RESEARCH/INVESTIGACIÓN

ABAMECTIN, THIOPHANATE-METHYL, AND IPRODIONE FOR MANAGEMENT OF STING NEMATODE ON GOLF TURF

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ABSTRACT

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Sting nematode (*Belonolaimus longicaudatus*) is an important nematode pest of turfgrasses in the southeastern United States. Three pesticides, including an insecticide (abamectin) and two fungicides (thiophanate-methyl and iprodione), were evaluated for efficacy against sting nematode in greenhouse and field trials. In the greenhouse, maximum labeled rates of the three experimental pesticides were evaluated for nematicidal effects on sting nematode on creeping bentgrass and were compared to untreated control and the industry standard nematicide fenamiphos treatments. In the greenhouse, all the pesticides demonstrated activity against sting nematode. A 2-yr field trial was conducted on a 'Jones Dwarf' bermudagrass putting green infested with sting nematode. This trial evaluated treatment regimes that included the three experimental pesticides singly, in combination, and in rotation. Regimes that included abamectin and/or thiophanate-methyl decreased numbers of sting nematode and improved root lengths compared to the untreated control in the second year. Regimes that included abamectin had the greatest impact on turf percent green cover, increasing green cover compared to the untreated control on most evaluation dates in both years.

Key words: abamectin, *Belonolaimus longicaudatus*, iprodione, nematode management, pesticide, sting nematode, thiophanate-methyl

RESUMEN

Gu, M., and W. T. Crow. 2018. Abamectina, tiofanato-metilo, e iprodiona para el tratamiento del nematodo del aguijón en el césped de golf. Nematropica 48:38-44.

El nematodo del aguijón (*Belonolaimus longicaudatus*) es una plaga importante de los céspedes en el sureste de los Estados Unidos. Se evaluaron tres plaguicidas, incluyendo un insecticida (abamectina) y dos fungicidas (tiofanato-metilo e iprodiona), para determinar su eficacia contra el nematodo del aguijón en ensayos de invernadero y de campo. En el invernadero, se evaluaron las tasas máximas etiquetadas de los tres plaguicidas experimentales para determinar los efectos nematicidas en el nematodo del aguijon en el bentgrass rastrero y se compararon con el control no tratado y los tratamientos con neamida fenamiphos, el estándar de la industria. En el invernadero, todos los pesticidas demostraron actividad contra el nematodo aguijón. Se llevó a cabo una prueba de campo de 2 años en un campo de pasto bermuda 'Jones Dwarf' infestado de nematodos. Este ensayo evaluó los regímenes de tratamiento que incluían los tres plaguicidas experimentales solos, en combinación y en rotación. Los regímenes que incluyeron abamectina y / o tiofanato-metilo disminuyeron el número de nematodos del aguijón y mejoraron la longitud de las raíces en comparación con el control no tratado en el segundo año. Los regímenes que incluyeron abamectina tuvieron el mayor impacto en la cobertura verde del porcentaje de césped, aumentando la cobertura verde en comparación con el control no tratado en la mayoría de las fechas de evaluación en ambos años.

Palabras claves: abamectina, *Belonolaimus longicaudatus*, iprodione, manejo de nematodos, nematodo de picadura pesticida, nematodo de picadura, tiofanato-metilo

INTRODUCTION

Nematicides were first applied to turfgrass in the 1950s. Most of the early turfgrass nematicides were fumigants such as 1,2-dibromo-3-chloropropane and 1,2-dichloropropane-1,3-dichloropropene. During the late 1960s and thereafter, organophosphates like fenamiphos and ethoprop were used to manage nematodes on turfgrass. Fenamiphos was the nematicide most commonly used on golf course turfgrasses during the past 35 years. However, the manufacturer of fenamiphos (Bayer CropSciences, Research Triangle Park, NC) agreed to a voluntary cancellation of fenamiphos production in 2007 (Anonymous, 2002) and its use is prohibited after 6 October 2017 (Keigwin Jr., 2014). For these reasons, it is important to identify new and more sustainable nematicides for turfgrasses.

It takes years of time and millions of dollars for a new pesticide to move through the EPA registration process. However, adding a new pest or a new use to an existing pesticide product label is much quicker and less expensive. Therefore, identifying pesticides that are currently labeled for other pests on turf that may also have nematode activity, or are labeled for nematodes on other crops, are attractive options.

