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EVALUATION OF NEMATICIDES, FUNGICIDES, INSECTICIDES, MOLLUSCICIDES AND FERTILIZERS FOR NEMATODE MANAGEMENT IN TURFGRASS IN CALIFORNIA

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ABSTRACT

Registration of the post-plant nematicide fenamiphos (Nemacur) has been recently cancelled, leaving California with no products registered for nematode control on turfgrass. Trials were conducted to evaluate potential products to replace fenamiphos. Two trials with 28 treatments each (including an untreated control and a standard fenamiphos treatment) were conducted in randomized complete block designs, with three replicates per treatment. Each trial consisted of the same treatments but was conducted in a different location. Treatments were repeated three times at the same location at two to four week intervals. Ten nematicide treatments, 7 fungicides, 7 insecticides, 2 fertilizers, and 1 molluscicide were tested for activity against nematodes on *Poa annua* putting greens in California, USA. Four weeks after the final treatment, trials were sampled for nematodes and visually rated for turf quality. Nematodes present at the sites included root-knot (*Meloidogyne* sp.), spiral (*Helicotylenchus* sp.), ring (*Mesocriconema* sp.), and seed and leaf gall (*Anguina pacificae*). Root-knot nematode demonstrated the most consistent populations, and showed reductions with several treatments.

***Key words*:** annual bluegrass, *Meloidogyne* sp., *Poa annua*, root-knot nematode, turfgrass,

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Running Head: Nematode Management in Turfgrass: Harivandi *et al.*

INTRODUCTION

Plant parasitic nematodes are microscopic roundworms that can be a major problem in turfgrass maintenance. The University of California publication Turfgrass Pests (Radewald and Westerdahl, 1988) identifies the following nematodes as causing damage in California turfgrass: root knot (*Meloidogyne* sp.), ring (*Mesocriconema* sp.), dagger (*Xiphinema* sp), lesion (*Pratylenchus* sp.), stubby root, (*Trichodorus* sp.), and pin (*Paratylenchus* sp.). The UC Pest Management Guidelines for turfgrass (Westerdahl et al., 2000) add the seed and leaf gall (*Anguina pacificae*) (Cid del Prado Vera and Maggenti, 1984; Winterlin et al, 1986) and sting nematode (*Belonolaimus longicaudatus*) to this list. In addition, large numbers of spiral nematode (*Helicotylenchus* sp.) have been recovered from problem turfgrass locations (B. B. Westerdahl, personal communication).

Registration of the post-plant nematicide fenamiphos (Nemacur), which was widely and effectively used on turfgrass in California (Winterlin et al, 1986) has been recently cancelled at the request of the registrant (Bayer, Kansas City, MO, personal communication), leaving California with no products registered for nematode control on turfgrass. Unlike many deep rooted agricultural crops, a significant portion of turf roots are within the top 5 cm of soil making them accessible by conventional application methods such as drenching, or spraying followed by irrigation. A number of organophosphates (e.g. diazinon and carbaryl) with similar modes of action to those that have achieved turfgrass registrations (e.g. ethoprop and fenamiphos) have been tested as nematicides but their physical characteristics make them difficult to move through soil (J. D. Radewald, personal communication), and so were not suitable for agricultural crops, and were less effective than products that did achieve registration as nematicides. Given the shallow rooted nature of turfgrass, it is possible that given the loss of the more effective nematicides, some previously neglected, older products could be utilized for nematode suppression. Based on this and other background information, and given the lack of products currently registered as nematicides on turfgrass, we hypothesize that a variety of products currently registered or being tested as nematicides on other crops (Westerdahl et al. 1992, 1995), or other products that have been used in turfgrass management (Table 1) could have potential for suppressing nematodes in turfgrass,

