# Action of Systemic Nematicides in Control of *Xiphinema index* on Grape

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*Abstract:* In greenhouse tests using potted grape plants three nematicides, aldicarb 10 G at 4.5 ai/ha, phenamiphos 15 G at 22 kg ai/ha, and oxamyl liquid at 4.5 kg ai/ha, were tested against *Xiphinema index* on 'Thompson Seedless' grape. Different timings for chemical treatments and *X. index* inoculations were used to determine some of the aspects of the mode of action. When nematodes and nematicides were applied simultaneously, nematodes were reduced from the initial 500 to the averages 5, 1, and 4, respectively, for aldicarb, phenamiphos, and oxamyl. Similar counts (respectively, 3, 1, and 2) were obtained when the nematicides were added first and the nematodes 14 d later. Nematode counts were 83, 112, and 1,346 when nematicides were applied first, and 14 days later plants were washed free of soil, repotted in untreated soil, and then inoculated. In untreated controls the population increased to an average of 2,703. Plant growth was inversely related to the level of nematode population resulting from the treatment.
*Key words:* Dagger nematodes, organophosphates, carbamates.

The plant-parasitic nematode, *Xiphinema index* Thorne and Allen, is a serious parasite on grapevine throughout the world (24,32). It causes direct damage by feeding on roots (16,32), and indirect damage by transmitting the pathogen, grapevine fanleaf virus (10). Thus the control of plant-parasitic nematodes in established vineyards is a subject of considerable economic importance. Several systemic nematicides, mainly organophosphates and carbamates, have been effective against plant-parasitic nematodes (1,2,6,7,8,15,21,27,29,30,33). Organophosphate and carbamate nematicides cause treated nematodes to become inactive rather than killing them directly (14,20,22, 23,30). Nelmes et al. (22) suggested that direct contcat of nematodes with organophosphate or carbamate nematicides, or their metabolites, in soil or plants, may influence both the behavior and development of nematodes. Further, nematicide solutions were shown to affect the posture of nematodes (20).

Phenamiphos (0-ethyl-0-(3-methyl-4-methylthiophenyl)-isopropylamido-phosphate) is a systemic nematicide. If applied to soil it is absorbed by the plant roots and kills both ectoparasitic and endoparasitic nematodes (31). When used as a foliar treatment phenamiphos is translocated basipetally to the roots, kills nematodes living in the roots, and protects the plants against further nematode infestation (7,33). It has a residual activity of several months (33).

Aldicarb (2-methyl-(methylthio) propionaldehyde 0-(methyl-carbamoyl) oxime) gives broad residual protection against most phytophagous pests for up to 10 wk (27). Oxamyl (methyl $N^1$, $N^{-1}$ dimethyl-N (methylcarbamyl) oxy-1-thiooxamimidate) has been postulated to work by repelling nematodes before roots penetration, by hindering development or reproduction after penetration (5,26), or by preventing egg hatch or root penetration (18). Nematicidal exudate from the roots of oxamyl-sprayed plants may have a longer nematicidal persistence

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in the soil than the parent material (29), which is not a good direct nematicide (13).

It has been suggested that the activity of certain carbomyloximes, like aldicarb and oxamyl, may be due to the inhibition of acetylocholine hydrolysis. Acetylcholine hydrolysis was inhibited below the concentration required for nematicidal activity (28). Inhibition of the cholinestrase enzymes results in disruption of the normal neuromuscular functions of nematodes. Effects on egg hatching, larval movement, feeding behavior, root invasion, male orientation, and development have been reported (2,4,11,12, 15,20,21,23,30,33). This investigation was conducted to study the effect of the carbamates, aldicarb and oxamyl, and the organophosphate, phenamiphos, on *X. index* and grape.

## MATERIALS AND METHODS

*Nematode inoculum:* Virus-free *X. index* was isolated from grape at Christian Brothers vineyards, Napa County, California, and raised on fig (*Ficus carica*) in a greenhouse. The nematodes were extracted from soil by Cobb's method (5) using sieves with 864 and 74 micron openings. The resulting filtrate was placed on a Baermann funnel for 48 h under intermittent mist (17). Aqueous suspensions containing 500 *X. index* were pipetted into four holes 4–6 cm deep and 5 cm from the crown of grape plants. The holes were closed after the suspension had been absorbed and plants were watered immediately.

