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Role of Nematodes, Nematicides, and Crop Rotation on the Productivity and Quality of Potato, Sweet Potato, Peanut, and Grain Sorghum[1]

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Abstract: The objective of this experiment was to determine the effects of fenamiphos 15G and short-cycle potato (PO)-sweet potato (SP) grown continuously and in rotation with peanut (PE)-grain sorghum (GS) on yield, crop quality, and mixed nematode population densities of *Meloidogyne arenaria, M. hapla, M. incognita,* and *Mesocriconema ornatum.* Greater root-gall indices and damage by *M. hapla* and *M. incognita* occurred on potato than other crops. Most crop yields were higher and root-gall indices lower from fenamiphos-treated plots than untreated plots. The total yield of potato in the PO-SP and PO-SP-PE-GS sequences increased from 1983 to 1985 in plots infested with *M. hapla* or *M. arenaria* and *M. incognita* in combination and decreased in 1986 to 1987 when root-knot nematode populations shifted to *M. incognita.* The total yields of sweet potato in the PO-SP-PE-GS sequence were similar in 1983 and 1985, and declined each year in the PO-SP sequence as a consequence of *M. incognita* population density increase in the soil. Yield of peanut from soil infested with *M. hapla* increased 82% in fenamiphos-treated plots compared to untreated plots. Fenamiphos treatment increased yield of grain sorghum from 5% to 45% over untreated controls. The declining yields of potato and sweet potato observed with both the PO-SP and PO-SP-PE-GS sequences indicate that these crop systems should not be used longer than 3 years in soil infested with *M. incognita, M. arenaria,* or *M. hapla.* Under these conditions, these two cropping systems promote a population shift in favor of *M. incognita,* which is more damaging to potato and sweet potato than *M. arenaria* and *M. hapla.*

Key words: Arachis hypogaea, crop rotation, fenamiphos, grain sorghum, *Ipomoea batatas, Meloidogyne arenaria, Meloidogyne hapla, Meloidogyne incognita, Mesocriconema ornatum,* nematode, peanut, potato, root-knot, root-knot nematode, *Solanum tuberosum, Sorghum vulgare,* sweet potato.

Sweet potato (*Ipomoea batatas* (L.) Lam.) and potato (*Solanum tuberosum* L.) are grown in Georgia as cash crops for fresh market and processing. Potato production has expanded gradually from traditional cool environmental conditions at higher altitudes into warmer and humid subtropical areas, where potato is grown as a short-cycle crop (90 to 100 days) (5,15). These new production areas are optimum for the development of many pests and pathogens, including root-knot nematodes. Although many species of *Meloidogyne* attack potato, only four species are considered potential pests in the southeastern United States. *Meloidogyne incognita* (Kofoid & White) Chitwood is the most widely distributed species in Georgia, followed by *M. javanica* (Treub) Chitwood, *M. arenaria* (Neal) Chitwood, and *M. hapla* Chitwood. Most infested production fields contain more than one species of *Meloidogyne* (17,19).

Continuous cropping of sweet potato or potato is considered a poor production practice because of the possibility of the increase of soilborne pests and the expected reduction in marketable yields (8, 15,35). The integration of crop rotation, resistant cultivars, nonhost crops, and nematicides is probably the most economical means of controlling nematodes on potatoes (15,35).

Potato and sweet potato are grown on the same land in one year in the southeastern United States. Potato is planted in February and harvested in April or May, and sweet potato is planted in June and harvested 90 to 140 days later. Both crops are hosts of numerous nematode species (4,15, 24), and in the southern United States *Meloidogyne incognita* is a major pest of potato and sweet potato (3,11,22).