MATERIALS AND METHODS

Two trials, with 28 treatments each (including an untreated control and fenamiphos as a standard product), were conducted in randomized complete block designs with three replicates per treatment. Each trial consisted of the same treatments (Table 1), but was conducted in a different location. Trial locations were chosen because extensive sampling had shown them to have a history of multiple genera of nematodes present. One trial was conducted at Olympic Club located south of San Francisco, San Mateo County, California and the other at Spyglass Hill Golf Course, located in Pebble Beach, Monterey County, California. The turfgrass type at each site was *Poa annua.* Both sites had a sandy textured soil. The soil at Olympic Club was 93% sand, 4% silt, and 3% clay with an organic matter content of 0.65%. The soil at Spyglass Hill was 94% sand, 4% silt, and 2% clay with an organic matter content of 1.84%.

For each replicate, a metal ring 0.2 meters^2, and 25 cm tall, was inserted 2.5 cm deep into actively growing turf. Measurements to identify the location of each ring were taken from reference locations. Rings were spaced 50 cm apart. Liquid and emulsifiable products were diluted in 1 liter of water per treatment and drenched on the turfgrass. This is approximately one-fourth the volume of water required by the label following applications of fenamiphos. Granular products were applied to the turfgrass, and drenched with 1 liter of water. For products registered for use on turfgrass, the high label rate was selected for testing

For products without a current turfgrass registration, rates were selected based on experience with various annual crops (B. B. Westerdahl, personal communication). Rings were removed after the water had penetrated the soil and standard cultural practices were followed. With the exception of fenamiphos granules, each treatment was repeated three times, at each location. Treatments at Olympic club were on 22 July, 8 Aug, and 6 Sept 2002. Treatments at Spyglass were on 23 July, 9 Aug, and 5 Sept. For the granular formulation of fenamiphos, in addition to the high label rate which was only applied on the first treatment date, a lower rate was selected and applied either two (2X) (first and second treatment dates) or three times (3X) (all three treatment dates). On 3 (Olympic) or 4 (Spyglass) Oct., treated areas were visually rated for turf quality relative to untreated areas, and a nematode sample consisting of 5 cores, 2.5 cm in diameter, to a 10 cm depth was taken from each treated area. Nematodes were extracted from soil around roots via a 'Baermann funnel' (Ayoub, 1977). From each sample, 50 cm^3 soil was placed in the funnels for 48 hours, and extracted nematodes were counted under a dissecting microscope and numbers converted to nematodes per liter of soil. Nematodes present at the sites included root-knot (*Meloidogyne*), spiral (*Helicotylenchus* sp.), ring (*Mesocriconema* sp.), and seed and leaf gall (*Anguina pacificae*). Root-knot nematode demonstrated the most consistent populations and was selected for data analysis. Preliminary statistical analysis on data from the two experiments showed that the effects on nematodes were not significantly different between experiments ($P = 0.05$). The results presented here are pooled data from the two experiments. Analysis of Variance followed by Fisher's Protected Least Significant Difference Test was performed using SuperAnova (SAS Institute, Cary, NC). Prior to analysis, nematode counts were subjected to the transformation $\log_{10}(x+1)$.

Table 1. List of treatments and product information.

