# Control of *Tylenchulus semipenetrans* on Citrus with Fenamiphos and Oxamyl

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**ABSTRACT**

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In a 2-yr field study, fenamiphos and oxamyl applied to citrus trees by drip irrigation significantly reduced numbers of juvenile citrus nematodes (*Tylenchulus semipenetrans*) but did not increase fruit yield or size. Fenamiphos applied directly to the soil in flood-irrigated plots was more effective in reducing numbers of the nematode than was fenamiphos or oxamyl applied by drip irrigation, but again, neither yield nor quality of fruit was improved. Mortality of juveniles in the soil may not be a good indicator of the benefits of a nematicide on citrus since yields were not improved and neither nematicide reduced the numbers of mature females feeding on roots.

Citrus yields are reduced in orchards with high numbers of the citrus nematode (*Tylenchulus semipenetrans* Cobb) (4,8). Although many chemicals have been tested for control of citrus nematodes, none in current use has increased yields consistently in Texas (3,7,9). It has been speculated that nematicides applied through drip-irrigation systems would provide optimum control of the citrus nematode since the chemicals would be concentrated in the root zone. This experiment examined the benefits of applying the nematicides fenamiphos and oxamyl by injection into drip-irrigation lines and as soil surface sprays in flood-irrigated orchards.

## MATERIALS AND METHODS

Nematicides were applied to red grapefruit (*Citrus paradisi* Macf. cv. Star Ruby) trees on sour orange (*C. aurantium* L.) rootstock planted in 1975 with a spacing of 4.8 × 7.2 m. The soil type was Harlingen clay (42% sand, 10% silt, 48% clay, pH 7.8, and 1% organic matter). The trees were set in rows 14 trees long and were drip-irrigated or flood-irrigated with permanent, raised soil borders surrounding every three rows. Fenamiphos (Nemacur 3SC) was either sprayed on the ground with an herbicide applicator and followed immediately by flood irrigation or injected into drip-irrigation lines. Rates of material delivered were calculated according to the area actually treated, i.e., in a swath 2.4 m wide on each side of the trees in the flood-irrigated plots and in a circular area 16.4 $m^2$/tree in the drip-irrigated plots. Fenamiphos was applied once a year for 2 yr. Oxamyl (Vydate 2L) was injected into the drip irrigation four times a year for 2 yr. Flood-irrigated or drip-irrigated untreated trees served as controls.

Treatments were arranged in a randomized complete block design with three replicated plots of 14 trees each in the test with fenamiphos and two replicated plots of 14 trees each in the test with oxamyl. Chlorobenzilate was applied three times a year either alone or in combination with oil or methidathion to minimize the effects of mites and insects on fruit quality and yield.

Numbers of juvenile nematodes were determined in three soil samples collected from each plot on each sampling date. Each sample was a composite of four 200-g soil cores collected 15 cm deep from each site. Soil cores were collected at random at the drip lines of the trees in the flood-irrigated plots and near the emitter from drip-irrigated trees. The nematodes were extracted by Baermann funnel (1), with 50 $cm^3$ of soil per funnel as described previously (2). Nematodes were counted in each of three 0.5-ml aliquots from each sample.

Fruit yield was determined by weighing the fruit from 12 individual trees in each replicate in December of each year. Fruit size was determined by sorting fruit with a commercial sizer.

Nematicides were also applied to 1-$m^2$ plots located at the drip lines of 15-yr-old sweet orange (*C. sinensis* (L.) Osbeck cv. Valencia) trees on sour orange rootstock planted in Hidalgo fine sandy loam (62% sand, 12% silt, 26% clay, pH 7.8, and 1% organic matter). Plots were defined by 1-$m^2$ wooden boxes and received water to a depth of 10 cm with the applications of nematicides. Treatments were replicated twice. A composite sample consisting of 12 soil cores was collected at random 15 cm deep within each plot to determine numbers of nematodes. Citrus nematodes were extracted by Baermann funnel from each of three 50-$cm^3$ subsamples taken from each composite sample. Nematodes were counted in each of three 0.5-ml aliquots from each subsample.

