Chemical Control of *Longidorus elongatus* on Peppermint with Nonvolatile Nematicides

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ABSTRACT

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The mint nematode *Longidorus elongatus* causes a serious yield decline in peppermint fields in floodplains of western Oregon. Experiments with foliar sprays of oxamyl and later with granular incorporation of aldicarb and oxamyl in soil resulted in significantly increased yields of hay and oil the first year after treatment. Timing of application was of primary importance, with November and/or March applications resulting in the greatest yield response. The most effective treatments were two broadcast sprays or one granular incorporation of oxamyl. Nematode populations were only slightly and temporarily reduced but did not correlate with yield response. Although root protection by oxamyl is brief, previously damaged plants were able to reestablish vigorous root systems and resume normal growth.

Additional key words: *Mentha piperita*, nematode populations

Longidorus elongatus (de Man) Thorne & Swanger, commonly called the mint nematode in Oregon, was recognized as an important pest of peppermint (*Mentha piperita* L.) in 1954 (3). This pest is common in floodplains along the Santiam and Willamette rivers of western Oregon. The normal peppermint root system consists of a dense mat of secondary feeder roots near the soil surface at a depth of 5–10 cm and a well-developed primary root system extending to a much greater depth. Nematodes feed on and usually destroy most of the root system, which is reduced to a few short remnants. This greatly restricts the plant's ability to obtain nutrients and water for growth. Nematodes can often be seen (without magnification) when clods containing root remnants are broken open. Pink to red foliage, thinning stands, and reduced regrowth after harvest are above-ground symptoms generally related to nematode damage. The pest typically occurs in localized areas or patches; entire plantings are rarely damaged.

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In greenhouse experiments, plant growth was reduced 10-fold when rooted mint cuttings and rhizomes planted in steam-sterilized soil were compared with similar plantings in infested field soil (3). Control by soil fumigation in newly established field stands produced 16-fold increases in "green hay" (3). Fumigation treatments can be applied only before the initial planting. Surviving nematodes or those infecting planting stocks can multiply to destructive levels within 2–4 yr, eventually requiring removal of the stand.

Development of nonvolatile nematicides that can be applied before, during, or after planting enables us to evaluate new control strategies. Foliar sprays of oxamyl significantly reduced populations of mint nematodes in a greenhouse study (4).

Previous studies indicate that oxamyl treatments effectively reduce nematode populations when applied as foliar sprays before, during, or after plant exposure to nematodes. This information suggests that such treatments could give adequate control in field conditions. Field experiments in 1977 and 1978 to control the mint nematode in established and new peppermint stands are described in this report.

MATERIALS AND METHODS

1977 tests. Field plots were established in a grower's field on the Willamette River floodplain. The peppermint stand (cultivar Todd Mitcham) had been established 5 yr earlier, and high populations of mint nematodes were associated with large areas of sparse stunted growth. A study was initiated to evaluate treatments that could improve yields in previously established fields without reestablishing the stand and to reestablish a new stand in a severely infested field. In the first test, 3.4, 6.7, and 10.1 kg a.i./ha of granular formulation of oxamyl were surface-incorporated into the soil on 19 May. Foliar applications were made on 19 May, 2 June, and 16 June. The three rates (1.1, 2.2, and 3.4 kg a.i./ha) of oxamyl were applied in 2 L of water as a broadcast spray with a backpack sprayer to peppermint foliage and adjacent soil in 9.3-m^2 plots. The experiment was replicated four times in a randomized block design. Plots sprayed with the 1.1-kg rate received 1.1, 2.2, or 3.4 kg a.i./ha, depending on the number of applications. Other plots sprayed at the 2.2-kg rate received 2.2, 4.4, or 6.6 kg a.i./ha, and those sprayed at the 3.4-kg rate received 3.4, 6.8, or 10.2 kg a.i./ha.

