

Efficacy of Multiple Applications of Oxamyl and Phenamiphos for Control of *Pratylenchus penetrans* in Birdsfoot Trefoil¹

L. S. THOMPSON and C. B. WILLIS

Abstract: Preplant soil applications of granular phenamiphos effectively reduced *Pratylenchus penetrans* in soil during the seeding year and 1 year after, and in the roots of birdsfoot trefoil 2 years after seeding. Forage yields were increased in the season following application of phenamiphos, but stands of plants/m² were not greater ($P = 0.05$) than those in the checks 1 and 2 years after treatment. Additional spring applications of phenamiphos 1 and 2 years after seeding further reduced numbers of nematodes in the soil but did not improve forage yields or plant stand over that of a single application. Broadcast preplant soil sprays of oxamyl followed by several foliar sprays at different rates and frequencies of application over a 3-year period restricted populations of *P. penetrans* in the soil and roots of birdsfoot trefoil but did not consistently result in increased forage yields. Stands of birdsfoot trefoil continued to decline each year even with oxamyl treatments. **Key Words:** *Lotus corniculatus*, root-lesion nematode.

Root-lesion nematodes, *Pratylenchus penetrans* (Cobb) Filipv. and Schuurm.-Stekh., suppress yields of birdsfoot trefoil, *Lotus corniculatus* L. (3, 5). Under greenhouse conditions, oxamyl applied as a soil drench at seeding, or as a foliar spray 4 weeks after seeding, controlled *P. penetrans* and resulted in increased foliage yield and root weight of birdsfoot trefoil in comparison with those of nontreated plants (6). Greater nematode control and foliage yields were obtained by supplementing a drench application with two foliar spray applications. Phenamiphos granules broadcast just prior to seeding birdsfoot trefoil in the field reduced the number of root-lesion nematodes recovered from soil and roots 2 and 16 months after seeding, and increased first cut forage yields (3). Nematodes were not eliminated, however, and soil and plant roots gradually became as heavily infested as the nontreated areas.

The present study was conducted in the field to compare the effects of preplant-nematicide applications with preplant plus supplementary applications on *P. penetrans* populations in soil and roots, on prevention of subsequent build-up of *P. penetrans*, and on yield and persistence of birdsfoot trefoil.

MATERIALS AND METHODS

The first field experiment was initiated in 1971 near Charlottetown, Prince Edward Island, on Charlottetown fine-sandy loam

(70% sand, 20% silt and 10% clay). The field was infested with approximately 8,000 *P. penetrans*/kg of dry soil. A randomized complete block design with five replications was used. Plots were 4.2 x 4.5 m with 1.5-m buffer areas between plots. Treatments were: (i) no treatment; (ii) phenamiphos broadcast preplant in 1971 at 22.4 kg(a.i.)/ha; (iii) phenamiphos broadcast preplant in 1971 at 22.4 kg(a.i.)/ha plus spring applications in 1972 and 1973 at 11.2 kg(a.i.)/ha; (iv) oxamyl sprayed preplant on soil in 1971 at 4.48 kg(a.i.)/ha followed by two foliar sprays 6 and 14 weeks later at 2.24 kg(a.i.)/ha, plus eight sprays at 3-week intervals in 1972 (1st at 4.48 kg and remainder at 2.24 kg(a.i.)/ha), and five sprays at 5-week intervals in 1973 at 4.48 kg(a.i.)/ha.

Phenamiphos 15 G was applied preplant by hand and rototilled into the top 10-cm soil layer. Postplant applications were broadcast by hand over the plants in the spring. Oxamyl (240 gm(a.i.)/liter) was applied as a preplant-spray treatment to the soil with a sprayer-equipped garden tractor or a CO₂ pressurized precision plot sprayer and then rototilled into the top 10-cm soil layer. Postplant-oxamyl treatments were applied as broadcast foliar sprays at predetermined intervals.

