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Nematode Population Densities and Yield of Sweet Potato and Onion as Affected by Nematicides and Time of Application[1]

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Abstract: Nematode population densities and yield of sweet potato and onion as affected by nematicides and time of application were determined in a 3-year test. Population densities of *Meloidogyne incognita* race 1 in untreated plots of sweet potato increased each year, but *Helicotylenchus dihystera* and *Criconemella ornata* did not. Ethoprop (6.8 kg a.i./ha) incorporated broadcast in the top 15-cm soil layer each spring before planting sweet potato reduced population densities of nematodes in the soil and increased marketable yield in 1982, but not in 1983 and 1984. When DD, fenamiphos, and aldicarb were applied just before planting either sweet potato or onion, nematode population densities at harvest were lower in treated than in untreated plots. No additional benefits resulted when the nematicides were applied immediately before planting both sweet potato and onion. Correlation coefficients ($P \leq 0.05$) between yield of marketable and cracked sweet potato storage roots vs. densities of *M. incognita* juveniles in the soil at harvest among years ranged from $r = -0.33$ to $r = -0.54$ and $r = 0.31$ to $r = 0.54$ ($P \leq 0.05$), respectively. Temperatures of −6 to −8 C in December 1981 and −11 to −13 C in December 1983 killed the onion crops. Correlation coefficients for marketable yield of onion seeded in 1982 and harvested in 1983 vs. densities of *M. incognita* juveniles and *H. dihystera* in the soil at harvest were $r = -0.42$ and $r = -0.31$ ($P \leq 0.05$), respectively.

Key words: aldicarb, *Allium cepa,* chemical control, crop rotation, DD, ethoprop, fenamiphos, *Ipomoea batatas, Meloidogyne incognita,* root-knot nematode.

Sweet potato (*Ipomoea batatas* (L.) Lam.) and onion (*Allium cepa* L.) are grown in several areas of the United States as cash crops for fresh market and processing. Continuous cropping of sweet potato or onion is considered a poor management practice because of the possibility of the concomitant increase of soil-borne pests and the expected reduction in marketable yields (5,15); however, sweet potato is sometimes grown in the same field for several years without major problems.

Temperatures in the southeastern United States may allow sweet potato and onion to be grown in 1 year. Sweet potato is planted in May or June and harvested 90–100 days later, then onion is seeded in September and October and harvested in May.

Meloidogyne spp. are major nematode pests on sweet potato in the southern United States (9,12), but the effects of nematodes on onion needs further characterization (6,16). Plant-parasitic nematodes are widespread in southern Georgia and require stringent management programs including resistant cultivars, crop rotation, and nematicides for susceptible crops (14). Our objective was to determine the effect of nematicide application timing on the population densities of *Meloidogyne incognita* (Kofoid & White) Chitwood (race 1), *Helicotylenchus dihystera* (Cobb) Sher, and *Criconemella ornata* (Raski) de Grisse & Loof, and yield of sweet potato and onion.

MATERIALS AND METHODS

The experiment was initiated in October 1981 on a Tifton loamy sand (fine, loamy, siliceous, thermic Plinthic Paleudults—85% sand, 7% silt, and 8% clay, pH 6.0–6.5, < 1% organic matter [wet oxidation]). The soil was naturally infested with *M. incognita* race 1, *H. dihystera*, and *C. ornata*. The test plots were planted to several cultivars and breeding lines of sweet potato in a nursery during the summer before the study was initiated.

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Soil preparation before each crop included disk harrowing and turning 25–30 cm deep with a moldboard plow. Two adjacent beds (1.8 × 18 m) were formed for each plot using standard cultural methods for sweet potato (3) and onion (2). Nematicide treatments were 1) DD (1,3-dichloropropene, 1,2-dichloropropane) at 190 liters/ha injected into the soil 15–20 cm deep with chisels spaced 23 cm apart 2 weeks before planting and sealed with a bed shaper; 2) fenamiphos (ethyl 3-methyl-4-(methylthio) phenyl(1-methylethyl) phosphoramidate) at 6.8 kg a.i./ha applied broadcast on the soil surface and incorporated into the top 15 cm with a tractor-mounted rotary tiller; 3) aldicarb (2-methyl-2-(methylthio) propionaldehyde *O*-(methylcarbamoyl) oxime) at 6.8 kg a.i./ha applied as described for fenamiphos; 4) ethoprop (*O*-ethyl *S,S*-dipropyl phosphorodithioate) at 6.8 kg a.i./ha as described for fenamiphos; and 5) an untreated control. DD, fenamiphos, and aldicarb were applied in the fall before seeding onion or in the spring before transplanting sweet potato or both times. Ethoprop was applied only before transplanting sweet potato. Nematicide treatments were arranged in a randomized complete block design with four replications.

