Journal of Nematology 37(4):477–482. 2005.
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Alternatives to Fenamiphos for Management of Plant-Parasitic Nematodes on Bermudagrass[1]

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Abstract: Plant-parasitic nematodes can be very damaging to turfgrasses. The projected cancellation of the registration for fenamiphos in the near future has generated a great deal of interest in identifying acceptable alternative nematode management tactics for use on turfgrasses. Two field experiments were conducted to evaluate the effectiveness of repeated applications of several commercially available nematicides and root biostimulants for reducing population densities of plant-parasitic nematodes and (or) promoting health of bermudagrass in nematode-infested soil. One experimental site was infested with *Hoplolaimus galeatus* and *Trichodorus obtusus,* the second with *Belonolaimus longicaudatus.* In both trials, none of the experimental treatments reduced population densities ($P \geq 0.1$) of plant-parasitic nematodes, or consistently promoted turf visual performance or turf root production. Nematologists with responsibility to advise turf managers regarding nematode management should thoroughly investigate the validity of product claims before advising clientele in their use.

Key words: Belonolaimus longicaudatus, bermudagrass, *Cynodon dactylon, Hoplolaimus galeatus,* lance nematode, sting nematode, stubby-root nematode, *Trichodorus obtusus,* turf.

Turfgrasses contribute greatly to the quality of life in the United States and around the world. Turf in lawns, parks, and roadways helps to beautify our landscapes, but the contributions go beyond simple aesthetic appeal. Turf contributes indirectly to our health by being the primary surface on many of our sport and recreation fields. In urban areas turf serves as a biological filter, reducing infiltration of pollutants into our water supply and reducing air pollution by being heat islands (Beard and Green, 1994). Plant-parasitic nematodes can be limiting factors in the growth and maintenance of turfgrasses, especially in sandy soils in the southeastern United States. In addition to causing declines in turf visual quality, damage resulting from plant-parasitic nematodes can increase herbicide (Busey, 2003) and water (Trenholm et al., 2005) use and potentially increase nitrate leaching into ground water (Luc and Crow, 2004). In Florida, *Belonolaimus longicaudatus, Hoplolaimus galeatus,* and *Trichodorus obtusus* are among the most common plant-parasitic nematodes on bermudagrass (*Cynodon dactylon* L. and *Cynodon* hybrids) (Crow, 2005), the major turfgrass used on golf courses and athletic fields in the southeastern United States (Trenholm et al., 2003).

Thirty years ago, postplant nematicides available for use on turfgrasses included organophospate (fenamiphos, ethoprop, dichlorofenthion, diazinon) and fumigant (DBCP) nematicides. Of these, only fenamiphos is still labeled for use on turf, and it will no longer be manufactured as of May 2007 (Anonymous, 2002). The pending loss of fenamiphos is of great concern to turf managers in Florida, especially as acceptable alternatives are not available for many turf uses.

In recent years, there has been a proliferation of alternative products on the market that claim to be effective against plant-parasitic nematodes on turf. Many of these are botanically derived compounds that are classified as "minimum risk" by the U.S. Environmental Protection Agency (EPA) and are exempt from the requirements of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (Anonymous, 2004) or are classified as a "biopesticide" and therefore have a quicker and less rigorous review than a conventional pesticide (U.S. Environmental Protection Agency, 2004). Field efficacy data for these products are often minimal or lacking.

An alternative method for turf managers to manage the effects of plant-parasitic nematodes is to enhance the tolerance of the turf to the nematodes. Root biostimulants promote root development by increasing soil microflora through addition of enzymes, hormones, or bacteria to the soil. Previous research indicates that some of these are able to enhance tolerance to drought and stress, and it has been suggested for nematodes as well (Schmidt et al., 2003).

The objectives of these experiments were to (i) evaluate the field efficacy of several commercially available fenamiphos alternatives in reducing population densities of plant-parasitic nematodes on bermudagrass and in promoting turf health and (ii) determine if any of several commercially available root biostimulants could impart tolerance in bermudagrass to plant-parasitic nematodes.