The soil pH at seeding was approximately 6.2, and fertilizer applications were made at seeding and throughout the experimental period according to soil analyses and in keeping with crop recommendations for the area. The plots were seeded with 'Leo' birdsfoot trefoil on 4 June 1971 with a cultipacker-type seeder.

Received for publication 13 April 1976.

¹Contribution No. 354, Research Station, Agriculture Canada, Charlottetown, Prince Edward Island, C1A 7M8. Oxamyl and phenamiphos used in this investigation were supplied by DuPont of Canada Ltd., and Chemagro Ltd., respectively.

Soil samples were collected from each plot at monthly intervals during the growing period of each year. Root samples were collected in July and October. In 1971, samples were not collected from the phenamiphos-treated plots which received additional phenamiphos in 1972 and 1973. Soil samples were mixed and screened through a 2-mm sieve. Nematodes were recovered from a 50-gm subsample of the sieved soil after 7 days in modified Baermann pans (4). Root samples were washed free of soil, and 10 gm of rootlets (trimmed from main roots) were placed in a mist chamber at 25 C for 7 days. Extracted root-lesion nematodes were counted, and densities calculated as number/kg of dry soil and /gm of dry rootlet.

Densities of birdsfoot trefoil plants within a 0.27-m² area of each plot were determined in late June 1971 and in the same areas in September 1972 and October 1973. Forage (50% bloom stage) was cut in August of 1971 and in June and August 1972, and dry matter yields were recorded. Because of extensive weed invasion in almost all plots in 1973, yield data were not recorded. All nematode data were subjected to square root ($x + 1$) transformations, and all data were analyzed by analysis of variance and Duncan's multiple range test; nontransformed means are presented in the tables.

In 1972, a second field experiment was initiated adjacent to the first experiment. The experimental design was similar, except that plots were 3.6 x 4.5 m. Treatments were: (i) no treatment; (ii) oxamyl sprayed preplant in 1972 at 8.96 kg(a.i.)/ha followed by seven foliar sprays at 3-week intervals at 2.24 kg(a.i.)/ha, plus three sprays in 1973 at 4.48 kg(a.i.)/ha (May 15, July 4, Sept. 4), plus three sprays in 1974 at 4.48 kg(a.i.)/ha (May 14, July 9, Sept. 24); (iii) oxamyl sprayed preplant in 1972 at 13.44 kg(a.i.)/ha followed by four foliar sprays at 5-week intervals at 4.48 kg(a.i.)/ha, plus five sprays in 1973 at 4.48 kg(a.i.)/ha (May 15-Oct. 2), plus five sprays in 1974 at 4.48 kg(a.i.)/ha (May 14-Oct. 1).

The plots were seeded with 'Leo' birdsfoot trefoil on 7 June 1972. Soil samples were collected from each plot at monthly intervals, whereas rootlet samples were collected during July and again during

October each year. Forage (50% bloom stage) was cut in August of 1972, and in June or July and August of 1973 and 1974. Plant counts were made in May and October 1973, and in May of 1974. Other procedures followed were similar to those reported for the first experiment.

RESULTS AND DISCUSSION

In comparison with the checks, a preplant application of phenamiphos in 1971 reduced the numbers of *P. penetrans* in soil (92% by October) in the seeding year and during the year following seeding (Table 1). This finding is in agreement with an earlier study (3). Root-lesion nematode numbers in soil were comparable to those in the checks, however, by mid- to late 1973. When phenamiphos was applied again to designated plots in the spring of 1972, a further reduction in numbers of nematodes in soil occurred relative to those in plots receiving the single treatment in 1972, but differences were only significant in September and October. The numbers of nematodes in soil from plots receiving an additional treatment of phenamiphos in the spring of 1973 were 90% lower in October than those in the nontreated checks or the plots receiving the single application of phenamiphos.

