Effects of Nematicides on Nematode Densities in Turf in Connecticut

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Abstract: The plant-parasitic nematodes *Criconemoides lobatum, Hoplolaimus tylenchiformis,* and *Tylenchorhynchus dubius* were present in the top 7.5 cm of sod consisting of numerous stolons and fibrous roots. Phenamiphos and 1,2-dibromo-3-chloropropane (DBCP) controlled all three species, whereas ethoprop and oxamyl controlled *H. tylenchiformis* and *T. dubius* but not *C. lobatum.* Benomyl and carbofuran controlled *H. tylenchiformis* but had poor control of *C. lobatum* and *T. dubius.* The effectiveness of carbofuran varied with the type of formulation, being most effective as a quick-release formulation. *C. lobatum* was the most difficult to control with chemicals. No chemical treatment improved the growth of 'Astoria colonial' bentgrass (*A. tenuis* Sibth.) or Kentucky bluegrass (*Poa pratensis L.*) under the moist condtions prevalent in these tests. *Key Words: Criconemoides lobatum, Tylenchorhynchus dubius, Hoplolaimus tylenchiformis,* nematicides, bentgrass, and Kentucky bluegrass.

Plant-parasitic nematodes can damage turf (1, 10, 15, 18). Much of the information available, however, on nematode disease in turf and its control pertains to southern grasses, not to grasses grown in northeastern turf areas. Yet there is evidence that parasitic nematodes are a major cause of turf disease in northern areas (1, 2, 9, 14, 17, 18). In a greenhouse test, several bentgrass species grew poorly and showed severe injury when seeded in soil infested with a number of parasitic nematodes (1). Kentucky bluegrass, fescue, and rye grass showed little or no disease in the presence of nematodes. Reduction of nematode populations in soils is difficult with chemicals

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(7, 8, 15). Nematodes can damage not only newly seeded turf but established turf such as golf greens, lawns, and turf farms. Chemical control was therefore examined on an established bluegrass lawn and in an area to be seeded to Astoria bentgrass.

MATERIAL AND METHODS

The pesticides used were carbofuran (15G or 25% emulsifiable concentrate), ethoprop (15G), fensulfothion (15G), oxamyl (10G), phenamiphos (15G), 1,2-dibromo-3-chloropropane (DBCP) (75% emulsifiable concentrate), benomyl (50% wettable powder), and streptomycin sulfate (16½% soluble powder). Benomyl was included as a systemic fungicide possessing anthelminthic properties (13), and streptomycin was included to test any effects of soil bactericides on nematodes. The chemicals were applied to turf as granules or drenches. About 2.5 cm of water was then applied by irrigation. On plowed land, the chemicals were incorporated into the top 10-cm soil layer by rototilling before irrigation. Nematodes were extracted from 100-gm soil samples by the flotation (12) or the tissue method (11), depending on the soil type.

Treatments were applied to an established turf of Kentucky bluegrass (*Poa pratensis*) and a newly prepared soil where Astoria bentgrass (*Agrostis tenius*) was to be planted. The sites chosen were naturally infested with large populations of *Tylenchorhynchus dubius* and *Criconemoides lobatum*. Nematicides, alone and in combination with benomyl to control possible root-rotting fungi as well as to add nematode control, were applied on 30 April 1973 to Kentucky bluegrass turf in plots of 0.7 x 1 m, replicated 3 times in a randomized complete block design. Immediately after application of the chemicals, all plots received 5 cm of water via sprinkler irrigation. Soil samples from the top 10-cm layer were assayed for nematodes on 30 May and 31 July 1973.

