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Population Dynamics of *Meloidogyne incognita, M. arenaria,* and Other Nematodes and Crop Yields in Rotations of Cotton, Peanut, and Wheat Under Minimum Tillage[1]

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Abstract: Wheat, cotton, and peanut were arranged in three cropping sequences to determine the effects of fenamiphos (6.7 kg a.i./ha) and cropping sequence on nematode population densities and crop yields under conservation tillage and irrigation for 6 years. The cropping sequences included a wheat winter cover crop each year and summer crops of cotton every year, peanut every year, or cotton rotated every other year with peanut. The population densities of *Meloidogyne* spp. and *Helicotylenchus dihystera* were determined monthly during the experiment. Numbers of *M. incognita* increased on cotton and decreased on peanut, whereas *M. arenaria* increased on peanut, and decreased on cotton; both nematode species remained in moderate to high numbers in plots of wheat. Root damage was more severe on cotton than peanut and was not affected by fenamiphos treatment. The *H. dihystera* population densities were highest in plots with cotton every summer, intermediate in the cotton-peanut rotation, and lowest in plots with peanut every summer. Over all years and cropping sequences, yield increases in fenamiphos treatment over untreated control were 9% for wheat, 8% for cotton, and 0% for peanut. Peanut yields following cotton were generally higher than yields following peanut. These results show that nematode problems may be manageable in cotton and peanut production under conservation tillage and irrigation in the southeastern United States.
Key words: Arachis hypogaea, cotton, crop rotation, *Gossypium hirsutum, Helicotylenchus dihystera,* management, *Meloidogyne arenaria, M. incognita,* nematicide, nematode, peanut, root-knot nematode, spiral nematode, *Triticum aestivum,* wheat.

In the southeastern United States, peanut (*Arachis hypogaea* L.) and cotton (*Gossypium hirsutum* L.) have been widely grown for many decades as full-season summer annual crops, usually with winter cover crops or fallow. Since the 1950s, farmers have prepared land for planting with what is locally referred to as conventional tillage. This production method begins with turning the soil 25 to 30 cm deep with a moldboard plow followed by disking to 15 cm to provide a friable seedbed that is relatively smooth, flat or slightly raised, and with little crop residue and few weeds. Compared to the less intensive tillage systems used previously, the conventional tillage system resulted in improved peanut pod yields (Garren and Duke, 1958) and less loss to southern blight (*Sclerotium rolfsii* Sacc.) and limb rot (*Rhizoctonia solani* Kühn) (Boyle, 1956; Mixon, 1963). Because peanut has been a major cash crop for Georgia and farmers have large investments in tractors and conventional tillage implements, tillage for most crops tended to be by the conventional method (Samples, 1987). Today, farmers are returning to less rigorous tillage operations, referred to as conservation tillage, to save time, labor, fuel, and equipment expenses. By definition, conservation tillage involves leaving at least 30% of the residue of each crop on the soil surface. In cotton, subsoiling to 36 cm deep under the row at planting is a standard operation. Farmer experience in the short term has been generally good. However, there remains concern that the long-term practice of conservation tillage may exacerbate problems with perennial weeds, nematodes, and soil fertility. Nematicides and plant nutrients must be applied to the soil surface and may be difficult to incorporate. However, fluid fertilizer formulations and emulsified pesticide application via irrigation water

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(chemigation) provide alternatives for applying fertilizer and managing nematodes and insects (Johnson et al., 1986a). Research on conservation tillage under sprinkler irrigation in the southeastern United States has been very limited (Dowler et al., 1999). Recently, tillage experiments have shown that peanut yields can be reduced 20% to 25% with no tillage when compared with conventional tillage, if appropriate modifications in agrochemical application technology are not made (Hook et al., 1998).

Cotton hectarage has expanded rapidly in the Coastal Plain region because of the increase in demand for cotton, the eradication of the boll weevil (*Anthonomus grandis* Boheman), and the widespread use of insect-resistant transgenic cotton cultivars. Cotton hectarage in Georgia has more than quadrupled in the past 4 years and, at 586,807 hectares in 1999, surpassed the hectarage and value of peanut, which has been the crop with greatest value for many years.

Wheat (*Triticum aestivum* L.) is the most valuable winter grain crop in Georgia and is easily double-cropped with cotton or peanut (Morey et al., 1983). Wheat can be grazed by livestock, collected as green chopped material for immediate feeding or silage, or harvested for grain. Double-cropping with winter wheat increases income while providing winter cover, soil surface residue, and nutrient retention (Hook et al., 1998).

Many nematode species damage peanut (Dickson, 1998; Minton, 1984; Minton and Baujard, 1990), cotton (Heald and Orr, 1984; Starr, 1998; Starr and Page, 1990), and wheat (Birchfield, 1983; Roberts et al., 1981). In the southeastern United States, the most damaging to peanut is *Meloidogyne arenaria* (Neal) Chitwood race 1 (Rodríguez-Kábana et al., 1987, 1994) and the most damaging to cotton is *M. incognita* (Kofoid & White) Chitwood race 3 (Johnson et al., 1974, 1975, 1998b, 1999; Starr, 1998). Some cultivars of wheat are susceptible to *M. incognita* (Birchfield, 1983; Roberts et al., 1981) and other *Meloidogyne* species (Johnson and Motsinger, 1989). *Meloidogyne* spp. may not be economically damaging to a winter wheat crop (Johnson and Motsinger, 1989), but the combination of a mild winter season and a susceptible cultivar could greatly affect the number of *Meloidogyne* spp. second-stage juveniles (J2) to which the subsequent crop may be exposed (Johnson and Motsinger, 1990).