Materials and Methods

Hoplolaimus and Trichodorus experiment: This research studied the effects of several commercially available alternative nematicides and root biostimulants on populations of plant-parasitic nematodes and turf health. The research was conducted on a 'Floradwarf' bermudagrass putting green located at the G. C. Horne Turfgrass Research Unit in Gainesville, Florida. Soil at this site was 90% sand, 5% silt, 4% clay, 1% O.M. and

Received for publication 12 January 2005.

[1] Florida Agricultural Experiment Station Journal Series no. R-10661. These experiments were funded in part by grants from the Environmental Institute for Golf, the Florida Golf Course Superintendents Association, and the United States Golf Association.

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This paper was edited James A. LaMondia.

was infested with potentially damaging populations of *H. galeatus* and *T. obtusus*.

The experimental design was randomized block with 4 replications. Plots were 1.5 m^2 with 0.7-m non-treated borders between plots. There were eight treatments in this experiment. These treatments were (i) non-treated control; (ii) fenamiphos (Nemacur 10G, Bayer CropScience, Research Triangle Park, NC), an industry standard treatment, applied once topically at 11.2 kg a.i./ha and watered in with 7.5 liters of water plot; (iii) Neo-Tec (Parkway Research, Houston, TX), a botanical nematicide, applied every 4 weeks at 6.4 liters/ha as a soil drench in 7.5 liters of water/plot; Neo-Tec is 0.56% extract of Southern red oak (*Quercus falcata*), Texas prickly pear (*Opuntia lindheimeri*), fragrant sumac (*Rhus aromatica*), and red mangrove (*Rhizophora mangle*); (iv) Quillaja 35 (Desert King International, San Diego, CA), a botanical nematicide, applied every 4 weeks as a soil drench in 7.5 liters of water/plot. The treatment was applied at 41 liters/ha in the first application and 9.35 liters/ha in follow-up applications. Quillaja 35 is a 35% extract of the soapbark tree (*Quillaja saponaria*); (v) Superbio Microbial Blend (Advanced Microbial Solutions, Pilot Point, TX), a root biostimulant, applied every 4 weeks at 18.7 liters/ha as a soil drench in 7.5 liters of water/plot. SuperBio Microbial Blend contains a blend of patented bacterial isolates; (vi) Synzyme (Howard Fertilizer, Groveland, FL), a root biostimulant, applied every 4 weeks at 28 liters/ha as a soil drench in 7.5 liters of water/plot. Synzyme contains a proprietary blend of enzymes and patented bacterial isolates; (vii) TurfVigor LN (Novozymes Biologicals, Salem, VA), a root biostimulant, applied every 4 weeks at 76.4 liters/ha as a soil drench in 7.5 liters of water/plot. TurfVigor LN contains a blend of patented bacterial isolates; and (viii) Safe-T Green (Safe Materials, Valdosta, GA), a fungicide/nematicide, applied topically at 87.6 kg/ha every 4 weeks and watered in with 7.5 liters of water/plot. Safe-T Green is a 99.7% a.i. proprietary blend of linear secondary alcohols reacted with ethylene oxide.

Each plot was sampled for population densities of plant-parasitic nematodes 2 weeks prior to the first treatment application, 2 weeks after the first treatment application, and every 4 weeks thereafter. The first treatment applications were applied 23 April 2002. Nematode samples consisted of nine soil cores 1.9 cm diam. × 7.5 cm deep from each plot. The samples were mixed thoroughly and then nematodes were extracted into water from a 100-cm^3 subsample using a centrifugal-flotation method (Jenkins, 1964) for identification and counting (×25 magnification).

At each sampling date, except for the final date, the turf was evaluated visually for turf color and density. Turf color was rated on a 1-to-9 scale with 1 being no green grass present and 9 being bright green. Turf density was based on percent cover by healthy turf (0 to 100%). Nematode data were subjected to one-way analysis of covariance with the initial measurement being the covariant, and individual treatment means were compared to the non-treated control (Ott, 1993). Turf color and density data were subjected to analysis of variance, and individual treatments were compared to the non-treated using the contrast procedure (Ott, 1993). Average turf color and density throughout the study were measured by combining the data from all the evaluations into a single data set with evaluation date assigned as a class variable. The data were then subjected to analysis of variance for a split-plot design with treatment as the whole-plot and evaluation date being the split-plot (Ott, 1993). Treatment contrasts were then conducted as described for individual sampling dates.

