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Efficacy of Fenamiphos Formulations Applied through Irrigation for Control of *Meloidogyne incognita* on Squash[1]

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Abstract: Management of *Meloidogyne incognita* by chemigation with fenamiphos was studied in an infested field planted to *M. incognita*-susceptible yellow summer squash cv. Dixie Hybrid. Fenamiphos (VL 73.1% a.i. manufacturing concentrate in propylene glycol) was mixed with Unitol DSR-90 or used as fenamiphos 3 SC (spray concentrate). Both formulations, applied with 63.5 kl irrigation water per hectare, decreased numbers of *M. incognita* second-stage juveniles in the soil and root-gall indices, and increased yield of squash compared with the untreated control. There was no benefit achieved by mixing the fenamiphos concentrate with Unitol DSR-90 over the use of fenamiphos 3 SC formulation. Fenamiphos application rates between 3.36 and 6.72 kg a.i./ha could provide control of *M. incognita* comparable to that obtained with 6.72 kg a.i./ha. Reduced rates of fenamiphos applied with irrigation water used to control plant-parasitic nematodes could reduce the potential for groundwater pollution as well as cost to the grower.
Key words: Cucurbita pepo, fenamiphos, *Meloidogyne incognita,* nemagation, nematicide, nematode, root-knot nematode, summer squash.

Many growers use irrigation systems to apply agricultural chemicals with water. The method, called chemigation, initially included only materials such as plant nutrients that generally required incorporation into the soil for effectiveness. Chemigation technology is expanding, however, in response to advances in irrigation system design, improved chemical injection equipment, and widespread development and use of agricultural chemicals (7). The use of chemigation has increased rapidly during the last 10 years, and an estimated 5.2 million ha in the United States were chemigated during 1985 (10). Chemicals applied by this technique include fertilizers, herbicides, insecticides, fungicides, nematicides, growth regulators, and biorationals (7).

The commercial formulation of fenamiphos 3 SC (spray concentrate) has been applied through sprinkler irrigation systems for control of nematodes on several crops (1,3–6,8). Management of important nematodes in crops should be enhanced by gaining more information on nematode population densities as influenced by different formulations and application rates of fenamiphos applied through sprinkler irrigation systems. Our objective was to determine the effects of oil vs. water formulations of fenamiphos applied with irrigation water on *Meloidogyne incognita* population densities and yields of yellow summer squash.

MATERIALS AND METHODS

Field plots were established in May 1987 on Bonifay sand (siliceous thermic, Grossarenic, Plinthic Paleudult; 93% sand, 3% silt, 4% clay; 0.5% organic matter; pH 6.0–6.7). The plots were naturally infested with the root-knot nematode, *Meloidogyne incognita* race 1 and the ring nematode, *Criconemella ornata.* The soil was disc-harrowed, plowed 25–30 cm deep with a moldboard plow, and shaped into beds 10–15 cm high. Plots were three 1.8-m wide × 9.1-m long beds. Fertilizer (1,344 kg/ha, 5-10-15, N-P_2O_5-K_2O) was applied broadcast to all plots and incorporated 10 cm deep with a tractor-mounted rototiller.

Two formulations of fenamiphos were evaluated at two rates for control of nematodes on yellow summer squash (*Cucurbita pepo* var. *melopepo* cv. Dixie Hybrid). The oil formulation was fenamiphos (VL 73.2% a.i. manufacturing concentrate in propylene glycol) dissolved in tall oil-fatty

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acids (Unitol DSR-90, a byproduct of the pulp and paper industry, Union Camp, Savannah, GA) that will transit the irrigation system as discrete droplets of oil-fenamiphos (7). The other formulation was fenamiphos 3 SC.

Treatments were: (i) fenamiphos VL + Unitol DSR-90, 3.36 kg a.i./ha; (ii) same as treatment i, 6.72 kg a.i./ha; (iii) fenamiphos 3 SC, 3.36 kg a.i./ha; (iv) fenamiphos 3 SC, 6.72 kg a.i./ha; (v) Unitol DSR-90, 3.3 liters/ha; and (vi) untreated control. All treatments contained a total volume of 3.3 liters/ha and were injected with a pump (Fluid Metering, Oyster Bay, NY) into the water during application. All treatments were applied through an irrigation simulator (8) equipped with seven whirljet nozzles spaced 102 cm apart and calibrated to deliver 63.5 kl water/ha at 68 kPa in the boom with a 93 coefficient of uniformity as it moved across the field plots. All treatments were arranged in a randomized complete block design with four replications.

Yellow squash seeds were planted 30 cm apart in rows 0.9 m apart on 19 May. Chloramben was sprayed broadcast 3.36 kg a.i./ha in 187 liters water/ha for weed control on 20 May. Plants in all plots were side-dressed with ammonium nitrate (34% N) at 336 kg/ha on 4 June.

Twenty cores of soil, 2.5-cm-d × 25 cm deep, were collected from the rows of squash on 19 May, 17 June (4 weeks), and 10 July (7 weeks after planting). Soil cores were mixed, and nematodes were extracted from a 150-cm^3 subsample by a centrifugal-flotation method (2). Two plants per plot were uprooted and rated for galls 4 weeks after planting. All plants were uprooted and rated for galls after the final harvest, 7 weeks after planting. On each sampling date, root-gall indices were recorded for the upper 10-cm root system and the entire root system. The root-gall index was based on a 1–5 scale: 1 = no galling, 2 = 1–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100% roots galled.

Squash fruit was hand-harvested eight times from 22 June to 10 July, classified as marketable or cull, counted, and weighed. The data were subjected to a least-squares analysis of variance (9). Means were separated according to Duncan's multiple-range test. Squash yields, nematode population densities in the soil, and root-gall indices were subjected to correlation analysis. Only significant ($P = 0.05$) effects are discussed unless stated otherwise.