From the standpoint of nematode management, cotton fits well in rotation with peanut in fields infested with *M. arenaria* race 1, *M. incognita* race 3, or both since peanut is a nonhost of *M. incognita* and cotton is a nonhost of *M. arenaria* (Johnson et al., 1998b, 1999; Rodríguez-Kábana et al., 1994). The impact of wheat rotations on nematode management is uncertain.

The objective of this study was to examine the long-term effects of a cotton-peanut rotation and the nematicide fenamiphos on crop yields and population densities of *M. arenaria, M. incognita,* and *H. dihystera* when utilizing sprinkler-irrigation agrichemical application technology, conservation tillage, and a winter wheat cover crop.

Materials and Methods

Field plots were established under sprinkler irrigation in December 1991 and maintained through November 1997 on a Tifton loamy sand (fine-loamy, siliceous, thermic Plinthic Kandiudults; 85% sand, 10% silt, 5% clay; 0.5% organic matter; pH 5.8 to 6.3). The plots were naturally infested with *M. incognita* race 3, *M. arenaria* race 1, *Helicotylenchus dihystera* (Cobb) Sher, *Pratylenchus brachyurus* (Godfrey) Filipjev & Schuurmans Stekhoven, *Mesocriconema ornata* de Grisse and Loof, and *Paratrichodorus minor* (Colbran) Siddiqi.

The experiment was a split-plot with cropping sequences (whole-plots) in strips replicated twice, and nematicide treatments (subplots) with three 1.8-m-wide × 7.7-m-long beds replicated six times. Whole plots were separated on each side by alleys 3.7 m wide. The cropping sequences were cotton every year, peanut every year, and peanut rotated with cotton annually. Wheat cv. Andy was seeded in all plots at 95 kg/ha in

December 1991–1994, and cv. Morey was seeded in all plots at 101 kg/ha in December 1995 and 1996 in rows 15 cm apart into the preceding crop residue with a grain drill with no tillage. Nematicide treatments were fenamiphos and no fenamiphos. Fenamiphos, formulated as Nemacur 3 SC (Bayer, Kansas City, MO), was applied broadcast at 6.7 kg a.i./ha in 31 k1/ha irrigation water via sprinkler irrigation over half of each whole plot for nematode control immediately after planting each crop, as described by Johnson et al. (1981, 1986b). The remaining half of each whole plot was left untreated.

A nonselective foliar-applied herbicide (either paraquat at 0.08 kg a.i./ha plus bentazon at 0.56 kg a.i./ha, or glyphosate at 1.12 kg a.i./ha) was applied to all plots 3 to 7 days before planting wheat, cotton, or peanut to control existing weeds. After wheat was harvested, plots were subsoiled 36 cm deep with a row-till conservation tillage-planter equipped with fluted colters and a smoothing device mounted behind the subsoiler shank to refirm the soil (Dowler et al., 1999). Fifty percent or more of the wheat stubble remained undisturbed on the soil surface.

Peanut seeds (112 kg/ha) of cvs. Agra Tech 127 (1992–1993) and Andru 93 (1994–1997) and cotton seeds (9.5 kg/ha) of cvs. Georgia King (1992–1994) and SureGrow 404 (1995–1997) were planted in rows 91 cm apart following the colters in late May or June, and harvested during October and November, respectively. Cultivars chosen were early maturing types recommended by the University of Georgia Extension Service.

In cotton, fluometuron (1.66 kg a.i./ha) and pendimethalin (0.92 kg a.i./ha) were applied through irrigation water (38 kl/ha) for preemergence weed control. Paraquat (0.55 kg a.i./ha) was applied via a boom sprayer immediately after planting for postemergence weed control in cotton. No insecticides were applied to cotton.

For peanut, pendimethalin (1.12 kg a.i./ha) was applied through the irrigation water (38 kl/ha) and paraquat (0.55 kg a.i./ha) was applied 1 day after planting with a tractor-mounted boom sprayer for preemergence weed control. Paraquat (0.08 kg a.i./ha) and the sodium salt of bentazon (0.56 kg a.i./ha) were applied via a boom sprayer about 21 days after planting peanut for postemergence weed control. Chlorothalonil was applied at 1.26 kg a.i./ha for leaf spot control on ca. 10-day intervals from 1 month after planting until 1 month before harvest. The first four applications of chlorothalonil were applied via a boom sprayer and the remaining applications via irrigation in 124 to 196 kl water/ha.

Supplemental irrigation was applied when rainfall was insufficient to enhance seedling emergence or plant growth. All crops were irrigated at least once. Liquid formulations of fertilizer (10% nitrate nitrogen + 34% phosphorus, a 32% solution of NH_4NO_3-urea, and 60% KCl) were applied broadcast through the irrigation system in multiple applications after each crop was planted based on soil test recommendations (Plank, 1989). The total kilograms per hectare applied to each crop each year were: 112 to 134 nitrogen (N), 0 to 38 phosphorus (P), and 75 to 90 potassium (K) for wheat; 67 to 90 N, 0 to 57 P, and 112 to 140 K for cotton; and 0 to 13 N, 0 to 45 P, and 0 to 40 K for peanut. In addition, peanut received 0.56 kg/ha boron in 1992 and 1996.

Ten soil cores (2.5-cm-diam. × 15-cm-deep) for nematode assay were collected from crop rows in all plots at monthly intervals. Soil samples from each plot were mixed thoroughly, and a 150-cm^3 subsample was processed by a centrifugal flotation method (Jenkins, 1964).

Wheat was harvested with a combine when grain moisture was ca. 14% in May or June each year. The crop residue was spread over the plots during harvest.

Cotton was harvested with a mechanical picker and weighed. Yield is reported as kilograms lint per hectare. After harvest, 10 randomly selected plants were dug from each plot and rated for root galling by *M. incognita* 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% of roots galled (Barker et al., 1986). Twenty female nematode specimens from galled roots were examined for species identification. The remaining stalks were lifted from the soil with a mechanical puller and chopped with a flail mower.