Onion cultivar Granex 33 was direct seeded (1.7–2.2 kg seed/ha) in twin rows 9 cm apart, with four sets of twin rows spaced 30 cm apart per bed. The seeding dates were 29 September 1981, 12 October 1982, and 20 October 1983. Temperatures of −6 to −8 C in December 1981 and −11 to −13 C in December 1983 killed the onion crops. The soil remained undisturbed until time of preparation for planting sweet potato. The onion crop from the seeding in 1982 was harvested 16–17 May 1983.

On 25 June 1982 and 16 June 1983, vine cuttings (30 cm long) of sweet potato cultivar Georgia Jet were transplanted 30 cm apart in a single row in the center of each bed. To obtain information on another cultivar of sweet potato, Georgia Jet was transplanted in one bed and Red Jewel in the other bed of each plot on 2 May 1984. Crops were irrigated as needed to maintain adequate soil moisture for plant growth and development.

Georgia Jet was harvested 89, 96, and 97 days after transplanting in 1982, 1983, and 1984, respectively, and Red Jewel was harvested 119 days after transplanting in 1984. Sweet potato roots were lifted mechanically from the soil and sorted by hand into four U.S. grades: No. 1 = roots 5–9 cm d, 8–23 cm long, well shaped and free of defects; canner = roots 2–5 cm d, 5–18 cm long; jumbos = roots exceeding the No. 1 grade in size and marketable; and cull = roots 3 cm d or more, but misshapen, cracked, or with unattractive skin and not marketable. Total weights of marketable grades were reported in marketable yield. Cull roots that were cracked but not misshapen and with attractive skin were reported as total yield of cracked storage roots. Ten storage roots, at least two from each grade, were randomly selected from each experimental plot, sliced into pieces 2 mm thick, and examined for adult female *M. incognita*. The number of females was recorded on a 1–5 scale: 1 = no infection site, 2 = 1, 3 = 2–3, 4 = 4–6, and 5 = 7 or more females in each storage root. Fibrous roots were rated for galls caused by *M. incognita* on a 1–5 scale: 1 = no galling, 2 = 1–25, 3 = 26–50, 4 = 51–75, and 5 = 76–100% of roots galled.

Mature onion bulbs were removed from the soil, graded by size (2), and weighed. Twenty bulbs with roots were removed from each plot and rated for galls as described for fibrous roots of sweet potato. Only marketable bulbs were reported in yield. All sweet potato storage roots and onion tops and bulbs were removed from the plots after each harvest.

Soil samples (20 cores, 2.1 cm d by 20 cm deep) containing both rhizosphere and nonrhizosphere soil were collected from within the rows of onion 8 February, 23 March, and 8 June 1982, and 8 February, 23 March, and 7 April 1983; and from rows of sweet potato 8 June, 23 June, 2 August, 20 September, 11 October, 11 November, and 21 December 1982; 1 June, 29 June, 28 July, and 29 August 1983; and 16 April, 30 May, 25 June, 25 July, and 30 August 1984. Soil samples were mixed thoroughly, and nematodes were extracted from a 150-cm^3 subsample using a centrifugal-flotation method (7).

Data were analyzed with least squares analysis of variance, Duncan's multiple-range test, and correlation statistical programs. Only significant ($P \leqq 0.05$) correlation coefficients and data are reported.

RESULTS

Nematode densities in untreated plots were usually greatest at harvest (Table 1) and were low on other sampling dates (data not included). Densities of *M. incognita* juveniles (J2) were lower in sweet potato plots treated with ethoprop than in control plots in 1982, but not in 1983 and 1984. Densities of *M. incognita* J2 in most plots of sweet potato treated with DD, fenamiphos, and aldicarb in the spring and spring + fall each year were lower at harvest than those in control plots. In sweet potato plots following application of nematicides in the fall before seeding onion, densities of *M. incognita* J2 were lower in plots treated with DD (1982, 1983, Georgia Jet 1984), fenamiphos (1982), and aldicarb (1982, 1983) than in untreated plots. Compared with fenamiphos and aldicarb, application of DD in the fall before seeding onion provided more residual control of *M. incognita* on Georgia Jet, but not on Red Jewel. Harvest population densities of *M. incognita* J2 increased over time on sweet potato in all plots treated with nematicides in the fall, ethoprop in the spring, and control plots.