A preplant-broadcast spray of oxamyl at 4.48 kg(a.i.)/ha applied to the soil in 1971, followed by foliar sprays (2.4 kg(a.i.)/ha) 6 and 14 weeks later did not lower nematode densities in soil relative to those in the checks (Table 1). Abawi and Mai (1) found greater numbers of *P. penetrans* in soil around roots of oxamyl-treated, fruit-tree seedlings than around nontreated seedlings during the first 3-4 weeks after nematode inoculation. They suggested that oxamyl in roots prevented invasion by *P. penetrans*. Radewald et al. (2) also suggested that foliar sprays with oxamyl were prophylactic in action. When soil treated with oxamyl was compared with soil in nontreated plots, no significant increase in numbers of nematodes was detected in either this or the second experiment at the time the first soil sample was taken (approximately 2 weeks after treatment). Oxamyl applied as a foliar spray (4.48 kg(a.i.)/ha) early in the spring of 1972 and

TABLE 1. Numbers of *Pratylenchus penetrans* in soil and in rootlets of birdsfoot trefoil as influenced by nematicides (Experiment 1).

Treatment	No. nematodes (in 1,000's)*						
	per kg dry soil					per gm dry wt rootlet	
	June	July	Aug.	Sept.	Oct.	July	Oct.
	1971						
Check	5.4 ab	2.3 a	4.4 a	9.0 a	12.3 a	4.0 a	5.9 a
Phenamiphos ^x	3.8 b	0.4 b	1.0 b	0.7 b	1.0 b	0.8 b	0.2 c
Phenamiphos ^y	—	—	—	—	1.0 b	—	0.0 c
Oxamyl ^z	6.8 a	2.2 a	3.5 a	5.0 a	8.2 a	1.5 b	2.3 b
	1972						
Check	8.2 a	10.7 a	15.3 a	10.5 a	10.8 a	34.0 a	34.0 a
Phenamiphos ^x	0.9 b	1.0 b	2.3 c	5.4 b	4.2 b	3.0 c	3.2 b
Phenamiphos ^y	0.2 b	0.7 b	0.7 c	1.6 c	1.5 c	1.6 c	2.7 b
Oxamyl ^z	6.1 a	5.7 a	8.9 b	4.8 b	3.6 bc	9.8 b	5.4 b
	1973						
Check	5.7 a	2.6 a	2.7 a	5.2 a	5.3 a	24.3 a	15.7 a
Phenamiphos ^x	2.0 b	3.0 a	1.8 a	4.3 a	4.4 a	5.0 b	3.6 b
Phenamiphos ^y	0.0 c	0.1 c	0.0 c	0.1 b	0.2 b	1.3 b	1.6 c
Oxamyl ^z	2.2 b	0.6 b	0.7 b	0.8 b	0.3 b	1.9 b	2.9 bc

*Means within the same group of a column followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

^xPreplant application only in 1971.

^yApplied in 1971, 1972 and 1973.

^zThree applications in 1971, eight in 1972, and five in 1973.

followed by seven foliar sprays (2.24 kg (a.i.)/ha) at 3-week intervals reduced soil nematode populations from August to October (Table 1). Oxamyl applied at 4.48 kg(a.i.)/ha five times in 1973 at 5-week intervals resulted in lower numbers of nematodes in treated soil than in soil of the checks throughout the growing season. An annual application of granular phenamiphos in the spring of each year was as effective as several oxamyl sprays each year in preventing build-up of root-lesion nematodes in soil.

The preplant soil treatments of phenamiphos in 1971 reduced the number of *P. penetrans* in birdsfoot trefoil roots (relative to those in the checks) 97% in October 1971 and 91% in October 1972 (Table 1). The number of nematodes in roots remained low into 1973 (77% in October). Although further reduction in numbers of *P. penetrans* in roots occurred with additional phenamiphos treatments in the spring of 1972 and 1973, differences were significant only in October 1973 from the single phenamiphos treatment.

In comparison with the numbers of *P. penetrans* in the nontreated checks, the numbers in roots of birdsfoot trefoil were reduced significantly each year by the oxamyl sprays (Table 1).

