Efficacy of Oxamyl Against Heterodera schachtii on Cabbage

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Abstract: The efficacy of oxamyl in controlling *Heterodera schachtii* on cabbage was determined by applying various combinations of soil drenches at 6.7 kg (a.i.)/ha and foliar sprays at 0.04 kg (a.i.)/100 liters of water to cabbage seedlings. Pretransplant drenches provided some control of *H. schachtii* over a 13-week period. A single foliar spray of oxamyl 1 week before transplanting apparently prevented penetration of *H. schachtii* larvae; post-transplant sprays were relatively ineffective. A pretransplant or transplant drench combined with a foliar application 2 weeks after transplanting provided the most effective control. The effectiveness of drenches plus post-transplant sprays is probably due to the spray augmenting the action of the drench in inhibiting the development of larvae after penetration. *Key Words:* Vydate®, DuPont® 1410, sugarbeet cyst nematode, *Brassica oleracea* var. *capitata*, nonfumigant nematicide, chemical control.

Until recently, control of plant-parasitic nematodes has involved using nonselective fumigant nematicides. The relative inefficiency of fumigants against cyst nematodes precludes their use with most host crops. Cyst nematodes should be controlled more efficiently by applying a nematicide during the active period after larval hatch. The new water-soluble systemic nematicide, oxamyl (methyl *N*, *'N'*-dimethyl-*N*[(methyl carbamoyl)oxy]-1-thiooxamimidate), which is translocated downward in the plant, could possibly effect this type of control on a commercial basis. Radewald et al. (7) first recorded the effectiveness of oxamyl against *Meloidogyne incognita* (Kofoid and White) Chitwood and *Pratylenchus scribneri* Steiner when it was applied as a foliar spray on several host plants. They concluded that foliar sprays of oxamyl either repelled the nematodes before penetration or hindered development or reproduction after penetration. Birchfield (1) reported that foliar sprays of oxamyl suppressed egg numbers within egg masses of *Rotylenchulus reniformis* Linford and Oliveira, and these results support Radewald's contention that oxamyl may hinder reproduction. Whitehead et al. (8) showed that dipping potato shoots in a 2,000-μg/ml solution of oxamyl did not retard development of *Heterodera rostochiensis* Wollenweber after penetration. Miller (4) indicated that the mixing of oxamyl with soil did not kill eggs of *Heterodera tabacum* Lownsbery and Lownsbery in cysts, but did protect tomato plants from attack. Thus oxamyl either affected hatching or prevented penetration of roots. Subsequent work with foliar applications yielded similar results (5). Harrison (3) indicated that foliar applications of oxamyl may protect potato plants by inhibiting hatching of *H. rostochiensis* from cysts.

Our objectives were to determine the effectiveness of foliar sprays and soil drench treatments of oxamyl, both separately and in various combinations, against the sugarbeet cyst nematode (*Heterodera schachtii* Schmidt) on cabbage, and to determine the behavior of the chemical in plants and soil. Some observations have been presented in a preliminary report (6).

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MATERIALS AND METHODS

Commercial cabbage (*Brassica oleracea* var. *capitata* L.) cultivars were used as test plants in all experiments. Air-dried Fox loamy sand that had the moisture level returned to "field capacity" (8% moisture by wt) was used throughout. All soil drenches of oxamyl were applied at 6.7 kg (a.i.)/ha in aqueous solution. All foliar sprays of oxamyl were applied at 0.04 kg (a.i.)/100 liters water, and an aluminum-foil shield was used to prevent run-off into the soil. Nematode inoculum for all experiments was reared on cabbage 'Jersey Queen' in the greenhouse. All nematode count data were subjected to log (x + 1) transformation and analysed by analysis of variance and Duncan's multiple range test ($P = 0.05$); nontransformed means are presented in the tables.

A preliminary experiment indicated that oxamyl applied as a soil drench at either 7 or 14 days before transplanting equally reduced attack by *H. schachtii*. Therefore, in subsequent experiments, the action of foliar sprays (alone or in combination with drenches) at transplanting or shortly before transplanting received emphasis.

Experiment 1: A pretransplant drench of oxamyl was applied to thirty 12.7-cm diam pots containing 900 g of *H. schachtii*-infested soil (3-4 larvae/g of soil), and a water drench to 30 other comparable pots. After 72 h, two 4-week-old cabbage seedlings 'Early Marvel' were transplanted into each of the 30 oxamyl-treated pots. Ten of these pots received no further treatment; 10 received a foliar spray 2 weeks after transplanting; and 10 received a foliar spray 2 and 4 weeks after transplanting. Of the 30 water-drenched pots, 10 were planted with two seedlings each which received no further treatment and served as nontreated controls; 10 were planted with two seedlings which had been sprayed with oxamyl 72 h before transplanting and received a foliar spray 2 weeks after transplanting; and 10 were planted with two seedlings which received foliar sprays 2 and 4 weeks after transplanting.