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Peanut (*Arachis hypogaea* L.), susceptible to *M. javanica, M. hapla,* and *M. arenaria* race 1, but a nonhost of *M. incognita* (29, 36,37), has been suggested for use in rotations to reduce *M. incognita* populations (17,18). Peanut is generally planted from mid-March through mid-June and harvested in August through October. There is variability in the levels of resistance to root-knot nematodes in sorghum cultivars (2,10,21,27,38). Grain sorghum is planted in July or August and harvested from October through December. The objective of this experiment was to determine the effects of fenamiphos 15G and short-cycle potato-sweet potato grown continuously and in rotation with peanut-grain sorghum on nematode population densities, yield, and crop quality on *Meloidogyne incognita, M. arenaria,* and *M. hapla.*

Materials and Methods

Rotation experiments were established in 1983 in irrigated fields located near the Coastal Plain Experiment Station, Tifton, Georgia. One field (Site 1) was Bonifay sand (siliceous thermic, grossarenic, Plinthic Paleudult; 93% sand, 3% silt, and 4% clay; 0.5% organic matter; pH 5.8 to 6.0). The soil was planted to peanut and grain sorghum in 1982. This site was naturally infested with three species of root-knot nematodes *Meloidogyne incognita* race 1, *M. arenaria,* and *M. javanica,* and ring nematode, *Mesocriconema ornatum* (Raski) Loof & De Grisse. The second field (Site 2) was a Tifton loamy sand (fine-loamy, siliceous, thermic Plinthic Paleudults; 85% sand, 10% silt, 5% clay; 0.5% organic matter; pH 5.8 to 6.0). This site was fallowed with weeds in 1982 and also naturally infested with the same three species of root-knot nematodes and ring nematode.

The experimental design was a split-split-plot with locations as whole-plots, cropping sequences as subplots, and nematicide treatments as sub-subplots. Each experimental unit was 5.5 m wide × 12.2 m long at Site 1 and 5.5 m wide × 7.6 m long at Site 2, with treatments replicated four times. The soil was disc-harrowed, plowed 25 to 30 cm deep with a moldboard plow, and shaped into beds 10 to 15 cm high. In both sites, fenamiphos 15G was broadcast at 6.7 kg a.i./ha in a 0.76-m band and incorporated into the top 15-cm soil layer with a tractor-mounted rototiller immediately before planting potato and sweet potato in four rows 1.32 m apart per plot. Also, at both sites, fenamiphos 15G was broadcast at 6.7 kg a.i./ha over a 1.82-m-wide bed and incorporated with a tractor-mounted rototiller immediately before planting peanut and grain sorghum in six rows 0.91 m apart per plot. Untreated plots of all crops served as controls. The plot location and treatments remained the same for 5 years. Cultural and pest management activities were similar for both experimental sites. All pest management practices followed recommendations of the University of Georgia Cooperative Extension Service (6).

The cropping sequences at both locations were continuous annual double cropping of Red Lasoda (PO)-sweet potato cv. Yellow Jewel (SP) and a 2-year rotation of PO-SP alternated with peanut cv. Pronto (PE)-grain sorghum cv. NK-2244 (GS). Potato seed pieces were planted 30 cm apart in rows in February or March and harvested in May or June each year. Immediately after harvest, fibrous roots of 20 plants were rated for root galling by *Meloidogyne* spp. on a 1-to-5 scale: 1 = 0%, 2 = 1% to 25%, 3 = 26% to 50%, 4 = 51% to 75%, and 5 = 76% to 100% galling (1). At harvest, yield was recorded and roots and tubers were collected randomly from each plot for *Meloidogyne* species determination. Twenty mature *Meloidogyne* females were selected randomly, removed from roots, and identified by perineal patterns (41). Percentage of mixed species was calculated from the total number of perineal patterns examined.

Vine cuttings of sweet potato (30 cm long containing 3 to 4 nodes) were transplanted 30 cm apart in single rows in June and harvested in October each year. Sweet potato storage roots were lifted mechanically from the soil; sorted by hand into three grades: Marketable = roots 2 to 9 cm diam., 5 to 23 cm long, well-shaped, and free of defects; cull = roots 3 cm diam. or more but misshapen, or with unattractive skin and not marketable; and crack = cracked storage roots; and weighted. Six storage roots (two from each grade) were randomly selected from each plot, sliced into cross sections 2 mm thick, and examined for internal infection by *Meloidogyne* spp. The infection index, based on number of females, was recorded on a 1-to-5 scale: 1 = no females, 2 = 1, 3 = 2 to 3, 4 = 4 to 6, and 5 = 7 or more *Meloidogyne* females per storage root (11). Fibrous roots of sweet potato were rated for galls caused by *Meloidogyne* spp. as described for potato, and samples were collected from each plot for *Meloidogyne* species determination.