Despite a significant reduction in nematodes in the roots, forage yields were not significantly increased in treated plots during the seeding year (Table 2). In 1972, however, plots treated with phenamiphos in 1971 yielded more than the checks at the August cut, as did plots which received additional phenamiphos in 1972. Increased yields were not obtained in the oxamyl-treated plots in 1972.

The number of birdsfoot trefoil plants/m² was significantly greater in phenamiphos- and oxamyl-treated plots than in nontreated plots in 1971. Plant stands in 1972 and 1973, however, were not affected significantly by nematicides.

In the second experiment, oxamyl applied to the soil surface in 1972 as a preplant-broadcast spray (8.96 kg(a.i.)/ha) and to the foliage seven times at 3-week intervals (2.24 kg(a.i.)/ha) reduced the

TABLE 2. Effects of nematicides on forage yields of birdsfoot trefoil (Experiments 1 and 2).

Treatment	Forage yield (kg/ha)*				
	1971	1972			
		June	Aug. [‡]		
Experiment 1					
Check	1353 a	2013 a	255 a		
Phenamiphos [‡]	1517 a	2105 a	1001 b		
Phenamiphos [‡]	1722 a	2059 a	1036 b		
Oxamyl [‡]	1374 a	1936 a	541 a		
Experiment 2					
	1972	1973 [‡]		1974 [‡]	
		June	Aug.	July [‡]	Aug. [‡]
Check	1270 a	2615 a	1045 a	679 a	880 a
Oxamyl [‡]	1549 a	2744 a	1241 b	1048 a	1159 b
Oxamyl [‡]	1496 a	2946 a	1369 b	1155 a	1219 b

*Figures within a column followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

[‡]Trefoil separated from weeds, etc. and only the trefoil yields are shown.

[‡]Preplant application only.

[‡]Applied in 1971, 1972 and 1973.

[‡]Three applications in 1971, eight in 1972, and five in 1973.

[‡]Based on 4 replications (fifth replicate winterkilled, 1972-73).

[‡]Applied eight times in 1972 and three times in 1973 and 1974.

[‡]Applied five times in 1972, 1973 and 1974.

number of nematodes recovered from the soil (June-October) but the reduction in July was not significant (Table 3). The initial rate and frequency of treatment were greater than in the seeding year in the first experiment, which probably accounts for the overall greater reduction in numbers of *P. penetrans*. When oxamyl was applied as a preplant-broadcast spray to the soil in 1972 at 13.44 kg(a.i.)/ha and followed by four foliar sprays (4.48 kg(a.i.)/ha) at 5-week intervals, nematode reduction in the soil was similar to that in the other oxamyl treatment.

In 1973 and 1974, the initial and supplementary rate of oxamyl was 4.48 kg (a.i.)/ha. When oxamyl was applied to the foliage in the spring and again 7 or 8 and 16 or 19 weeks later, numbers of *P. penetrans* in the soil were lower in comparison with those in the checks at all sampling dates except August 1973 and July 1974 (Table 3). When oxamyl was applied to the foliage early in the spring (1973 and 1974) and again 4 times at 5-week intervals, the number of nematodes in the soil in the treated plots was lower than in the nontreated plots, and on some sampling

dates, lower than in the other oxamyl-treated plots.

Numbers of *P. penetrans* in roots of plants in plots treated with oxamyl were significantly lower by October 1972 than in roots of plants in nontreated plots (Table 3). Eight applications were more effective than five applications in reducing numbers of *P. penetrans* in the roots, regardless of rates. In 1973, both oxamyl treatments effectively restricted numbers of nematodes in roots to low levels (in comparison with numbers in the checks) and again, the more frequent the spray application, the greater the reduction. The more frequent sprays in 1974 also reduced root-nematode numbers.

