Systemic Nematicides for Control of *Pratylenchus penetrans* During Apple Orchard Establishment in Ontario

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ABSTRACT

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The combination of a soil application of aldicarb plus a foliar overspray of oxamyl was a practical and effective method of establishing apple orchards on soil infested by the root-lesion nematode. This treatment combination resulted in increased trunk girth, reduced soil and root nematode populations, and controlled the first two generations of spotted tentiform leafminer. Use of either chemical alone gave nematode control and growth response, but only the oxamyl foliar overspray gave leafminer control.

The pathogenicity of *Pratylenchus penetrans* (Cobb) Filip. and Stek. to apple is well documented (10,12,15,16) and the benefit of preplant fumigation demonstrated (3,6,7,9,13,14). Abawi and Mai (1) found a reduction in levels of *P. penetrans* in apple roots after foliar spray applications of oxamyl. The usefulness of aldicarb for apple orchard establishment has also been demonstrated (8), and the effectiveness of several nonfumigant nematicides in controlling *P. penetrans* population levels in the roots of several tree fruit species has been shown (2).

Only preplant fumigants are now registered for nematode control in apple in Ontario. When orchards are planted on soils subsequently found to be infested by *P. penetrans*, a postplant treatment or control measure would be very desirable. This paper presents evidence on the efficacy of several postplant nematicide treatments in controlling root-lesion nematode in a newly planted apple orchard and observations on control of spotted tentiform leafminer (STLM), *Phyllonorycter blancardella* Fabr., by nematicide applications.

MATERIALS AND METHODS

A planting of 252 trees of 1-yr-old McIntosh apple (*Malus pumila* Mill.) on M26 rootstock was made in April 1976 at Vineland, Ontario. The land, previously planted to a mixture of apple varieties on M VII rootstock, had been cleared 6 mo previously. Trees were planted in a spacing of 2.4 × 4.9 m on a Vineland silt loam soil. In May 1976, the soil nematode level was 4,262 ± 662 *P. penetrans* per kilogram. A randomized block experiment using three nematicide treatments and an untreated control, replicated nine times, was superimposed over the orchard. Each treatment plot consisted of six trees; the remaining 36 trees served as buffers.

Treatments used were an untreated control, aldicarb 10G, fenamiphos 15G, and oxamyl 15G. These nematicides were applied to the soil in a 90-cm-diameter circle around the base of each tree at 0.16 g a.i./m^2 and immediately incorporated with a hand rake.

Plots were split into two equal subplots, and three trees in each plot received four foliar applications of oxamyl at 1.12 kg a.i./ha. Oxamyl application commenced on the same day as the soil nematicide application and followed at 14-day intervals over the next 6 wk. Foliar applications were made with a knapsack sprayer.

The nematicide soil treatments were applied on 18 June 1976, 14 June 1977, and 12 June 1978. The four biweekly foliar oxamyl applications were applied in all three years. Normal recommended practices of orchard management were used, and a cover crop of creeping red fescue (*Festuca rubra* L.) was planted in spring 1977.

Soil samples for nematode counts were taken in May and September of each year. The samples, consisting of four bulked cores from the drip line of each tree in each three-tree subplot, were taken to a depth of 20 cm with a 2.5-cm (i.d.) soil tube. Each sample was thoroughly mixed and screened through a four-mesh (6,000 μm) sieve. Nematodes were extracted from a 50-g subsample using

Table 1. Effect of nematicides on tree growth and root population levels of *Pratylenchus penetrans* in McIntosh apple

Treatment	Trunk girth (cm)[a]				*P. penetrans*/g of root[b],
	Oct. 1976	Oct. 1977	Oct. 1978	2-yr increment	Sept. 1978
Control	2.4	6.4	8.7	6.3	183
Oxamyl	2.4	6.4	8.8	6.4	130
Fenamiphos	2.4	6.1	8.4	6.0	76
Aldicarb	2.3	7.2	9.6	7.3	37
Foliar overspray	2.4	6.9	9.4	7.0	62
No foliar overspray	2.3	6.2	8.3	6.0	152
	Mean separation[c]				
Soil treatments					
Control vs. nematicides	ns	ns	ns	ns	*
Aldicarb vs. other nematicides	ns	**	**	**	*
Oxamyl vs. fenamiphos	ns	ns	ns	ns	*
Subplot effects					
Foliar spray effect	ns	**	**	**	*
Interaction foliar spray with soil treatments	ns	ns	ns	ns	ns
Aldicarb vs. other soil treatments	ns	**	**	**	*

[a] Measurements made 30 cm above the soil line.
[b] Dry weight.
[c] * and ** indicate that the comparison is significant at $P = 0.05$ and $P = 0.01$, respectively; ns = not significant. Soil treatment means for tree girth, $N = 54$; for root populations, $n = 18$.

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the modified Baermann pan method (17).

Root samples were collected in September 1978 and combined on a plot basis, and nematodes were extracted using a mistifier technique. Trunk girth of each tree was measured at 30 cm above the soil line in October 1976, 1977, and 1978.

