Effects of Nonfumigant Nematicides Applied Through Low-Pressure Drip Irrigation on Control of *Meloidogyne incognita* on Tomatoes

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ABSTRACT

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The efficacy of two experimental nematicides, aldoxycarb and carbosulfan, was compared with that of carbofuran and oxamyl for control of *Meloidogyne incognita* on tomatoes. Chemicals were placed in PVC injectors through a low-pressure drip-irrigation system at rates from 0.37 to 3.37 kg a.i./ha as single or multiple applications. Single and multiple applications of all four chemicals proved effective in reducing root gall ratings at harvest. Chemicals lost their effectiveness between the second and third week after application. When chemicals were applied at 1.68 kg a.i./ha every 2 wk (total of 5.04 kg a.i./ha) or at 0.37 kg a.i./ha every 3 or 6 days (total of 2.22 kg a.i./ha), significant reductions in root gall ratings were observed, with substantial increases in tomato yield.

Widespread use of nonfumigant nematicides to control plant-parasitic nematodes began in the late 1960s. Their use as standard nematicides was not very successful because they were applied in a manner similar to fumigant nematicides. With an increased shift to low-pressure drip-irrigation systems in California and other irrigated regions of the world for environmental and economic reasons, however, the search for more effective and economical methods of applying nonfumigant nematicides became essential. Soil around the water emitter is moistened by drip irrigation to a depth of 30 cm, allowing a dense root system rich in rootlets to develop in the moistened area. This also provides an efficient method for applying nutrients and chemicals (7).

Because many growers use irrigation systems to apply fertilizers, the same equipment can be used to apply pesticides. Only a few reports are available on the application of nematicides through low-pressure drip-irrigation systems (1,4–6).

The objective of this study was to evaluate the efficacy of aldoxycarb, carbosulfan, carbofuran, and oxamyl for control of *Meloidogyne incognita* (Kofoid & White) Chitwood by comparing a single treatment aimed at oversaturating the soil and forming a reservoir for prolonged root uptake versus multiple treatments at low concentrations aimed at inhibiting nematodes from entering roots for a period of time after each application.

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MATERIALS AND METHODS

Low-pressure drip-irrigation system. A PVC injector (4) was used to apply liquid formulations of nematicides through low-pressure drip-irrigation systems. Irrigation water from the main was passed through a series of filters and regulators, reducing the pressure to about 0.34 kg/cm^2. Some water was then forced through a 0.6-cm-diameter line entering the PVC canister where the water and chemicals were previously mixed and eventually forced out through another 0.6-cm-diameter line and back into 1.3-cm tubing. Each 1.3-cm line was split five times, one line to each replicate, for a total of five completely randomized replicates. A surface emitter delivering about 2 L of water per hour was used at each plant.

Experiment 1. This experiment was out carried during summer 1982 on sandy loam soil at South Coast Field Station near Tustin, CA. The soil was naturally infested with *M. incognita*. The test area had been planted to carrots (*Daucus carota* L.) the previous fall and winter to increase nematode infestations.

Treatments consisted of oxamyl L 24%, carbosulfan 4EC, and aldoxycarb L 28%, using a single application at 3.37 kg a.i./ha and three multiple applications at 0.84 kg a.i./ha each. The first multiple application was made in the first irrigation at transplanting. Second and third multiple applications were made 3 and 6 wk after transplanting. Four-week-old tomato seedlings (*Lycopersicon esculentum* Mill. cv. UC 82) were transplanted at 12 plants per plot.

One plant from each plot was removed each week for the first 5 wk. At the final sampling, five plants per plot were removed. Nematode eggs per gram of root, fresh weight of total fruit, and fresh and dry weights of shoots were recorded.

Root systems were rated for nematode galling by the following scale (2): 0 = no infection, 1 = 1–20% (trace), 2 = 21–40% (slight), 3 = 41–60% (moderate), 4 = 61–80% (severe), and 5 = 81–100% (very severe).

Experiment 2. This experiment was carried out during summer 1982 in another field of loamy soil previously cropped to figs (*Ficus carica* L.) infested with *M. incognita*. The field was located at the Citrus Experiment Station at Riverside, CA. The frequency of nematicide applications in this experiment was different from that in experiment 1.

