Applying Nematicides through an Overhead Sprinkler Irrigation System for Control of Nematodes[1]

A. W. Johnson, J. R. Young, and B. G. Mullinix[2]

Abstract: Phenamiphos, ethoprop, and carbofuran each at 6.7 kg a.i./ha were applied to squash, southern pea, and corn via injection into a sprinkler irrigation system. This method was then compared with a conventional application of phenamiphos and ethoprop granules spread on the soil surface and incorporated into the top 15 cm for control of *Macroposthonia ornata* and *Meloidogyne incognita*. Nematode populations in the soil and root-gall indices were lower, and yields greater, in treated than in untreated plots, but there were no significant differences between the methods of application in most comparisons. *Key words:* root-knot nematodes, *Meloidogyne incognita,* ring nematodes, *Macroposthonia ornata,* chemical control, pest management.

Methods of crop production in the Georgia Coastal Plain have changed considerably during the last 10 yr. Previously, many growers produced a variety of vegetables and agronomic crops in small fields without irrigation or regular pest control. Presently, almost all commercial vegetables and many agronomic crops are grown in fields (5–50 ha) under overhead sprinkler irrigation with a planned pest management program. Application of chemicals through irrigation water is a promising method of pest management. Fungi (3), weed (C. C. Dowler, personal communication), and insect (4) control has been obtained by applying pesticides through irrigation water. However, only limited information is available on the growth and yield of crops treated with nematicides applied through sprinkler irrigation (2,3). This research was conducted to supplement that paucity of information.

MATERIALS AND METHODS

Plots were established in July 1979 on Lakeland sand (93.5% sand, 2.9% silt, and 3.6% clay, pH 6.0–6.7) infested with root-knot nematodes, *Meloidogyne incognita* (Kofoid and White) Chitwood, and ring nematodes, *Macroposthonia ornata* (Raski) de Grisse & Loof. Each plot contained three 1.8 × 12.2-m-beds. The experimental design was a randomized complete block with treatments replicated four times. All nematicides were applied at 6.7 kg a.i./ha supplied in 123,000 L irrigation water/ha (System Ir), or incorporated 15 cm deep with a tractor drawn rototiller (System Ro) after broadcast spreading. Treatments and methods of application were 1) untreated control; 2) ethyl 4-(methylthio)-*m*-tolyl isopropylphosphoramidate (phenamiphos 3SC), System Ir; 3) phenamiphos 15G, System Ro; 4) *O*-ethyl *S,S*-dipropyl phosphorodithioate (ethoprop 6SC), System Ir; 5) ethoprop 10G, System Ro; and 6) 2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate (carbofuran 4F), System Ir. One bed each in all plots was planted to squash (*Cucurbita pepo* L. 'Summer Crookneck'), corn (*Zea mays* L. 'Pioneer × 304 C') and southern pea (*Vigna unguiculata* (L.) Walp. 'White Conch') on 17 July. Nematicides supplied in the irrigation water (System Ir) were applied the day after planting. Fertilizer was applied at planting with ground applicators and by irrigation as needed. Insecticides and fungicides were applied as needed with ground sprayers.

Twenty soil cores (2.5 × 15 cm) collected from the center 6 m of each bed prior to treatment, 60 d after planting, and at harvest were used for nematode assay. A 150-cm^3 soil aliquot was processed by the centrifugal-flotation method to separate nematodes from the soil (1). Ten plants from each bed were examined for galls caused by *M. incognita* each 30 d after planting and after harvest.

Squash was harvested six times from 21 Aug. to 10 Sept., and the total number of

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[2]Respectively, Supervisory Research Nematologist and Research Entomologist, USDA SEA AR; and Agricultural Research Statistician, Coastal Plain Experiment Station, Tifton, GA 31793.

fruit and their cumulative weight determined. Southern peas were hand picked and weighed on 4 Oct. Corn was hand harvested on 24 Oct., weighed for silage, and dried. Ear length and diameter, percent fill, and yield (silage and grain) per ha were recorded.