Fourteen weeks following the first treatment applications, two soil cores were collected from each plot for root length analysis. These cores were 3.8 cm diam. × 15 cm deep. The root cores from each plot were analyzed separately, so there were two root length measurements for each plot. Roots were manually separated from soil and placed into 30 ml of water containing three drops of 1% methylene blue to stain the roots. The roots were later scanned on a flatbed scanner to create a bitmap image of the root system. The images were then imported into the GSRoot software program (Louisiana State University, Baton Rouge, LA) for root length analysis. Root length data were subjected to analysis of variance and individual treatments were compared to the untreated using the contrast procedure.

Belonolaimus experiment: This research studied the effects of several commercially available root biostimulants, botanical nematicides, and an alternative nematicide on populations of *B. longicaudatus* and turf health. The research site was a 'Tifway 419' bermudagrass polo field. Soil at this site was 96% sand, 2% silt, 2% clay, <1% O.M., and was infested with potentially damaging populations of *B. longicaudatus*.

The experimental design and data analysis were similar to those described in the previous experiment, except five replications were used. The first treatments were applied on 20 May 2003. Treatments that were unchanged from the previous experiment were untreated control, fenamiphos, Neo-Tec, Quillaja 35, TurfVigor LN, and Safe-T Green. In this experiment Synzyme was applied at the same rate as in the previous experiment, but applications were made every 2 weeks instead of every 4 weeks. The manufacturer of SuperBio Microbial Blend ceased production of that formulation, so in this experiment SuperBio Soil Builder, a new formulation with different bacterial isolates, was used. Products that were evaluated in this study but not in the previous study were (i) Dragonfire CPP (Poulanger USA, Lakeland, FL), a botanical nematicide, applied every 4 weeks at 46.75 liters/ha as a soil drench in 7.5 liters of water/plot, is 100% sesame (*Sesamum indicum*) oil; (ii) Neo-Tec S. O. (Parkway Research, Houston, TX), a botanical nematicide, applied every 4 weeks at 46.75 liters/ha as a soil drench in 7.5 liters of water/

plot, is 50% sesame (*Sesamum indicum*) oil; (iii) Agroneem (Agro Logistic Systems, Walnut, CA), a botanical nematicide, applied every 4 weeks at 102 liters/ha as a soil drench in 7.5 liters of water/plot, is 0.15% azadirachtin derived from the neem plant (*Azadirachta indica*); and (iv) Prosper Nema (Circle-One International, Brooksville, FL), a mycorrhizal fungi inoculum product claimed to rebuild root systems damaged by nematodes, is applied topically at 0.37 kg/ha every 4 weeks and watered in with 7.5 liters of water/plot.

Results

Hoplolaimus and Trichodorus experiment: Only Synzyme, 18 weeks after the first application, had lower ($P \leq 0.1$) population densities of *H. galeatus* than the un-treated control (Table 1). Safe-T Green had higher ($P \leq 0.01$) population densities of *H. galeatus* than the un-treated control 2 weeks after the first application. No treatments affected population densities of *T. obtusus* ($P \geq 0.1$) relative to un-treated control.

Compared to the un-treated control, fenamiphos improved turf density ($P \leq 0.05$) 2 weeks after treatment and turf color ($P \leq 0.01$) 6 weeks after treatment (Table 2). Quillaja 35 improved ($P \leq 0.05$) turf density 14 weeks after the first application. SuperBio Microbial Blend improved ($P \leq 0.1$) turf density compared to the un-treated control 6 and 14 weeks after the first application. Synzyme decreased turf density relative to the non-treated control ($P \leq 0.05$) 10 and 18 weeks after the first application. Average turf color and density over all five evaluations were improved ($P \leq 0.1$) relative to the non-treated control only by fenamiphos. Average turf density decreased ($P \leq 0.05$) relative to the treated control in the Synzyme treatment. Relative to the un-treated control, root lengths 14 weeks following the first applications were not affected ($P \geq 0.1$) by any treatment (Table 3).

Belonolaimus experiment: No treatments were effective at reducing ($P \geq 0.1$) population densities of *B. longicaudatus* relative to the non-treated control at any sampling date (Table 4). However, fenamiphos at 14, 18, and 20 weeks after application; Neo-Tec, Dragonfire CPP, Agroneem, and TurfVigor LN 10 weeks after the first applications; and TurfVigor LN 18 weeks after the first application increased ($P \leq 0.1$) population densities of *B. longicaudatus* relative to the un-treated control.