Treatment	Rate of product/ ha	Typical use †	Percent ai	Brand name	Company	Location
1,3-Dichloropropene	10.8 liters	N	89.30	Telone EC	DowElanco	Indianapolis, IN
Ammonium Sulfate	248.1kg	F	24.00	Best Sulfate of Ammonia	Pursell Industries, Inc.	Sylacauga, AL
Calcium Polysulfate	102.3 liters	Fu	28.70	Lily /Miller Polysul Summer and Dormant Spray Concentrate	The Garden Grow Company	Independence, OR
Carbaryl	53.8 liters	I	22.50	GardenTech Sevin		
Chlorophenoxy	193.8 liters	Fu	0.88	Greenlight Fung-Away	Green Light	San Antonio, TX
Chlorothalonil	38.8 liters	Fu	29.60	Ortho Daconil 2787	The Ortho Group	Columbus, OH
Chlorpyrifos	32.3 liters	I	12.60	Home Defense Ortho-Klor Insect and Termite Killer (Dursban)	The Ortho Group	San Ramon, CA
Cyfluthrin	19.4 liters	I	0.75	Bayer Advanced Lawn & Garden Multi-Insect Killer	Bayer - Pursell	Birmingham, AL
Diazinon	21.5 liters	I	22.40	Ortho Diazinon Ultra Insect Spray	The Ortho Group	Columbus, OH
Dicofol Acephate	32.3 liters	I	3.00 8.00	Ortho Orthene Systemic Insect Control	The Ortho Group	Columbus, OH
Esfenvalerate	6.5 liters	I	0.43	Ortho Bug B Gon	The Ortho Group	San Ramon, CA
Fenamiphos	18.3 liters	N	35.00	Nemacur 3EC	Bayer	Kansas City, MO
Fenamiphos 1X	107.6 kg	N	10.00	Nemacur 10G	Bayer	Kansas City, MO
Fenamiphos 2X	55.8 kg	N	10.00	Nemacur 10G	Bayer	Kansas City, MO
Fenamiphos 3X	55.8 kg	N	10.00	Nemacur 10G	Bayer	Kansas City, MO
Fosthiazate	3.2 liters	N	50.00	Nemathorin	ISK Biosciences	Concord, OH
Humic Acid	4.3 liters	F	100.00	Humax	JH Biotech	Ventura, CA
Malathion	86.1 liters	I	50.00	Ortho Malathion	The Ortho Group	Columbus, OH
Metaldehyde	21.5 liters	M	4.00	OSH Easy Gone	Orchard Supply Hardware	San Jose, CA
Metam sodium	10.8 liters	N, I, Fu	42.00	Vapam	Amvac	Los Angeles, CA
Myclobutanil	44.1 liters	Fu	1.55	Spectracide Immunox	Spectrum Brands	Atlanta, GA
Myrothecium verucariae	107.6 kg	N	95.00	DiTera DF	Valent Biosciences	Libertyville, IL
Neem Cake	679.2 kg	N	100.00	GreNeem Cake	GreeNeem	Virudhunagar, India
Sodium tetrathiocarbonate	107.6 liters	N, I, Fu		Enzone	Arysta LifeScience	Research Triangle Park, NC
Sulfur	30.3 kg	Fu	92.00	Grant's Sulfur Dust	Grant Laboratories	San Leandro, CA
Thiophanate methyl	64.9 kg	Fu	2.30	Scotts Thiophanate methyl	O.M. Scott & Sons	Marysville, OH
Triadimefon	151.2 kg	Fu	1.00	Advanced Lawn Triadimefon	Bayer	Kansas City, MO
Untreated	0					

† F = fertilizer, Fu = fungicide, M = molluscicide, N = nematicide

RESULTS AND DISCUSSION

At the time of sampling, five treatments had lower populations of root-knot nematode juveniles (P = 0.05) in the soil surrounding roots than the untreated control (Table 2).

Table 2. Root-knot nematode juveniles in soil.

Treatment	Number per liter of soil	$log_{10}(x+1)$	0.05
1,3-Dichloropropene	176	1.06	a
Ammonium Sulfate	432	2.08	abcd
Calcium Polysulfate	1,680	2.32	abcd
Carbaryl	736	2.66	abc
Chlorophenoxy	1,728	2.45	abcd
Chlorothalonil	2,672	3.04	ab
Chlorpyrifos	688	2.26	abcd
Cyfluthrin	384	1.94	abcd
Diazinon	432	1.20	cd
Dicofol, Acephate	736	2.65	abc
Esfenvalerate	432	2.13	abcd
Fenamiphos	352	1.98	abcd
Fenamiphos 1X	512	2.11	abcd
Fenamiphos 2X	384	1.64	bcd
Fenamiphos 3X	144	1.73	abcd
Fosthiazate	416	1.91	abcd
Humic Acid	1,904	2.46	abcd
Malathion	528	1.74	abcd
Metaldehyde	1,312	1.75	abcd
Metam Sodium	288	1.13	cd
Myclobutanil	832	2.63	abcd
Myrothecium verucariae	816	1.79	abcd
Neem Cake	608	2.62	abcd
Sodium tetrathiocarbonate	496	2.48	abcd
Sulfur	2,912	1.47	bcd
Thiophanate methyl	1,120	2.91	ab
Triademefon	4,512	2.67	abc
Untreated	1,872	3.23	a