Some fungicides currently labeled for use on turfgrasses have active ingredients that have shown some degree of activity against plant-parasitic nematodes in previous research trials include: thiophanate-methyl (Faghihi *et al*., 2007; McClure and Schmitt, 2012), and iprodione (Moore *et al*., 2010; Meier *et al*., 2011). Abamectin is the active ingredient in several insecticides, including the insecticide Avid 0.15 EC (Syngenta Crop Protection, Research Triangle Park, NC). Abamectin has been recognized as a nematicide for decades (Stretton *et al*., 1987), but was not used as a treatment against plant-parasitic nematodes in soil until recently due to its soil immobility. Beginning in 2011, several U.S, states approved Section 24(c) Special Local Needs labels for Avid 0.25 EC as a nematicide on golf greens.

Our objectives were to evaluate thiophanate-methyl, iprodione, and abamectin for efficacy against the most important nematode pest of turfgrasses in the southeastern USA, sting nematode (*Belonolaimus longicaudatus*) individually, in rotation, and in combination. Greenhouse trials were conducted to test efficacy of the three pesticides individually, and a 2-yr field trial evaluated their efficacy individually, and in combination and rotation.

MATERIALS AND METHODS

Greenhouse experiment

A greenhouse experiment was conducted and repeated to evaluate direct toxicity of thiophanate-methyl, iprodione, and abamectin against sting nematode in soil. The thiophanate-methyl formulation used was Cleary's 3336 Plus (Cleary Chemicals LLC, Dayton, NJ), the iprodione formulation was Iprodione SPC (NuFarm Americas Inc., Burr Ridge, IL), and the abamectin formulation was Avid 0.15 EC. The three experimental pesticides were each tested using a single application of the maximum labeled rate and were compared to untreated control and a standard nematicide (Nemacur 10G, Bayer CropScience, Research Triangle Park, NC) treatments. Rates of thiophanate-methyl and iprodione tested were: 6.1 kg a.i./ha, the rate for abamectin tested was 35 g a.i./ha, fenamiphos was applied at 11.2 kg a.i./ha.

Agrostis stolonifera ('Penncross' creeping bentgrass, Outsidepride.com, Inc., Independence, OR) was seeded at 0.13 g per 10-cm-diam. clay pot. Pots were filled with 450 cm^3 USGA specification sand (USGA, 1993). Each clay pot was inoculated with 50 *B. longicaudatus* 2-wk after seed germination. Nematode inoculum was extracted using a modified Baermann funnel method (Rodriguez-Kabana and Pope, 1981). Nematode suspensions were stirred to even the distribution of inoculum; then two 2-ml aliquots, each containing approximately 25 nematodes, were pipetted and released into two 2-cm-deep holes punched into the soil in each clay pot. Pots were arranged in a randomized block design with 5 replications in the first repetition and 8 replications in the second repetition.

Treatments were applied 2-wk after inoculation. Thiophanate-methyl, iprodione, and abamectin treatments were mixed in water and drenched onto the respective pots in 50-ml solution. Fenamiphos, a granular formulation, was applied topically and then irrigated with 50 ml of tap water to move it into the soil. The untreated control received 50 ml of tap water.

Two weeks after application, enough time to allow decomposition of dead nematodes, but not enough time for *B. longicaudatus* to complete its lifecycle of 18 to 25 days (Han *et al*., 2006), the soil from each clay pot was collected for nematode assay. Nematodes were extracted from the entire 450 cm^3 soil volume by centrifugal-flotation technique (Jenkins, 1964) using a 38-μm pore sieve (Thermo Fisher Scientific Inc., Waltham, MA) to collect the nematodes. Nematodes were identified and counted using an inverted microscope at 20×

magnification. Nematode count data were subjected to analysis of variance and treatment means were separated according to Duncan's multiple-range test ($P \leq 0.05$).

Field experiment

A 2-yr field experiment was conducted in 2014-2015 to evaluate the effects of thiophanate-methyl, iprodione, and abamectin individually and in combination or rotation on turfgrass health and population density of sting nematode. Treatment programs (Table 1) including each of three pesticides individually and in combination, were compared to a no-pesticide control. Pesticide treatments were tank-mixed with a soil penetrant to ensure uniform movement of the pesticides into the soil profile. To account for any nematode or turf effects resulting from the soil penetrant, the no-pesticide control was sprayed with the soil penetrant at each application date. The experiment was conducted on a 'Jones Dwarf' bermudagrass putting green located at the University of Florida Plant Science Research and Education Unit in Citra, FL. This site is naturally infested with sting nematode, root-knot nematode (*Meloidogyne graminis*), lance nematode (*Hoplolaimus* sp.), ring nematode (*Mesocriconema ornatum*), and spiral nematode (*Helicotylenchus paxilli*). The experimental design was a randomized complete block with 5 replications of the 8 treatments. Plots were 1.5 m^2, with 0.6 m untreated borders between adjacent plots. To help minimize variability, 60 plots were initially laid out, and nematode counts were assayed from all plots. Subsequently, 40 plots were assigned to blocks based on their initial population density of sting nematode, with the plots in each block having similar sting nematode numbers. The treatments were applied to the same plots in both years. No nematicides or fungicides other than the experimental treatments were applied to the research plots.