Turf color relative to the non-treated control was improved ($P \leq 0.1$) by Prosper Nema 2 weeks after the first application and by fenamiphos, Neo-Tec, Quillaja 35, Neo-Tec S. O., Agroneem, SuperBio Soil Builder, Synzyme, Safe-T Green, and Prosper Nema ($P \leq 0.05$) 14 weeks after the first applications (Table 5). Turf density was improved by fenamiphos, Neo-Tec, Quillaja 35, Neo-Tec S. O., Agroneem, Safe-T Green, and Prosper Nema ($P \leq 0.05$) 14 weeks after the first applications were applied but decreased with applications of Synzyme 10 and 18 weeks after the first application and TurfVigor LN 18 weeks after the first application. Average turf color over all five evaluations was improved relative to the non-treated control by fenamiphos ($P \leq 0.05$), Agroneem ($P \leq 0.1$), and SuperBio Soil Builder ($P \leq 0.05$). Average turf density was improved ($P \leq 0.1$) relative to the non-treated control only by fenamiphos. Root length 14 weeks after the first applications was improved ($P \leq 0.1$) only by fenamiphos (Table 6).

Discussion

None of the botanical nematicides (Neo-Tec, Quillaja 35, Dragonfire CPP, Neo-Tec S. O., Agroneem) or Safe-T Green were nematicidal in these experiments.

Table 1. Effects of nematicide or biostimulant treatments on population density of *Hoplolaimus galeatus* and *Trichodorus obtusus* over time.

	2 WBFT[a]		2 WAFT[b]		6 WAFT		10 WAFT		14 WAFT		18 WAFT		22 WAFT	
Treatment	Lance[c]	Stubby[d]	Lance	Stubby	Lance	Stubby	Lance	Stubby	Lance	Stubby	Lance	Stubby	Lance	Stubby
Non-treated	348[e]	122	294	69	305	95	288	257	381	190	327	330	153	247
Fenamiphos[f]	328	107	279	43	293	71	349	175	329	225	293	272	196	234
Neo-Tec[g]	355	170	320	60	285	74	310	184	301	213	190	187	122	215
Quillaja 35[h]	342	166	328	55	324	93	341	195	507	20	317	300	219	252
Superbio Microbial[i]	341	171	280	47	318	89	402	181	308	178	295	217	123	262
Synzyme[j]	340	170	309	67	322	75	329	174	219	191	129*	396	99	371
TurfVigor LN[k]	328	170	335	118	303	104	325	282	197	221	164	378	130	267
Safe-T Green[l]	320	200	536***	131	316	79	380	201	335	198	280	295	237	287

All data are means of four replications. Individual treatment means are compared to the non-treated using analysis of covariance.
*, ***Treatment mean is different from non-treated at $P < 0.10$, and $P < 0.01$, respectively.
[a] Weeks before the first applications were made.
[b] Weeks after the first applications were made.
[c] *Hoplolaimus galeatus*.
[d] *Trichodorus obtusus*.
[e] Number of nematodes/100 cm^3 of soil.
[f] Fenamiphos applied once at 11.2 kg a.i./ha.
[g] NeoTec applied at 6.4 liters/ha every 4 weeks.
[h] Quillaja 35 applied at 41 liters/ha in the first application, and 9.35 liters/ha in follow-up applications every 4 weeks.
[i] Superbio Microbial Blend applied at 18.7 liters/ha every 4 weeks.
[j] Synzyme applied at 28 liters/ha every 4 weeks.
[k] TurfVigor LN applied at 76.4 liters/ha every 4 weeks.
[l] Safe-T Green applied at 87.6 kg/ha every 4 weeks.

TABLE 2. Effects of nematicide or biostimulant treatments on turf color and density of 'Floratine' bermudagrass grown in soil infested with *Hoplolaimus galeatus* and *Trichodorus obtusus* over time.