Nematicides were applied to soil containing 45 *Hoplolaimus tylenchiformis*, 44 *T. dubius*, 35 *C. lobatum*, and 20 *Xiphinema americanum* in a renovated rye-grass plot that was to be replanted to Astoria bentgrass. On 28 April 1973, DBCP was injected at the rate of 10 l/ha and to a depth of 15 cm with a hand fumigun in points 30 cm apart on 4 plots of 1 x 2 m in a randomized design. On 2 May, nonvolatile nematicides (Table 2) were spread on the soil surface and incorporated into the top 10 cm of soil with a self-propelled rototiller. Then all plots received 2.5 cm of water by sprinkler irrigation. One month after chemical application, the soil was sampled for nematodes and seeded with Astoria bentgrass. On 31 July, other samples were taken at depths of 0 to 5 and 5 to 10 cm.

RESULTS

The bluegrass sod layer was assayed for nematodes 3 months after treatment (Table 1). The pretreatment population density was 106 *T. dubius*, 53 *C. lobatum*, and 9 *H. tylenchiformis*/100 gm of untreated soil. DBCP, oxamyl, phenamiphos, and combinations of benomyl and oxamyl, phenamiphos, and DBCP reduced *T. dubius* populations the most. The emulsifiable concentrate of carbofuran was less effective than the regular or quick-release formulations. Populations

TABLE 1. Numbers of *Tylenchorhynchus dubius* and *Criconemoides lobatum* 2 months after chemical application on established bluegrass turf.

Nematicide	Rate [kg (a. i.)/ha]	Number nematodes/100 gm of soil[a] *T. dubius*	*C. lobatum*
None	0	106 a	82 a
Phenamiphos	6	11 c	21 c
Ethoprop	6	32 c	54 b
Benomyl	30	32 c	32 c
Carbofuran (10G)	6	24 c	29 c
Carbofuran (quick-release formulation)	6	17 cd	25 c
Carbofuran (emul. conc.)	6	46 b	48 b
Oxamyl	6	9 d	49 b
Phenamiphos + benamyl	6 + 30	5 d	9 d
DBCP	15	6 d	3 d
DBCP + benomyl	15 + 30	4 d	11 d
Oxamyl + benomyl	6 + 30	5 d	7 d

[a]Average of 4 replicates. Numbers followed by the same letter are not different, according to Duncan's New Multiple-Range Test ($P = 0.05$).

of *C. lobatum* were reduced to a low number by DBCP, and by combinations of benomyl with DBCP, oxamyl, or phenamiphos, and less by oxamyl or phenamiphos alone.

All nematicides applied to plowed ground reduced *H. tylenchiformis* populations (Table 2). The most effective were phenamiphos, DBCP, carbofuran, 10G oxamyl, and benomyl. Populations of *T. dubius* were too low to include in Table 3, but streptomycin sulfate alone or with phenamiphos increased *T. dubius* numbers at the 5-to-10-cm depth on 7 July. Neither special formulation of carbofuran (the quick-release or emulsifiable concentrate)

TABLE 2. Numbers of *Hoplolaimus tylenchiformis* in new Astoria bentgrass treated with nematicides alone and with benomyl or streptomycin sulfate.

Treatment[y]	Rate (Kg/ha)	Date	Sample depth (cm)	Number *H. tylenchiformis* in 100 gm soil[z]
None		5/30	0-10	31 c[z]
		7/31	0-5	65 b
			5-10	46 c
Ethoprop	6	5/30	0-10	9 e
		7/31	0-5	3 e
			5-10	7 e
Phenamiphos	6	5/30	0-10	1 e
		7/31	0-5	7 e
			5-10	7 e
Phenamiphos + streptomycin SO_4	6 + 20	5/30	0-10	11 e
		7/31	0-5	0 e
			5-10	114 a
Phenamiphos + benomyl	6 + 30	5/30	0-10	3 e
		7/31	0-5	0 e
			5-10	1 e
Benomyl	30	5/30	0-10	1 e
		7/31	0-5	0 e
			5-10	6 e
Streptomycin sulfate	20	5/30	0-10	5 e
		7/31	0-5	28 c
			5-10	46 c
Oxamyl	6	5/30	0-10	5 e
		7/31	0-5	0 e
			5-10	5 e
DBCP	30	5/30	0-10	0 e
		7/31	0-5	0 e
			5-10	0 e
DBCP + benomyl	30	5/30	0-10	0 e
		7/31	0-5	2 e
			5-10	2 e
Carbofuran (10G)	6	5/30	0-10	1 e
		7/31	0-5	9 e
			5-10	45 a
Carbofuran (quick-release formulation)	6	5/30	0-10	12 e
		7/31	0-5	0 e
			5-10	0 e
Carbofuran (emulsifiable concentrate)	6	5/30	0-10	20 d
		7/31	0-5	8 e
			5-10	18 d