Peanut seeds (100 to 112 kg/ha) were planted in rows 0.91 m apart in April and harvested in August. Peanut plants were dug, inverted, and roots and pods of 10 randomly selected plants from each plot were rated for percentage galled by *Meloidogyne* spp. as described for potato. When the moisture content of the pods declined to approximately 6%, the pods were combined and weighted.

Grain sorghum was seeded at 2.31 kg/ha in rows 0.91 m apart in August and harvested in November or December. Sorghum was harvested as silage due to an early freeze in 1984 and as grain in 1986. Roots of grain sorghum were not rated for galls caused by *Meloidogyne* spp.

Twenty cores of soil, 2.5 cm diam. × 25 cm deep, were collected from the center two rows of all crops at monthly intervals from February 1983 through October 1986. Soil cores from each plot were mixed and nematodes were extracted from a 150-cm^3 subsample using a centrifugal-flotation method (16).

Data were analyzed and means separated at the $P = 0.05$ level with least squares analysis of variance (40), Waller-Duncan's k ratio *t*-test (42), and correlation statistical programs (40).

Results

Numbers of *Meloidogyne* spp. second-stage juveniles (J2) and *M. ornatum* in plots, at both sites, were greater in March, June, and October than on other sampling dates each year; therefore, only data from those months are presented. Number of root-knot nematode J2, in all plots, at Site 1 were below detection levels in March and June 1983 and increased thereafter on sweet potato and potato in both cropping systems (Table 1). A great number of those J2 were *M. incognita* since this nematode was preponderant (>80%) in potato roots in 1983, 1985, and following years. Less than 20% of the female population in the potato roots were *M. arenaria* in 1983 and 1985. This species was below detectable levels in 1986-87, whereas *M. incognita* increased at this site. In Site 2, root-knot nematode J2 were greater, in all plots, in March than June or October 1983. These were *M. hapla* J2 since only females of this species were found in potato roots in 1983. The predominance of *M. hapla* on potato in 1983 and 1985 was also confirmed by small galls with extensive lateral root formation.

Roots of sweet potato were not galled at either site (Table 2). *Meloidogyne hapla* J2 declined in all crops at Site 2 in 1984 (Table 1). At this site, however, root-knot nematode J2 peaked on potato and sweet potato in the PO-SP cropping sequence in 1985 and 1986, when only *M. incognita* females were found in the potato roots. Presumably, these root-knot nematode J2 in 1985 and 1986 were *M. incognita,* which had increased over the *M. hapla* population (Tables 1,2). Numbers of *M. hapla* and *M. incognita* J2 were usually lower in fenamiphos-treated plots than in untreated plots, but differences on most sampling dates were not significant. Densities of *M. incognita* J2 in 1986 and 1987 at both sites were larger in PO-SP than PO-SP-PE-GS cropping sequence. In the PO-SP-PE-GS cropping system, peanut and grain sorghum did not support large population densities of *M. hapla* and *M. incognita* J2

TABLE 1. Number of *Meloidogyne* spp. second-stage juveniles/150 cm^3 soil recovered from two cropping systems treated with and without a nematicide at two locations near Tifton, Georgia.