Experiment 2: A pretransplant drench of oxamyl was applied to forty 12.7-cm diam pots of *H. schachtii*-infested soil (0.5 larvae/g of soil). Of these 40 pots, 10 were planted with two 11-week-old cabbage plants 'Jersey Queen' which had been sprayed to run-off with oxamyl 72 h before transplanting; 10 with two plants which had not been oxamyl-treated; 10 with two plants that were sprayed 1 week after transplanting; and 10 with two plants sprayed 2 weeks after transplanting. Of 20 pots of nematode-infested, water-drenched soil, 10 were planted with two plants which received an oxamyl spray 72 h before transplanting, and 10 were planted with nontreated plants. Ten pots of noninfested soil were planted with two plants each as checks.

Experiment 3: Eight-week-old cabbage seedlings 'Badger Shipper' were transplanted, one per pot, into 115 ten-cm diam pots. Five seedlings were immediately sprayed to run-off with oxamyl and 7 days later, 1200 *H. schachtii* larvae/pot (2 larvae/g of soil) were injected into the root zone in 2 ml of water. Seven days after inoculation, the five seedlings were removed from the soil, fresh root weights were recorded, and the roots were stained by the de Guiran technique (2) in order to determine the numbers of larvae or developing cysts in the roots. Numbers of larvae/50 g of soil were also determined.

The remaining 110 seedlings were inoculated at transplanting by injecting larvae into the root zone as before. Forty-five of these pots were drenched with oxamyl directly after inoculation; the plants in 25 pots received no further treatment, and the other 20 were sprayed with oxamyl 2 weeks after transplanting. Sixty-five pots were drenched with water directly after inoculation; the plants in 20 pots received an oxamyl spray 1 week after transplanting; 20 received a spray at 2 weeks after transplanting; and the remaining 25 received no treatment and served as checks. One week after inoculation, 5 check pots and 5 pots of the transplant-oxamyl-drench treatment were destructively sampled, as was done with the 5 pretransplant-spray treatment pots. At 29 days and at 72 days, 10 additional pots of each treatment were destructively sampled.

RESULTS

Experiment 1: Cyst counts at 13 weeks

after transplanting indicated that all oxamyl treatments except the post-transplant double spray provided some control of *H. schachtii* (Table 1). However, the pretransplant drench plus sprays provided better control than either the pretransplant drench alone or the pretransplant spray plus 2-week post-transplant spray. Although nematode infection was only moderate, there was generally an inverse relationship between fresh top weights and cyst numbers on the root systems at harvest. There was no evidence of phytotoxicity with any of the oxamyl treatments in the experiment.

Experiment 2: This experiment confirmed that a drench plus a foliar spray gave effective control after 11 weeks (Table 2). It also showed that the degree of control was similar whether the supplementary post-transplant spray was applied 1 or 2 weeks after transplanting. The pretransplant drench plus pretransplant spray and the pretransplant drench plus 1-week post-transplant spray of oxamyl were the only treatments to result in greater top weights than the check with nematodes. The pretransplant drench plus pretransplant spray treatment resulted in better growth than the pretransplant drench alone.

Experiment 3: Because the time from transplanting to harvest in this experiment varied with the treatments, results are only comparable for treatments harvested the same number of days after transplanting. At 1 week after inoculation, the transplant drench (in comparison with the check) did not inhibit penetration or retard the rate of development after penetration (Table 3). The pretransplant spray inhibited penetration without reducing the number of larvae in the soil.

Twenty-nine days after inoculation, larval populations in the soil were minimal (Table 3). At this time, the single pretransplant drench and the drench plus 2-week post-transplant spray were equally effective in suppressing larval populations in the root systems and in retarding the development of cysts. There were no differences among the means of the two post-transplant sprays and the check. None of the treatments affected root growth.

TABLE 1. Experiment 1: Effects of oxamyl soil drenches and foliar sprays on growth of cabbage and development of *Heterodera schachtii*.[a]

Treatment	Total fresh top wt (g)	Cysts/ pot
Nontreated check with nematodes	29.9 c	50.5 a
Pretransplant drench	39.6 a	16.8 bc
Drench + post-transplant spray after 2 weeks	36.2 abc	2.8 d
Drench + post-transplant sprays after 2 and 4 weeks	37.7 ab	2.9 d
Pretransplant spray + post-transplant spray after 2 weeks	32.0 bc	10.9 c
Post-transplant sprays after 2 and 4 weeks	29.4 c	37.7 ab

[a]Column means followed by the same letter do not differ significantly ($P = 0.05$), according to Duncan's multiple range test. Means of 10 replicates at 13 weeks after inoculation (2 plants/pot).