[y]Chemicals were applied 19 May to spaded soil, rototilled in the top 10-cm soil layer, and planted to Astoria bentgrass. About 2.5 cm of water was applied to all plots after chemical applications.
[z]Numbers followed by same letter are not different ($P = 0.05$), according to Duncan's New Multiple-Range Test.

was as active as the regular granular formulation against *H. tylenchiformis,* and the emulsifiable formulation of carbofuran increased *T. dubius* populations at a depth of 5 to 10 cm.

Populations of *X. americanum* were low on 30 May, decreased by 31 July, and were absent in the 5-to-10-cm depth, so they are not included in Table 2. Ethoprop, phenamiphos, and oxamyl gave about 50% control by 30 May and complete control by 31 July. The quick-release formulation of carbofuran was ineffective against *X. americanum* on 30 May, but it and other formulations of carbofuran were active later.

Pratylenchus penetrans was not detectable in untreated soil on 30 May and was present only at a depth of 5 to 10 cm on 31 July, although in populations so low that they are not included in Table 2. Most nematicides gave complete control, but phenamiphos gave only 45% control, streptomycin gave no control, and ethoprop resulted in a 75% increase in *P. penetrans* populations.

After 2.5 months of growth of Astoria bentgrass, *H. tylenchiformis* and *T. dubius* were found to a depth of 10 cm in untreated plots. *Xiphinema americanum* was found only in the 0-to-5-cm layer, whereas *P. penetrans* was found in the 5-to-10-cm layer of untreated sod (Table 2). Benomyl, the quick-release formulation of carbofuran, DBCP, oxamyl, and phenamiphos effectively controlled all nematodes by 31 July. Combining benomyl with DBCP or with phenamiphos had no effect on the efficacy of the two nematicides.

Different formulations of carbofuran gave different control of *H. tylenchiformis.* The regular formulation was most effective on 30 May, yet it was almost ineffective at 5 to 10 cm on 31 July. The quick-release formulation gave only moderate control on 30 May, but it gave complete control on 31 July at both 0 to 5 and 5 to 10 cm of depth. On 31 July, the emulsifiable concentrate formulation gave only 40% control of *H. tylenchiformis* at the 5-to-10-cm depth.

DISCUSSION

Control of nematodes, which varied with formulation, indicated problems associated with nematicide distribution, release of the active ingredient in the soil, or both. On established bluegrass turf, the effectiveness of carbofuran descended as follows: quick-release granular, regular granular, and emulsifiable concentrate. However, differences in numbers of *T. dubius* and *C. lobatum* between bluegrass plots treated with the regular formulation and the quick-release formulation were not significant. Two weeks after application to plowed ground, the regular granules were the most effective, the quick-release granules were somewhat effective, and the least effective was the emulsifiable concentrate. Seventy-five days after chemical application, the most effective formulation at the 5-to-10-cm depth was the quick-release granules. All formulations of carbofuran were about equally effective against nematodes near the soil surface.