Treatment solutions were applied using a CO_2-powered backpack sprayer (Weed Systems, Hawthorn, FL) calibrated to deliver 2,421 L solution/ha. Immediately after treatment application, all plots, including the untreated controls, were irrigated with 0.64 cm of water. The initial applications were made on 22 April in 2014 and 1 April in 2015. The treatment schedule is shown in Table 1.

Each year nematode and root samples were collected before the first treatment application, and 2-wk after the final treatment application. Nematode samples consisted of nine cores (1.9-cm-diam. × 10-cm-deep) from each plot that were composited into a single sample. After turf and thatch were removed, nematodes were extracted from a 100 cm^3 subsample using centrifugal-flotation (Jenkins, 1964). Turf root samples

Table 1. Treatment regimens used in a 2-year field trial evaluating treatment regime effects on population dynamics of sting nematode (*Belonolaimus longicaudatus*) and plant health of 'Jones Dwarf' bermudagrass.

Code[z]	Treatment regime	Trade name	Rate a.i/ha	Applications on week
U	Ethylene Glycol Butyl Ether	Lesco Wet Plus	22.6 kg	0, 2, 4, 6, 8, 10, 12
B	Iprodione	Iprodione SPC	6.1 kg	0, 4, 8, 12
	Ethylene Glycol Butyl Ether	Lesco Wet Plus	22.6 kg	0, 2, 4, 6, 8, 10, 12
C	Thiophanate-Methyl	Cleary's 3336 Plus	6.1 kg	0, 2, 4, 6, 8, 10, 12
	Ethylene Glycol Butyl Ether	Lesco Wet	22.6 kg	0, 2, 4, 6, 8, 10, 12
D	Abamectin	Avid 0.15 EC	17.5 g	0, 2, 4, 6, 8, 10, 12
	Ethylene Glycol Butyl Ether	Lesco Wet Plus	22.6 kg	0, 2, 4, 6, 8, 10, 12
E	Iprodione	Iprodione SPC	6.1 kg	0, 4, 8, 12
	Thiophanate-Methyl	Cleary's 3336 Plus	6.1 kg	0, 4, 8, 12
	Ethylene Glycol Butyl Ether	Lesco Wet Plus	22.6 kg	0, 2, 4, 6, 8, 10, 12
F	Iprodione	Iprodione SPC	6.1 kg	0, 4, 8, 12
	Thiophanate-Methyl	Cleary's 3336 Plus	6.1 kg	2, 6, 10
	Ethylene Glycol Butyl Ether	Lesco Wet Plus	22.6 kg	0, 2, 4, 6, 8, 10, 12
G	Iprodione	Iprodione SPC	6.1 kg	0, 4, 8, 12
	Thiophanate-Methyl	Cleary's 3336 Plus	6.1 kg	2, 6, 10
	Abamectin	Avid 0.15 EC	17.5 g	0, 2, 4, 6, 8, 10, 12
	Ethylene Glycol Butyl Ether	Lesco Wet Plus	22.6 kg	0, 2, 4, 6, 8, 10, 12
H	Iprodione	Iprodione SPC	6.1 kg	0, 4, 8, 12
	Thiophanate-Methyl	Cleary's 3336 Plus	6.1 kg	0, 4, 8, 12
	Abamectin	Avid 0.15 EC	17.5 g	2, 6, 10
	Ethylene Glycol Butyl Ether	Lesco Wet Plus	22.6 kg	0, 2, 4, 6, 8, 10, 12

[z]U = no-pesticide control, B = iprodione, C = thiophanate-methyl, D = abamectin, E = iprodione + thiophanate-methyl tank-mix, F = iprodione + thiophanate-methyl alternating, G = iprodione + thiophanate-methyl alternating and tank-mixed with abamectin, H = iprodione + thiophanate-methyl tank-mixed and alternating with abamectin.