The effectiveness of the nematicides was also assessed by counting mature females embedded in feeder roots. Five weeks after the second application of oxamyl, eight 6-mo-old sour orange seedlings grown in a glasshouse in a sterilized potting medium were transplanted into each microplot. Eight weeks later, the plants were harvested. Roots were gently washed in water and placed in water in an ultrasonic cleaner for 15 min to further remove soil and debris from the roots. The roots were then stained in acid fuchsin/lactophenol and cleared in lactophenol for observation (6). Mature females were counted under a dissecting scope on 10 root tips (1 cm long) from each seedling.

Because reduced fruit yields indicated possible phytotoxicity problems with oxamyl, a glasshouse test was conducted to determine the effects of oxamyl on seedling growth. Six-month-old sour orange seedlings were grown three per pot in a potting mix (3:2:1, v/v, peat moss, vermiculite, sand) and fertilized weekly with a complete nutrient solution (5). Oxamyl was applied either to the foliage (0.24, 0.48, 0.96, and 1.92 mg a.i./ml) until runoff or as a soil drench (0.175, 0.35, 0.70, and 1.40 mg a.i./100 ml/pot). Treatments were replicated on three pots and applied once a week for 10 wk. Untreated plants received foliar sprays or soil drenches of water. Plant

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heights and dry weights were determined at the end of the experiment.

## RESULTS AND DISCUSSION

Numbers of juvenile nematodes were significantly reduced by fenamiphos compared with the untreated plots on most sampling dates in 1982 regardless of irrigation method (Table 1). In 1983, the high rate of fenamiphos reduced numbers of nematodes in the drip-irrigated plots on the initial posttreatment sampling date but had no effect thereafter. The low rate of fenamiphos was ineffective on drip-irrigated trees. In the flood-irrigated plots, both rates significantly reduced the numbers of juvenile nematodes generally throughout the entire year. Fruit yields and size were not increased by fenamiphos in either year (Table 1).

In 1982, the high rate of oxamyl reduced numbers of juvenile nematodes compared with the untreated plots on the last two sampling dates, and the low rate, only on the last sampling date (Table 2). In 1983, the high rate of oxamyl reduced numbers of juvenile nematodes on three of the four posttreatment sampling dates. In both years, the high rate of oxamyl caused a significant reduction in fruit yield. Neither rate of oxamyl affected fruit size.

Three weeks after the initial application of the nematicides to the microplots, only the high rates of the nematicides reduced numbers of nematodes compared with the untreated plots (Table 3). Thereafter, the nematicides failed to reduce numbers of juvenile nematodes. On the last sampling date, numbers were highest in the plots treated with the highest rate of oxamyl. There were no significant differences in the number of female citrus nematodes embedded in the roots of the seedlings transplanted to the plots of the various treatments. The average number of female nematodes embedded in the roots was 2.2/cm of root.

Seedling growth was not affected by foliar sprays or soil drenches of oxamyl. Plant height and plant dry weights were similar in the untreated and treated plants.

Fenamiphos was generally more effective in the flood-irrigated plots than in the drip-irrigated plots. Because this nematicide was applied only once a year,