			Year														
			1983			1984			1985			1986			1987		
Location	Cropping system[a]	Nematicide[b]	Mar	June	Oct	Mar	June	Oct	Mar	June	Oct	Mar	June	Oct	Mar	June	Oct
Site 1	PO-SP-PE-GS	+	0 b	0 b	1 b	5 c	0 b	0 b	203 ab	0 c	268 b	45 b	0 b	0 b	0 c	5 b	58 a
		−	0 b	0 b	160 a	48 bc	0 b	3 b	246 a	34 bc	775 b	76 ab	8 b	28 b	5 c	160 a	163 a
	PO-SP	+	0 b	0 b	9 b	10 c	18 ab	179 ab	86 bc	90 ab	695 b	3 b	133 b	580 b	10 c	3 b	53 a
		−	0 b	0 b	240 a	30 bc	6 ab	290 a	138 abc	161 a	483 b	11 b	215 b	548 b	14 c	42 b	85 a
Site 2	PO-SP-PE-GS	+	363 a	0 b	5 b	145 a	3 b	6 b	145 abc	0 c	20 b	55 b	0 b	50 b	30 c	0 b	3 a
		−	393 a	59 a	70 b	118 ab	25 a	29 b	100 abc	0 c	366 b	285 ab	5 b	10 b	93 bc	1 b	53 a
	PO-SP	+	150 ab	0 b	0 b	15 c	8 ab	0 b	43 c	0 c	550 b	245 ab	73 b	2,038 ab	220 ab	0 b	34 a
		−	270 ab	3 b	10 b	45 bc	15 ab	323 a	50 c	38 bc	1,923 a	580 a	1,270 a	4,995 a	265 a	0 b	10 a
			Means across sites, cropping systems, or nematicide treatments														
Site 1			0 b	0 a	100 a	23 b	6 a	118 a	168 a	71 a	555 a	34 b	89 b	289 b	7 b	53 a	90 a
Site 2			294 a	16 a	21 b	81 a	13 a	90 a	85 b	9 b	715 a	332 a	448 a	2,354 a	152 a	0 a	25 a
	PO-SP-PE-GS		189 a	15 a	59 a	79 a	7 a	10 b	174 a	9 b	357 b	115 a	3 b	22 b	32 b	42 a	69 a
	PO-SP		105 a	1 a	65 a	25 b	12 a	198 a	79 b	72 a	913 a	7 b	423 a	2,040 a	127 a	11 a	46 a
		+	128 a	0 a	4 b	44 a	7 a	46 b	119 a	23 a	383 b	27 b	52 b	667 b	65 a	2 a	37 a
		−	166 a	16 a	120 a	60 a	12 a	161 a	134 a	58 a	887 a	96 a	375 a	1,395 a	94 a	51 a	78 a

Data are means of four replications. Means in columns followed by the same letter are not different ($P = 0.05$) according to Waller-Duncan's k ratio t-test. Means in the lower portion of the table are composites of 16 replications and should be compared between sites, cropping systems, and nematicide treatments.

[a] PO = Potato cv. Red Lasoda, SP = sweet potato cv. Yellow Jewel, PE = peanut cv. Pronto, and GS = grain sorghum cv. NK-2244.

[b] + = Fenamiphos 15G applied at 6.7 kg a.i./ha and incorporated into the top 15-cm soil layer with a tractor-mounted rototiller immediately before planting each crop and − = untreated.

TABLE 2. Root-gall indices[a] of crops in two cropping systems treated with and without a nematicide at two locations near Tifton, Georgia.

Location	Cropping system[b]	Nematicide[c]	Year 1983 PO	1983 SP	1984 PO	1984 SP	1984 PE	1984 GS	1985 PO	1985 SP	1986 PO	1986 SP	1986 PE	1986 GS	1987 PO	1987 SP
Site 1	PO-SP-PE-GS	+	1.00 c	1.00 a			1.00 a	–[d]	1.20 b	1.00 c			1.00 a	–	1.35 cd	1.18 a
		–	1.28 c	1.00 a			1.00 a	–	1.28 b	1.20 a			1.00 a	–	1.85 bcd	1.05 a
	PO-SP	+	1.00 c	1.00 a	1.33 c	1.00 a			1.68 b	1.00 c	1.73 b	1.00 a			1.05 b	1.00 a
		–	1.63 bc	1.00 a	4.65 a	1.00 a			3.58 a	1.10 b	2.80 a	1.00 a			2.50 b	1.00 a
Site 2	PO-SP-PE-GS	+	1.05 c	1.00 a			2.43 b	–	1.23 b	1.00 c			1.00 a	–	1.18 cd	
		–	3.28 a	1.00 a			3.30 a	–	1.55 b	1.00 c			1.00 a	–	1.65 cd	
	PO-SP	+	1.00 c	1.00 a	1.00 c	1.00 a			1.10 b	1.00 c	1.45 b	1.00 a			1.93 bc	
		–	2.53 ab	1.00 a	2.10 b	1.00 a			1.65 b	1.00 c	3.38 a	1.00 a			4.00 a	
Means across sites, cropping systems, or nematicide treatments																
Site 1			1.23 b	1.00 a	2.99 a	1.00 a	1.00 b	–	1.94 a	1.08 a	2.27 a	1.00 a	1.00 a	–	1.69 b	1.06
Site 2			1.97 a	1.00 a	1.55 b	1.00 a	2.87 a	–	1.38 b	1.00 a	2.42 a	1.00 a	1.00 a	–	2.19 a	—
	PO-SP-PE-GS		1.85 a	1.00 a			1.93	–	1.05 a	1.05 a			1.00	–	1.51 b	1.12 a
	PO-SP		1.75 a	1.00 a	2.27	1.00		–	2.00 a	1.03 a	2.34	1.00			2.37 a	1.00 a
		+	1.01 b	1.00 a	1.17 b	1.00 a	1.72 b	–	1.30 b	1.00 a	1.59 b	1.00 a	1.00 a	–	1.38 b	1.09 a
		–	2.59 a	1.00 a	3.38 a	1.00 a	2.15 a	–	2.02 a	1.08 a	3.09 a	1.00 a	1.00 a	–	2.50 a	1.00 a

