and *Meloidogyne* spp. were positively correlated without significance (P > 0.05). The same overall trends were observed again at 56 days. The final root dry weight was not highly correlated with the final nematode densities for any of the nematode species.

The Pi, Pm and Pf densities of *H. galeatus* were negatively correlated with the Pi, Pm, and Pf densities of *C. ornata* (r = –0.58, –0.52, and –0.42, and P = 0.0001, 0.0002, and 0.0029, respectively). In addition, the Pi, Pm, and Pf levels of *B. longicaudatus* and *Meloidogyne* spp. were negatively correlated (r = –0,35, –0.25, and –0.18, and P = 0.0154, 0.0810, and 0.2322, respectively). Population levels of *M. graminis* were affected by *B. longicaudatus* in bermudagrass (1,4). Johnson (6) demonstrated in greenhouse pot studies that *B. longicaudatus* was a better competitor than *C. ornata* on many bermudagrass cultivars. The positive correlations in visual ratings to *C. ornata* and *Meloidogyne* spp. densities are probably related to the negative correlations between *B. longicaudatus* and *Meloidogyne* spp. and between *H. galeatus* and *C. ornata* and the relative pathogenicity of each species of nematode. The relative pathogenicity of these nematodes in turfgrass is suspected as being *B. longicaudatus* > *H. galeatus* > *Meloidogyne* spp. > *C. ornata* (2). Obviously, much more work is needed to assess the impact of different plant-parasitic nematode species which occupy different niches and manifest different levels of pathogenicity to their perennially managed host.

Fenamiphos is considered a highly efficacious nematicide for management of plant-parasitic nematodes in turfgrass (2,3). As labeled, it can be applied twice per year at a rate of up to 22.4 kg a.i./ha broadcast.

The results of this study indicate that fenamiphos applied broadcast at 13.5 kg a.i./ha produces a short term depression (< 8 weeks) of *B. longicaudatus* and *Meloidogyne* spp. and longer term (> 8 weeks) increases in turfgrass quality and root dry weights. Although fertilizer is critical for high performance turfgrass management it did not improve the relative efficacy of fenamiphos. Lastly, soil amendation had long term positive effects on overall turfgrass performance and may alter the population composition of phytoparasitic nematodes (Table 1). A drawback to the sewage amended area was noted as the high volume of organic matter oxidized slowly causing subsidence.

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