*Test plants:* Dormant two-bud cuttings of *Vitis vinifera* cv Thompson Seedless were obtained from virus-free canes and placed in cold storage. The cuttings were rooted in flats of autoclaved sand in a growth chamber for 4 wk. Rooted cuttings were transplanted singly into an autoclaved mixture of one-third soil and two-thirds sand in 20-cm-d clay pots. These plants were kept 8 wk in the greenhouse to establish good root systems before treatment. Six replicates of each of the treatments were arranged in a completely randomized design on benches in the greenhouse. The greenhouse temperature was maintained 20–25 C, plants were irrigated with distilled water as needed, and half strength Hoaglund's nutrient solution was added once a week.

*Treatments:* Three nematicides—aldicarb 10 G, phenamiphos 15 G, and oxamyl liquid—at one rate each, 4.5, 22.5, and 4.5 kg ai/ha, respectively, were tested against *X. index*. Three different timings for chemical treatments and nematode inoculation were used to determine some aspects of the nematicidal mode of action: A—Chemical and nematode inoculum applied simultaneously; B—Chemical applied, 14 d later plants washed, transplanted to untreated soil, and inoculated; C—Chemical applied, nematode inoculum added 14 d later in the same treated soil. An untreated control also was provided. The granular materials were broadcast over the soil surface, incorporated in the top 5 cm of the soil, and watered immediately. For the liquid formulation the calculated amount of the chemical required for six replicates was mixed with 150 ml water and each pot was treated with 25 ml.

*Observations recorded:* The experiment was terminated after 60 d. Plant growth response to the different treatments was evaluated by measuring fresh weight and height of shoots and root fresh weight. Roots were washed free of soil, blotted dry, weighed, and photographed. Efficacy of the nematicides in controlling *X. index* was assessed by measuring the final population of *X. index* in the soil. The entire soil mass from each pot was placed in a pan where the soil was grossly removed from the roots and carefully mixed for uniformity. The roots were washed free of remaining soil in a second pan using a minimum amount of water. One half of the soil from the first pan was mixed carefully into the contents of the second pan. The entire contents of the second pan were then screened according to Cobb's method (5) as described above, and the number was used as a relative measure of the number of nematodes per replicate.

## RESULTS AND DISCUSSION

*Nematicidal efficacy:* When nematodes and nematicides were added to soil simultaneously (treatment A), nematode populations were significantly reduced ($P = 0.01$), as indicated in Table 1. There were no significant differences among the three chemicals. In the untreated control, the population increased from 500 to 2,703 after 2

Table 1. Effect of systemic nematicides on populations of *Xiphinema index* and the growth of grapevine.

| Treatments | Chemical and nematode inoculum applied simultaneously A | | | | Chemical applied at planting, nematode inoculum 14 d later | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Plants transplanted to untreated soil B | | | | Plants kept in treated soil C | | | |
| | Final nematode population | Fresh weight (g) root | Fresh weight (g) shoot | Plant height (cm) | Final nematode population | Fresh weight (g) root | Fresh weight (g) shoot | Plant height (cm) | Final nematode population | Fresh weight (g) root | Fresh weight (g) shoot | Plant height (cm) |
| Aldicarb 10 G 4.5 kg ai/ha | 4.6 | 18.0 | 50.75 | 40.2 | 82.6 | 12.5 | 44.5 | 27.1 | 2.5 | 16.5 | 38.75 | 32.3 |
| Phenamiphos 15 G 22 kg ai/ha | 1.2 | 15.8 | 54.75 | 38.1 | 113.5 | 11.5 | 39.3 | 25.8 | 1.0 | 15.1 | 42.60 | 30.6 |
| Oxamyl Liquid 4.5 kg ai/ha | 4.5 | 18.8 | 52.75 | 40.3 | 1,346.4 | 14.4 | 48.7 | 24.9 | 2.0 | 16.6 | 44.55 | 33.4 |
| No chemical treatment | 2,703.3 | 10.9 | 34.75 | 25.5 | 2,703.3 | 10.7 | 34.8 | 25.5 | 2,703.3 | 10.9 | 34.75 | 25.5 |
| No chemical treatment or nematode | | 19.5 | 55.50 | 44.5 | | 19.5 | 55.5 | 44.5 | | 19.5 | 55.50 | 44.5 |