Oxamyl L 24%, carbosulfan 4EC, aldoxycarb 28%, and carbofuran 41% were applied at 1.68 kg a.i./ha at the start of the experiment, then every 2 wk (total of 5.04 kg a.i./ha). They were also applied at 0.37 kg a.i./ha at the start of the experiment, then 3 and 6 days later (total of 1.11 kg a.i./ha) and again 2 wk later (total of 2.22 kg a.i./ha).

One plant from each plot was removed every 10 days over a period of 40 days after the treatments. Twelve weeks after treatments, fresh and dry weights of shoots, root gall ratings, fresh weight of total fruit, and eggs per gram of root were recorded.

RESULTS

Experiment 1. All treatments showed significant reduction in root gall ratings throughout the 5-wk sampling period. However, all applications of carbosulfan, aldoxycarb, and oxamyl began to lose their effectiveness between the second and third week (Table 1). At harvest, root gall ratings were lower in all treated plots than in untreated control plots. The lowest average gall ratings were in plots treated with carbosulfan and oxamyl at 0.84 kg a.i./ha every 3 wk (Table 1).

Aldoxycarb at 3.37 kg a.i./ha was the only treatment that resulted in a higher yield than the control, although this was not statistically significant. None of the chemicals significantly suppressed the number of eggs per gram of root compared with their significant effect on gall production (Table 1).

Experiment 2. In this experiment, a longer interval was allowed between samples for gall rating. At the end of 40 days, all chemicals applied at 1.68 kg a.i./ha every 2 wk maintained a significant reduction in root gall ratings (Table 2). When treatments were applied at 0.37 kg a.i./ha every 3 days, aldoxycarb and oxamyl were the only chemicals maintaining a significant reduction in root gall ratings (Table 2).

At harvest, although all treatments were heavily galled, they were significantly less so than the control (except oxamyl at 1.68 kg a.i./ha every 2 wk).

Egg production per gram of root was significantly less in all treatments except oxamyl at 1.68 kg a.i./ha (Table 2).

Yield was increased in all treatments compared with the control (Table 2). However, only plants treated with carbofuran, aldoxycarb, and oxamyl at 0.37 kg a.i./ha every 3 days and aldoxycarb at 1.68 kg a.i./ha had a significantly higher yield than the control (Table 2).

DISCUSSION

Use of individual PVC injectors for chemical application of liquid nonvolatile pesticides through low-pressure drip-irrigation systems on small plots (4) represents a potential method for their preliminary evaluation or thorough investigation in the field. Although the initial cost for setting up such research materials in the field is high, the setup can be removed at the end of the experiment and used in future experiments with minimum time and expense for cleaning and maintaining equipment. Such devices may also be used to apply soilborne pathogens to small field plots that do not have adequate propagule populations to conduct field experiments. Thus, the researcher may be able to obtain adequate control of the pathogen population desired in the field.

Our results indicate that nonfumigant nematicides have potential for controlling *M. incognita* in the field at more efficient rates than now recommended by the manufacturer. Single applications with liquid formulations of materials only give early protection and plants become heavily galled at the end of the season (Table 1). With nonvolatile nematicides, it appears that frequency of application is a highly important factor in extending the efficacy and efficiency of these chemicals. These nematicides are water-soluble and must be distributed and maintained at low concentrations throughout the root zone in the water phase.

In experiment 2, it was demonstrated clearly that when low rates were applied at short intervals, adequate yield increases and nematode control were obtained (Table 2). The objective of this technique was to keep a small amount of active chemical in the root zone to protect new roots from infection by nematode larvae. This technique has been used successfully for treatment of the citrus nematode (*Tylenchulus semipenetrans*) on citrus (8). It should be recognized, however, that nonvolatile nematicides at the low concentrations used in the field do not kill nematodes but rather act as nemastats (3). Therefore, these nematicides should be considered as a pest management tool for reducing the nematode population in the field to a level adequate to allow protection of new roots from infection by nematode larvae. This would allow growth and function of new roots and, subsequently, vigor and yield increase of the crop.