Four of the nine replicates were sampled in September 1978 to assess the effects of the nematicide treatments on STLM. Sixty leaf samples, 20 per tree, were taken from each three-tree plot. The number of mines produced by the first two generations (old mines) was ascertained by the examination of 50 leaves per plot. Twenty of these leaves, chosen at random, were dissected under a binocular microscope, and the numbers of newly produced, inhabited mines (new mines) and the number of larvae present in each leaf were recorded.

Data collected were subjected to a split-plot analysis in which main soil treatments were considered as main plot effects, tested on the main plot error. The oxamyl overspray effect and the overspray × soil treatment interaction effects were tested against the subplot error term.

Single degree of freedom contrasts were used to determine the significance of particular treatment effects on nematode population means, means of tree girths at 30 cm, and leafminer effects. Significance of specific treatment contrasts, where indicated, was used to establish treatment differences in preference to use of the multiple range test. The latter was inappropriate because only single degree of freedom comparisons were made (4,5).

RESULTS

The effects of soil treatment and foliar oxamyl treatment on tree growth and nematode root populations are shown in Table 1. No discernible growth response to either soil or foliar treatment was evident in the first year, but increased tree growth in plots with aldicarb soil treatments and those with oxamyl overspray treatments was observed after the second and third years. Analysis of the 2-yr increase in tree circumference showed that only the aldicarb treatment and the oxamyl overspray increased girth significantly. Because there was no indication of interaction between soil treatment and overspray ($P = 0.05$), means are shown as averages. The overspray effect appeared to be additive. The oxamyl and fenamiphos soil treatments resulted in growth similar to the check.

Root samples collected in September 1978 showed a reduction in the number of nematodes per gram (dry wt) of root from all nematicide treatments. Aldicarb was the most effective in reducing nematode numbers, followed by fenamiphos, oxamyl, and the control. The foliar overspray of oxamyl gave a further additive reduction in root nematode populations (Table 1).

Soil population densities of *P. penetrans* are shown in Table 2. There was considerable variability in the nematode counts made on successive dates from the nematicide-treated plots. The reduction in nematode levels in all plots, including the control plots, from the May 1976 level of 4,262 ± 662/kg of soil was probably associated with the clean, fallowlike condition around the newly planted trees. Over the five sampling dates, the greatest reduction ($P = 0.05$) in nematode population levels was found in the aldicarb-treated plots, followed by those treated with oxamyl and fenamiphos. The foliar overspray of oxamyl resulted in a moderate reduction in soil nematode populations.

Examination of the 1978 soil counts showed that aldicarb was the most effective in reducing nematode levels, followed by oxamyl, fenamiphos, and the control; oxamyl overspray provided a further additive reduction in soil population levels. Interaction between the oxamyl foliar overspray and any of the soil nematicide treatments was not evident either for tree growth, 1978 root populations of *P. penetrans*, or any of the soil population counts of the nematode (Tables 1 and 2).

Ratings of the incidence of mines and larvae of STLM are summarized in Table 3. Soil treatments had no effect on STLM, but the oxamyl overspray reduced leafminer injury. Of the three

Table 2. Effect of nematicides on soil population levels of *Pratylenchus penetrans* under McIntosh apple

Treatment	*P. penetrans*/kg of soil					
	Sept. 1976	May 1977	Sept. 1977	May 1978	Sept. 1978	Mean
Control	690	929	1,192	993	2,176	1,192
Oxamyl	696	492	670	452	1,792	820
Fenamiphos	706	394	622	478	1,358	712
Aldicarb	572	258	339	168	1,195	506
Foliar overspray	745	572	702	482	1,329	764
No foliar overspray	586	465	710	563	1,932	851
Mean separation[a]						
Soil treatments						
Control vs. nematicides	ns	*	*	*	*	**
Aldicarb vs. other nematicides	ns	ns	*	*	*	**
Oxamyl vs. fenamiphos	ns	ns	ns	ns	*	ns
Subplot effects						
Foliar spray effect	ns	ns	ns	ns	*	ns
Interaction, foliar spray with soil treatments	ns	ns	ns	ns	ns	ns
Aldicarb vs. other soil treatments	ns	*	*	*	*	**

[a] * and ** indicate that the comparison is significant at $P = 0.05$ and $P = 0.01$, respectively; ns = not significant.

Table 3. Effect of nematicides on the incidence of spotted tentiform leafminer, *Phyllonorycter blancardella*, in McIntosh apple leaves in September 1978

Treatment	New mines per leaf	Larvae per leaf	Old mines per leaf	
			Overspray	No overspray
Control	6.2	4.5	0	0.33
Oxamyl	6.0	4.6	0	0.48
Fenamiphos	6.0	4.0	0	0.53
Aldicarb	5.7	4.0	0	0.32
Foliar overspray	6.5	4.7	0	
No foliar overspray	5.5	3.8		0.42
Mean separation[a]				
Soil treatment				
Control vs. nematicides	ns	ns	ns	
Aldicarb vs. other nematicides	ns	ns	*	
Oxamyl vs. fenamiphos	ns	ns	ns	
Subplot effects				
Foliar spray effect	*	*	**	
Interaction, foliar spray vs. soil treatments	ns	ns	ns	
Aldicarb vs. other soil treatments	ns	ns	*	

[a] * and ** indicate that the comparison is significant at $P = 0.05$ and $P = 0.01$, respectively; ns = not significant.

generations of STLM (11), oxamyl overspray controlled the first two, which produce mines in May, June, and July. At sampling in September 1978, old mines (Table 3) were uninhabited. Mines produced by the third generation (new mines) were more abundant in all treatments and contained similar numbers of feeding larvae.