Peanut plants were dug, based on an optimum maturity index (Williams and Drexler, 1981), and inverted. Roots and pods of 10 randomly selected plants from each plot were examined and rated immediately after digging for percentage galled by *M. arenaria* and species identification as described for cotton. When the moisture content declined to ca. 14%, the pods were harvested with a combine, dried to ca. 8% moisture, and weighed.

The data were subjected to ANOVA and means separation (P = 0.05) with the SAS General Linear Models procedure (SAS Institute, Cary, NC). Nematode data were transformed with log (x + 1) before statistical analysis with ANOVA and presented as raw data. Only significant (P = 0.05) differences are discussed, unless stated otherwise.

Results and Discussion

Only *M. incognita* was identified from galled roots of cotton, and only *M. arenaria* was identified from peanut roots. Numbers of *M. incognita* and *M. arenaria* J2 were generally low in the cotton-wheat and peanut-wheat treatments at cotton or peanut planting and increased by harvest (Figs. 1,2). In the peanut-cotton rotation, population densities of *M. incognita* J2 were higher on cotton than were *M. arenaria* J2 on peanut. Numbers of J2 in the soil were not measurably affected by fenamiphos treatment (Fig. 3). Numbers of J2 remained moderate to high from wheat planting in December until wheat harvest in May. It is not known whether the J2 in soil during the wheat crop were carryover from cotton and peanut or progeny of females on wheat. In previous research in a nearby field at the Coastal Plain Experiment Station, several cultivars of wheat supported reproduction by *M. incognita* and *M. arenaria* (Johnson and Motsinger, 1989). The researchers suggested that reproduction of root-knot nematodes might be avoided or reduced by delaying planting of cereal crops until soil temperatures declined below the root-knot nematode penetration threshold (18 °C) (Roberts et al., 1981), but that no long-term benefits could be expected. The wheat cultivars in our study were planted 1 to 9 December,

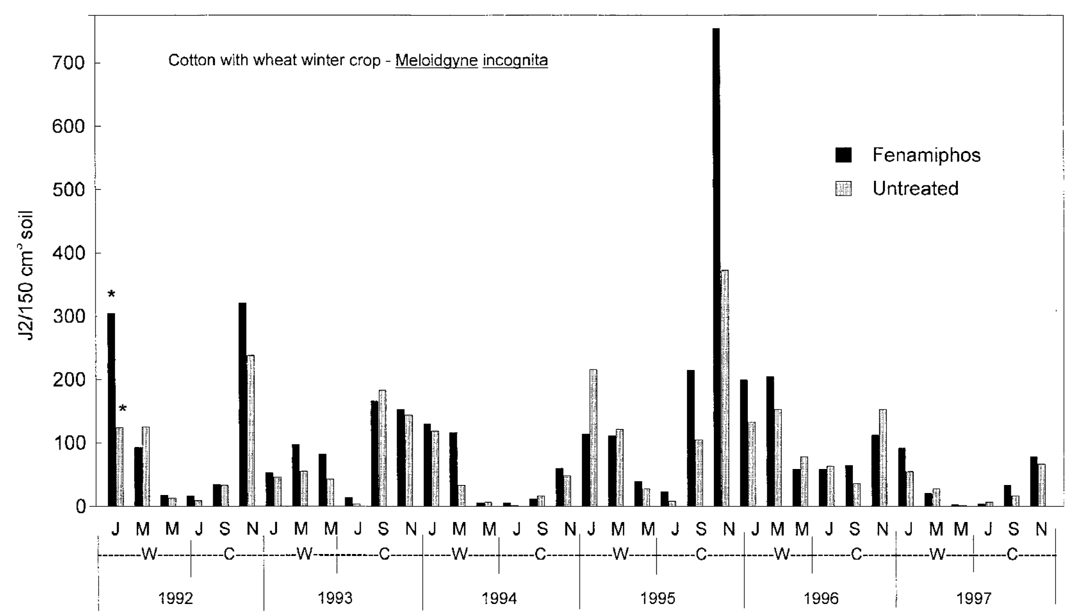

FIG. 1. Population densities of *Meloidogyne incognita* second-stage juveniles (J2) in soil as influenced by fenamiphos (6.7 kg a.i./ha) in a cotton-wheat cropping sequence, 1992–1997. An asterisk above a pair of bars indicates that numbers are different (P = 0.05) between fenamiphos-treated and untreated plots.

