Control of Heterodera schachtii with Foliar Application of Nematicides[1]

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Abstract: Foliar applications of ethyl 4-(methylthio)-m-tolyl isopropylphosphoramidate (phenamiphos) or *S*-methyl 1-(dimethylcarbamoyl)-*N*-[(methylcarbamoyl)oxy] thioformimidate (oxamyl) retarded infection of sugarbeets by the sugarbeet nematode, *Heterodera schachtii* under greenhouse conditions. Maximum nematode control was obtained when treatments were applied previous to, or at the time of, inoculation of plants with the nematode. Consecutive foliar applications inhibited nematode development, with four applications giving greatest inhibition of maturation. A treatment with either phenamiphos or oxamyl at 2,000 μg/ml (ppm) resulted in the greatest increase in plant growth, and 4,000 μg/ml gave the best nematode control. A treatment of 4,000 μg/ml of either phenamiphos or oxamyl was phytotoxic. However, this was due to container confinement of the chemical since phytotoxicity at this rate has not been observed under field conditions. *Key words: Beta vulgaris,* multiple treatment.

Radewald et al. (7) described the control of *Meloidogyne incognita* (Kofoid & White) Chitwood and *Pratylenchus scribneri* Steiner with foliar applications of oxamyl (*S*-methyl 1 - (dimethylcarbamoyl) - *N* - [(methylcarbamoyl)oxy] thioformimidate) on several plant species. Since then, there has been an increased interest in the possible use of foliar sprays to control soil-borne plant-parasitic nematodes (1, 2, 4, 5, 6, 8).

Each year there is an increase in the use of preplant soil fumigants and applications of nonfumigants at time of planting for control of the sugarbeet nematode, *Heterodera schachtii* Schmidt. In some instances, however, a postplant application would be advantageous.

Because a foliar application would be the simplest method of applying a postplant nematicide, a greenhouse study was conducted to determine the efficacy of applying nematicides to sugarbeet foliage to control the sugarbeet nematode.

MATERIALS AND METHODS

S-methyl 1-(dimethylcarbamoyl)-*N*-[(methylcarbamoyl)oxy] thioformimidate (oxamyl) and ethyl 4-(methylthio)-m-tolyl isopropylphosphoramidate (phenamiphos) were the systemic nematicides used.

All test plants were grown in 10-cm-square plastic containers, placed in steel trays (80 × 56 × 2 cm), in a greenhouse at 22 ± 4 C. Plants were watered from the bottom by adding water to the trays.

It was determined in preliminary experiments that the most effective treatment procedure was to transplant the seedlings into the test containers, and then to spray the foliage with a low pressure sprayer until runoff. To prevent any of the chemical from reaching the soil or root tissue, the plants were inverted at time of treatment and the foliage was dried before the plants were turned upright.

In preliminary investigations, it appeared that plant age at time of treatment was important to subsequent plant growth. Therefore in the first experiment, sugarbeet plants (*Beta vulgaris* L.) in the 4 to 6-, 8 to 10-, and 12 to 14-leaf stages were used. The plants were transplanted to a sandy loam soil infested with *H. schachtii* (M. H. C. = 21%; 2.4 larvae/g soil). The foliage was sprayed with concentrations of 500, 1,000, 2,000, and 4,000 μg/ml of oxamyl or phenamiphos. Six weeks after treatment, top and root weights of treated plants were compared with those of nontreated control plants.

In a similar experiment, with the same concentration of phenamiphos as used in the first experiment, sugarbeet plants in the 4 to 6-leaf stage were transplanted into methyl bromide-treated Provo sand (M. H. C. = 17%) and inoculated with *H. schachtii* larvae (2.5 larvae/g soil). Six weeks after treatment, top and root weights of treated plants were compared with those of nontreated control plants.

A third experiment was designed to determine the relationship of sugarbeet

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growth with time of foliar treatment and nematode infection. Plants in the 4 to 6-leaf stage were inoculated with *H. schachtii* larvae (2.5 larvae/g soil) either 28 days before foliar treatment, immediately before foliar treatment, or 14 days after foliar treatment. Forty-two days after the last foliar treatment plants were harvested and weighed, and the number of females and cysts per root was determined.