RESULTS

Pretreatment population densities of *M. ornata* and *M. incognita* were not different among plots (Tables 1–3). Sixty days after planting, numbers of *M. ornata* were not affected by nematicide treatments on squash and southern pea but were suppressed on corn. Numbers of *M. ornata* in plots of southern pea and corn were suppressed more by phenamiphos than ethoprop. *Meloidogyne incognita* increased rapidly on all crops and was reduced by treatments on squash and corn, but not southern pea. Numbers of *M. incognita* on corn were lower in plots treated with phenamiphos than with ethoprop.

After harvest, the numbers of *M. ornata* on southern pea and corn and *M. incognita* on corn were lower in phenamiphos-treated plots than in ethoprop-treated plots.

Methods of application of phenamiphos and ethoprop did not affect numbers of nematodes on squash and corn, but numbers of *M. incognita* on southern pea were lower in Ro than in Ir plots 60 d after planting and at harvest.

Root-gall indices of all crops recorded 30 d after planting were lower in treated plots than in untreated plots. At that time, root-gall indices of squash and corn were lower in plots treated with phenamiphos than in plots treated with ethoprop. Root-gall indices of squash and corn at harvest were lower in treated plots than in untreated plots and lower in phenamiphos-treated plots than in ethoprop-treated plots. Root-gall indices of squash 30 d after planting and at harvest and southern pea at harvest were lower in Ro plots than in Ir plots. There were no significant differences in nematode population densities and root-gall indices in plots treated with carbofuran (Ir) vs phenamiphos (Ir) or in the P vs E

Table 1. Population densities of *Macroposthonia ornata* and *Meloidogyne incognita* and root-gall indices on squash as influenced by nematicides* and method of application.

		Number nematodes/150 cm³ soil				Root-gall index‡	
		15 July (pretreatment)		60 d after planting			
Treatment	Method of application†	*M. ornata*	*M. incognita*	*M. ornata*	*M. incognita*	30 d after planting	At harvest
Control (CK)		15	20	40	1900	3.95	5.00
Phenamiphos (P)	Ir	20	23	20	516	1.70	2.70
Phenamiphos (P)	Ro	30	20	6	394	1.10	1.70
Ethoprop (E)	Ir	13	28	34	974	2.75	4.68
Ethoprop (E)	Ro	10	23	24	242	1.78	4.25
Carbofuran (C)	Ir	18	18	16	580	2.00	3.63
Comparisons:							
CK vs other treatments		15 18§	20 22	40 20	1900 541	3.95 1.87	5.00 3.39
CIr vs PIr		18 20	18 23	16 20	580 516	2.00 1.70	3.63 2.70
P(Ir + Ro) vs E(Ir + Ro)		25 12	22 24	13 29	455 608	1.30 2.27	2.20 4.47
Ir(P + E) vs Ro(P + E)		17 20	26 22	27 15	745 318	2.23 1.44	3.69 2.98
Interactions:							
P vs E and Ir vs Ro		18 21	23 24	22 20	379 684	1.74 1.93	3.48 4.31

*Nematicides applied at 6.7 kg a.i./ha.

†Ir = injected via sprinkler irrigation system; Ro = granules incorporated 15-cm deep with tractor-powered rototiller.

‡1–5 scale: 1 = no galls, 2 = 1–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100% roots galled.

§Means underlined by contiguous line are not significantly (P = 0.05) different.

Table 2. Population densities of *Macroposthonia ornata* and *Meloidogyne incognita* and root-gall indices on southern pea as influenced by nematicides* and method of application.

