Role of Fenamiphos as a Nemastat for Control of *Heterodera schachtii* in Cabbage Production

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ABSTRACT

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The influence of fenamiphos on the sugar beet cyst nematode (*Heterodera schachtii*) associated with cabbage (*Brassica oleracea* var. *capitata* cv. Roundup) was studied under field conditions in clay drainage tiles. The nematicide efficacy was determined by assaying the number of *H. schachtii* penetrating roots. A rate of 3.6 kg a.i./ha of fenamiphos reduced nematode penetration and subsequent development for 8 wk. A split application of 3.6 kg a.i./ha at seeding and 3.6 kg a.i./ha 4 wk after seeding, or 7.2 kg a.i./ha at seeding reduced nematode penetration and development for 12 wk. Fenamiphos functioned as a nemastat by impairing the ability of second-stage juveniles of *H. schachtii* to penetrate roots and by slowing the rate of development of juveniles penetrating roots. Few *H. schachtii* second-stage juveniles survived 4–8 wk in soil treated with 7.2 kg a.i./ha or a split application of 3.6 + 3.6 kg a.i./ha, compared with soil treated with 3.6 kg a.i./ha or untreated soil. Fenamiphos application significantly increased cabbage yield by sixfold.

Cabbage (*Brassica oleracea* var. *capitata*) yield losses in fields infested with the sugar beet cyst nematode (*Heterodera schachtii* Schmidt) can be reduced by using nematicides (2,6). Fenamiphos (Nemacur) is effective in controlling *H. schachtii* associated with cabbage production (4,5). At recommended application rates, fenamiphos is thought to control *H. schachtii* by depressing hatch of eggs, reducing infectivity of second-stage juveniles, and reducing *H. schachtii* reproduction (5,10,11). The effect that predominates depends on the dosage. Infectivity of second-stage juveniles is affected at very low rates of fenamiphos application (5). Information on the mode of action is important to properly assess the efficacy of nematicide application. The objective of this study was to assess the efficacy of fenamiphos on *H. schachtii* associated with cabbage production, with special reference to the nemastatic effect of this nematicide in the control of *H. schachtii*.

MATERIALS AND METHODS

H. schachtii for this study was cultured in a greenhouse with day and night temperatures of 27 and 22 C, respectively. The nematode culture was developed and maintained in wooden culture boxes 1.5 m long, 1.0 m wide, and 0.3 m deep. The culture boxes were filled with sandy clay loam soil (6% silt, 26.5% clay, 67.5% sand, and 1.8% organic matter) infested with *H. schachtii* cysts, and cabbage seedlings were transplanted into the culture boxes. After 6 mo, the population density of the culture was 120 cysts of *H. schachtii* per 100 cm^3 of soil.

One hundred twenty clay drainage tiles (24 cm in diameter and 42 cm deep) were filled with proportions of steamed sandy clay loam soil (6% silt, 26.5% clay, 67.5% sand, and 1.8% organic matter) mixed with soil infested with *H. schachtii* cysts to obtain an initial population density (P_i) of 20 eggs and second-stage juveniles per 1 cm^3 of soil. Cabbage (cultivar Roundup) seeds were germinated on moist filter paper for 48 hr and planted in the clay drainage tiles on 15 June 1983 under field conditions. Each experimental unit received 30 kg/ha of 20-20-20 fertilizer at seeding and an additional 100 kg/ha of 20-20-20 fertilizer at 4-wk intervals.

Immediately after seeding, fenamiphos (Nemacur 3S) was applied to the soil surface as a drench in 200 ml of solution at 3.6 kg a.i./ha to 60 nematode-infested tiles and 7.2 kg a.i./ha was applied to 30 infested tiles. Half of the treatments that received 3.6 kg a.i./ha at seeding received an additional 3.6 kg a.i./ha 4 wk after seeding. The untreated tiles were used as the experimental controls. The tiles were arranged in a completely randomized design of 30 replicates of the four treatments.