In a second test, similar foliar and granular treatments were applied to adjacent plots (1.22 × 1.83 m) established after all vegetation had been removed and replaced by 10 rooted peppermint (Todd Mitcham) cuttings per plot. The experiment consisted of four replicates of 13 treatments in a randomized block. The plot areas received routine cultural practices given to the remainder of the field.

Peppermint in both tests was harvested on 5 August by removing three 0.8-m^2 samples of peppermint foliage (hay) at random from each plot in the established stand (test 1). All hay was removed from transplanted cuttings in the reestablished stand (test 2). Green weights of hay were recorded after the hay had been air-dried, and oil was extracted by distillation. Oil samples were weighed and sent to the Agricultural Chemistry Department, Oregon State University, for residue analysis. Composite soil samples (five subsamples) were taken from each plot before treatment, at midseason, and at harvest, processed in Baermann funnels for 4 days, and nematode soil populations were determined.

1978 tests. The experimental design was similar to those used previously, except aldicarb was added and application dates and chemical rates were modified. Chemical applications included soil incorporation of aldicarb and oxamyl granules and broadcast spray of oxamyl. As in 1977, tests were conducted in a grower's 5-yr-old planting of Todd Mitcham peppermint. A randomized block design of four replicates (9.3-m^2 plots) and three rates (0.6, 1.1, and 2.2 kg a.i./ha) of each of the two chemicals were used. Treated plots received either one or two applications on 11–25 November 1977 (fall), 27 February–1 March (winter), and 16 June (spring). Plots receiving one application were treated once during fall, winter, or spring, and those receiving two applications were treated a second time during two of the three time periods. Nematode populations were sampled before treatment and immediately after harvest. Evaluation of yield response was based on green weight of hay harvested from a 3.35-m^2 strip in each plot.

Table 1. Effect of oxamyl on populations of *Longidorus elongatus* on peppermint

Application	Rate (kg a.i/ha)	Application dates 19 May	2 June	16 June	*L. elongatus* pretreatment 19 May	Per 500 cc soil Midseason 11 July	Harvest 8 August
Spray	1.1	X			396	87	269
broadcast	1.1	X	X		312	92	322
	1.1	X	X	X	354	201	201
	2.2	X			586	164	219
	2.2	X	X		428	238	135
	2.2	X	X	X	238	119	174
	3.4	X			108	206	190
	3.4	X	X		77	132	132
	3.4	X	X	X	206	108	108
Granular	3.4	X			422	206	164
broadcast and	6.7	X			309	111	164
incorporated	10.1	X			449	166	127
Untreated Check	0				590	92	333

ANOVA		
	Date	$F = 11.359$ (significant at the $P = 0.05$ level)
	Date × treatment	$F = 0.838$ (not significant)

Table 2. Effect of oxamyl control of *Longidorus elongatus* on peppermint growth in 1977 field trials

Treatment (kg a.i./ha)	Established stand (4 M^2) Green hay (kg)	Oil (ml)	Cuttings (10 plants) Green hay (kg)	Oil (ml)
1.1 oxamyl, 2 L, one application	4.46 ab[z]	12.68 b[z]	0.59 f[z]	1.53 g[z]
1.1 oxamyl, 2 L, two applications	3.39 ab	11.58 b	0.76 de	1.75 efg
1.1 oxamyl, 2 L, three applications	5.03 a	14.23 ab	0.76 de	1.98 defg
2.2 oxamyl, 2 L, one application	4.35 ab	13.95 ab	0.69 ef	1.55 fg
2.2 oxamyl, 2 L, two applications	4.07 ab	13.55 ab	0.81 cde	2.20 bcd
2.2 oxamyl, 2 L, three applications	4.69 ab	13.80 ab	1.11 ab	2.68 b
3.4 oxamyl, 2 L, one application	4.20 ab	14.20 ab	0.94 c	2.13 bcdef
3.4 oxamyl, 2 L, two applications	5.10 a	15.38 a	1.20 a	3.18 a
3.4 oxamyl, 2 L, three applications	4.56 ab	13.45 ab	1.10 b	2.65 b
3.4 oxamyl granules, one application	4.22 ab	13.45 ab	0.86 cd	2.40 bcd
6.7 oxamyl granules, one application	4.79 ab	12.78 ab	0.95 c	2.05 cdefg
10.1 oxamyl granules, one application	5.16 a	14.93 ab	1.14 ab	2.55 b
Control	2.45 b	8.18 c	0.07 g	0.13 h