In conclusion, because phytotoxicity was not observed and yield of tomatoes was increased (Table 2), results of this study are encouraging for use of multiple applications of nonvolatile nematicides at low concentrations. In some cases,

Table 1. Influence of carbosulfan, aldoxycarb, and oxamyl treatments applied in May 1982 at South Coast Field Station through low-pressure drip irrigation on control of *Meloidogyne incognita* (experiment 1)

Chemical and formulation	Rate (kg a.i./ha)	Method of application	Total applied (kg a.i./ha)	Root gall rating[w] (wk 1-5)					Harvest		
				1st	2nd	3rd	4th	5th	Root gall rating[w]	Eggs/g of root ($\times 10^2$)	Yield (kg)
Carbosulfan 47%	3.37	Single[x]	3.37	0.0 b[y]	1.0 b	1.6 bcd	1.6 bcd	1.6 cd	3.92 b	86.0 abc	7.3 a
	0.84	Multiple[z]	2.52	1.0 a	1.2 ab	1.8 bcd	2.8 bc	2.0 cd	3.64 bc	106.0 ab	6.5 a
Aldoxycarb 28%	3.37	Single	3.37	0.0 b	1.0 b	1.8 bcd	2.2 bcd	3.4 ab	3.84 b	105.6 ab	10.3 a
	0.84	Multiple	2.52	0.0 b	1.4 ab	2.4 bc	2.2 bcd	2.8 bc	4.04 b	95.4 abc	6.7 a
Oxamyl 24%	3.37	Single	3.37	0.0 b	1.0 b	2.6 b	1.8 bcd	1.8 cd	3.88 b	112.0 a	8.0 a
	0.84	Multiple	2.52	0.0 b	1.0 b	2.2 bcd	1.4 cd	2.2 cd	3.68 bc	83.9 bcd	7.5 a
Control	···	···	···	1.0 a	1.6 a	4.2 a	4.6 a	4.2 a	4.88 a	112.0 a	8.8 a

[w] 0 = No infection, 1 = 1–20% (trace), 2 = 21–40% (slight), 3 = 41–60% (moderate), 4 = 61–80% (severe), and 5 = 81–100% (very severe).
[y] Means followed by the same letter do not differ ($P = 0.05$) according to Duncan's multiple range test.
[x] Chemicals applied only once at the start of the experiment.
[z] Liquid formulation applied through an injector every 21 days for a total of three times.

Table 2. Influence of carbosulfan, carbofuran, aldoxycarb, and oxamyl treatments applied in June 1982 at Citrus Field Station through low-pressure drip irrigation on control of *Meloidogyne incognita* (experiment 2)

Chemical and formulation	Rate (kg a.i./ha)	Method of application	Total applied (kg a.i./ha)	Root gall rating[w] (days)				Harvest		
				10	20	30	40	Root gall rating[w]	Eggs/g of root ($\times 10^2$)	Yield (kg)
Carbosulfan 47%	1.68	Multiple[x]	5.04	0.20 bc[y]	0.42 b	0.40 c	1.60 bcd	2.62 bcd	51.84 de	6.5 abcd
	0.37	Multiple[z]	2.22	0.32 bc	0.44 b	1.00 bc	2.00 abc	2.68 bcd	54.09 de	7.0 abcd
Carbofuran 41%	1.68	Multiple	5.04	0.28 bc	0.26 b	0.80 c	0.20 d	2.76 bcd	70.40 cde	5.1 bcd
	0.37	Multiple	2.22	0.16 bc	0.78 b	1.00 bc	2.80 abc	3.16 bcd	96.12 bc	8.6 abc
Aldoxycarb 28%	1.68	Multiple	5.04	0.36 bc	0.36 b	0.80 c	1.20 cd	2.36 d	48.20 e	9.4 a
	0.37	Multiple	2.22	0.16 bc	0.20 b	0.40 c	1.40 bcd	2.72 bcd	53.72 de	9.2 ab
Oxamyl 24%	1.68	Multiple	5.04	0.32 bc	0.28 b	0.80 c	1.24 cd	3.56 abc	96.80 ab	8.5 abcd
	0.37	Multiple	2.22	0.26 bc	0.28 b	1.41 bc	1.66 bcd	2.44 cd	59.81 de	9.6 a
Control	···	···	···	1.28 a	2.20 a	2.80 a	3.68 a	4.40 a	134.23 a	4.4 d

[w] 0 = No infection, 1 = 1–20% (trace), 2 = 21–40% (slight), 3 = 41–60% (moderate), 4 = 61–80% (severe), and 5 = 81–100% (very severe).
[x] Chemicals applied once at the start of the experiment and every 2 wk for a total of three treatments.
[y] Means followed by the same letter do not differ ($P = 0.05$) according to Duncan's multiple range test.
[z] Liquid formulation applied through an injector either every 3 wk or every 3 days for a total of 6 days, then followed by the same treatments 3 wk later.

there appear to be some positive plant responses associated with repeated applications of these chemicals.

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