	2 WAFT[a]		6 WAFT		10 WAFT		14 WAFT		18 WAFT		Average[b]	
Treatment	Color[c]	Density[d]	Color	Density	Color	Density	Color	Density	Color	Density	Color	Density
Non-treated	6.3	60	5.9	69	6.8	68	5.0	43	6.4	65	6.0	61
Fenamiphos[e]	6.8	70**	7.1***	74	7.3	71	5.1	46	6.5	65	6.5***	65***
Neo-Tec[f]	6.0	58	6.0	65	6.3	63	4.8	46	6.3	64	5.9	59
Quillaja 35[g]	6.5	63	6.5	69	6.3	68	5.3	50**	6.3	66	6.2	63
Superbio Microbial[h]	5.8	63	6.6	75*	6.5	63	4.6	49*	6.1	63	5.9	63
Synzyme[i]	6.5	60	6.6	66	6.1	60**	4.8	39	6.3	45**	6.1	57**
TurfVigor LN[j]	6.0	60	6.0	68	6.3	63	4.9	44	6.3	65	5.9	60
Safe-T Green[k]	6.5	65	6.3	68	6.4	66	4.5	44	6.4	65	6.0	62

All data are means of four replications. Individual treatment means are compared to the non-treated using analysis of covariance.
*, **, ***Treatment mean is different from non-treated at $P < 0.10$, $P < 0.05$, and $P < 0.01$, respectively.
[a] Weeks before the first applications were made.
[b] Average measurements from all 4 observations.
[c] Turf color is a 1 to 9 scale with 9 being optimum turf color.
[d] Turf density is the percent cover by live turf (0 to 100%).
[e] Fenamiphos applied once at 11.2 kg a.i./ha.
[f] NeoTec applied at 6.4 liters/ha every 4 weeks.
[g] Quillaja 35 applied at 41 liters/ha in the first application, and 9.35 liters/ha in follow-up applications every 4 weeks.
[h] Superbio Microbial Blend applied at 18.7 liters/ha every 4 weeks.
[i] Synzyme applied at 28 liters/ha every 4 weeks.
[j] TurfVigor LN applied at 76.4 liters/ha every 4 weeks.
[k] Safe-T Green applied at 87.6 kg/ha every 4 weeks.

Nor did they result in consistent improvement of either turf visual performance or root production, indicating that they were able to protect the turf from nematode damage.

The root biostimulants and mychorrhizae inoculum evaluated (SuperBio Microbial Blend, SuperBio Soil Builder, Synzyme, TurfVigor LN, and Prosper Nema) did not stimulate root development sufficiently to overcome the effects of plant-parasitic nematodes. Also, most of these treatments did not provide consistent turf visual improvement. Only one product (SuperBio Soil Builder) improved average turf color but did not improve average turf density or root development. These results do not support the hypothesis that root biostimulants enhance turf tolerance to plant-parasitic nematodes.

TABLE 3. Effects of nematicide or biostimulant treatments on root length of 'Floradwarf' bermudagrass in soil infested with *Hoplolaimus galeatus* and *Trichodorus obtusus*. Root samples were collected 14 weeks after the first applications were made.

Treatment	Root length (mm)
Non-treated	104[a]
[b]Fenamiphos	123
[c]Neo-Tec	39
[d]Quillaja 35	94
[e]SuperBio Microbial Blend	196
[f]Synzyme	36
[g]TurfVigor LN	32
[h]Safe-T Green	88

All data is the means of four replications. Individual treatment means were compared to the non-treated control using the contrast procedure. However, no treatment differences ($P \geq 0.1$) were detected.
[a] Millimeters of roots/11.4 cm^2 of turf surface area.
[b] Fenamiphos applied once at 11.2 kg a.i./ha.
[c] NeoTec applied at 6.4 liters/ha every 4 weeks.
[d] Quillaja 35 applied at 41 liters/ha in the first application, and 9.35 liters/ha in follow-up applications every 4 weeks.
[e] Superbio Microbial Blend applied at 18.7 liters/ha every 4 weeks.
[f] Synzyme applied at 28 liters/ha every 4 weeks.
[g] TurfVigor LN applied at 76.4 liters/ha every 4 weeks.
[h] Safe-T Green applied at 87.6 hg/ha every 4 weeks.