The effects of foliar applications on infection and maturation of *H. schachtii* on sugarbeet were investigated in a fourth experiment. Plants in the 4 to 6-leaf stage were inoculated with 100 *H. schachtii* larvae immediately before foliar treatment. Ten plants per treatment were harvested 14 days after treatment to determine infection, and 42 days after treatment to determine nematode maturation.

The efficacy of multiple chemical application on control of the sugarbeet nematode was studied in a fifth experiment. Plants in the 4 to 6-leaf stage were planted into *H. schachtii*-infested soil (2.4 larvae/g soil) immediately before foliar treatment. Of the 24 plants per replicate, 18 received a second treatment 15 days after the initial treatment, 12 of these received another treatment 35 days after the initial treatment, and 6 received a fourth treatment 60 days after the initial treatment. Plant weights and nematode maturation (females and cysts per root) were determined 26 days after this final foliar treatment.

RESULTS

Effects of plant age on response to foliar application: Foliar application of both phenamiphos and oxamyl resulted in increased plant growth (top and root weight) of sugarbeet seedlings transplanted into *H. schachtii*-infested soil (Fig. 1). Plants treated with 2,000 μg/ml of either nematicide grew better than at other rates, and young seedling growth was better than that of older seedlings treated with comparable rates of either material. For example, plants treated in the 4 to 6-leaf stage with 2,000 μg/ml of phenamiphos had an increase of 76% in top weight and 46% in root weight over controls, compared with increased top and root weight of 17% and 20% of plants treated in the 12 to 14-leaf stage. Similar results were found for oxamyl-treated plants, although top growth on phenamiphos-treated plants treated in the 4 to 6- and 8 to 10-leaf stages was slightly better than that of oxamyl-treated plants.

Plants treated with 2,000 μg/ml of phenamiphos showed a slight leaf phytotoxicity, whereas those treated with 4,000 μg/ml showed a severe phytotoxicity (stunting and leaf necrosis). There was no observable phytotoxicity on plants treated with 2,000 μg/ml of oxamyl, but at 4,000 μg/ml slight phytotoxicity was observed.

TABLE 1. Effects of time of foliar application of phenamiphos on maturation of *Heterodera schachtii* on sugarbeet[a].

Time of treatment	Rate (μg/ml)	Plant weight (% of control)[b]	Females and cysts per root[b]
14 days before inoculation	500	126	24
	1,000	138	17
	2,000	164	9
	4,000	109	7
At inoculation	500	119	21
	1,000	127	16
	2,000	168	12
	4,000	117	7
28 days after inoculation	500	106	62
	1,000	114	54
	2,000	121	39
	4,000	102	26
Control			72
LSD ($P = 0.05$) =		19	13

[a]Plants inoculated with 2.5 larvae per gram of soil.
[b]Readings made 70 days after plants were inoculated with *H. schachtii* larvae. Average control plant weight = 46.9 g.

These results were verified in an experiment where transplants were inoculated with 2.5 larvae per gram of soil and treated with comparable rates of phenamiphos.

Effects of time of foliar treatment on plant growth in Heterodera schachtii-infested soil: There was an increase in plant growth of sugarbeets treated with phenamiphos either 14 days before or at time of transplanting compared to nontreated control plants. However, there was no increase in plant growth over nontreated control plants when plants were treated with phenamiphos 28 days after transplanting (Table 1).