consisted of two cores 3.8-cm-diam. × 15-cm-deep from each plot that were composited (v = 350 cm^3). Roots were removed manually, scanned, and root lengths measured using WinRHIZO software (Regent Instruments, Quebec City, Canada) as described by Pang *et al*. (2011). Turf percent green cover was used to measure turf health. Digital images of the center 1 m^2 of each plot were taken using a digital camera mounted on a custom-built photo box. The percentage of green pixels (Hue 45 to 115, Saturation 5 to 100) from each image was measured using a macro developed by Karcher and Richardson (2005) for use with SigmaScan Pro 5 software (SPSS Inc., Chicago, IL).

Nematode count, root length, and percent green cover data were subjected to analysis of covariance with the initial measurement used as the covariant. Differences indicated are shown according to the *P*-value generated ($P \leq 0.1$, 0.05, 0.01) when the treatment was compared with the untreated control. The plot selection and arrangement into blocks based on initial population density of *B. longicaudatus* minimized variability in data; however, data on other nematodes were so highly variable that no treatment differences were observed ($P > 0.1$). Therefore, only data for sting nematode are reported herein.

RESULTS

Greenhouse experiment

All four pesticides reduced population densities of sting nematode compared to the untreated in both repetitions of the experiment ($P \leq 0.05$). All three experimental pesticides worked as well as the standard nematicide fenamiphos in the first repetition of the experiment. However, in the second repetition only thiophanate-methyl was as effective as fenamiphos against sting nematode (Table 2).

Field experiment

Treatment-related reductions in population density of sting nematode were not observed until the final sampling date in 2015 (Table 3), when treatment regimens that included abamectin and/or thiophanate-methyl had fewer sting nematodes than the untreated control. Root length was improved only by treatment regimens that included abamectin (Table 3). Some of the fungicide-only regimes showed improved turf percent green cover on some dates early in 2014 (Table 4). However, regimes that included abamectin had improved turf percent green cover on many dates in both years.

DISCUSSION

Maximum labeled rates of each of the three pesticides exhibited some efficacy against sting nematode in greenhouse tests. However, in the field trial, iprodione was not effective in reducing population densities of sting nematode. Despite having similar effects on sting nematode in the field, abamectin yielded greater turf percent green cover in both years, and root lengths in 2015, than thiophanate-methyl. While thiophanate-methyl was as effective as abamectin against sting nematode in the greenhouse and field, turf percent green cover was not improved by regimes that only contained thiophanate-methyl but was improved by all regimes containing abamectin.

Numbers of sting nematode occurred at damaging levels at the beginning of the field trial, but declined from spring to summer each year and decreased from 2014 to 2015. Our recent research has found that during the summer months sting nematode moves deeper in the soil profile of turf in Florida, whereas the turfgrass root-knot nematode (*Meloidogyne graminis*) remains active in the

Table 2. Effects of soil drench with the maximum labeled rate of the pesticides thiophanate-methyl, iprodione and abamectin, and a standard nematicide fenamiphos, on population density of sting nematode (*Belonolaimus longicaudatus*) recovered from pots planted with creeping bentgrass in a greenhouse experiment.

Treatment	Trade name	Rate (a.i./ha)	Nematodes repetition 1[x]	Nematodes repetition 2[x]
Untreated	---	---	26[y]a[z]	45 a
Thiophanate-Methyl	Cleary’s 3336 Plus	6.1 kg	5 b	7 c
Iprodione	Iprodione SPC	6.1 kg	3 b	24 b
Abamectin	Avid 0.15 EC	35.0 g	2 b	28 b
Fenamiphos	Nemacur 10G	11.2 kg	6 b	6 c

[x]Data are means of 5 replications in repetition 1 and 8 replications in repetition 2.
[y]Number of *B. longicaudatus*/450 cm^3 of soil.
[z]Treatment means followed by common letters are not different according to Duncan’s multiple-range test ($P \leq 0.05$).

Table 3. Effects of the treatment regimens on population density of sting nematode (*Belonolaimus longicaudatus*) in a field trial conducted on 'Jones Dwarf' bermudagrass in 2014 and 2015.