Data are means of four replications. Means in columns followed by the same letter are not different ($P = 0.05$) according to Waller-Duncan's k ratio t-test. Means in the lower portion of the table are composites of 16 replications and should be compared between sites, cropping systems, and nematicide treatments.

[a] Percentage root galling, indexed on a 1-to-5 scale as follows: 1 = no galls, 2 = 1% to 25%, 3 = 26% to 50%, 4 = 51% to 75%, and 5 = 76% to 100%.

[b] PO = Potato cv. Red Lasoda, SP = sweet potato cv. Yellow Jewel, PE = peanut cv. Pronto, and GS = grain sorghum cv. NK-2244.

[c] + = Fenamiphos 15G was broadcast at 6.7 kg a.i./ha and incorporated into the top 15-cm soil layer with a tractor-mounted rototiller immediately before planting each crop and – = untreated.

[d] Data were not recorded.

(range 0 to 50 J2/150 cm^3 soil) at either site (Table 1).

Greater root-gall indices by *M. hapla* and *M. incognita* occurred on potato roots than other crops (Table 2). At Site 2, root-gall indices by *M. hapla* in 1983 and *M. incognita* in 1986 and 1987 on potato roots were greater than those by *M. incognita* at Site 1. No galls by *M. hapla* or *M. incognita* were observed on sweet potato roots at either site on most sampling dates. Traces of *M. incognita* root galls were observed on this crop at Site 1 in 1985 and 1987. No *M. incognita* and *M. arenaria* root galls were observed on peanut at either site. Galls by *M. hapla* were detected on peanut in 1984 at Site 2 and were less severe in fenamiphos-treated plots than in the untreated plots.

Numbers of *M. ornatum* increased on peanut and declined over time in the PO-SP sequence at both sites (Table 3). Population densities of *M. ornatum* were not affected by fenamiphos on most sampling dates.

In 1983, the yield of marketable potato was lower at Site 2, infested by *M. hapla,* than at Site 1, slightly infested by *M. arenaria* and *M. incognita* (Table 4). In both sites and under both PO-SP and PO-SP-PE-GS cropping systems, the yield of marketable potato was not severely affected by *M. arenaria* and *M. incognita* in combination at Site 1 and *M. hapla* alone at Site 2 in 1984 and 1985. Marketable yield of potato decreased drastically in 1986 and 1987 at both sites, when *M. incognita* replaced *M. arenaria* at Site 1 and appeared to replace *M. hapla* at Site 2.

Sweet potato marketable yield also was affected more severely by *M. incognita,* when this nematode became the dominant species at both sites, than by *M. hapla* or by the mixed populations of *M. incognita* and *M. arenaria* under both cropping systems (Table 5). Marketable yield of potato and sweet potato increased in the plots treated with fenamiphos compared to the untreated plots. However, the effect of this nematicide varied with the site and the year.

In 1984, yields of peanut from Site 1 infested by *M. incognita* and *M. arenaria* in combination were three times higher than those from Site 2 infested by *M. hapla* (Table 6). The effect of fenamiphos on peanut and grain sorghum yield varied with site and year.

Discussion

Considerable variation in *Meloidogyne* spp. composition, nematode population densities, and host plant response occurred among years and between sites. Similar trends in plant response and nematode populations due to nematicide application were evident during most years.

