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Crop Yields and Nematode Population Densities in Triticale-Cotton and Triticale-Soybean Rotations[1]

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Abstract: Triticale cv. Beagle 82, cotton cv. McNair 235, and soybean cv. Twiggs were arranged in three cropping sequences to determine the effects of fenamiphos and cropping sequence on nematode population densities and crop yields under conservation tillage for 4 years. The cropping sequences were triticale (T)-cotton (C)-T-C, T-soybean (S)-T-S, and T-C-T-S. Numbers of *Meloidogyne incognita* second-stage juveniles declined on triticale but increased on cotton and soybean each year. Root-gall indices of cotton and soybean ranged from 1.00 to 1.08 (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) each year and were not affected by fenamiphos treatment or cropping sequence. Numbers of *Pratylenchus brachyurus* were maintained on triticale and generally increased more on soybean than on cotton. Population densities of *Helicotylenchus dihystera* were near or below detection levels in all plots during the first year and increased thereafter in untreated plots in the T-C-T-C and T-S-T-S sequences. Generally, yields of triticale in all cropping sequences declined over the years. Yields of cotton and soybean were not affected by fenamiphos at 6.7 kg a.i./ha. Cotton and soybean were grown successfully with little or no suppression in yields caused by nematodes in conservation tillage following triticale harvested for grain.

Key words: conservation tillage, cotton, crop rotation, fenamiphos, *Glycine max, Gossypium hirsutum, Helicotylenchus dihystera,* lesion nematode, management, *Meloidogyne incognita,* nematicide, nematode, *Pratylenchus brachyurus,* root-knot nematode, soybean, spiral nematode, triticale, *Triticosecale.*

The suspension of several important nematicides has prompted investigation into alternative, nonchemical methods for the management of plant-parasitic nematodes. Crop rotations and resistant cultivars have been and will continue to be a primary means of managing nematode population densities in annual crops.

Cotton (*Gossypium hirsutum* L.), (Heald and Orr 1984; Starr and Page, 1990) and soybean (*Glycine max* (L.) Merr.) (Schmitt and Noel, 1984; Sikora and Greco, 1990) are damaged by many nematode species. In the southeastern United States, the most damaging nematodes include *Meloidogyne incognita* (Kofoid & White) Chitwood for cotton (Johnson et al., 1974, 1975) and *Meloidogyne* spp. for soybean (Kinloch, 1980; Pedrosa et al., 1996). Cotton hectarage has increased across the Southeast with the largest increase in Georgia.

Triticale (*Triticosecale* Whittmack) Beagle 82 is an early-maturing, spring-type, small-grain cultivar (Barnett et al., 1982). Ibrahim et al. (1993) reported that Beagle 82 was a good host for *M. incognita* race 3 and *M. arenaria* (Neal) Chitwood races 1 and 2 under greenhouse conditions. Beagle 82 withstands certain diseases better than wheat and has a higher content of amino acids than corn or wheat; however, because the cultivar was developed as a spring crop, it is not winter-hardy (Barnett et al., 1982).

Because Beagle 82 triticale has such a desirable amino acid composition, interest has increased in its potential use in poultry and swine feeds. Animal scientists have shown that triticale can replace all the corn and a portion of the soybean meal in swine diets (Hale and Utley, 1985). Although recognized for its nutritional value, triticale is not widely grown in Georgia. Approximately 10,000 to 12,000 ha of triticale are planted each year, compared with more than 202,000 ha of wheat grown in the state.

The hectarage of environmentally friendly farming systems known as conservation tillage, where a minimum 30% of the previous crop residue remains on the soil surface, continues to increase in the southern states (Conservation Technology Information Center, 1995), led by substantial in-

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creases in soybean production. Georgia and North Carolina have been leaders among southern states, where conservation tillage in cotton increased by almost 46,945 ha in the past 5 years. Growers in Georgia and North Carolina produced an additional 35,614 ha of cotton under conservation tillage in 1995, and Louisiana growers added more than 6,070 cotton ha.

Information is not available on the compatibility of triticale in crop production systems. The objective of this study was to determine the effects of triticale-cotton and triticale-soybean cropping systems and fenamiphos on nematode population densities and crop yields under conservation tillage.