	B. longicaudatus/100 cm^3 soil[y]				cm roots/350 cm^3 soil[y]			
	2014		2015		2014		2015	
Code	Initial	Final	Initial	Final	Initial	Final	Initial	Final
U[z]	30	4	14	9	231	209	388	526
B	28	9	11	5	209	293	252	637
C	31	8	5	3**	277	251	324	651
D	28	14**	15	2***	267	219	345	935***
E	31	8	17	3***	300	229	312	560
F	28	10	9	2***	262	241	316	551
G	28	13*	6	4	275	273	337	878**
H	32	11	7	4*	221	269	358	856***

[y]Data are means of 5 replications.

[z]U = no-pesticide control, B = iprodione, C = thiophanate-methyl, D = abamectin, E = iprodione + thiophanate-methyl tank-mix, F = iprodione + thiophanate-methyl alternating, G = iprodione + thiophanate-methyl alternating and tank-mixed with abamectin, H = iprodione + thiophanate-methyl tank-mixed and alternating with abamectin.

*,**,***Different from the no-pesticide control according to analysis of covariance ($P \leq 0.1$, $P \leq 0.05$, $P \leq 0.01$, respectively).

thatch and upper 2.5-cm of the profile throughout the summer (W. T. Crow, unpublished). Abamectin binds to organic matter (Stretton *et al.*, 1987), and much of it remains locked in the thatch (Gannon *et al.*, 2016) where turfgrass root-knot nematode proliferates.

Therefore, much of the turf visual improvement associated with abamectin application during summer months may be attributed to management of turfgrass root-knot nematode. University of Florida nematologists have developed a method for extracting turfgrass root-knot nematode from thatch and turf roots that was not in place when the field trial was initiated. We have also determined that soil counts such as used in this trial, while excellent for sting nematode, do not provide accurate assessment of turfgrass root-knot nematode. In our future turfgrass nematicide trials we are taking separate samples and running two procedures to quantify effects on both of these important turf pests. In this field trial a 2-cm-deep thatch layer was present, which may explain why abamectin was more effective on sting nematode in the greenhouse trial, where no thatch layer was present, compared to the field trial.

On 9 June 2015, the day prior to the final treatment applications, the green was core-aerified and top-dressed, explaining the overall drop in turf percent green cover on 10 June 2015. This aerification may have allowed more abamectin to penetrate through the thatch into the soil and resulted in sting nematode reductions from abamectin in 2015.

In summary, abamectin, iprodione, and thiophanate-methyl all had efficacy against sting nematode in the greenhouse experiment, but iprodione was ineffective against sting nematode in the field while abamectin and thiophanate-methyl were only marginally effective. It is possible that abamectin and thiophanate-methyl provide some level of nematode suppression but are likely not stand-alone treatments for control of sting nematode. Abamectin is more likely to be effective against nematodes that predominate in the thatch like root-knot nematode than sting nematode that predominates in the soil below the thatch.

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Table 4. Effects of the treatment regimens on turf percent green cover in a field trial conducted on 'Jones Dwarf' bermudagrass infested with sting nematode (*Belonolaimus longicaudatus*) in 2014 and 2015.

	2014									2015							
Code	4/22	5/6	5/20	6/3	6/16	7/1	7/15	7/29	8/12	4/1	4/15	4/28	5/13	5/27	6/10	6/24	7/8
U[y]	7[z]	4	111	21	36	15	16	10	10	5	34	42	27	48	1	44	41
B	6	13	16***	31***	44*	18	20*	12	11	4	36	41	31	53	2	50	43
C	7	12	12	22	42	18	15	10	6	5	34	42	38	55	2	54	43
D	7	11	12	26	52**	24**	41***	25***	28***	6	37	49	39	60	2	64**	61**
E	6	13	11	27**	43*	15	21**	13	10	6	27	33	26	41	2	39	34
F	6	8	10	20	39*	14	15	6	5	5	28	40	29	43	2**	37	31
G	6	12	12	30***	63***	28***	49***	32***	26***	4	35	47	37*	63**	2	69***	62***
H	5	8	9*	20*	44***	23***	32***	21***	13**	5	32	42	34	54**	2	58**	51*

Data are means of 5 replications.

[y]U = no-pesticide control, B = iprodione, C = thiophanate-methyl, D = abamectin, E = iprodione + thiophanate-methyl tank-mix, F = iprodione + thiophanate-methyl alternating, G = iprodione + thiophanate-methyl alternating and tank-mixed with abamectin, H = iprodione + thiophanate-methyl tank-mixed and alternating with abamectin.

[z]Percent green cover (0-100%).

*,**,***Different from the untreated control according to analysis of covariance ($P \leq 0.1$, $P \leq 0.05$, $P \leq 0.01$, respectively).

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