This study confirms previous reports that fenamiphos reduces nematode damage and increases yield of potato (7), sweet potato (11,22), peanut (32,38), and grain sorghum (20). This nematicide is usually equal or superior to other nonfumigants for nematode control on these and other crops (28). Our data support other reports that population densities vary with nematode species and crops within a sequence (17–19,23,33,34). The root-knot nematode population densities generally peaked near harvest for each crop and then declined. The decline, which was most prominent where nematode population densities were highest, may have been due to a decline in food supply and soil preparation for the subsequent crop.

Meloidogyne incognita and *M. arenaria* population densities at Site 1 increased in both cropping sequences, peaked during the third year, and generally declined thereafter. The percentage ratio of *M. incognita* and *M. arenaria* populations on potato in the PO-SP-PE-GS sequence remained constant for two cropping cycles and then shifted to *M. incognita.* The population shift indicates changes in aggressiveness or parasitic adaptation of *M. incognita* on potato, as observed for other nematode-crop relationships in crop rotations (33). *Meloidogyne incognita* J2 developed into reproductive females more efficiently

TABLE 3. Number of *Mesocriconema ornatum* per 150 cm^3 soil recovered from two cropping systems treated with and without a nematicide at two locations near Tifton, Georgia.

			Year														
			1983			1984			1985			1986			1987		
Location	Cropping system[a]	Nematicide[b]	Mar	June	Oct	Mar	June	Oct	Mar	June	Oct	Mar	June	Oct	Mar	June	Oct
Site 1	PO-SP-PE-GS	+	363 a	41 a	10 abc	38 b	30 ab	485 b	3 b	50 b	35 a	15 a	43 a	718 b	153 b	34 ab	18 ab
		−	344 a	33 a	19 abc	23 b	21 ab	911 a	3 b	84 a	28 a	41 a	43 a	573 b	140 b	56 a	123 a
	PO-SP	+	204 b	34 a	29 ab	60 b	41 a	15 c	23 b	30 bcd	25 a	1 a	8 a	33 c	13 b	13 ab	83 ab
		−	291 ab	35 a	31 a	178 a	21 ab	19 c	15 b	43 bc	25 a	48 a	15 a	55 c	21 b	8 ab	58 ab
Site 2	PO-SP-PE-GS	+	23 c	6 b	3 c	0 b	0 b	61 c	140 b	13 cd	4 a	30 a	50 a	815 b	783 a	28 ab	45 ab
		−	3 c	0 b	5 abc	0 b	0 b	169 c	285 a	9 cd	36 a	15 a	15 a	1,490 a	1,220 a	9 ab	10 b
	PO-SP	+	8 c	8 b	10 abc	0 b	0 b	1 c	0 b	0 d	0 a	0 a	0 a	0 c	5 b	0 b	0 b
		−	10 c	6 b	6 abc	0 b	0 b	1 c	3 b	0 d	0 a	0 a	0 a	0 c	3 b	0 b	0 b
Means across sites, cropping systems, or nematicide treatments																	
Site 1			301 a	36 a	22 a	75 a	28 a	358 a	11 b	52 a	28 a	26 a	27 a	345 a	82 b	28 a	71 a
Site 2			11 b	5 b	6 b	0 b	0 b	58 b	107 a	6 b	10 b	11 a	16 b	576 a	503 a	9 a	14 b
	PO-SP-PE-GS		183 a	20 a	9 a	15 b	13 a	407 a	108 a	39 a	26 a	25 a	38 a	899 a	574 a	32 a	49 a
	PO-SP		128 b	5 a	19 a	60 a	16 a	9 b	10 b	18 b	13 a	12 a	6 b	22 b	11 b	5 b	35 a
		+	150 a	22 a	13 a	25 a	18 a	141 b	42 a	23 a	16 a	12 a	25 a	392 a	239 a	19 a	37 a
		−	162 a	19 a	15 a	50 a	11 a	275 a	77 a	34 a	22 a	26 a	18 a	530 a	346 a	18 a	48 a

Data are means of four replications. Means in columns followed by the same letter are not different ($P = 0.05$) according to Waller-Duncan's k ratio *t*-test.
Means in the lower portion of the table are composites of 16 replications and should be compared between sites, cropping systems, and nematicide treatments.
[a] PO = Potato cv. Red Lasoda, SP = sweet potato cv. Yellow Jewel, PE = peanut cv. Pronto, and GS = grain sorghum cv. NK-2244.
[b] + = Fenamiphos 15G was broadcast at 6.7 kg a.i./ha and incorporated into the top 15-cm soil layer with a tractor-mounted rototiller immediately before planting each crop and − = untreated.