Treatment	Method of application†	Number nematodes/150 cm^3 soil: 15 July (pretreat) *M. ornata*	15 July (pretreat) *M. incognita*	60 d after planting *M. ornata*	60 d after planting *M. incognita*	At harvest *M. ornata*	At harvest *M. incognita*	Root-gall index‡: 30 d after planting	Root-gall index‡: At harvest
Control (CK)		20	40	16	312	28	50	1.33	1.48
Phenamiphos (P)	Ir	20	23	5	63	7	51	1.05	1.53
Phenamiphos (P)	Ro	13	5	2	34	18	50	1.03	1.38
Ethoprop (E)	Ir	25	35	20	366	52	120	1.05	2.25
Ethoprop (E)	Ro	20	28	36	46	42	52	1.00	1.45
Carbofuran (C)	Ir	15	10	6	258	67	260	1.05	2.20
Comparisons:									
CK vs other treatments		20 19§	40 20	16 14	312 153	28 25	50 107	1.33 1.04	1.48 1.76
Ir vs PIr		15 20	10 23	6 5	258 63	67 7	260 51	1.05 1.05	2.20 1.53
P(Ir + Ro) vs E(Ir + Ro)		16 23	14 31	4 28	48 206	13 47	50 86	1.04 1.03	1.45 1.85
Ir(P + E) vs Ro(P + E)		23 16	29 16	13 19	214 40	30 30	85 51	1.05 1.01	1.89 1.41
Interactions:									
P vs E and Ir vs Ro		20 19	25 20	21 11	54 200	25 35	51 85	1.03 1.04	1.49 1.81

*Nematicides applied at 6.7 kg a.i./ha.

†Ir = injected via sprinkler irrigation system; Ro = granules incorporated 15-cm deep with tractor-powered rototiller.

‡1–5 scale: 1 = no galls, 2 = 1–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100% roots galled.

§Means underlined by contiguous line are not significantly (P = 0.05) different.

Table 3. Population densities of *Macroposthonia ornata* and *Meloidogyne incognita* and root-gall indices on corn as influenced by nematicides* and method of application.

Treatment	Method of application†	Number nematodes/150 cm³ soil: 15 July (pretreat) *M. ornata*	15 July (pretreat) *M. incognita*	60 d after planting *M. ornata*	60 d after planting *M. incognita*	At harvest *M. ornata*	At harvest *M. incognita*	Root-gall index‡: 30 d after planting	Root-gall index‡: At harvest
Control (CK)		23	18	90	951	58	960	2.18	3.73
Phenamiphos (P)	Ir	20	25	8	121	2	48	1.03	1.38
Phenamiphos (P)	Ro	15	10	2	76	2	18	1.05	1.28
Ethoprop (E)	Ir	15	40	37	756	94	677	1.48	2.68
Ethoprop (E)	Ro	13	25	76	556	66	219	1.15	2.25
Carbofuran (C)	Ir	15	10	7	304	10	315	1.10	2.35
Comparisons:									
CK vs other treatments		23 16§	18 22	90 26	951 362	58 35	960 256	2.18 1.16	3.73 1.99
Ir vs PIr		15 20	10 25	7 8	304 121	10 2	315 48	1.10 1.03	2.35 1.38
P(Ir + Ro) vs E(Ir + Ro)		18 14	18 33	5 57	98 656	2 80	33 448	1.04 1.32	1.33 2.47
Ir(P + E) vs Ro(P + E)		18 14	33 18	23 39	438 316	48 34	363 119	1.25 1.10	2.03 1.76
Interactions:									
P vs E and Ir vs Ro		16 15	25 25	42 20	338 416	34 48	134 348	1.09 1.26	1.81 1.98

*Nematicides applied at 6.7 kg a.i./ha.
†Ir = injected via sprinkler irrigation system; Ro = granules incorporated 15-cm deep with tractor-powered rototiller.
‡1–5 scale: 1 = no galls, 2 = 1–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100% roots galled.
§Means underlined by contiguous line are not significantly (P = 0.05) different.

Table 4. Yield of squash, southern pea and corn as affected by nematicides* and method of application.

