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Influence of Aldicarb and Fenamiphos on *Tylenchulus semipenetrans* Population Densities and Orange Yield

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Abstract: The effect of aldicarb and fenamiphos on *Tylenchulus semipenetrans* population densities and on orange yield was investigated during a 3-year (1986–88) field trial in Italy. Rates were 10 and 20 kg a.i./ha as an early spring single application, 5 kg a.i./ha in spring and 5 kg after flowering, and 5 kg a.i. in spring followed by 2.5 kg/ha after flowering and 2.5 kg/ha in early autumn. Rates and times of application of the two nematicides did not affect numbers of females of *T. semipenetrans* on the roots but suppressed ($P = 0.05$) egg, male, and second-stage juvenile population densities from October 1986 to 1988. Yield of fruit was not affected by any treatment during 1986–87. Yield was increased ($P = 0.05$) in 1988 by i) a single application of 20 kg a.i./ha aldicarb, ii) 10 kg a.i./ha fenamiphos, and iii) an application of 5 kg a.i. aldicarb/ha in spring, followed by two more applications of 2.5 kg/ha each in June and September. Fruit size was not affected by the nematicide treatments. Concentrations of fenamiphos and its metabolites, in rind and pulp, were below 0.02 ppm.
Key words: aldicarb, citrus nematode, *Citrus sinensis*, control, fenamiphos, nematicide, nematode, orange, residue, *Tylenchulus semipenetrans*.

The citrus nematode, *Tylenchulus semipenetrans*, is associated with slow decline and yield losses of citrus worldwide (9,14). Yield loss estimates of citrus due to *T. semipenetrans* range from 8.7 to 12.2% (5). Dibromochloropropane (DBCP) effectively controlled this nematode (9), whereas nonvolatile nematicides applied in irrigation water (7) or broadcast (8,11,13,15) have been inconsistent. This erratic performance may be due to poor placement, nematode density, environmental conditions, or interactions between biotic and abiotic factors.

This study was conducted to compare the effects of some selected application regimes of aldicarb and fenamiphos on population densities of *T. semipenetrans* on orange (*Citrus sinensis*).

Materials and Methods

The orange grove selected was on a sandy loam soil (64% sand, 5% silt, 31% clay; pH 7.8) at Bernalda (Province of Matera) in southern Italy. The orange cv. Washington Navel had been grafted 3 years before on a 13-year-old mandarin. The rootstock was sour orange (*C. aurantium*). Each plot consisted of two trees of uniform size in the same row. Plants were spaced 4.7 m apart within and between rows. Each plot was 44.2 m^2.

Treatments, replicated six times and arranged in a randomized complete block design, were as follows: i) aldicarb applied at 10 kg a.i./ha in early April; ii) aldicarb at 20 kg a.i./ha in early April; iii) aldicarb at 5 kg a.i./ha in early April and 5 kg/ha after flowering (June) (5 + 5); iv) aldicarb at 5 kg a.i./ha in early April, followed by 2.5 kg/ha after flowering and 2.5 kg/ha in September (5 + 2.5 + 2.5); and v) untreated check plots maintained as for treated plots. Four more treatments consisted of applications of fenamiphos at the same rates and timing as the aldicarb. Both nematicides were uniformly distributed all over the plot surface and incorporated in the top 15 cm of soil. All plots were sprinkler-irrigated with an average of 400 m^3/ha of water after treatment in June and September to enhance activation of the nematicides. Treatments were applied each year (1986 to 1988). The experiment was terminated in 1989.

Root samples were collected under the canopy from two sites per tree in March or April each year before treatment. Feeder roots were separated from the soil,

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washed, cut into 0.5-cm-long pieces, and mixed. Female *T. semipenetrans* were extracted from a 5-g subsample that was macerated with a blender. In 1986 the resulting suspension of nematodes and debris was sieved through a 250-μm-pore sieve nested on a 70-μm-pore sieve. Nematodes retained on the latter sieve were counted with the aid of a dissecting microscope. In 1987–88, the suspension was centrifuged in a colloidal silica (10).