Materials and Methods

Field plots were established in November 1986 and maintained through December 1990 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 *Meloidogyne incognita* race 3, *Pratylenchus brachyurus* (Godfrey) Filipjev & Schuurmans Stekhoven, and *Helicotylenchus dihystera* (Cobb) Sher.

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. Initially, the soil was disc-harrowed, plowed 25 to 30 cm deep with a moldboard plow and shaped into beds 10 to 15 cm high. The location and treatments remained the same for 4 years.

The cropping sequences were triticale (T)-cotton (C)-T-C, T-soybean (S)-T-S, and T-C-T-S. Triticale cv. Beagle 82 was seeded at 108 kg/ha in rows 1.5 cm apart with a grain drill in November or December, and harvested for grain in late May each year. Fenamiphos 3SC was applied broadcast at 6.7 kg a.i./ha in 0.64 cm water via irrigation over one-half of each plot immediately after each crop was planted, as described by Johnson et al. (1986). The remaining half of each plot was left untreated. Immediately after triticale was harvested, paraquat was applied (broadcast at 0.23 kg a.i./ha) with a tractor-mounted sprayer to kill existing weeds. Plots were subsoiled 36 cm deep with a conservation tillage implement equipped with fluted colters mounted behind the subsoil shank to refirm the soil. Fifty percent or more of the triticale stubble remained undisturbed on the soil surface. Soybean cv. Twiggs (67 kg/ha) and cotton cv. McNair 235 (15.7 kg/ha) were planted in rows following the colters in June, and harvested during October and November, respectively. Fluometuron (1.68 kg a.i./ha) and fomesafen (0.42 kg a.i./ha) were applied through the irrigation water for preemergence weed control in cotton, and methazole (0.84 kg a.i./ha) and methylarsonic acid monosodium salt (2.24 kg a.i./ha) were applied with a tractor-mounted sprayer for postemergence weed control approximately 2 weeks after planting. For soybean, metribuzin (0.42 kg a.i./ha) and chlorimuron (0.009 kg a.i./ha) were applied for preemergence weed control, and fluazifop (0.21 kg a.i./ha) and lactofen (0.22 kg a.i./ha) were applied for postemergence weed control.

After harvest, cotton stalks were lifted from the soil with a mechanical puller and chopped with a flail mower, and soybean stalks were mowed. Paraquat was applied at 0.23 kg a.i./ha with a tractor-mounted sprayer to kill existing vegetation before triticale was planted.

Twenty cores of soil, 2.5-cm-diam. × 25-cm-deep, were collected from the rows of each subplot at monthly intervals from January 1987 through December 1990. Soil cores were mixed, and nematodes were extracted from a 150-cm^3 subsample with centrifugal flotation (Jenkins, 1964). Before soybean harvest and immediately after cotton harvest, 20 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%, 5 = 76% to 100% roots galled (Barker et al., 1986).

Supplemental irrigation was applied when rainfall was insufficient to enhance seedling emergence and plant growth. Liquid formulations of fertilizer (10% nitrate nitrogen + 34% phosphorus, a 32% solution of NH_4NO_3-urea, and 60% KC1) were applied broadcast through an irrigation system in multiple applications based on soil test recommendations after each crop was planted. 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 triticale; 67 to 90 N, 0 to 57 P, and 112 to 140 K for cotton; and 0 to 11 N, 0 to 38 P, and 112 to 157 K for soybean. In addition, triticale received 10 kg/ha sulfur in February 1990.

The data were subjected to analysis of variance and mean separation with the SAS General Linear Models procedure (SAS Institute, Cary, NC). Correlation analysis was used to determine the relationship between crop yields and the nematode population densities in the soil each month from 1987 through 1990 and root-gall indices.