All the experimental units were treated with 1.4 kg/ha of the fungicide maneb and 1.6 kg/ha of the insecticide acephate (Orthene) immediately after seeding. These pesticides were applied every other week throughout the experiment to minimize the impact of fungi and insects on plant growth. The microplots were watered daily until the seedlings were fully established. Seedling emergence occurred as early as 4 days after planting and was complete about 8 days after seeding.

Ten replicates of each of the four treatments were sampled 4, 8, and 12 wk after seeding. The whole plant, including the root system, was dug on each sampling date, and soil was collected from the tiles. The following parameters were evaluated:

1. Fresh weights of root and shoot systems were obtained by direct weighing.
2. About 0.1 g of the root system was selected at random, stained in a solution of lactophenol with 0.01% acid fuchsin, and observed under a light microscope to determine the number of second-stage juveniles, third- to fourth-stage juveniles, developing females, adult males, and females with eggs (3).
3. The soil (100 cm^3) was processed using a modified centrifugation-flotation technique with a sucrose solution of 1.37 specific gravity to recover cysts, eggs, and second-stage juveniles (7). The cysts and viable units were counted with a stereoscopic microscope.

The results are presented in a comparative nematode development format (Fig. 1). *H. schachtii* development for each treatment is illustrated by one of the columns of the figure (e.g., a, e, i, m, and q). The impacts of each nematicide treatment on each nematode developmental stage are illustrated by one of the rows of the figure (e.g., a–d).

RESULTS

Fenamiphos application significantly ($P = 0.05$) increased total plant weight (Fig. 2). Cabbage shoot weight was increased sixfold, fivefold, and threefold by treatment with fenamiphos at 7.2 kg a.i./ha at seeding, 3.6 kg a.i./ha at seeding plus 3.6 kg a.i./ha 4 wk after seeding, and 3.6 kg a.i./ha at seeding, respectively. Root weight in soil treated with fenamiphos increased about threefold compared with the untreated control. There was no marketable yield from cabbage plants grown in *H. schachtii*-infested soil that was not treated with fenamiphos. Marketable yields of cabbage increased with increasing dosages of fenamiphos. The relative marketable yields were 100, 78, 35, and 0% in treatments with 7.2, 3.6 + 3.6, 3.6,

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and 0 kg a.i./ha fenamiphos, respectively.

The number of viable units (eggs and second-stage juveniles) in the soil fluctuated throughout the growing season, and increased ($P = 0.05$) by week 12 (Fig. 1, a–d). Second-stage juveniles in roots peaked in week 4 and increased between weeks 8 and 12 (Fig. 1, e–h). The population dynamics of third- and fourth-stage juveniles (J_3 and J_4) plus developing females were similar to those of the second-stage juveniles in roots (Fig. 1, i–l). In the absence of fenamiphos, the population density of gravid females peaked in week 4 and increased between weeks 8 and 12, whereas in the presence of fenamiphos, the population density of this stage increased through week 12 (Fig. 1, m–p). The population dynamics of *H. schachtii* cysts in the soil were similar to those of the viable units in the soil (Fig. 1, q–t). Based on the numbers of viable units in the soil, the untreated, 3.6, 3.6 + 3.6, and 7.2 kg a.i./ha fenamiphos treatments had P_f (final *H. schachtii* population density)/P_i ratios of 11, 8, 3, and 2, respectively.

Application of 3.6 kg a.i./ha of fenamiphos significantly ($P = 0.05$) reduced the penetration of cabbage roots by *H. schachtii* for 8 wk (Fig. 1, g and h), whereas the split application and high rate of this nematicide significantly reduced nematode penetration for 12 wk (Fig. 1, e, f, and h). The single application of fenamiphos at 3.6 kg a.i./ha resulted in significantly ($P = 0.05$) lower root population densities of J_3, J_4, developing females, and gravid females for 8 wk compared with the untreated control (Fig. 1, k, l, o, and p), whereas these stages were significantly ($P = 0.05$) reduced for 12 wk with the split application and high rate of fenamiphos (Fig. 1, i, j, l, m, n, and p). The low rate of the nematicide did not significantly ($P = 0.05$) alter the soil population density of cysts or viable units (Fig. 1, c, d, s, and t). Both the split application and high rate of fenamiphos, however, resulted in significantly ($P = 0.05$) lower soil cyst and