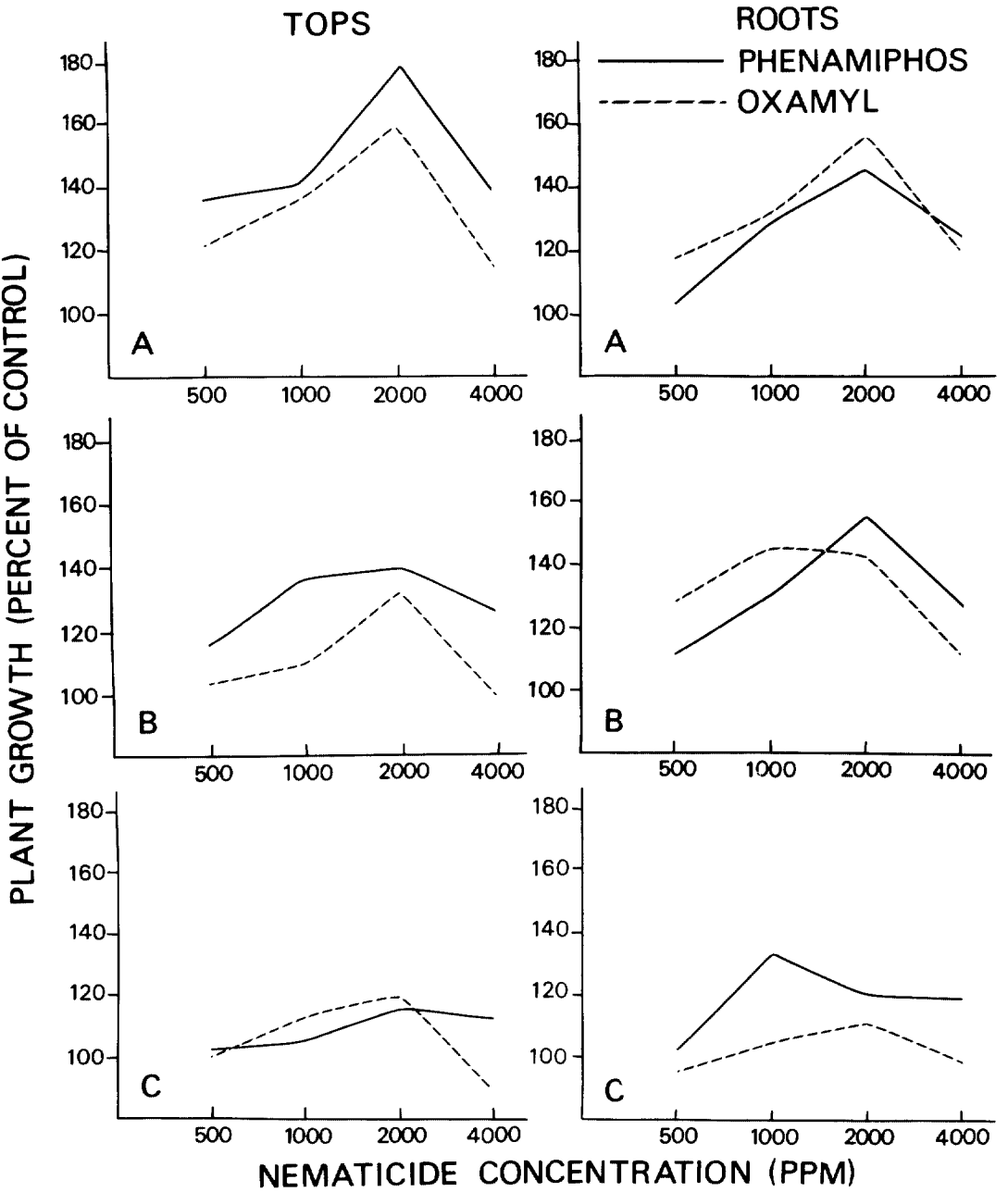

FIG. 1-(A to C). The effects of foliar applications of phenamiphos and oxamyl and age of plant at time of treatment on growth of sugarbeet transplants in *Heterodera schachtii*-infested soil (2.4 larvae per gram soil) as determined by top and root weights. **A)** Plants treated in 4 to 6-leaf stage. **B)** Plants treated in 8 to 10-leaf stage. **C)** Plants treated in 12 to 14-leaf stage.

TABLE 2. Effects of foliar applications of phenamiphos and oxamyl to sugarbeet on development of *Heterodera schachtii*[a].

Nematicide concentration (μg/ml)	Larvae per plant[b]		Females per plant[c]	
	phenamiphos	oxamyl	phenamiphos	oxamyl
0	42	42	37	37
500	32	29	25	22
1,000	27	26	18	14
2,000	26	21	12	10
LSD ($P = 0.05$) =	9	9	5	5

[a]Plants inoculated in 4 to 6-leaf stage at time of foliar treatment with 100 larvae per plant.
[b]Infection determined 14 days after inoculation.
[c]Nematode development determined 42 days after inoculation.

TABLE 3. Effect of multiple foliar applications of phenamiphos and oxamyl on development of *Heterodera schachtii* on sugarbeet transplants[a].