**Table 1.** Effect of fenamiphos on numbers of *Tylenchulus semipenetrans* and yield and size of grapefruit

| Irrigation Treatment | Rate (kg a.i./ha) | 1982 No. of juveniles (in 1,000s)/100 cm³ of soil | | | | | Yield (kg/tree) | Fruit size[a] (%>9.2 cm in diam.) |
|---|---|---|---|---|---|---|---|---|
| | | Pretreatment | Posttreatment | | | | | |
| | | 2 Apr. | 12 May | 23 Jun. | 6 Aug. | 7 Sept. | | |
| Drip[b] | | | | | | | | |
| None | ... | 9.7 | 9.4 | 29.3 | 6.6 | 4.6 | 202 | 68 |
| Fenamiphos | 11.2 | 8.1 | 6.4 | 1.6 | 3.6 | 2.7 | 212 | 71 |
| | 22.4 | 9.0 | 2.4 | 1.2 | 2.9 | 1.1 | 195 | 73 |
| ±SE | | 2.0 | 4.1 | 2.3 | 3.8 | 2.0 | 30 | 8 |
| Flood[c] | | | | | | | | |
| None | ... | 5.2 | 14.9 | 16.8 | 13.7 | 7.2 | 166 | 57 |
| Fenamiphos | 11.2 | 7.9 | 5.4 | 10.2 | 4.9 | 2.7 | 171 | 59 |
| | 22.4 | 6.6 | 6.7 | 7.9 | 2.6 | 1.6 | 174 | 58 |
| ±SE | | 2.8 | 2.4 | 2.7 | 2.5 | 1.6 | 22 | 5 |
| | | 1983 | | | | | | |
| Drip[b] | | 14 Apr. | 11 May | 30 Jun. | 30 Aug. | 4 Oct. | | |
| None | ... | 13.3 | 7.0 | 23.7 | 7.7 | 7.6 | 123 | 83 |
| Fenamiphos | 11.2 | 9.2 | 4.2 | 21.8 | 7.5 | 9.5 | 129 | 82 |
| | 22.4 | 13.3 | 2.0 | 17.3 | 7.8 | 8.6 | 124 | 75 |
| ±SE | | 4.3 | 3.3 | 6.5 | 1.4 | 2.1 | 17 | 10 |
| Flood[c] | | | | | | | | |
| None | ... | 14.8 | 11.3 | 23.6 | 3.9 | 6.8 | 146 | 83 |
| Fenamiphos | 11.2 | 8.0 | 1.3 | 12.5 | 1.7 | 2.3 | 151 | 81 |
| | 22.4 | 7.9 | 1.5 | 16.9 | 1.6 | 1.6 | 152 | 79 |
| ±SE | | 5.9 | 2.0 | 6.8 | 1.2 | 1.9 | 11 | 8 |

[a] Percentage of total fruit weight composed of fruit 9.2 cm in diameter or larger.
[b] Injected into irrigation water 6 April 1982 and 16 April 1983.
[c] Sprayed onto soil surface on 6 April 1982 and 16 April 1983.

**Table 2.** Effect of oxamyl applied by drip irrigation on numbers of *Tylenchulus semipenetrans* and yield and size of grapefruit

| Treatment | Rate (kg a.i./ha) | 1982 No. of juveniles (in 1,000s)/100 cm³ of soil | | | | | Yield (kg/tree) | Fruit size[a] (%>9.2 cm in diam.) |
|---|---|---|---|---|---|---|---|---|
| | | Pretreatment | Posttreatment | | | | | |
| | | 13 Apr. | 11 May | 30 Jun. | 23 Aug. | 18 Oct. | | |
| None | ... | 9.0 | 12.2 | 7.2 | 5.9 | 5.7 | 66 | 72 |
| Oxamyl | 0.28[b] | 10.2 | 11.0 | 6.9 | 4.8 | 2.4 | 66 | 74 |
| | 1.1[b] | 8.7 | 13.8 | 5.8 | 2.7 | 2.3 | 32 | 84 |
| ±SE | | 2.1 | 2.9 | 1.8 | 2.2 | 2.0 | 18 | 13 |
| | | 1983 | | | | | | |
| | | 21 Apr. | 26 May | 13 Jul. | 23 Aug. | 19 Sept. | | |
| None | ... | 13.0 | 9.2 | 7.9 | 6.7 | 5.9 | 51 | 73 |
| Oxamyl | 0.28[c] | 10.7 | 7.2 | 5.8 | 2.7 | 5.3 | 45 | 76 |
| | 1.1[c] | 11.2 | 6.9 | 3.2 | 2.3 | 5.7 | 20 | 82 |
| ±SE | | 3.1 | 1.4 | 2.9 | 2.4 | 1.7 | 9 | 11 |

[a] Percentage of total fruit weight composed of fruit 9.2 cm in diameter or larger.
[b] Injected into irrigation water 20 April, 16 June, 4 August, and 4 October 1982.
[c] Injected into irrigation water 2 May, 21 June, 2 August, and 2 September 1983.