Densities of nematodes in onion plots were less than 100/150 cm^3 soil on all sampling dates. Nematode data were collected from untreated onion plots and analyzed and compared among years. There were no differences ($P \leqq 0.5$) in nematode population densities among years. Densities of *M. incognita* J2 were lower in plots of onion treated with DD and fenamiphos in the fall and fall + spring and aldicarb in fall + spring than in control plots harvested in 1983 (Table 1). Densities of *M. incognita* J2 in plots of sweet potato or onion at harvest were not affected by time of application of DD and fenamiphos. Plots treated in the fall with aldicarb contained larger numbers of *M. incognita* J2 than those treated in spring or fall + spring in 1982 and 1984.

Densities of *H. dihystera* were lower in sweet potato plots treated with ethoprop than those in control plots in 1982, but not thereafter (Table 1). DD, fenamiphos, and aldicarb suppressed densities of *H. dihystera* to low levels in sweet potato and most plots of onion. Densities of *H. dihystera* were not affected by time of application of DD, fenamiphos, and aldicarb treatments.

Population densities of *C. ornata* declined in all plots from 1982 to 1984 (Table 1). Densities of *C. ornata* were lower in plots treated with nematicides than those in control plots in 1982, but not thereafter. Time of nematicide application did not affect densities of *C. ornata* on most sampling dates.

The number of *M. incognita* females was less than one per sweet potato storage root in 1982, and the root-gall indices in 1982 and 1983 were 1.00 for all soil chemical treatments (data not included). The numbers of *M. incognita* females in 1983 were lower in sweet potato from plots treated with DD (1.2), fenamiphos (1.1), and aldicarb (1.0) than those from untreated control (1.6), but they were not affected by time of nematicide application (data not included). The number of females in storage roots (1.9) and root-gall indices (1.18) of Red Jewel from control plots and those treated with ethoprop were greater than in storage roots (1.3) and root-gall indices (1.0) of Georgia Jet in 1984. Neither nematicides nor time of application affected the number of *M. incognita* females or root-gall indices of Georgia Jet. The application of DD (fall + spring), fenamiphos (spring), fenamiphos (fall + spring), aldicarb (spring), and aldicarb (fall + spring) reduced the number of infection sites in Red Jewel (range 1.0 to 1.2) compared with the control (1.9). The root-gall indices of Red Jewel were lower in all plots treated with

TABLE 1. Densities of nematodes† (no./150 cm³ soil) at harvest in a sweet potato (Georgia Jet, Red Jewel)–onion‡ (Granex 33) cropping system following application of nematicides, 1982–84.

Treatment	Time of application§	Georgia Jet 20 September 1982			Granex 33 1 June 1983			Georgia Jet 29 August 1983			Georgia Jet 25 July 1984			Red Jewel 30 August 1984		
		M.i.	H.d.	C.o.	M.i.	H.d.	C.o.	M.i.	H.d.	C.o.	M.i.	H.d.	C.o.	M.i.	H.d.	C.o.
Control		158 a	50 a	180 a	28 a	95 a	45 a	103 ab	30 a	20 a	253 a	34 ab	1 bc	324 a	103 a	5 b
Ethoprop	S	10 c	18 b	24 bc	20 ab	20 b	38 a	130 a	20 ab	16 a	293 a	61 a	9 a	194 a–c	138 a	6 b
DD	F	25 bc	3 c	21 bc	0 b	0 b	0 a	13 c	8 bc	3 a	3 b	0 b	0 c	158 a–c	5 b	0 b
	S	23 bc	3 c	0 c	11 ab	0 b	0 a	0 c	0 c	5 a	8 b	0 b	1 bc	90 a–c	0 b	0 b
	F + S	4 c	0 c	0 c	0 b	1 b	4 a	8 c	0 c	0 a	33 b	0 b	0 c	15 c	0 b	0 b
Fenamiphos	F	49 bc	5 bc	41 bc	0 b	3 b	23 a	51 bc	1 c	1 a	83 ab	0 b	0 c	253 a–c	0 b	0 b
	S	0 c	0 c	28 bc	15 ab	53 ab	18 a	34 c	0 c	16 a	1 b	0 b	0 c	8 c	0 b	3 b
	F + S	20 bc	0 c	13 bc	3 b	0 b	5 a	4 c	0 c	0 a	3 b	0 b	0 c	0 c	0 b	0 b
Aldicarb	F	69 b	1 c	93 b	6 ab	1 b	139 a	23 c	3 c	178 a	205 ab	0 b	8 ab	294 ab	8 b	0 b
	S	3 c	9 bc	83 b	13 ab	15 b	38 a	5 c	0 c	23 a	3 b	4 b	11 a	38 bc	10 b	21 a
	F + S	3 c	5 bc	28 bc	0 b	0 b	19 a	3 c	0 c	30 a	0 b	0 b	0 c	5 c	0 b	6 b