Soil samples, each an approximately 2.5 kg composite of 30 cores, were collected per plot (two orange trees). The sampled area was 3.7 m × 4.0 m. An auger 1.5 cm in diameter and 30 cm long was used to collect the soil samples twice a year: 1 month after the second nematicide application (usually late June to early July), and 1 month after the third application (October). Eggs, second-stage juveniles (J2), and males were extracted from 500 cm^3 soil by Coolen's method (6).

Annual yield data, collected in October–November, consisted of total fruit weights per plot and fruit size. Ten fruits per tree, of different orientation and 1.5 m from ground level, were arbitrarily selected and their equatorial diameters were measured. Fresh pulp and rind (150 g) from 10 fruits were collected in 1988 for assay of fenamiphos and its sulfone and sulfoxide (1,2). Aliquants of 100 g of either pulp and rind were comminuted in a blender containing 150 ml acetone and 50 ml distilled water (for pulp) or 250 ml acetone and 100 ml distilled water (for rind). The suspension was centrifuged for 10 minutes at 8,000*g* and filtered. The nematicide was extracted twice from the filtrate in 150 ml of $CHCl_3$ and filtered on anhydrous Na_2SO_4. The extracts were evaporated to dryness and analyzed with a gas chromatograph (Perkin-Elmer SIGMA 3B) with a nitrogen–phosphorous detector (1,2).

The orange grove was maintained according to normal practices; however, no insecticides or fungicides were applied during the experimental period. Irrigation was by overhead sprinklers, every 8–10 days, from late spring to early fall. All data were statistically analyzed, and means were compared with orthogonal contrasts.

Results

No differences were found among numbers of females of *T. semipenetrans* in the roots of orange trees (Table 1). Numbers of eggs, J2, and males in the soil did not differ among treatments in 1986 (Table 2). Both nematicides reduced nematode soil population densities during October 1986–88 to levels only 20 to 63% of those in control plots. There were few differences among application regimes for aldi-

TABLE 1. Number of females of *Tylenchulus semipenetrans* on the roots of 'Washington Navel' oranges grafted on sour orange growing in soil treated with aldicarb and fenamiphos.

Application regimes			Females/5g roots			
Nematicide	Rate (kg a.i./ha)	Time	1986	1987	1988	1989
Aldicarb	10	April	1,063 a	495 a	848 a	622 a
Aldicarb	20	April	1,100 a	484 a	754 a	862 a
Aldicarb	5 + 5	April + June	934 a	244 a	592 a	911 a
Aldicarb	5 + 2.5 + 2.5	April + June + Sept.	609 a	357 a	601 a	765 a
Fenamiphos	10	April	755 a	635 a	915 a	779 a
Fenamiphos	20	April	694 a	457 a	410 a	874 a
Fenamiphos	5 + 5	April + June	564 a	622 a	531 a	944 a
Fenamiphos	5 + 2.5 + 2.5	April + June + Sept.	777 a	578 a	725 a	939 a
Control			454 a	911 a	1,013 a	978 a

Means followed by the same letter within columns are not significantly different according to orthogonal contrast analysis.

TABLE 2. Eggs, second-stage juveniles (J2), and males of *Tylenchulus semipenetrans* in the rhizosphere of 'Washington Navel' oranges growing in soil treated with aldicarb and fenamiphos.