Treatments	Rate (μg/ml)	Number of applications and females and cysts per plant[b]				LSD ($P = 0.05$)
		1	2	3	4	
Phenamiphos	500	40	11	7	5	7
	1,000	23	7	4	2	8
	2,000	10	4	3	1	6
Oxamyl	500	38	18	16	12	11
	1,000	18	16	11	9	10
	2,000	11	11	4	3	5
Control		63	63	63	63	...
LSD ($P=0.05$) =		9	6	5	5	

[a]Sugarbeets (4 to 6-leaf stage) transplanted into infested soil (2.4 larvae per gram of soil) immediately before first chemical application.
[b]Applications were made at planting, and 15, 35, and 60 days after planting. Plants were harvested 26 days after fourth application of chemical.

Fair-to-good control of *H. schachtii* was obtained with foliar applications made before or at time of inoculation. The best control occurred at 2,000 and 4,000 μg/ml applied before and at the time of transplanting. Although treatments 28 days after inoculation resulted in sub-optimal nematode control, the higher rates inhibited nematode maturation.

Effects of foliar treatments on infection and maturation of Heterodera schachtii: All rates of oxamyl or phenamiphos retarded infection and maturation of *H. schachtii* in sugarbeet (Table 2). Eighty-eight percent of the larvae that infected nontreated plants matured to adult females compared to 78, 66, and 46% for phenamiphos and 76, 54, and 48% for oxamyl at 500, 1,000, and 2,000 μg/ml, respectively.

Influence of multiple foliar treatments on control of Heterodera schachtii: Multiple applications of phenamiphos and oxamyl also retarded development of females and cysts (Table 3). There were no differences between nematodes in plants treated with phenamiphos and oxamyl after one treatment. However, two applications resulted in fewer females and cysts in phenamiphos-treated plants than in oxamyl-treated plants. This effect decreased with increased applications.

A single application of phenamiphos or oxamyl resulted in greater plant growth over nontreated control plants except in those that received 500 μg/ml (Table 4). An increase in growth of sugarbeets occurred after multiple applications of phenamiphos or oxamyl compared to plants which received a single application of 500 and 1,000 μg/ml, but not 2,000 μg/ml. No differences were noted between plants which received 2-4 applications of either chemical at any rate.

DISCUSSION

The fact that phenamiphos and oxamyl can

TABLE 4. Effects of multiple foliar applications of phenamiphos and oxamyl on growth of sugarbeet transplants infected with *Heterodera schachtii*[a].

Treatments	Rate (μg/ml)	Number of applications and plant weights (% of control)[b] 1	2	3	4	LSD ($P = 0.05$)
Phenamiphos	500	117	150	160	159	19
	1,000	136	159	163	164	14
	2,000	149	161	166	170	16
Oxamyl	500	113	137	142	146	18
	1,000	130	148	147	154	13
	2,000	142	153	156	167	20
LSD ($P=0.05$)=		22	26	24	31	

[a]Sugarbeets (4 to 6-leaf stage) transplanted into infested soil (2.4 larvae per gram of soil) immediately before first chemical application.
[b]Applications were made at planting, and 15, 35, and 60 days after planting. Average control plant weight = 57.4 g.

be translocated from sugarbeet foliage to the roots in sufficient amounts to control *H. schachtii,* and thereby increase plant growth has important ramifications to the sugarbeet industry if such treatments prove to be effective under field conditions. Results from foliar applications of phenamiphos and oxamyl to sugarbeet were similar to results obtained when sugarbeet seed was planted into *H. schachtii*-infested soil treated with systemic nematicides (3).

Since foliar applications on older plants resulted in minimal increases in plant growth, effective field treatments may necessitate a preplanting or at-planting treatment in combination with a foliar application. Because plant response to foliar treatments applied 28 days after transplanting did not affect plant growth, foliar treatment(s) may be necessary before plants show symptoms of nematode damage; more than one application may also be required to give adequate control. The use of multiple chemical applications may prove advantageous in a chemical control program. However, there were no significant differences in plant growth of sugarbeet plants which received 2-4 applications.

Highest application rates resulted in best nematode control, but resulted in the poorest plant growth due to phytotoxicity. Phytotoxicity would not be expected to be as severe under field conditions where foliage coverage would not be as complete as in controlled tests, and no phytotoxicity has been observed with 4,000 μg/ml of oxamyl. However, a foliar application of 6,000 μg/ml phenamiphos was phytotoxic to sugarbeet seedlings in the field. A less complete foliage cover may result in less effective nematode control and may not be sufficient to guarantee proper plant growth, but multiple rates at lower concentrations may give satisfactory control. Further study is needed to determine the practicality of using foliar treatments in nematode control programs.

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