Results

Numbers of *M. incognita* second-stage juveniles (J2) in the T-C-T-C sequence declined on triticale in both fenamiphos-treated and untreated plots in 1987 (Fig. 1). The numbers of *M. incognita* J2 ranged from 0 to 90/150 cm^3 soil at harvest of triticale and increased on cotton each year. The application of fenamiphos in the T-C-T-C sequence did not suppress numbers of *M. incognita* J2 in the soil on any sampling data ($P \leq 0.05$). Population densities of *M. incognita* J2 in the T-S-T-S sequence ranged from 0 to 130/150 cm^3 soil on soybean throughout the study and were not affected by the fenamiphos treatment ($P \leq 0.05$; data not included). Numbers of *M. incognita* J2 in the T-C-T-S sequence declined on triticale in both fenamiphos-treated and untreated plots in 1987, remained low until harvest of triticale, and increased slightly on cotton and soybean in November each year thereafter (Fig. 2). Population densities of *M. incognita* J2 in the T-C-T-S sequence were lower on cotton treated with fenamiphos than in untreated plots in September and November 1987 and 1989 ($P \leq 0.05$), and were not affected by fenamiphos on triticale and soybean.

Root-gall indices of cotton and soybean ranged from 1.00 to 1.08 each year and were not affected by the fenamiphos treatment or cropping sequences ($P \leq 0.05$; data not included).

Numbers of *P. brachyurus* were maintained on triticale and generally increased to greater numbers on soybean than on cotton (Figs. 3, 4). When numbers of *P. brachyurus* differed among plots, numbers were fewer in fenamiphos-treated than in untreated plots ($P \leq 0.05$).

Population densities of *H. dihystera* were near or below detection levels in all plots during the first year of the study and increased thereafter in untreated plots in the T-C-T-C and T-S-T-S sequences (Figs. 5, 6). When population densities differed in monthly sampling, numbers of *H. dihystera* were lower in fenamiphos-treated than in untreated plots ($P \leq 0.05$). Numbers of *H. dihystera* in the T-C-T-S sequence ranged from 0 to 113/150 cm^3 soil on all sampling dates and were not affected by the fenamiphos treatment ($P \leq 0.05$; data not included).

Generally, yields of triticale in all cropping sequences declined over the years (Table 1). During the growing period of triticale, the air temperature at 152 cm above the soil surface was below 0 °C 10 days in 1986 to 1987, 37 days in 1987 to 1988 (range 0 °C to −5 °C), 14 days in 1988 to 1989 (range −2 °C to −5 °C, 23–26 February 1989), and 21 days in 1989 to 1990 (range −3 °C to −11 °C, 22–27 December 1989). The application of fenamiphos increased yield of triticale in 1987 in the T-C-T-S sequence ($P \leq 0.05$), and the yield increase was related to fewer *P. brachyurus* ($r = -0.76$) in fenamiphos-treated plots than in untreated plots. The yields of triticale in fenamiphos-treated and untreated plots were greater in the T-S-T-S sequence than in other cropping sequences in 1990.

Yield of cotton was greater in fenamiphos-treated than untreated plots only in 1989 in the T-C-T-C and the T-C-T-S sequences