As in the first experiment, birdsfoot-trefoil yields in this experiment were not increased in the seeding year as a result of the oxamyl-spray treatments, even though the numbers of nematodes in soil and roots were reduced substantially (Table 2). Increased yields occurred in 1973 and 1974 in all oxamyl-treated plots in comparison with yields in the nontreated plots, but yield differences were significant only for the cut in August. In 1973 and 1974, plant stands were greater in plots treated with

TABLE 3. Numbers of *Pratylenchus penetrans* in soil and in rootlets of birdsfoot trefoil as influenced by nematicides (Experiment 2).

Treatment	No. nematodes (in 1,000's)*						
	per kg dry soil					per gm dry wt rootlet	
	June	July	Aug.	Sept.	Oct.	July	Oct.
	1972						
Check	8.6 a	4.9 a	15.5 a	33.3 a	18.5 a	6.9 a	30.7 a
Oxamyl [†]	5.0 b	4.4 a	5.1 b	13.0 b	4.8 b	4.3 a	7.7 c
Oxamyl [‡]	4.6 b	6.0 a	10.8 ab	10.3 b	4.8 b	5.2 a	14.9 b
	1973						
Check	18.2 a	11.1 a	7.9 a	9.4 a	7.9 a	56.3 a	13.0 a
Oxamyl [†]	4.0 b	2.1 b	6.6 a	4.1 b	2.3 b	11.3 b	8.5 b
Oxamyl [‡]	3.1 b	1.4 b	1.7 b	0.9 c	1.3 b	9.0 b	3.0 c
	1974						
Check	6.2 a	4.9 a	8.6 a	11.3 a	11.8 a	27.5 a	19.6 a
Oxamyl [†]	1.6 b	3.4 a	1.8 b	5.5 b	6.1 b	17.0 a	13.7 a
Oxamyl [‡]	1.2 b	1.0 b	0.6 c	1.9 c	2.2 c	6.2 b	2.5 b

*Means within a column followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

[†]Applied eight times in 1972 and three times in 1973 and 1974.

[‡]Applied five times in 1972, 1973 and 1974.

frequent sprays, but the differences were not significant.

These experiments demonstrate that continued use of oxamyl in foliar sprays or annual applications of granular phenamiphos in the spring of each year prevented the build-up of *P. penetrans* in birdsfoot trefoil roots (and soil) to levels observed in nontreated plots. When the treatments were applied to second and third year birdsfoot trefoil plants, significant increases in forage yields resulted (in comparison with increases in the nontreated plants), but plant stands continued to decline, despite the control of *P. penetrans* obtained in soil and roots. Since an annual application of granular phenamiphos was as effective as multiple sprays of oxamyl each year in preventing build-up of nematodes, the former would be the most practical treatment for field use. Current prices, however, and the registration status of these nematicides prohibit their use on birdsfoot trefoil at present.

LITERATURE CITED

1. ABAWI, G. S., and W. F. MAI. 1972. Mode of action of Vydate in controlling *Pratylenchus penetrans*. *J. Nematol.* 4:219.
2. RADEWALD, J. D., F. SHIBUYA, J. NELSON, and J. BIVENS. 1970. Nematode control with 1410, an experimental nematicide-insecticide. *Plant Dis. Rep.* 54:187-190.
3. THOMPSON, L. S., and C. B. WILLIS. 1970. Effect of nematicides on root lesion nematodes and forage legume yields. *Can. J. Plant Sci.* 50:577-581.
4. TOWNSHEND, J. L. 1963. A modification and evaluation of the apparatus for the Oostenbrink direct cottonwool filter extraction method. *Nematologica* 9:106-110.
5. WILLIS, C. B., and L. S. THOMPSON. 1969. Effect of the root-lesion nematode on yield of four forage legumes under greenhouse conditions. *Can. J. Plant Sci.* 49:505-509.
6. WILLIS, C. B., and L. S. THOMPSON. 1973. Control of *Pratylenchus penetrans* in birdsfoot trefoil with oxamyl. *Plant Dis. Rep.* 57:237-240.