Fenamiphos is known to have nemastatic effects (Opperman and Chang, 1991) in that it can prevent nematodes from feeding and thereby promote turf health, without causing detectible nematode population reductions. Therefore, while fenamiphos was not effective in suppressing plant-parasitic nematode that does not mean that it did not achieve the primary goal of promoting turf health. Fenamiphos was the only product in either experiment to improve both average color and density. In some situations, increases in plant-parasitic nematode populations could indicate improvement in turf health. An increased root system could provide more food and hence support higher plant-parasite populations. In the *Belonolaimus* experiment, the fenamiphos treatment had the greatest root lengths, greatest average turf density, and also higher *B. longicaudatus* population densities than the non-treated control by 14 weeks after application.

It should be noted that these studies did not evaluate all of the botanical nematicides, root-biostimulants, or products marketed for reduction of plant-parasitic nematode damage on turf. Therefore, it is entirely possible that other products that were not evaluated might be effective. Recently there have been reports of other botanical materials reducing plant-parasitic nematode populations on turf (Crow et al., 2004; Perez and Lewis, 2004) and of root biostimulants enhancing tolerance in turf to plant-parasitic nematodes (Sun et al., 1997). It also should be noted that just because a product did not perform well in these experiments does not mean

Table 4. Effects of nematicide or biostimulant treatments on population densities of *Belonolaimus longicaudatus*.

Treatment	2 WBFT[a]	2 WAFT[b]	6 WAFT	10 WAFT	14 WAFT	18 WAFT	22 WAFT
Non-treated	235[c]	217	154	64	44	35	22
Fenamiphos[d]	224	159	102	96	73*	67*	45*
Neo-Tec[e]	222	220	196	113**	61	38	25
Quillaja 35[f]	199	224	161	79	24	39	20
Dragonfire CPP[g]	232	249	195	106*	53	60	20
Neo-Tec S.O.[h]	239	172	105	92	51	57	21
Agroneem[i]	214	236	145	114**	31	37	21
Superbio Soil Builder[j]	229	236	147	87	51	38	24
Synzyme[k]	207	191	154	97	25	44	27
TurfVigor LN[l]	215	261	161	126**	44	67	29
Safe-T Green[m]	209	240	173	72	46	46	39
Prosper Nema[n]	209	223	164	99	25	27	15

All data are means of five replications. Individual treatment means within columns are compared to the non-treated using analysis of covariance.
*,**,*** Treatment mean is different from non-treated at $P < 0.10$, $P < 0.05$, and $P < 0.01$, respectively.
[a] Weeks before the first applications were made.
[b] Weeks after the first applications were made.
[c] Number of *B. longicaudatus*/100 cm^3 of soil.
[d] Fenamiphos applied once at 11.2 kg a.i./ha.
[e] NeoTec applied at 6.4 liters/ha every 4 weeks.
[f] Quillaja 35 applied at 41 liters/ha in the first application, and 9.35 liters/ha in follow-up applications every 4 weeks.
[g] Dragonfire CPP applied at 46.75 liters/ha every 4 weeks.
[h] Neo-Tec S.O. applied at 9.35 liters/ha every 4 weeks.
[i] Agroneem applied at 102 liters/ha every 4 weeks.
[j] Superbio Soil Builder applied at 18.7 liters/ha every 4 weeks.
[k] Synzyme applied at 28 liters/ha every 2 weeks.
[l] TurfVigor LN applied at 76.4 liters/ha every 4 weeks.
[m] Safe-T Green applied at 87.6 kg/ha every 4 weeks.
[n] Prosper Nema applied at 0.37 kg/ha every 4 weeks.

that it will never perform well. With improved formulations or application methods, or under conditions other than those in these experiments, different results could be achieved. However, our results do suggest that many of the claims being made for fenamiphos replacements on turf are not supported by our research. Nema-

Table 5. Effects of nematicide or biostimulant treatments on turf color and density of 'Tifway 419' bermudagrass grown in soil infested with *Belonolaimus longicaudatus*.