Means within columns followed by the same letter are not different ($P \leq 0.05$) according to Duncan's multiple-range test.
† M.i. = *Meloidogyne incognita* J2. H.d. = *Helicotylenchus dihystera*. C.o. = *Criconemella ornata*.
‡ No data available for onion in 1982 and 1984 because subfreezing temperatures destroyed the crops.
§ Spring (S) = nematicide applied before planting sweet potato. Fall (F) = nematicide applied before seeding onion. F + S = both.

TABLE 2. Marketable yields (MT/ha) of sweet potato (Georgia Jet, Red Jewel) and onion (Granex 33) after nematicide application in a sweet potato–onion cropping system.†

Treatment	Time of application‡	Georgia Jet	Granex 33	Georgia Jet		Red Jewel
		1982	1983	1983	1984	1984
Control		26.9 e	14.8 d	3.6 e	17.6 d	29.8 c
Ethoprop	S	37.4 a–d	18.4 b–d	6.7 e	24.1 cd	29.3 c
DD	F	29.0 de	26.4 ab	23.3 cd	36.8 ab	46.1 ab
	S	25.2 e	16.6 cd	32.3 bc	41.4 a	43.7 a–c
	F + S	34.5 b–e	29.7 a	34.9 bc	33.9 a–c	44.3 a–c
Fenamiphos	F	37.3 a–d	21.3 b–d	37.9 b	33.4 a–c	36.8 a–c
	S	44.3 a	16.0 d	52.2 a	43.2 a	48.4 ab
	F + S	39.2 a–c	25.5 a–c	64.2 a	43.6 a	50.0 ab
Aldicarb	F	29.1 de	22.3 a–d	10.5 de	29.3 bc	35.7 bc
	S	37.5 a–d	18.1 b–d	56.8 a	42.6 a	47.8 ab
	F + S	42.6 ab	20.1 b–d	58.1 a	44.6 a	52.2 a

Means within columns followed by the same letter are not different ($P \leq 0.05$) according to Duncan's multiple-range test.
† No data available for onion in 1982 and 1984 because freezing temperatures destroyed crops before harvest.
‡ Spring (S) = application before planting sweet potato. Fall (F) = application before planting onion. F + S = both.

nematicides (range 1.0 to 1.1), except ethoprop (1.28), than in the control (1.18). Root-gall indices on onion harvested in 1983 were lower from nematicide treated plots (1.0) than from control (1.08).

Marketable yields of sweet potato in 1982 from plots treated with ethoprop, fenamiphos, aldicarb (spring), and aldicarb (fall + spring) were greater than those from untreated control (Table 2). As densities of nematodes increased in the plots in 1983 and 1984, marketable yields of Georgia Jet were greater in all nematicide treated plots, except those treated with ethoprop and aldicarb (fall 1983), than in controls. Marketable yield of Red Jewel from plots treated with DD (fall), fenamiphos (spring), fenamiphos (fall + spring), aldicarb (spring), and aldicarb (fall + spring) was greater than yield from control plots.

Fewer cracked sweet potato storage roots occurred in plots treated with ethoprop, DD (spring), fenamiphos, aldicarb (spring), and aldicarb (fall + spring) than in control plots during 1982 (Table 3). In 1983 and 1984 fewer cracked storage roots from Georgia Jet occurred in plots treated with DD (spring), DD (fall + spring), fenamiphos, aldicarb (spring), and aldicarb (fall + spring) than in control plots. Yield of cracked storage roots from Red Jewel was lower in plots treated with DD, fenamiphos

TABLE 3. Yield (MT/ha) of cracked storage roots of sweet potato after nematicide application in a sweet potato–onion cropping system.