		Yield					Corn		
		Squash		Southern pea	Corn				
					Silage	Grain			
Treatment	Method of application†	No. fruit/ha (× 1000)	kg/ha	kg/ha	metric tons/ha	kg/ha	Fresh ear wt. (kg/plot)	Ear length (cm)	Fill length (cm)
Control (CK)		22.4	2659	1317	24.28	2372	9.38	17.3	13.8
Phenamiphos (P)	Ir	60.5	8054	1433	34.30	3306	11.75	18.2	14.7
Phenamiphos (P)	Ro	63.0	9204	1189	35.63	3959	13.33	18.6	15.1
Ethoprop (E)	Ir	43.5	7884	1067	32.15	3405	11.92	17.3	14.0
Ethoprop (E)	Ro	48.7	6403	1382	32.22	3603	12.41	18.4	14.7
Carbofuran (C)	Ir	56.6	7810	901	37.53	3965	13.60	17.6	14.7
Comparisons:									
CK vs other treatments		22.4 54.5‡	2659 7871	1317 1194	24.28 34.37	2372 3648	9.38 12.60	17.3 18.0	13.8 14.6
CIr vs PIr		56.6 60.5	7810 8054	901 1433	37.53 34.30	3965 3306	13.60 11.75	17.6 18.2	14.7 14.7
P(Ir + Ro) vs E(Ir + Ro)		61.8 46.1	8629 7144	1311 1225	34.97 32.19	3633 3504	12.54 12.17	18.4 17.9	14.9 14.3
Ir(P + E) vs Ro(P + E)		42.0 55.9	7969 7804	1250 1286	33.23 33.93	3356 3781	11.84 12.87	17.8 18.5	14.3 14.9
Interactions:									
P vs E and Ir vs Ro		54.6 53.3	7229 8544	1408 1128	33.26 33.89	3455 3682	12.08 12.63	18.3 18.0	14.7 14.5

*Nematicides applied at 6.7 kg a.i./ha.

†Ir = injected via sprinkler irrigation system; Ro = granules incorporated 15-cm deep with tractor-powered rototiller.

‡Means underlined by contiguous line are not significantly ($P = 0.05$) different.

and Ir vs Ro interactions on most sampling dates.

Numbers and weight of squash were 143% and 196%, respectively, greater from treated plots than from untreated plots (Table 4). Yield of southern pea was not significantly affected by treatments compared with untreated controls, but yield from plots treated with phenamiphos (Ir) was 59% greater than yield from plots treated with carbofuran (Ir). Yield of corn silage was 42% greater from treated plots than from untreated plots, 9% greater from plots treated with carbofuran (Ir) than from plots treated with phenamiphos (Ir), and 9% greater from plots treated with phenamiphos (Ir + Ro) than from plots treated with ethoprop (Ir + Ro). Grain yield was 54% greater from treated plots than from untreated plots, 9% greater from occurred in fresh ear weight, ear length, and fill length. No differences in yields of crops occurred between methods of application for phenamiphos and ethoprop or the interactions.

DISCUSSION

Our data indicate that phenamiphos, ethoprop, and carbofuran can be effectively applied through a sprinkler irrigation system for nematode control on squash, southern pea, and corn. Based on root-gall indices, the efficacy of phenamiphos was greater than ethoprop, but the efficacy of phenamiphos (Ir) was not different from carbofuran (Ir) on most sampling dates. Numbers of nematodes and root-gall indices were not affected by methods of application of phenamiphos and ethoprop at most sampling dates, but when differences occurred, numbers were lower in Ro plots. The nonsignificant differences in nematode population densities, root-gall indices, and yields among interactions indicate that these parameters responded similarly to phenamiphos and ethoprop and methods of application.

Because no symptoms of phytotoxicity were observed and yields of squash and corn were greatly increased by applying nematicides through an overhead sprinkler irrigation system, the results of this study were encouraging. Many growers are using their irrigation systems to apply nitrogen fertilizers to crops. The same equipment can be used to apply nematicides. The practicality of the commercial use of nematicides applied through irrigation systems for nematode control needs further investigation. The application of nematicides through sprinkler irrigation offers several advantages: 1) more uniform application, 2) greater control of nematodes with liquid formulations, 3) reduced need for applying a nematicide before planting each crop, 4) reduced human exposure and risks, 5) reduced field traffic and soil compaction, and 6) reduced application costs. More research is needed on a number of crops, soil types, and costs to determine whether application of nematicides through the sprinkler irrigation system can be a feasible alternative to conventional methods of applying nematicides.

LITERATURE CITED

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