TABLE 4. Marketable potato yields (kg/ha × 1.000) associated with two sites, two crop rotation systems, and nematicides.

Site/rotation[a]/nematicide[b]			Year 1983	1984	1985	1986	1987
1	PO-SP-PE-GS	+	24.8 a		25.8 a		9.3 a–c
		−	20.6 a		24.0 a		3.4 b–d
	PO-SP	+	20.6 a	15.6 a	24.2 a	9.0 a	5.9 a–d
		−	21.7 a	3.9 b	23.4 ab	5.4 a	1.1 d
2	PO-SP-PE-GS	+	10.9 b		20.5 bc		11.7 a
		−	5.4 c		18.2 c		10.8 ab
	PO-SP	+	6.4 bc	19.4 a	23.5 ab	14.5 a	9.4 a–c
		−	2.5 c	15.6 a	23.1 ab	11.5 a	1.9 cd

Data are means of four replications. Means in columns followed by the same letter are not different ($P = 0.05$) according to Waller-Duncan's k ratio *t*-test.

[a] PO = Potato cv. Red Lasoda, SP = sweet potato cv. Yellow Jewel, PE = peanut cv. Pronto, and GS = grain sorghum cv. NK-2244.

[b] + = Fenamiphos 15G was broadcast at 6.7 kg a.i./ha and incorporated into the top 15-cm soil layer with a tractor-mounted rototiller immediately before planting each crop and − = untreated.

than *M. arenaria* in the mixed populations so that *M. incognita* became the dominant species. When this shift to *M. incognita* occurred, severe damage to potato resulted. Potatoes planted when temperatures are conductive to *M. incognita* activity suffer severe damage (3).

Numbers of *M. incognita, M. arenaria,* and *M. hapla* J2 increased in plots, produced severely galled roots and tubers, and lowered the quality of potato but did not cause galls on sweet potato roots or internal damage to storage roots. The infection incidence of sweet potato storage roots was related to root-gall indices and not to numbers of *Meloidogyne* J2 in the soil at harvest. These data confirm previous reports that cultivar Yellow Jewel has low internal infection of the storage roots by root-knot nematodes and is resistant to *M. incognita* (26). Since little or no galling occurred on roots and only a few female infection sites were observed in storage roots in the presence of large numbers of J2 in the soil, the results indicate that cultivar Yellow Jewel is also highly resistant to *M. arenaria* and *M. hapla.* The extent of damage to sweet potato yields was more severe than indicated by the root-gall indices and number of infection sites in storage roots.

TABLE 5. Marketable sweet potato yields (kg/ha × 1.000) associated with two sites, two crop rotation systems, and nematicides.

Site/rotation[a]/nematicide[b]			Year 1983	1984	1985	1986
1	PO-SP-PE-GS	+	27.5 a		18.7 bc	
		−	20.7 bc		12.6 c	
	PO-SP	+	24.8 ab	14.1 b	18.7 bc	15.1 a
		−	16.9 c	5.2 c	15.5 c	14.0 a
2	PO-SP-PE-GS	+	25.9 ab		33.1 a	
		−	23.9 ab		29.5 a	
	PO-SP	+	24.3 ab	33.3 a	22.6 b	18.7 a
		−	21.8 a–c	34.0 a	17.7 bc	14.1 a

Data are means of four replications. Means in columns followed by the same letter are not different ($P = 0.05$) according to Waller-Duncan's k ratio *t*-test.

[a] PO = Potato cv. Red Lasoda, SP = sweet potato cv. Yellow Jewel, PE = peanut cv. Pronto, and GS = grain sorghum cv. NK-2244.

[b] + = Fenamiphos 15G was broadcast at 6.7 kg a.i./ha and incorporated into the top 15-cm soil layer with a tractor-mounted rototiller immediately before planting each crop and − = untreated.

TABLE 6. Peanut and grain sorghum yields (kg/ha × 1.000) associated with two sites, one crop rotation, and nematicides.