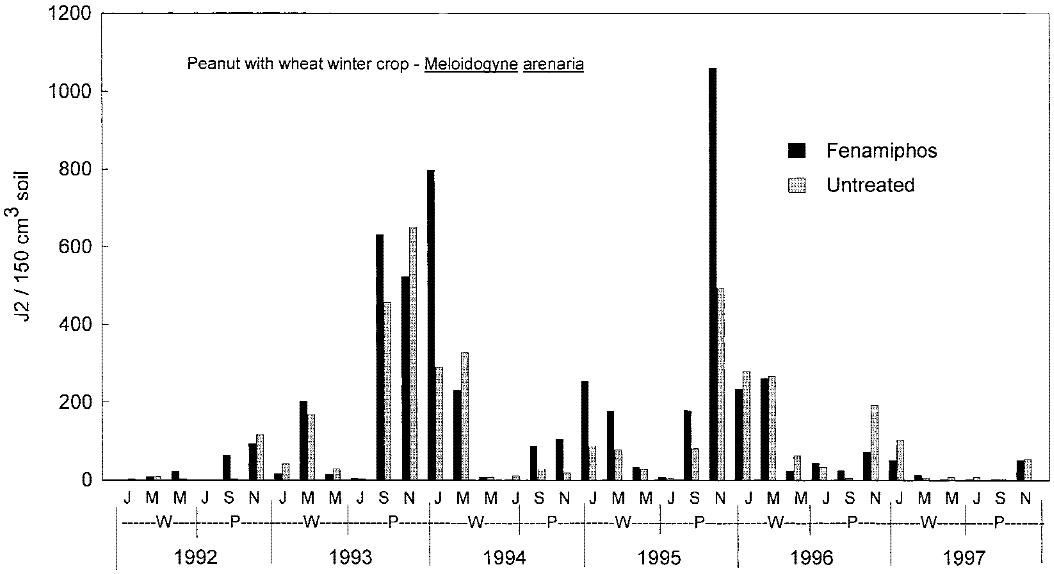

FIG. 2. Population densities of *Meloidogyne arenaria* second-stage juveniles (J2) in soil as influenced by fenamiphos (6.7 kg a.i./ha) in a peanut-wheat cropping sequence, 1992–1997. An asterisk above a pair of bars indicates that numbers are different (P = 0.05) between fenamiphos-treated and untreated plots.

and soil temperatures 10 cm deep during December, January, and February each year were below 18 °C. The data suggest that wheat cv. Andy (1991–1995) is more susceptible to *M. incognita* and *M. arenaria* than cv. Morey (1996–1997).

Root-gall indices of cotton and peanut ranged from 1.0 to 2.9 each year and were not affected by the fenamiphos treatment (Table 1). No galls were observed until 1995 on roots of cotton and until 1997 on roots of peanut in any cropping sequence. The mean gall indexes of fenamiphos-treated and untreated cotton in the cotton treat-

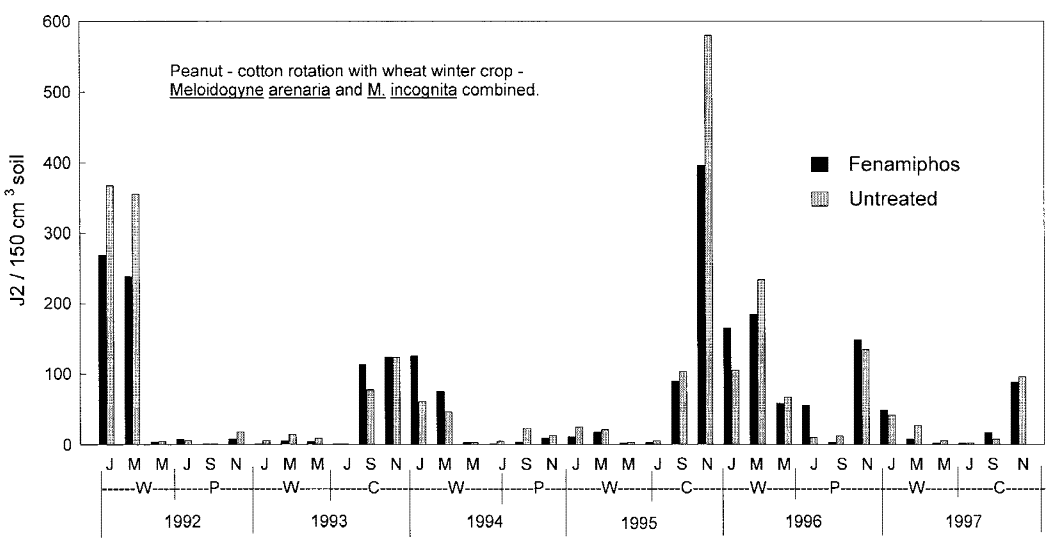

FIG. 3. Population densities of *Meloidogyne incognita* + *M. arenaria* second-stage juveniles (J2) in soil as influenced by fenamiphos (6.7 kg a.i./ha) in a peanut-wheat-cotton-wheat cropping sequence, 1992–1997. An asterisk above a pair of bars indicates that numbers are different (P = 0.05) between fenamiphos-treated and untreated plots.

TABLE 1. Root-gall indices of cotton and peanut as influenced by fenamiphos and cotton-peanut rotation under conservation tillage with wheat as a winter cover crop.

		1995		1996		1997	
Cropping sequence	Crop sampled	Fenamiphos[a]	Control	Fenamiphos	Control	Fenamiphos	Control
Wheat-cotton	Cotton	1.5 a	1.3 a	2.0	1.9	2.9 a	2.8 a
Wheat-peanut	Peanut	1.0	1.0	1.0 a	1.0 a	1.2	1.1
Wheat-cotton	Cotton	1.3 a	1.2 a	—	—	2.3 b	2.4 b
Wheat-peanut	Peanut	—	—	1.0 a	1.0 a	—	—

Data are means of 12 replications. Means in columns for the same crop followed by the same letter are not different, LSD 0.05. There were no differences between nematicide treatments according to ANOVA LSD $P = 0.05$.

[a] Fenamiphos applied broadcast at 6.7 kg a.i./ha in 31 kl irrigation water/ha immediately after each crop was planted.

ment in 1995, 1996, and 1997 were 1.4, 2.0, and 2.9, respectively. The mean root-gall index of cotton was lower in the peanut-cotton rotation than in the cotton treatment in 1997. Only traces of galling were observed on peanut in the peanut-cotton rotation in 1996 and in the peanut-wheat treatment in 1997. These results support those reported by Johnson et al. (1998b, 1999) and Rodríguez-Kábana et al. (1994).