Means not followed by the same letter are different from each other according to Fisher's Protected Least Significant Difference Test at $P = 0.05$.

Several additional treatments were statistically significant at $P = 0.10$. Fenamiphos provided nematode control when applied as either two applications ($P = 0.05$). , or as three applications ($P = 0.10$). The other fenamiphos treatments provided nematode reductions compared to the untreated, but were not statistically lower than the control. Split applications were included because research in grape vineyards where fenamiphos has been extensively tested has shown improved efficacy with multiple lower rate applications compared to a single high rate (M. V. McKenry and J. D. Radewald, personal communication).

1,3-Dichloropropene is a widely used preplant fumigant nematicide for many crops. In these trials, an emulsified formulation, Telone EC, used at approximately one-fifth that of the standard preplant rate, provided the greatest nematode reduction ($P = 0.05$). A similar formulation of this product has recently received a U.S. EPA registration for use on turfgrass.

Metam sodium, another widely used preplant nematicide, used in these trials at a substantially reduced rate to minimize potential for phytotoxicity, also reduced root-knot nematode populations compared to the untreated ($P = 0.05$).

Fosthiazate, a relatively new organophosphate nematicide which has recently received a U.S. EPA registration for use on tomatoes, reduced nematode populations in these trials ($P = 0.10$). Another recently registered nematicide, a toxin produced in fermentation by the fungus *Myrothecium verucariae* and marketed as DiTera DF on cole crops, grapes, and walnuts in California, also provided nematode reductions ($P = 0.10$) in these trials.

Among the insecticides tested, diazinon ($P = 0.05$) and malathion ($P = 0.10$) both provided reductions in root-knot nematode relative to the untreated plots. The molluscicide metaldehyde also reduced nematode populations (P = 0.10). This product was selected for these trials based on several years of successful testing against lesion nematode on Easter lilies (Lee Riddle, personal communication).

Sulfur was selected for testing based on observations by M. Sosa of Poppy Hills Golf Course, Pebble Beach, CA (personal communication) of improved turf quality following applications of sulfur saturated water on turfgrass infested with *A. pacificae*. In the current trials, a granular sulfur formulation reduced nematode populations (P = 0.05). None of the other fungicides tested provided nematode reductions.

Phytotoxicity was not observed from any of the treatments. The split applications of fenamiphos and fosthiazate were the only treatments in which some replicates appeared to be greener than the untreated (data not shown). However, statistical analysis did not reveal any significant visual differences among treatments.

In these trials, ten treatments showed statistically significant reductions, and several additional treatments had numerical reductions greater than 50% of the untreated at the time of sampling. The plot size for the trials was selected to keep all replicates in a relatively small area to minimize variability in nematode populations across the experimental sites. It is likely that there was some nematode movement in and out of treated areas during the course of the trials that could have reduced the number of treatments providing statistically significant nematode reductions. Product registrations are constantly changing and some previously registered products that were tested are no longer registered for use on turfgrass. They are included here because they help to demonstrate that products other than nematicides have potential for managing nematodes on turfgrass. Also, because industry and EPA decisions regarding registrations fluctuate, it is possible that products currently out of favor, or very similar products, could once again become registered for use on turfgrass. These trials have demonstrated that in addition to nematicides, there are promising candidates for nematode management on turfgrass to be found among the insecticides, and fungicides and molluscicides. The information developed could be beneficial to both commercial turfgrass managers and to home gardeners.

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