Site/rotation[a]/nematicide[b]			1984 Peanut	1984 Sorghum (silage)	1986 Peanut	1986 Sorghum (grain)
1	PO-SP-PE-GS	+	4.4 a	10.6 b	1.4 a	2.0 a
		−	3.2 b	8.3 c	1.4 a	1.4 b
2	PO-SP-PE-GS	+	1.6 c	14.2 a	1.2 a	2.4 a
		−	0.9 d	12.1 b	1.1 a	2.3 a

Data are means of four replications. Means in columns followed by the same letter are not different ($P = 0.05$) according to Waller-Duncan's k ratio *t*-test.

[a] PO = Potato cv. Red Lasoda, SP = sweet potato cv. Yellow Jewel, PE = peanut cv. Pronto, and GS = grain sorghum cv. NK-2244.

[b] + = Fenamiphos 15G was broadcast at 6.7 kg a.i./ha and incorporated into the top 15-cm soil layer with a tractor-mounted rototiller immediately before planting each crop and − = untreated.

Some of the yield differences between fenamiphos-treated and untreated plots may be due to controlling common soil insects such as the sweet potato flea beetle, *Chactocnema confinis* Crotch, and the southern potato wireworm *Conoderus folli* Lane. Fenamiphos is a nematicide-insecticide that controls nematodes and soil insects that attack sweet potato (25).

Roots and pods of peanut were not galled at either site following potato infected with a mixture of *M. incognita* and *M. arenaria,* but were galled severely following potato infected with *M. hapla* at Site 2. For peanut, *M. arenaria* race 1 and *M. hapla* are the major nematode pathogens (12–14,30). In our study, the race of *M. arenaria* was not determined, but since no galling occurred on peanut at Site 1 in 1984 and 1986, the population was probably race 2. Infection, reproduction, and root damage by *M. arenaria* race 2 on peanut is usually limited (12,13). The large population densities of *M. hapla* on potato at Site 2 in 1983 and large root-gall indices on the following crop of peanut in 1984 accounted for the low yield of peanut, especially in untreated plots where *M. hapla* was not controlled. Population densities of *M. hapla* increased on peanut in a turnip-peanut-cucumber-turnip-cucumber-soybean cropping sequence, and yield of peanut was low when the nematode was not controlled (19).

Population densities of *M. hapla* at Site 2 were high initially, and this nematode was the sole species identified from roots and tubers of potato in both cropping sequences until a mixed population of *M. incognita* and *M. arenaria* was identified in 1986 and only *M. incognita* in 1987. Several factors, including temperature, density-dependence, fecundity, and time-dependency, have been demonstrated to affect the interaction of concomitant nematode species, resulting in greater community prominence for favored species (9,39). The high *M. hapla* population densities caused severe yield reductions in potato initially at Site 2 compared to yield at Site 1 where *Meloidogyne* spp. J2 were below detection levels and root-gall indices were low. Yield and quality of potato were reduced by high population densities of *M incognita* and *M. hapla* alone or by mixtures of *M. incognita* and *M. arenaria. Meloidogyne arenaria* has been reported from potato but damage is usually slight (43). Infected roots and tubers of potato had galls of various sizes and shapes. Galling incidence and size is dependent upon nematode population density and nematode species (15).

The increase of *M. ornatum* on peanut in the PO-SP-PE-GS cropping system agrees with results reported by Minton and Bell (31), who found that large numbers of *M. ornatum* may be found around peanut pods and roots with little loss in yield or quality. Under certain conditions, *M. ornatum* causes discoloration of peanut pods (31).

Sorghum was beneficial in management

of cyst (*Heterodera glycines*, race 4) and *M. arenaria* in a sorghum-soybean rotation (38). Our results show that sorghum had no influence on total tuber weights of a subsequent potato crop even though root-gall indices on potato were lower following sorghum than sweet potato. These results support those reported by McSorley, et al. (27).

The declining yields of potato and sweet potato indicate that the PO-SP sequence should not be used longer than 3 years in soil infested with *M. incognita, M. arenaria,* or *M. hapla.* In soil heavily infested with *M. hapla,* a rotation including potato or peanut should be avoided when these crops follow susceptible crops. Additional work is needed to find useful crops and rotation crops that will suppress population densities of polyspecific *Meloidogyne* populations.

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