Population densities of *H. dihystera* in untreated plots were higher in the cotton-wheat treatment (Fig. 4) than in the other treatments on most sampling dates (Figs. 5,6). Greater numbers of *H. dihystera* in cotton-wheat plots than in peanut-wheat parallel differences in *H. dihystera* populations reported for monocultured cotton and peanut (Johnson et al., 1974,1975). The pathogenicity of *H. dihystera* to cotton and peanut is unknown. The large numbers of *H. dihystera* in fenamiphos-untreated plots of wheat in the cotton-wheat treatment from January through May indicate that wheat is a good host for *H. dihystera*. Similar results were reported for *H. dihystera* on triticale (*Triticose-*

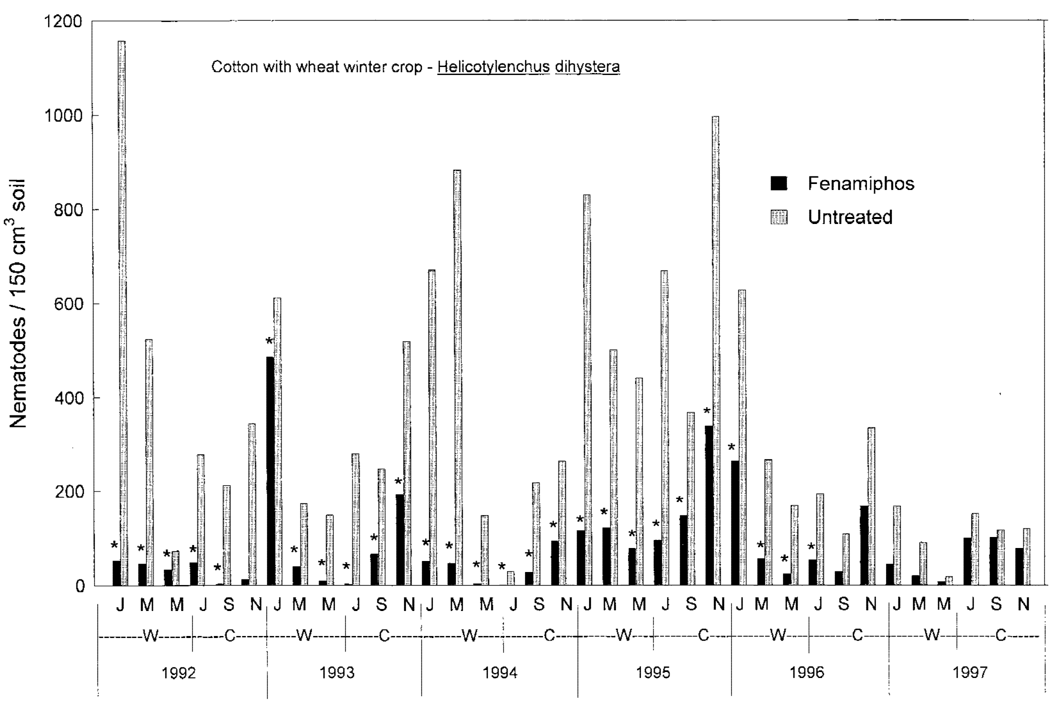

FIG. 4. Population densities of *Helicotylenchus dihystera* in soil as influenced by fenamiphos (6.7 kg a.i./ha) in a cotton-wheat cropping sequence, 1992–1997. An asterisk above a pair of bars indicates that numbers are different ($P = 0.05$) between fenamiphos-treated and untreated plots.

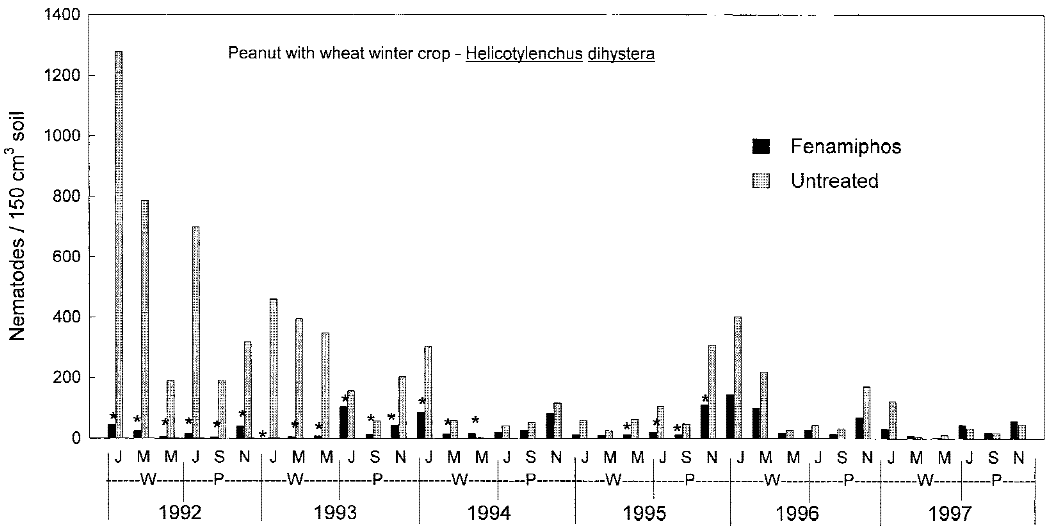

FIG. 5. Population densities of *Helicotylenchus dihystera* in soil as influenced by fenamiphos (6.7 kg a.i./ha) in a peanut-wheat cropping sequence, 1992–1997. An asterisk above a pair of bars indicates that numbers are different ($P = 0.05$) between fenamiphos-treated and untreated plots.

cale Whittmack) 'Beagle 82,' an early-maturing small-grain crop closely related to wheat (Johnson et al., 1998a). Numbers of *H. dihystera* in untreated plots in the peanut-wheat treatment generally declined after January 1992 and remained below 100/150 cm^3 soil on most sampling dates during the remainder of the study. The efficacy of fenamiphos was more consistent in suppressing populations of *H. dihystera* than *Meloidogyne* spp. When population densities differed in monthly sampling, numbers of *H. dihystera* were lower in fenamiphos-treated than in untreated plots.