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

Table 3. Effect of timing and single applications of oxamyl and aldicarb on peppermint hay yield and *Longidorus elongatus* populations

Treatment	Rate (kg a.i./ha)	Fall 23-25 November Yield[a]	% Δ Pop.[b]	Winter 27 February-1 March Yield	% Δ Pop.	Spring 16 June Yield	% Δ Pop.
Oxamyl	0.6	6.8	56	11.8[c]	95	5.0	75
broadcast	1.1	4.7	97	8.9	138	8.9	144
granular	2.2	4.7	244	13.2[c]	66	8.9	350
Oxamyl	0.6	6.0	214	6.6	131	9.4	98
broadcast	1.1	6.1	180	8.3	72	9.7	148
spray	2.2	5.6	214	10.0	308	7.9	170
Aldicarb	0.6	3.7	38	5.4	92	4.9	48
broadcast	1.1	4.8	91	12.1[c]	47	8.0	283
granular	2.2	6.1	35	12.7[c]	108	7.3	175
Untreated check	0	5.1	519				

[a]Fresh weight of hay (kg/4m^2).
[b]Percent population change pretreatment, 1 November 1977, to postharvest, 15 August 1978.
[c]Significantly greater than check (LSD 0.05).

RESULTS

1977 tests. Plants in declined areas (test 1) were recovering and making normal growth within 4 wk after the last application. By midseason, treated plots outperformed the controls and adjacent untreated areas in the planting. Treated plants were much taller, more vigorous, and well branched, and the foliage was a healthy dark green; root systems had increased biomass and deep soil penetration. Newly established cuttings (test 2) exhibited even more spectacular treatment responses; the volume of growth above and below the ground was two to three times that of untreated cuttings during the initial 4-wk period.

Assessment of *L. elongatus* populations varied from a mean of 0.7 nematodes per cubic centimeter of soil in April to a pretreatment mean of 0.4/cm^3 of soil (52 plots in test 1) in May. Nematode numbers (Table 1) indicate the following trends: a decline when compared with untreated controls and usually a decline at midseason followed by an increase at harvest. There was a wide variation in sample numbers of nematodes among replicated plots, often with the highest numbers in better yielding treatments at harvest, as expected. Population data, however, from various treatments (Table 1) are not significantly different from data of untreated plots.

Several treatments of established mint (test 1), particularly in plots receiving more than one application, resulted in significant ($P = 0.05$) increases in green hay yield over untreated plots (Table 2). Oil yields from chemically treated plots were also significantly greater ($P = 0.05$) than those from untreated control plots. Among treated plots there were no significant differences in green hay or oil yields. Evaluation of similar data obtained from test 2 indicates significant improvement of all treatments over the control, and in several instances, significant differences ($P = 0.05$) among treatments. No oxamyl residue was found in oil derived from any treatment at any rate.

1978 results. Nematode populations were variable throughout the experimental site, regardless of sampling date. Peppermint stand and vigor were also variable within the site because of weed competition and damage by root borer (*Fumibotys fumalis* Guenée). Green hay yields from single applications of granular aldicarb at 1.1 and 2.2 and oxamyl at 0.6 and 2.2 kg a.i./ha were significantly greater ($P = 0.05$) than those from untreated control plots when chemical applications were made during winter (Table 3). Similar comparisons of double applications indicated significant yield improvement ($P = 0.05$) over

Table 4. Effect of timing and applications of oxamyl and aldicarb on peppermint hay yield and *Longidorus elongatus* populations