DISCUSSION

The nonfumigant nematicides aldicarb and oxamyl applied after planting were useful in establishing apple orchards in southern Ontario. Soil and root populations of *P. penetrans* were reduced and plant growth increased by these chemicals. Although fenamiphos was not as effective as aldicarb, it also reduced root and soil nematode population densities considerably. Mai et al (13) stated that, in situations where root-lesion nematodes are a problem, the critical period for successful apple orchard establishment comes in the first 2 yr after planting. If trees have established a vigorous root system by then, they can tolerate later infestations.

Herne et al (8) showed that aldicarb controlled aphids and mites when used around young apple trees. However, in this study, control of STLM was achieved only by the oxamyl foliar spray. Oxamyl controlled the first two generations of STLM, which produce mines in May, June, and July (11), when oxamyl was still being applied; however, it did not control the third generation, which occurred after the treatment had stopped. Adjustments in the application schedule are necessary to control the third generation of this insect.

The postplant application of aldicarb plus foliar oversprays of oxamyl is an effective method of improving the establishment of apple orchards, primarily through nematode control, with the possible additional benefit of insect control.

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LITERATURE CITED

1. Abawi, G. S., and Mai, W. F. 1971. Root diseases of fruit trees in New York State. III. Control of *Pratylenchus penetrans* in roots of apple, peach, pear and cherry by foliar sprays with a nematicide-insecticide. Plant Dis. Rep. 55:617-620.
2. Allen, W. R., and Marks, C. F. 1977. Chemical control and population studies of *Pratylenchus penetrans* on fruit trees understocks. Plant Dis. Rep. 61:84-87.
3. Arneson, P. A., and Mai, W. F. 1976. Root diseases of fruit trees in New York State. VII. Costs and returns of preplant soil fumigation in a replanted apple orchard. Plant Dis. Rep. 60:1054-1057.
4. Baker, R. J. 1980. Multiple comparison tests. Can. J. Plant Sci. 60:325-327.
5. Chew, V. 1976. Comparing treatment means—A compendium. HortScience 11:348-357.
6. Covey, R. P., Jr., Benson, N. R., and Haglund, W. A. 1979. Effects of soil fumigation on the apple replant disease in Washington. Phytopathology 69:684-686.
7. Dunn, R. A., and Mai, W. F. 1972. Root diseases of fruit trees in New York State. V. Growth of apple trees in response to preplant treatment with nematicides and a broad-spectrum fumigant. Plant Dis. Rep. 56:577-580.
8. Herne, D. H. C., Simpson, C. M., and Townshend, J. L. 1972. Aldicarb: A systemic soil pesticide useful for establishing apple plantings. Proc. Entomol. Soc. Ont. 103:27-31.
9. Jackson, J. E. 1973. Effects of soil fumigation on the growth of apple and cherry rootstocks on land previously cropped with apples. Ann. Appl. Biol. 74:99-104.
10. Jaffee, B. A., and Mai, W. F. 1979. Growth reduction of apple seedlings by *Pratylenchus penetrans* as influenced by seedling age at inoculation. J. Nematol. 11:161-165.
11. Johnson, E. F., Laing, J. E., and Trottier, R. 1976. The seasonal occurrence of *Lithocolletis blancardella* (Gracillariidae), and its major natural enemies in Ontario apple orchards. Proc. Entomol. Soc. Ont. 107:31-45.
12. Mai, W. F. 1960. Growth of apple seedlings in relation to soil temperature and inoculation with *Pratylenchus penetrans*. Phytopathology 50:237-238.
13. Mai, W. F., Parker, K. G., and Hickey, K. O. 1970. Root diseases of fruit trees in New York State. II. Populations of *Pratylenchus penetrans* and growth of apple in response to soil treatment with nematicides. Plant Dis. Rep. 54:792-795.
14. Marks, C. F., and Davidson, T. R. 1973. Effects of preplant and postplant nematicides on populations of nematodes in the soil and on growth of fruit trees in the Niagara peninsula. Can. Plant Dis. Surv. 53:170-174.
15. Parker, K. G., and Mai, W. F. 1974. Root diseases of fruit trees in New York State. VI. Damage caused by *Pratylenchus penetrans* to apple trees in the orchard growing on different rootstocks. Plant Dis. Rep. 58:1007-1011.
16. Pitcher, R. S., Patrick, Z. A., and Mountain, W. B. 1960. Studies on the host-parasite relations of *Pratylenchus penetrans* (Cobb) to apple seedlings. I. Pathogenicity under sterile conditions. Nematologica 5:309-314.
17. Townshend, J. L. 1963. A modification and evaluation of the apparatus for the Ostenbrink direct cottonwool filter extraction method. Nematologica 9:106-110.