months and there was a reduction ($P = 0.01$) in the growth of shoots and roots (Table 1 and Fig. 1). Where the chemicals and nematodes were added simultaneously, chemicals affected nematodes by both contact and systemic actions. When the nematicides were applied first and nematodes added to the same treated soil 14 d later (treatment C), nematode populations were reduced ($P = 0.01$; Table 1). Again there were no significant differences among the different chemicals. In treatments B and C the preinoculation treatment provides protection by preventing feeding, causing nematode death by starvation, or by direct toxic effect (2,25). Other possible indirect effects may include 1) disorientation which may prevent nematodes from locating feeder roots or which reduced the number of eggs laid (2,4,9,11,14,18,25); and 2) interference with the host-parasite interaction in the roots by changing the biochemical structure of the plants (9,19). When nematicides were applied first and then 14 d later plants were washed free of soil, repotted in untreated soil, and then inoculated (treatment B), nematode populations were reduced ($P = 0.01$; Table 1). With this treatment the direct contact action of these chemicals in the soil was almost eliminated. There are differences between oxamyl and aldicarb and between oxamyl and phenamiphos. There are also significant differences between treatments B and A and between B and C, but not between A and C ($P = 0.01$).

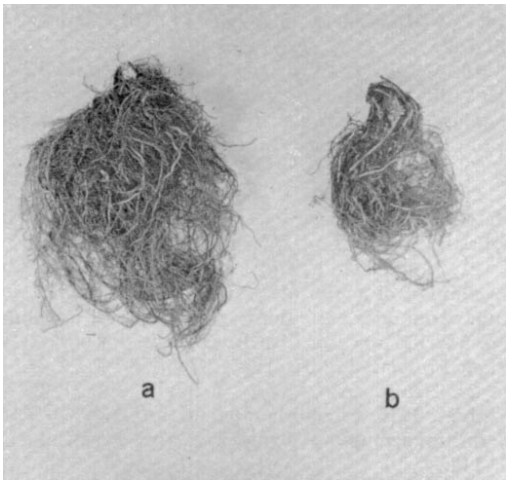


Fig. 1. Growth of 'Thompson Seedless' grapevine roots 60 d after inoculation with *Xiphinema index*, (a) in uninfested soil, (b) in infested soil.

In conclusion, aldicarb showed good control by both contact and systemic action in treatments A, B, and C. Treatment B gave less control than treatments A and C. It is possible that the concentration of toxic residues in the root tissues was not high enough to kill all the nematodes, and survivors multiplied. With time, also, the amount of toxic residue in the root tissues declines (Hafez and Raski, 1979, unpublished). Phenamiphos showed slightly better control of *X. index* than aldicarb in both treatments A and C, but in treatment B showed less control. This may be due to phenamiphos solubility, which is less than that of aldicarb. With less solubility the amount of toxic residue which is absorbed by the roots is not enough to provide protection. If the plants were left in the treated soil longer than 2 wk, it is possible that better control might be achieved because the roots would absorb more toxic material. Oxamyl gave the same level of control as aldicarb treatments A and C, but treatment B gave only 50% nematode control compared with the complete control. Oxamyl is characterized by higher solubility in water than the other two chemicals tested, which means the roots should take up more toxic material in a given period of time. Even so, this material did not suppress the nematodes, and this may be due to the short half life (12–15 days) of oxamyl (3).

Plant growth was inversely related to the level of nematode population resulting from the different treatments, as shown in Table 1 and Figure 2.

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Fig. 2. Roots of 'Thompson Seedless' grape 60 d after addition of *Xiphinema index* and/or nematicides. (A) left to right: no chemical treatment nematodes, aldicarb + nematodes, phenamiphos + nematodes, oxamyl + nematodes; (B) left to right: nematodes only, aldicarb + nematodes, phenamiphos + nematodes, oxamyl + nematodes.

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