	Rate	Application timing					
		Fall-winter		Winter-spring		Fall-spring	
	(kg a.i./ha)	Yield[a]	% Δ Pop.[b]	Yield	% Δ Pop.	Yield	% Δ Pop.
Oxamyl	0.6	12.8[c]	177	10.4	341	5.6	92
broadcast	1.1	12.8[c]	126	11.4[c]	261	8.7	150
granular	2.2	13.6[c]	89	11.7[c]	591	8.7	1763
Oxamyl	0.6	11.2	42	12.2[c]	54	3.9	93
broadcast	1.1	11.5[c]	161	10.6	22	10.2	110
spray	2.2	14.4[c]	38	10.9	23	12.8[c]	164
Aldicarb	0.6	7.9	110	8.0	89	11.6[c]	218
broadcast	1.1	10.3	182	11.4[c]	107	4.4	69
granular	2.2	12.4[c]	33	16.1[c]	97	7.1	102
Untreated check	0	5.1	519				

[a]Fresh weight of hay (kg/4m^2).
[b]Percent population change pretreatment, 1 November 1977, to postharvest, 15 August 1978.
[c]Significantly greater than check (LSD 0.05).

untreated plots for several treatments, regardless of application time (Table 4).

As in 1977, nematode populations were variable. Sample data taken before treatment and after harvest are presented in Tables 3 and 4. Single treatments (Table 3) were lower than the control, and except in two instances, all double-treatment nematode populations were lower than those in the untreated controls (Table 4). Other trends were not observed in these data.

DISCUSSION

Two years of field trials with oxamyl and one with aldicarb indicate that favorable growth responses can be obtained in established stands infected with *L. elongatus*. The 1977 green hay and oil yields (Table 2) and the 1978 green hay yields (Tables 3 and 4) were increased in most treated sites when compared with untreated controls. In 1978, significant increases in yields were obtained with single applications of some treatments (aldicarb and oxamyl granular) in winter and from some double applications (both materials) in fall-winter or winter-spring. When rates were varied, significant yield increases for both materials occurred at all levels. Time of application is evidently as critical as the chemical rate being used.

A control program for *L. elongatus* can be developed according to several options where significant yield increases were obtained, but growers will probably prefer a single application to avoid the added cost of the chemical, the extra time needed for application, and problems incurred from soil compaction of double applications. For economic reasons, the highest rates (6.7 and 10.1 kg/ha) are not likely to become popular. Therefore, a single application of granules in late February to early March or a single broadcast spray in early April to early May is most acceptable. A problem encountered with the use of granules is that they are difficult to incorporate into established mint without injuring the plants; such injury can, however, be reduced with early application. When new stands are planted, in-furrow granular application presents no mechanical or phytotoxic problems.

We observed wide variation in sample populations, frequently with no correlation to yield response, which agrees with other investigators. Nematicidal activity of oxamyl in plants or soil is limited (1,2,5). In plant tissue, oxamyl will translocate in two directions (acropetally and basipetally). After foliar applications, the half-life is approximately 1 wk because oxamyl rapidly breaks down into a nontoxic oxime (1,2). Breakdown in soil is much slower, with activity extending to 21 days, and root accumulation at the surface or outer cortex of oxamyl has been reported to be 13 times greater after root application than after foliar application (5). Therefore, most of the chemical activity occurs at the root-soil interface where most nematodes are found; this interrupts the nemtatode biology and feeding habits.

We have observed that treated peppermint plants reestablish a vigorous root system that greatly increases in depth of penetration and secondary branching due to the period of absence or inactivity of nematodes in the rhizosphere. The rejuvenated root system is more effective in nutrient and water uptake, resulting in increased yields of hay and oil. Unfortunately, however, the period of nematode inactivity is brief and the vigorous root system is a target for rapid recolonization and an increased buildup of the nematode population. Therefore, we usually observe a population decline in roots and soil at midseason followed by a rapid increase at harvest, necessitating continual control practices.

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