In established turf, nematodes were most abundant in the top 7.5 cm of soil or sod. In contrast, most nematode populations in cultivated fields or gardens are in the rhizosphere, 8 to 15 cm from the soil surface. Undoubtedly, turf nematodes are attracted to the dense layer of stolons and roots, most of which remain in this area, which form the thatch in the upper 7.5 cm of soil. This concentration of the nematodes near the soil surface in turf simplifies chemical control, for it would be very hard to obtain penetration of contact nematicides in the hard ground of established turf down to the 8-to-15-cm depth, where nematodes occur in gardens and fields.

Since thatch hinders penetration of the chemicals and actually renders them less active by absorption, more chemicals are required to be effective. Control in the bluegrass turf was greater with oxamyl, and less with ethoprop, benomyl, and carbofuran, when 5 cm of water followed application of the nematicides. The thatch here was also less dense than it would be on a golf green. The difficulties of penetrating undisturbed soil, of penetrating thatch, of nematicidal absorption by the thatch, and of greater resistance of turf nematodes to some contact nematicides (author, unpublished data) all combine to require that greater amounts of chemicals be used on turf than on gardens or fields for adequate nematode control. For example, preplanting broadcast treatment of tobacco with ethoprop requires only 25 to 33% of the amount suggested for use on turf. In one test on bluegrass, 6 kg of phenamiphos/ha, which would normally give excellent control of most nematodes in a field, hardly affected *C. lobatum* and *T. dubius*, and it required 25 kg/ha to give 85% control of those two species in an old established bluegrass sod on a silt loam.

Contact nematicides, which persist in soil for several weeks, reduced the *T. dubius* populations on bluegrass for at least 10 weeks. Johnson (4) found that fensulfothion gave good control of *X. americanum* (better than phenamiphos) after 5 months. Feldmesser and Golden (3) showed that ethoprop controlled plant-parasitic nematodes on a parade ground over a long period at a cost less than half that of replacing sod.

One of the difficulties of working with nematodes in turf in the northeastern United States is that pratically all nematodes attacking turf are ectoparasites, which, though deleterious, cause few diagnostic symptoms. *Pratylenchus penetrans* could injure bluegrass, but it usually does not because prior feeding by *T. dubius* prevents further feeding by *P. penetrans* (author, unpublished data), and *T. dubius* is almost always present in bluegrass in that area. If stains could be found that would show where ectoparasites have fed or penetrated the root, that would facilitate diagnosis of nematode injury on turf.

Because nutrients, as well as nematodes, often limit turf growth, it is advisable to apply both fertilizer and nematicide to obtain a growth response. Increased depth of root penetration is a more reliable response to nematicidal treatment than is increased top growh.

The difference in control of different nematodes between the various formulations of carbofuran shows the importance of formulation methods and agents to performance by these nematicides. The effects of different formulations of the same nematicide could also vary with soil depth and soil environment. For example, it is possible that the release of carbofuran in the regular formulation at soil depths below 5 cm is retarded directly or indirectly by temperature or moisture conditions of the soil.

The addition of benomyl and streptomycin to nematicides gave inconsistent results. They were included in the test because benomyl, maneb, and several other fungicides suppressed populations of *Pratylenchus penetrans* (author, unpublished data). Although partially effective as a nematicide (8, 13), benomyl did not affect control of *T. dubius* or *X. americanum*, whereas it increased control of *C. lobatum* by oxamyl and phenamiphos when applied in combination with them. Streptomycin sulfate reduced the populations of *H. tylenchiformis* on 30 May in the bentgrass plot but reduced the effectiveness of phenamiphos beyond a soil depth of 5 cm. The two-to-fourfold increase, following this treatment, in nematode populations at the lower depth suggests possible elimination of antagonistic bacteria or fungi by streptomycin, not the negation of nematicidal properties of phenamiphos by chemical changes.

It is evident that contact or nonfumigant nematicides can be applied to turf in the northeastern United States to reduce plant-parasitic nematode populations and turf damage. For maximum effectiveness, more information is needed on the effects of soil type on nematicides, the timing of treatments, the nematicide most effective for the nematode species in a particular soil, rates of application, and application procedures.

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