Results and Discussion

Numbers of *M. incognita* second-stage juveniles (J2) per 150 cm^3 soil were near or below detectable levels in all plots on 19 May and 17 June (data not included), but were higher on 10 July in the untreated plots and plots treated with Unitol DSR-90 3.3 liters/ha than in other plots (Table 1). Numbers of *C. ornata* were $\leq 28/150$ cm^3 soil on all sampling dates and were not different among treatments (data not included).

Root-gall indices of the upper 10-cm root system and the total root system from fenamiphos VL + Unitol DSR-90 and fenamiphos 3 SC treatments were lower than those from Unitol DSR-90 3.3 liters/ha and untreated plots on both sampling dates (Table 1). Four weeks after planting, the upper 10-cm root system of squash from all fenamiphos-treated plots was free of galls. As the season progressed, root-gall indices of the upper 10-cm root system increased in all fenamiphos-treated plots, but remained lower than those from untreated and Unitol DSR-90-treated plots. Four weeks after planting, root-gall indices of the entire root system were lower in all fenamiphos-treated plots than those in untreated plots and plots treated with Unitol DSR-90 3.3 liters/ha. After the final harvest, root-gall indices of the entire root systems of plants from plots treated with fenamiphos 3 SC 6.72 kg a.i./ha and fenamiphos VL 6.72 kg a.i./ha + Unitol DSR-90 were lower than those from plots treated with fenamiphos VL 3.36 kg a.i./ha + Unitol DSR-90 and fenamiphos 3 SC at 3.36 kg a.i./ha.

Squash yield (fruit numbers and weight per hectare) was improved in all treated plots, compared with the untreated control

TABLE 1. Influence of two fenamiphos formulations at two rates applied through an irrigation simulator on soil population densities of *Meloidogyne incognita*, root-gall indices, and yield of squash.

Treatment	Rate (kg a.i./ha)	Nematodes/150 cm^3 soil	Root-gall index†				Yield/ha	
			Upper 10 cm of root system‡		Total root system			
		7 weeks	4 weeks	7 weeks	4 weeks	7 weeks	Number (×1,000)	Metric ton
Control	—	43 a§	2.15 a	4.78 a	2.15 a	4.78 a	108.1 b	14.0 b
Unitol DSR-90 (U)	—	75 a	2.23 a	4.39 a	2.23 a	4.39 a	130.3 ab	19.1 a
Fenamiphos VL + U	3.36	5 b	1.00 b	1.43 b	1.15 b	2.05 c	144.2 a	20.7 a
Fenamiphos VL + U	6.72	5 b	1.00 b	1.23 b	1.13 b	1.30 d	144.4 a	19.1 a
Fenamiphos 3 SC	3.36	8 b	1.00 b	1.70 b	1.23 b	2.75 b	141.3 a	18.5 ab
Fenamiphos 3 SC	6.72	0 b	1.00 b	1.00 b	1.03 b	1.05 d	157.2 a	21.5 a

Data are means of four replications.
† Scale: 1 = no galls, 2 = 1–25%, 3 = 25–50%, 4 = 51–75%, and 5 = 76–100% roots galled.
‡ Roots below 10 cm were not included in these ratings.
§ Means followed by the same letter are not different ($P \leq 0.05$) according to Duncan's multiple-range test.

(Table 1). The number of squash fruit from Unitol DSR-90-treated plots was not significantly higher than those from the control or the fenamiphos-treated plots, but the weight of squash from plants in the Unitol DSR-90-treated plots was higher than that in the untreated control plots. All fenamiphos treatments, except 3 SC 3.36 kg a.i./ha, resulted in similar yields both in number and weight. The increases in yield (or weight of fruit), in the Unitol DSR-90-treated plots appeared to be independent of nematode control; the root-gall index is just one of the factors contributing to yield with the Unitol DSR-90 contributing to factors other than nematode control. This is evident in the root-gall index for the various dates of sampling. Additional studies are necessary to determine the role of Unitol DSR-90 on squash yields.

The fruit numbers ($r = -0.44$) and squash yields ($r = -0.46$) were inversely correlated with the soil population densities of *M. incognita* J2 after the final harvest. There was also a negative correlation between root-gall indices and fruit number ($r = -0.41$) and weight ($r = -0.63$) of squash.

The application of both fenamiphos formulations with irrigation water increased squash yield and decreased soil population densities of *M. incognita* J2 and root-gall indices. Similar results have been reported for fenamiphos 3 SC formulation applied with irrigation water (4–6). The efficacy of fenamiphos 3 SC applied with irrigation water and fenamiphos 15 G incorporated into the upper 15 cm soil layer at similar rates was not different (4,5). In the present study, crop response and efficacy of both fenamiphos formulations applied at 3.36 and 6.72 kg a.i./ha were similar. These results also indicated that there was no benefit due to mixing technical (73.1%) fenamiphos with Unitol DSR-90 over the use of fenamiphos 3 SC formulation applied with irrigation water for control of *M. incognita* on squash. In addition, the data indicated that rates of fenamiphos between 3.36 and 6.72 kg a.i./ha could provide control of *M. incognita* comparable to that obtained with 6.72 kg a.i./ha. Reduced rates of fenamiphos applied with irrigation water used to control plant-parasitic nematodes could reduce the potential for groundwater pollution as well as reduce costs to the grower. Additional research on applying fenamiphos 3 SC with irrigation water at reduced rates of application within various soil types and moisture regimes is required to confirm this hypothesis.

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