Numbers of *P. brachyurus* ranged from 0 to 165/150 cm^3 soil on wheat during 1992 and declined to less than 28/150 cm^3 soil on all crops thereafter, and were not affected by

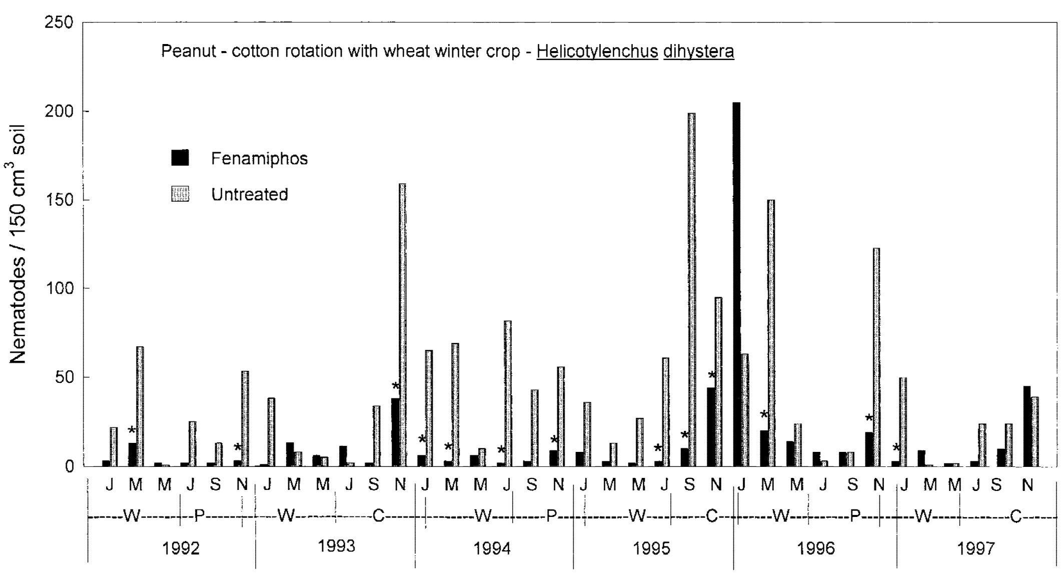

FIG. 6. Population densities of *Helicotylenchus dihystera* in soil as influenced by fenamiphos (6.7 kg a.i./ha) in a peanut-wheat-cotton-wheat cropping sequence, 1992–1997. An asterisk above a pair of bars indicates that numbers are different ($P = 0.05$) between fenamiphos-treated and untreated plots.

cropping sequence or fenamiphos treatment. Numbers of *M. ornata* were fewer than 10/150 cm^3 soil on cotton in the cotton-wheat treatment and peanut-cotton rotation and increased to 53/150 cm^3 soil on peanut at harvest in the peanut-wheat treatment and peanut-cotton rotation each year. Neither fenamiphos nor cropping sequence significantly affected the *M. ornata* population densities on most sampling dates. Numbers of *P. minor* were less than 35/150 cm^3 soil on all sampling dates and were not affected by fenamiphos treatment or cropping sequence. In general, fluctuations in population densities of *P. brachyurus, M. ornata,* and *P. minor* on peanut and cotton when grown under conservation tillage with a wheat winter crop were similar to those observed in monocultures of cotton and peanut (Johnson et al., 1974, 1998b).

Nematicide treatment × cropping system sequence interactions were not significant at $P = 0.05$; however, the plants in nematicide-treated plots yielded more than those in untreated plots in cotton, peanut, and peanut-cotton rotation in 4 of 6, 1 of 6, and 1 of 6 years, respectively. Wheat yield in all cropping sequences tended to be greater in fenamiphos-treated plots than in untreated plots; differences were observed in the cotton treatment in all years except 1996, in the peanut treatment in 1992 and 1993, and in the peanut-cotton rotation in all years except 1995 and 1997 (Table 2). Winter wheat yields in all cropping sequences were lower in 1993 and 1997 than in other years. The low yields in 1993 were related to cold weather in March; in 1997, low yields may have resulted from inadequate seeding rate, inadequate soil fertility, or unfavorable weather in April and May. Means across years and nematicide treatments indicate that wheat yields were highest (1,796 kg/ha) in the peanut treatment, intermediate (1,681 kg/ha) in the peanut-cotton rotation, and lowest (1,425 kg/ha) in the cotton treatment. Although data are limited for the southeastern Coastal Plain soils, research has shown wheat responds positively to no tillage following peanut (Hook et al., 1998).

Cotton yield was lower following peanut than following cotton in fenamiphos-treated plots (Table 2). Yield of cotton was greater in fenamiphos-treated than in untreated plots in the cotton-wheat treatment when the J2 population density was about 40 or more per 150 cm^3 soil each year except 1992 and 1994. The low yield in 1994 was attributed to extremely dry and hot conditions in May followed by a wet growing season beginning in early June. Excessive rainfall (10.5 cm) occurred between 4 July and 10 July,

TABLE 2. Yield (kg/ha) of wheat, cotton lint, and peanut as influenced by cropping sequence and fenamiphos soil treatment in a field infested with *Meloidogyne incognita* race 3 and *M. arenaria* race 1.

		Wheat-cotton		Wheat-peanut		Wheat-peanut-wheat-cotton		
Year	Fenamiphos[a]	Wheat	Cotton	Wheat	Peanut	Wheat	Peanut	Cotton
1992	+	2,016 a	508	2,392 a	3,019 a	2,204 a	2,591	—
	−	1,613 b	511	2,231 b	2,877 b	1,801 b	2,894	—
1993	+	1,021 a	725 ay	1,398 a	2,646	1,403 a	—	648 az
	−	887 b	627 b	1,306 b	2,708	1,269 b	—	618 b
1994	+	1,828 a	280	1,908	1,164	1,962 a	1,417	—
	−	1,667 b	279	1,989	1,273	1,613 b	1,368	—
1995	+	1,559 a	909 ay	2,043	2,310	1,855	—	826 z
	−	1,263 b	726 b	1,989	2,527	1,914	—	831
1996	+	1,693	963 a	1,855	1,421 z	1,828 a	2,706 y	—
	−	1,667	850 b	1,774	1,370 z	1,720 b	2,561 y	—
1997	+	1,048 a	736 ay	1,317	2,207	1,290	—	588 z
	−	833 b	675 by	1,344	2,408	1,317	—	555 z

Data are means of 12 replications. Means of data in columns comparing fenamiphos vs. untreated control in the same year followed by different letters (a vs. b) are different ($P = 0.05$). Means of data in rows comparing the same crop in different cropping sequences followed by different letters (y vs. z) are different ($P = 0.05$).