Application regimes			Eggs, J2, and males/500 cm^3 soil					
Nematicide	Rate (kg a.i./ha)	Time	18 June 1986	15 October 1986	1 July 1987	6 October 1987	20 June 1988	13 October 1988
Aldicarb	10	April	10,137 a	6,402 a	2,718 ab	2,202 a	4,418 a	1,714 a
Aldicarb	20	April	9,213 a	4,813 a	3,482 ab	2,485 a	3,385 a	1,503 a
Aldicarb	5 + 5	April + June	12,040 a	4,918 a	2,370 a	2,110 a	3,905 a	1,620 a
Aldicarb	5 + 2.5 + 2.5	April + June + Sept.	12,530 a	5,452 a	3,355 ab	1,898 a	3,454 a	1,461 a
Fenamiphos	10	April	9,172 a	8,545 ab	3,111 ab	3,146 a	5,255 a	1,422 a
Fenamiphos	20	April	13,070 a	4,203 a	3,338 ab	1,208 a	4,092 a	956 a
Fenamiphos	5 + 5	April + June	12,730 a	5,777 a	4,905 b	2,985 a	4,442 a	881 a
Fenamiphos	5 + 2.5 + 2.5	April + June + Sept.	9,533 a	5,145 a	3,935 ab	1,607 a	4,181 a	753 a
Control			8,600 a	13,456 b	9,769 c	5,868 b	10,453 b	3143 b

Means followed by the same letter within columns are not significantly different according to orthogonal contrast analysis.

TABLE 3. Yield of 'Washington Navel' oranges in a grove infested with *Tylenchulus semipenetrans* and treated with aldicarb and fenamiphos.

Application regimes			Yield (kg/two plants)		
Nematicide	Rate (kg a.i./ha)	Time	1986	1987	1988
Aldicarb	10	April	80.0 a	95.3 a	71.5 cde
Aldicarb	20	April	85.9 a	81.5 a	88.5 abc
Aldicarb	5 + 5	April + June	93.5 a	86.2 a	83.0 abcd
Aldicarb	5 + 2.5 + 2.5	April + June + Sept.	88.9 a	89.7 a	98.1 a
Fenamiphos	10	April	102.7 a	78.2 a	93.3 ab
Fenamiphos	20	April	92.7 a	86.8 a	76.2 bcde
Fenamiphos	5 + 5	April + June	81.5 a	85.6 a	61.8 e
Fenamiphos	5 + 2.5 + 2.5	April + June + Sept.	87.7 a	81.1 a	77.1 bcde
Control			84.9 a	83.0 a	62.5 de

Means followed by the same letter within columns are not significantly different according to orthogonal contrast analysis.

carb or fenamiphos in their effects on densities of *T. semipenetrans* in soil.

Fruit yield was not affected by any treatment during 1986–87 (Table 3). In 1988, aldicarb (20 kg; and 5 + 2.5 + 2.5) and fenamiphos (10 kg) increased yield by 42, 57, and 49%, respectively. Fruit size was not influenced by treatment within years. Concentrations of fenamiphos + metabolites in the orange fruits were below 0.02 ppm both in the pulp and rind, with no differences among application regimes.

DISCUSSION

Aldicarb and fenamiphos suppressed soil populations of *T. semipenetrans,* but not females on the citrus roots. Sampling may partially account for these differences. Root samples were collected from only two sites per plant and may not be representative of root invasion. In contrast, soil samples were collected from a large area of the plot, and each was a composite of 30 cores. Time of sampling soil and roots also varied, which made comparison difficult. Root samples were collected 6–12 months after nematicide applications, whereas soil samples were collected 1–6 months after applications.

Several investigators failed to obtain significant yield increases with soil applications of carbamate and phosphate nematicides (7,8,11,12). We had some significant yield increases in the third year of our study. Most probably plant age, environmental conditions, and duration of the experiment may account for the observed differences.

Cost analysis demonstrates that treatment with 20 kg a.i. aldicarb/ha is not practical because the cost of the chemical is equal to the value of the orange yield increase. In contrast, application of 10 kg a.i. fenamiphos/ha or of aldicarb in three applications of 5 + 2.5 + 2.5 kg a.i./ha increased farmer net income by $2,700 and $3,600/ha, respectively.

Fenamiphos residues within pulp and rind were less than 0.02 ppm, thus confirming previous findings (1–4). These residues are well below the 0.1 ppm fruit tolerance limit allowed in Italy. In conclusion, our study shows that aldicarb and fenamiphos soil treatments may be effective in reducing soil population densities of *T. semipenetrans* and increasing orange yield and farmer net income, with no apparent risk for the consumer.

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