**Table 3.** Effect of fenamiphos and oxamyl on numbers of *Tylenchulus semipenetrans* in 1-m² field plots in an orange orchard on sour orange rootstock

| Treatment[a] | Rate (mg a.i./m²) | No. of juveniles (in 1,000s)/100 cm³ of soil | | | |
|---|---|---|---|---|---|
| | | 19 Jul. | 26 Jul. | 15 Aug. | 28 Aug. |
| None | ... | 2.8 | 2.4 | 1.2 | 1.2 |
| Fenamiphos | 560 | 2.8 | 2.2 | 1.6 | 1.3 |
| | 1,120 | 1.8 | 2.4 | 1.6 | 1.3 |
| | 2,240 | 1.0 | 1.7 | 1.5 | 1.2 |
| ±SE | | 0.5 | 0.6 | 0.6 | 0.5 |
| Oxamyl | 28 | 2.9 | 2.6 | 1.2 | 1.6 |
| | 56 | 3.0 | 2.2 | 1.4 | 1.7 |
| | 112 | 1.7 | 1.7 | 1.7 | 2.2 |
| ±SE | | 0.8 | 0.6 | 0.7 | 0.6 |

[a] Fenamiphos applied 5 July and oxamyl applied 5 and 27 July 1983. Pretreatment counts averaged 3.2 × 1,000 nematodes per 100 cm³ of soil.

it may have been degraded or leached relatively quickly under drip irrigation, where the trees received water more or less continuously throughout the growing season. Although there was a consistent reduction of numbers of juvenile citrus nematodes in the flood-irrigated trees and the level of infestation in the orchard was relatively high, there was no increase in fruit yield or size. Apparently, the reduction in the juvenile nematode population was too small to cause an increase in fruit yield or the part of the orchard actually treated was too small for an effective change in the total number of nematodes. In addition, results from the microplot experiment indicate that high mortality of juveniles may not reflect reductions of mature females feeding on roots.

Oxamyl also reduced numbers of citrus nematodes in the soil but did not improve fruit yield. Instead, yields were significantly reduced in trees treated with the high rate of oxamyl. This reduction in yield may have resulted from an indirect effect of oxamyl on the trees' performance, such as causing premature fruit drop, since there was no decrease in seedling growth in the glasshouse and symptoms of phytotoxicity were not observed on field trees or on seedlings.

Only the highest rates of fenamiphos and oxamyl reduced numbers of juvenile citrus nematodes in the microplots, and then only for a short period after application, indicating that high rates of the nematicides may be required in the clay soils of southern Texas. However, the highest rate of oxamyl actually increased citrus nematodes compared with the untreated plots on one sampling date, but the reason for this is unclear.

Other reports on chemical control of the citrus nematode indicate erratic increases in fruit yield despite decreases in numbers of juveniles of the citrus nematode in soil (3,7,9). Tree vigor and tree stress caused by poor soil, drought, insects, nutrition, or diseases may influence the detrimental effects of the citrus nematode on citrus growth and the effectiveness of nematicides. These factors need to be determined to discover the best use of nematicides on citrus. In addition, the economic threshold of numbers of juveniles in the soil or the number of nematodes actually feeding on the roots must be determined before the benefits of nematicides in citrus orchards can be predicted. Despite a relatively high infestation in the orchards in this test and significant reductions of numbers of juvenile nematodes in treated soil, the productivity of the trees was not increased. The use of fenamiphos and oxamyl on Texas citrus cannot be justified economically until consistent, positive returns to the grower can be demonstrated.

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