[a] Fenamiphos was applied broadcast at 6.7 kg a.i./ha in 31 kl irrigation water/ha immediately after wheat, cotton, and peanut were planted.

and plots remained saturated for several days. Plants recovered to produce excessive vegetative growth as continued rainy, cloudy weather conditions hampered fruiting and delayed upper-stalk boll development, boll opening, defoliation, and harvesting. Means across nematicide treatments indicate that yield of cotton was consistently higher in the cotton-wheat treatment than in the peanut-cotton rotation.

Peanut yield was greater following fenamiphos treatment compared with the untreated control only in 1992 in the peanut-wheat sequence (Table 2). The lower yield was related to the higher number of *H. dihystera* in the untreated plots. Peanut yield was affected by cropping sequence only in 1996, when yield in the peanut-cotton rotation was almost double the yield in peanut-wheat treatment. Yield of peanut was much lower in the peanut-wheat sequence in 1994 and 1996 and in the peanut-cotton rotation in 1994 than in other years. The low yields of peanut in the peanut-wheat and peanut-cotton rotations in 1994 were caused by unfavorable weather. Low peanut yields in 1996 were caused partially by Cylindrocladium black rot (*Cylindrocladium parasiticum* Crous, Wingfield & Alfenas (teleomorph *Calonectria ilicicola* Boedijin & Reitsma). Peanut yields were significantly higher in the peanut-cotton rotation than in the wheat-peanut treatment only when a disease like Cylindrocladium black rot was a substantial problem. Means across nematicide treatments indicated peanut yields were 22% higher in the peanut-cotton rotation than in the peanut-wheat sequence.

The reasons for the lack of consistent suppression of population densities of *Meloidogyne* spp. J2 by fenamiphos are uncertain. Johnson et al. (1998a) reported similar results in triticale-cotton and triticale-soybean rotations. Johnson et al. (1992) demonstrated that efficacy of fenamiphos diminished after 3 years of multiple applications in crop rotations, and additional research showed that the degradation of fenamiphos after multiple applications to the same land area was microbially mediated (Davis et al., 1993; Johnson, 1998).

Soil moisture at the time of application by irrigation water also may be important in the efficacy of fenamiphos. In moldboard-plowed plots with soil moisture near field capacity (Johnson et al., 1982), no difference was found between the concentration of fenamiphos achieved by incorporating with a tractor-mounted rototiller and that achieved by application through sprinkler irrigation with 178 kl water/ha. In our study, fenamiphos was applied at 6.7 kg a.i./ha in 31 kl water/ha immediately after planting each crop, regardless of the soil moisture content. Perhaps much of the nematicide was absorbed by the crop residue and failed to penetrate the soil adequately. Variable weather conditions also may have diminished the efficacy of the nematicide. More research is needed to determine the influence of water volume and soil moisture content at time of application on the movement and efficacy of fenamiphos under conservation tillage methods.

Based on root-gall indices, numbers of *Meloidogyne* spp. J2 in the soil, and crop yield response from fenamiphos soil treatment, the *Meloidogyne arenaria* population densities were below damaging levels on peanut, and most of the *Meloidogyne* spp. was *M. incognita.* The data also indicated that cotton and wheat are good hosts of *H. dihystera.* These results show that nematode problems may be manageable in cotton and peanut production under conservation tillage using agrichemical application technology, crop rotation, and a winter wheat cover crop.

Literature Cited

Barker, K. R., J. L. Townshend, G. W. Bird, I. J. Thomason, and D. W. Dickson. 1986. Determining nematode population responses to control agents. Pp. 283–296 *in* K. D. Hickey, ed. Methods of evaluating pesticides for control of plant pathogens. St. Paul, MN: APS Press.

Birchfield, W. 1983. Wheat and grain sorghum varietal reaction to *Meloidogyne incognita* and *Rotylenchus reniformis.* Plant Disease 67:41–42.

Boyle, L. W. 1956. Fundamental concepts in the development of control measures for southern blight and root rot of peanut. Plant Disease Reporter 40:661–665.

Davis, R. F., A. W. Johnson, and R. D. Wauchope. 1993. Accelerated degradation of fenamiphos and its metabolites in soil previously treated with fenamiphos. Journal of Nematology 25:679–685.

Dickson, D. W. 1998. Peanut. Pp. 523–566 *in* K. R. Barker, G. A. Pederson, and G. L. Windham, eds. Plant nematode interactions. Madison, WI: American Society of Agronomy.

Dowler, C. C., J. E. Hook, S. H. Baker, G. J. Gascho, and A. W. Johnson. 1999. Proceedings of the 22nd Annual Southern Conservation Tillage Conference for Sustainable Agriculture; July 6–8, 1999; Tifton, GA. The University of Georgia College of Agricultural and Environmental Sciences, Athens.

Garren, K. H., and G. B. Duke. 1958. The effects of deep covering of organic matter and non-dirting weed control on peanut stem rot. Plant Disease Reporter 42: 629–636.