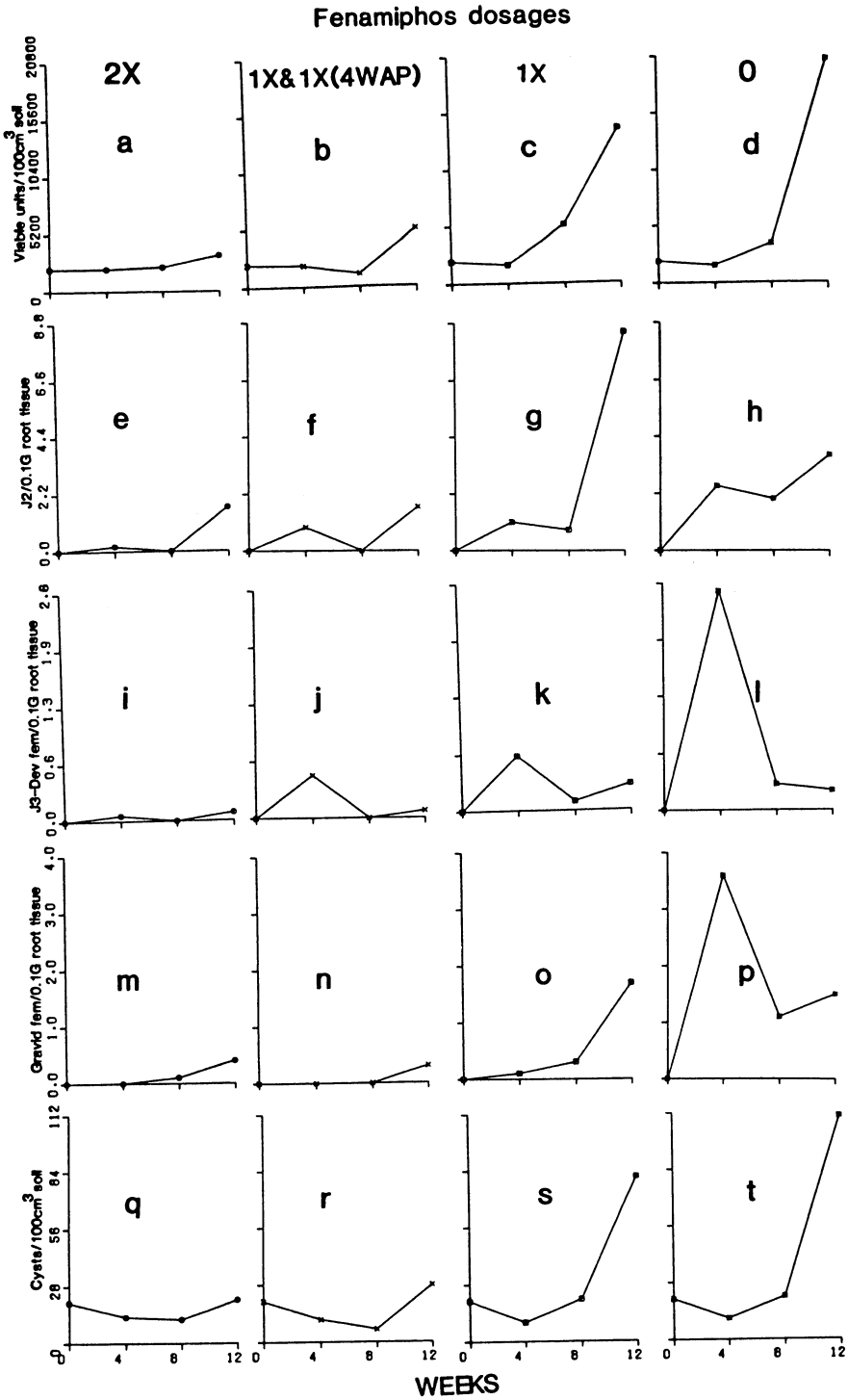

Fig. 1. a–d = Number of *Heterodera schachtii* eggs and second-stage juveniles (viable units) in 100 cm^3 of soil surrounding cabbage grown in the presence of *H. schachtii* and four dosages of fenamiphos (0, 1×, 1× plus 1× 4 wk after planting, and 2×: × = 3.6 kg a.i./ha). e–h = Number of *H. schachtii* second-stage juveniles in 0.1 g of root tissue of cabbage grown in the presence of *H. schachtii* and four dosages of fenamiphos (0, 1×, 1× plus 1× 4 wk after planting, and 2×: × = 3.6 kg a.i./ha). i–l = Number of *H. schachtii* third- and fourth-stage juveniles plus developing females in 0.1 g of root tissue of cabbage grown in the presence of *H. schachtii* and four dosages of fenamiphos (0, 1×, 1× plus 1× 4 wk after planting, and 2×: × = 3.6 kg a.i./ha). m–p = Number of *H. schachtii* females with eggs in 0.1 g of root tissue of cabbage grown in the presence of *H. schachtii* and four dosages of fenamiphos (0, 1×, 1× plus 1× 4 wk after planting, and 2×: × = 3.6 kg a.i./ha). q–t = Number of *H. schachtii* cysts in 100 cm^3 of soil surrounding cabbage grown in the presence of *H. schachtii* and four dosages of fenamiphos (0, 1×, 1× plus 1× 4 wk after planting, and 2×: × = 3.6 kg a.i./ha).

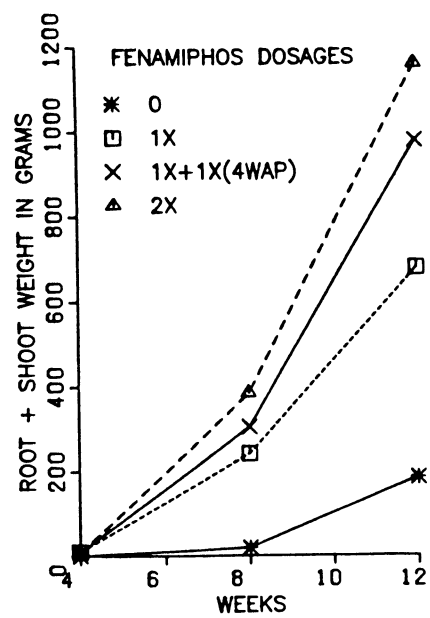

Fig. 2. Total fresh weight of cabbage grown in the presence of *Heterodera schachtii* and four dosages of fenamiphos (0, 1×, 1× plus 1× 4 wk after planting, and 2×: × = 3.6 kg a.i./ha).

viable unit population densities of *H. schachtii* 8 and 12 wk after initiation of the experiment (Fig. 1, a, b, d, q, r, and t).

DISCUSSION