	2 WAFT[a]		6 WAFT[b]		10 WAFT		14 WAFT		18 WAFT		Average[c]	
Treatment	Color[d]	Density[e]	Color	Density	Color	Density	Color	Density	Color	Density	Color	Density
Non-treated	6.3	60	6.4	58	6.4	61	4.1	44	7.8	80	6.2	61
Fenamiphos[f]	6.4	60	6.3	60	6.8	68	5.7***	61***	7.8	78	6.6***	65**
Neo-Tec[g]	6.5	64	6.1	59	6.2	56	5.2***	54**	8.0	79	6.4	62
Quilllaja 35[h]	6.6	65	6.1	59	6.5	59	5.0**	54**	7.7	78	6.4	63
Dragonfire CPP[i]	6.6	64	5.8	53	6.2	55	4.6	48	7.9	76	6.2	59
Neo-Tec S.O.[j]	6.0	57	5.7	53	6.4	51	5.4***	59***	7.5	74	6.2	59
Agroneem[k]	6.3	60	6.0	55	6.3	62	5.8***	61***	7.9	78	6.5*	63
Superbio Soil Builder[l]	6.6	63	6.4	59	6.6	51	5.0**	51	7.9	78	6.5**	60
Synzyme[m]	6.4	59	6.2	59	6.4	46*	5.3***	55**	7.5	74**	6.4	59
TurfVigor LN[n]	6.0	57	6.0	54	6.5	61	4.6	49	7.8	76	6.2	59
Safe-T Green[o]	6.4	59	6.1*	55	6.4	61	5.5***	58***	7.9*	76**	6.	62
Prosper Nema[p]	6.7*	61	6.3	58	6.3	63	5.1**	54**	8.0	79	6.5*	63

All data are means of five replications. Individual treatment means within columns are compared to the non-treated using analysis of covariance.
*,**,*** Treatment mean is different from non-treated at $P < 0.10$, $P < 0.05$, and $P < 0.01$, respectively.
[a] Weeks before the first applications were made.
[b] Weeks after the first applications were made.
[c] Average measurements from all five observations.
[d] Turf color is a 1 to 9 scale with 9 being optimum turf color.
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[j] Neo-Tec S.O. applied at 9.35 liters/ha every 4 weeks.
[k] Agroneem applied at 102 liters/ha every 4 weeks.
[l] Superbio Soil Builder applied at 18.7 liters/ha every 4 weeks.
[m] Synzyme applied at 28 liters/ha every 4 weeks.
[n] TurfVigor LN applied at 76.4 liters/ha every 4 weeks.
[o] Safe-T Green applied at 87.6 kg/ha every 4 weeks.
[p] Prosper Nema applied at 0.37 kg/ha every 4 weeks.

TABLE 6. Effects of nematicide or biostimulant treatments on root length of 'Tifway 416' bermudagrass in soil infested with *Belonolaimus longicaudatus*. Root samples were collected 14 weeks after the first treatments were applied.

Treatment	Root length (mm)
Non-treated	198[a]
[b]Fenamiphos	358**
[c]Neo-Tec	183
[d]Quillaja 35	243
[e]Dragonfire CPP	143
[f]Neo-Tec S.O.	306
[g]Agroneem	183
[h]SuperBio Soil Builder	182
[i]Synzyme	217
[j]TurfVigor LN	204
[k]Safe-T Green	103
[l]Prosper Nema	227

All data are the means of five replications. Individual treatment means were compared to the non-treated control using the contrast procedure.

** Treatment mean is different from non-treated at $P < 0.05$.

[a] Millimeters of roots/11.4 cm^2 of turf surface area.

[b] Fenamiphos applied once at 11.2 kg a.i./ha.

[c] NeoTec applied at the rate of 6.4 liters/ha every 4 weeks.

[d] Quillaja 35 applied at the rate of 41 liters/ha in the first application, and 9.35 liters/ha in follow-up applications every 4 weeks.

[e] Dragonfire CPP applied at 46.75 liters/ha every 4 weeks.

[f] Neo-Tec S.O. applied at 9.35 liters/ha every 4 weeks.

[g] Agroneem applied at 102 liters/ha every 4 weeks.

[h] Superbio Soil Builder applied at the rate of 18.7 liters/ha every 4 weeks.

[i] Synzyme applied at the rate of 28 liters/ha every 4 weeks.

[j] TurfVigor LN applied at the rate of 76.4 liters/ha every 4 weeks.

[k] Safe-T Green applied at the rate of 87.6 kg/ha every 4 weeks.

[l] Prosper Nema applied at 0.37 kg/ha every 4 weeks.

tologists should take great care to validate product claims before recommending their use to turf managers.

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