Heald, C. M., and C. C. Orr. 1984. Nematode parasites of cotton. Pp. 147–166 *in* W. R. Nickle, ed. Plant and insect nematodes. New York: Marcel Dekker.

Hook, J. E., C. C. Dowler, A. W. Johnson, and H. R. Sumner. 1998. Economic and environmental sustainability of a double-crop rotation based on cotton and peanut. American Society of Agronomy 90:286 (Abstr.).

Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Disease Reporter 48:692.

Johnson, A. W. 1998. Degradation of fenamiphos in agricultural production soils. Journal of Nematology 30:40–44.

Johnson, A. W., C. C. Dowler, S. H. Baker, and Z. A. Handoo. 1998a. Crop yields and nematode population densities in triticale-cotton and triticale-soybean rotations. Journal of Nematology 30:353–361.

Johnson, A. W., C. C. Dowler, N. C. Glaze, R. B. Chalfant, and A. M. Golden. 1992. Nematode numbers of crop yield in a fenamiphos-treated sweet corn-sweet potato-vetch cropping system. Journal of Nematology 24: 533–539.

Johnson, A. W., C. C. Dowler, and E. W. Hauser. 1974. Seasonal population dynamics of selected plant-parasitic nematodes on four monocultural crops. Journal of Nematology 6:187–190.

Johnson, A. W., C. C. Dowler, and E. W. Hauser. 1975. Crop rotation and herbicide effects on population densities of plant-parasitic nematodes. Journal of Nematology 7:158–160.

Johnson, A. W., N. A. Minton, T. B. Brenneman, G. W. Burton, A. K. Culbreath, G. J. Gascho, and S. H. Baker. 1999. Bahiagrass, corn, cotton rotations, and pesticides for managing nematodes, diseases, and insects on peanut. Journal of Nematology 31:191–200.

Johnson, A. W., N. A. Minton, T. B. Brenneman, J. W. Todd, G. A. Herzog, G. J. Gascho, S. H. Baker, and K. Bondari. 1998b. Peanut-cotton-rye rotations and chemical soil treatment for managing nematodes and thrips. Journal of Nematology 30:211–225.

Johnson, A. W., and R. E. Motsinger. 1989. Suitability of small grains as hosts of *Meloidogyne* species. Supplement to the Journal of Nematology 21:650–653.

Johnson, A. W., and R. E. Motsinger. 1990. Effects of planting date, small grain crop destruction, fallow, and soil temperature on the management of *Meloidogyne incognita*. Journal of Nematology 22:348–355.

Johnson, A. W., W. A. Rohde, and W. C. Wright. 1982. Soil distribution of fenamiphos applied by overhead sprinkler irrigation to control *Meloidogyne incognita* on vegetables. Plant Disease 66:489–491.

Johnson, A. W., J. R. Young, and B. G. Mullinix. 1981. Applying nematicides through an overhead sprinkler irrigation system for control of nematodes. Journal of Nematology 13:154–159.

Johnson, A. W., J. R. Young, E. D. Threadgill, C. C. Dowler, and D. R. Sumner. 1986a. Chemigation for crop production management. Plant Disease 70:998–1004.

Johnson, A. W., J. R. Young, and W. C. Wright. 1986b. Management of root-knot nematodes by phenamiphos applied through an irrigation simulator with various amounts of water. Journal of Nematology 18: 364–369.

Minton, N. A. 1984. Nematode parasites of peanut. Pp. 373–394 *in* W. R. Nickle, ed. Plant and insect nematodes. New York: Marcel Dekker.

Minton, N. A., and P. Baujard. 1990. Nematode parasites of peanut. Pp. 285–320 *in* M. Luc, R. A. Sikora, and J. Bridge, eds. Plant-parasitic nematodes in subtropical and tropical agriculture. Wallingford, UK: CAB International.

Mixon, A. C. 1963. Effects of deep turning and non-dirting weed control on peanut stem rot. Bulletin 344, Alabama Experiment Station, Auburn.

Morey, D. D., W. H. Marchant, and F. K. Barnes. 1983. Small grain and ryegrass winter forage production in South Georgia. Research Report 426, University of Georgia College of Agriculture Experiment Station, Athens.

Plank, C. O. 1989. Soil test handbook for Georgia. Athens, GA: Georgia Cooperative Extension Service. University of Georgia.

Roberts, P. A., S. D. Van Gundy, and H. E. McKinney. 1981. The effects of soil temperature and planting date of wheat on *Meloidogyne incognita* reproduction, soil population, and grain yield. Journal of Nematology 13: 338–345.

Rodríguez-Kábana, R., H. Ivey, and P. A. Backman. 1987. Peanut-cotton rotations for management of *Meloidogyne arenaria*. Journal of Nematology 19:484–486.

Rodríguez-Kábana, R., N. Kokalis-Burelle, D. G. Robertson, P. S. King, and L. W. Wells. 1994. Rotations with coastal bermudagrass, cotton, and bahiagrass for management of *Meloidogyne arenaria* and southern blight in peanut. Supplement to the Journal of Nematology 26: 665–668.

Samples, L. E. 1987. Land preparation. Pp. 4/1–4/2 *in* Georgia Peanut Production Guide. Georgia Cooperative Extension Service, Athens.

Starr, J. L. 1998. Cotton. Pp. 359–379 *in* K. R. Barker, G. A. Pederson, and G. L. Windham, eds. Plant and nematode interactions. Madison, WI: American Society of Agronomy.

Starr, J. L., and S. L. J. Page. 1990. Nematode parasites of cotton and other tropical fibre crops. Pp. 539–556 *in* M. Luc, R. A. Sikora, and J. Bridge, eds. Plant-parasitic nematodes in subtropical and tropical agriculture. Wallingford, UK: CAB International.

Williams, E. J., and J. S. Drexler. 1981. A non-destructive method for determining peanut pod maturity. Peanut Science 8:134–141.