Fenamiphos applied to control *H. schachtii* increased cabbage growth, reduced the number of second-stage juveniles of *H. schachtii* penetrating cabbage roots, and slowed the development of juveniles in root tissue. The increased cabbage growth after *H. schachtii* control with fenamiphos was similar to that reported in New York, Canada, and California (1,8,9). The lower rate of fenamiphos application was not effective in controlling *H. schachtii* 8 wk after planting, and this resulted in 33% yield loss compared with the higher rate of fenamiphos application, which suppressed the population density of *H. schachtii* for the entire growing period.

Data presented in this paper indicate a higher population density of second-stage juveniles in roots treated with 3.6 kg a.i./ha of fenamiphos compared with roots in untreated soil at the end of the growing period. This appears to be a function of amount of root tissue available for the second-stage juveniles in the soil to penetrate. Higher population densities of *H. schachtii* in treated plots compared with the untreated plots has also been reported in California (5).

The research confirms the hypothesis that fenamiphos can function as a nemastat in the control of *H. schachtii* associated with cabbage production. The data also illustrate the importance of using the appropriate treatment rate and timing for optimal control of *H. schachtii* with fenamiphos. The data also indicate that these parameters must be incorporated into any *H. schachtii* simulation model or decision support system designed to predict the impact of fenamiphos in relation to cabbage growth. The data from this experiment should be well suited for validation of *H. schachtii* computer simulation models.

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