Treatment	Time of application†	Georgia Jet			Red Jewel
		1982	1983	1984	1984
Control		27.4 b	49.6 ab	23.5 a	11.7 a
Ethoprop	S	14.5 fg	52.8 a	18.9 ab	11.1 ab
DD	F	25.6 b–d	41.7 bc	16.7 a–c	1.9 cd
	S	34.9 a	32.7 cd	11.8 b–d	2.1 cd
	F + S	23.7 b–e	22.7 de	15.1 bc	2.7 b–d
Fenamiphos	F	19.7 d–g	28.5 d	11.3 cd	6.5 a–d
	S	13.0 g	14.3 ef	6.5 d	1.4 cd
	F + S	20.0 c–f	8.4 f	5.3 d	1.3 cd
Aldicarb	F	26.5 bc	43.3 ab	20.0 ab	9.9 a–c
	S	18.8 d–g	14.6 ef	4.8 d	3.5 a–d
	F + S	17.9 e–g	11.4 f	8.4 cd	0.9 d

Means within columns followed by the same letter are not different ($P \leq 0.05$) according to Duncan's multiple-range test.
† Spring (S) = application before planting sweet potato. Fall (F) = application before planting onion. F + S = both.

(spring), fenamiphos (fall + spring), and aldicarb (fall + spring) than yield from plants in control plots.

Correlation coefficients of yield of marketable and cracked sweet potato storage roots vs. densities of *M. incognita* J2 in the soil at harvest among years ranged from $r = -0.33$ to $r = -0.54$ and $r = 0.31$ to $r = 0.54$ ($P \leqq 0.05$), respectively. Yield of cracked storage roots was correlated ($r = 0.42$) with densities of *H. dihystera* at harvest in 1983, but not other years. Yield of marketable and cracked sweet potato storage roots was not correlated ($P \leqq 0.05$) with numbers of *C. ornata* in the soil.

Marketable yields of onion in 1983 following one crop of sweet potato were greater in plots treated with DD (fall), DD (fall + spring), and fenamiphos (fall + spring) than in untreated plots (Table 2). Other combinations of nematicide and time of application did not affect yield compared with the control. Correlation coefficients for marketable yield vs. densities of *M. incognita* J2 and *H. dihystera* in the soil at harvest were $r = -0.42$ and $r = -0.31$ ($P \leqq 0.05$), respectively.

Discussion

M. incognita causes cracking of sweet potato storage roots (11,13), and galling of fibrous roots of sweet potato (11,16) and onion (6). The effects of *H. dihystera* and *C. ornata* on sweet potato and onion are not known, but neither appeared to be a problem in these studies.

The lack of nematode control by ethoprop was consistent with earlier studies with sweet potato (9) and other crops in intensive production systems (8), although it was effective on Centennial sweet potato (10). Fall applications of DD, fenamiphos, and aldicarb also failed to provide adequate control to prevent increase of *M. incognita* J2 on sweet potato the following spring. In our study, the use of nematicides before planting prevented major damage by *M. incognita* to sweet potato storage roots.

Nematicides applied in the spring of 1982 before planting sweet potato provided sufficient control of *M. incognita* J2 for the successful production of onion, a poor host for *M. incognita* (6). The reduction in nematode populations and increase in yields were consistent with other reports for DD (4,9,10) and aldicarb (10,17) on sweet potato and aldicarb and fenamiphos (1) on potato. Our data on the relationship between numbers of *M. incognita* J2 in the soil, number of *M. incognita* females in storage roots, and reduced yield of sweet potato agree with other data, even though the numbers of *M. incognita* females in storage roots in our tests were less than those reported for the susceptible Centennial sweet potato cultivar (10).

Nonvolatile nematicides have been less effective than DD in reducing nematode populations in the soil and increasing marketable yield of sweet potato (17). In the present study aldicarb and fenamiphos consistently resulted in more marketable sweet potatoes. DD treatment was more effective in reducing nematode populations on onion.

Nematode population densities were lower in treated than in untreated plots of sweet potato and onion at harvest when nematicides were applied just before planting either crop. No additional benefits resulted when nematicides were applied immediately before planting both sweet potato and onion. This integrated crop production system can reduce the dependence on nematicides, minimize the threat of nematicides to the environment, and reduce general pollution hazards.

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