TABLE 2. Experiment 2: Effects of oxamyl soil drenches and foliar sprays on growth of cabbage and reproduction of *Heterodera schachtii*.[a]

Treatment	Total fresh top wt (g)	Larvae/ 50 g soil	Cysts/g of root
Nontreated check without nematodes	71.1 abc	—	—
Nontreated check with nematodes	58.7 c	1100 a	37.4 a
Pretransplant drench	61.7 bc	110 b	3.6 b
Pretransplant spray	66.6 abc	160 b	2.7 b
Drench + pretransplant spray	79.5 a	80 b	2.1 b
Drench + post-transplant spray after 1 week	75.2 ab	10 c	0.7 c
Drench + post-transplant spray after 2 weeks	64.6 abc	1 c	0.5 c

[a]Column means followed by the same letter do not differ significantly ($P = 0.05$), according to Duncan's multiple range test. Means of 10 replicates at 11 weeks after inoculation.

TABLE 3. Experiment 3: Effects of method and timing of application of oxamyl on activity and reproduction of *Heterodera schachtii* on cabbage.[a]

Treatment	Larvae /50 g of soil	Larvae /g of root	Cysts/g of root
	7 days after inoculation:		
Nontreated check with nematodes	45 a	35 a	1.2 a
Pretransplant drench	110 a	20 a	0 a
Pretransplant spray	140 a	0 b	0 a
	29 days after inoculation:		
Nontreated check with nematodes	1 a	15 ab	9 a
Drench	1 a	5 b	1 b
Post-transplant spray after 1 week	1 a	13 ab	4 a
Post-transplant spray after 2 weeks	0 a	18 a	4 a
Drench + post-transplant spray after 2 weeks	2 a	5 b	2 ab
	72 days after inoculation:		
Nontreated check with nematodes	5,970 a	18 b	13 a
Drench	2,870 a	9 b	5 a
Post-transplant spray after 1 week	3,280 a	50 a	8 a
Post-transplant spray after 2 weeks	6,070 a	18 b	6 a
Drench + post-transplant spray after 2 weeks	295 b	4 c	2 b

[a]Column means within a time interval followed by the same letter do not differ significantly ($P = 0.05$), according to Duncan's multiple range test (means of 10 replicates except 7-day extractions had only five replicates).

After 72 days, there were fewer larvae in the soil and roots, and fewer cysts on the roots of cabbage in the "drench plus 2-week post-transplant spray" treatment than in any others (Table 3). Conversely, there were more larvae in the host roots in the "1-week post-transplant spray" treatment than in any others. Root weights were not affected.

DISCUSSION

This work shows that a pretransplant or transplant drench of oxamyl plus a spray at 2 weeks after transplanting provided the most effective control of *H. schachtii* on cabbage. Combinations of drench plus spray provided better control than drench treatments alone; two sprays (at 2 and 4 weeks) were no better than a single spray at 2 weeks following a drench. Our results are in general agreement with those of Willis and Thompson (9) who showed that control of *Pratylenchus penetrans* (Cobb) with drench applications was enhanced with one or two sprays of oxamyl. Their data showed, however, that a second spray enhanced the control achieved with a drench; whereas our results show no enhancement of the control with a second spray after a drench. Radewald et al. (7) also found that additional sprays after 2 weeks failed to improve control of *M. incognita* on several crops. In contrast to our work and others (7, 9), Whitehead et al. (8) found that foliar sprays yielded no increase in control of *H. rostochiensis* when they were applied after planting and 10% granular oxamyl was incorporated into the soil. Some of these discrepancies may result from differences in hosts, nematodes, method and timing of treatments, and chemical formulation used.

Miller (5) reported that oxamyl incorporated into the soil at transplanting prevented penetration of *H. tabacum* larvae into roots. Our results with a transplant drench indicate that this is not the case with *H. schachtii;* however, the low numbers of cysts/g of root, as compared to the controls, after 29 days indicates a retardation in development after penetration. The similar low numbers of cysts/g of root with pretransplant drenches could be due to inhibition of larval penetration, or to retardation of development.

Pretransplant sprays of oxamyl suppressed penetration into cabbage roots by *H. schachtii* 1 week after the last chemical application. Further work indicated that a 1-week post-transplant spray (when some penetration had already occurred) appeared to retard the development of the larvae in the roots, whereas a 2-week spray (when practically all larval penetration was completed and a feeding relationship was established) did not affect development (unpublished data). These results agree with the conclusions of Radewald et al. (7) that foliar sprays either prevented penetration of *M. incognita* or hindered development after penetration.

The most effective control was a combination of a pretransplant or transplant drench with a post-transplant foliar spray. This effectiveness is probably due to the spray augmenting the action of the drench in suppressing the development of larvae after penetration, since neither post-transplant sprays alone nor drenches alone provided adequate protection. There is no difference in the degree of control whether the spray is applied 1 or 2 weeks after transplanting. Therefore, in the field, a grower could apply a transplant drench and have as much as 2 weeks leeway in applying a post-transplant spray.

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