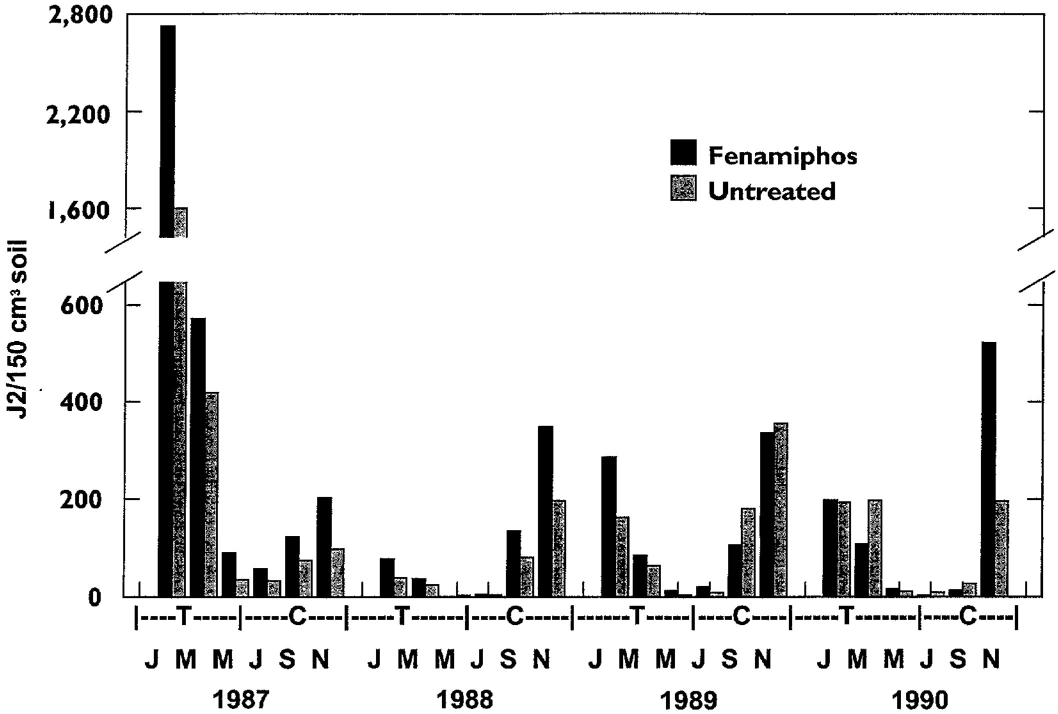

FIG. 1. Population densities of *Meloidogyne incognita* second-stage juveniles (J2) in soil as influenced by fenamiphos (6.7 kg a.i./ha) in a triticale (T)-cotton (C) cropping sequence 1987–1990. Numbers between treated and untreated plots were not different ($P \leqslant 0.05$).

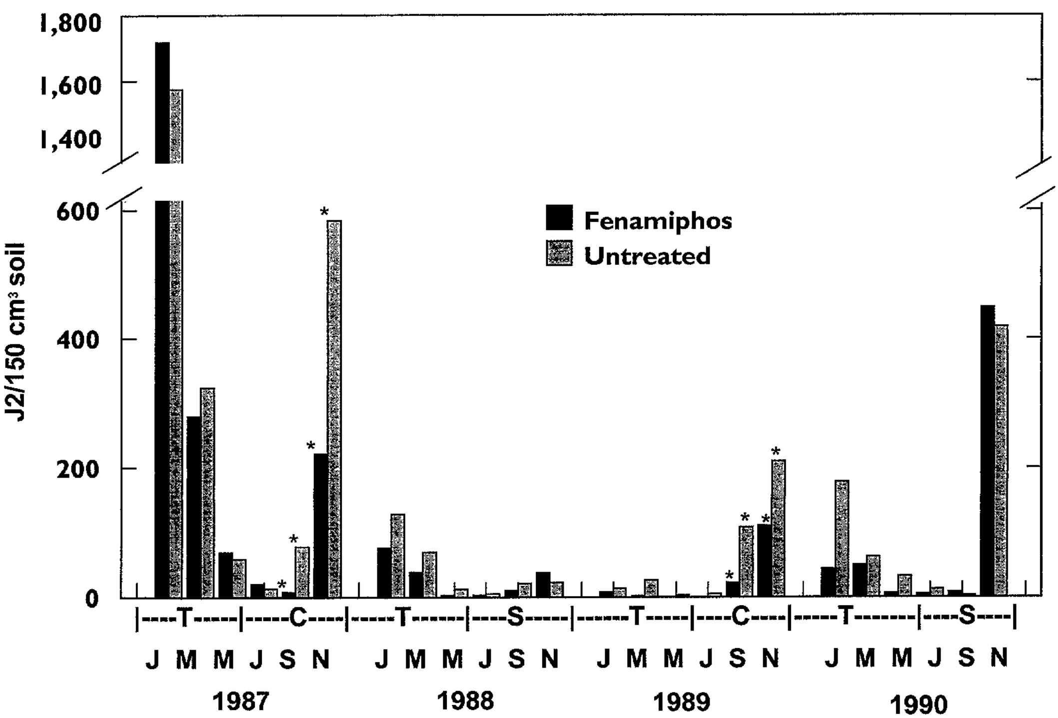

FIG. 2. Population densities of *Meloidogyne incognita* second-stage juveniles (J2) in soil as influenced by fenamiphos (6.7 kg a.i./ha) in a triticale (T)-cotton (C)-T-soybean (S) cropping sequence 1987–1990. Asterisks for a given month indicate numbers were different ($P \leqslant 0.05$) between treated and untreated plots.

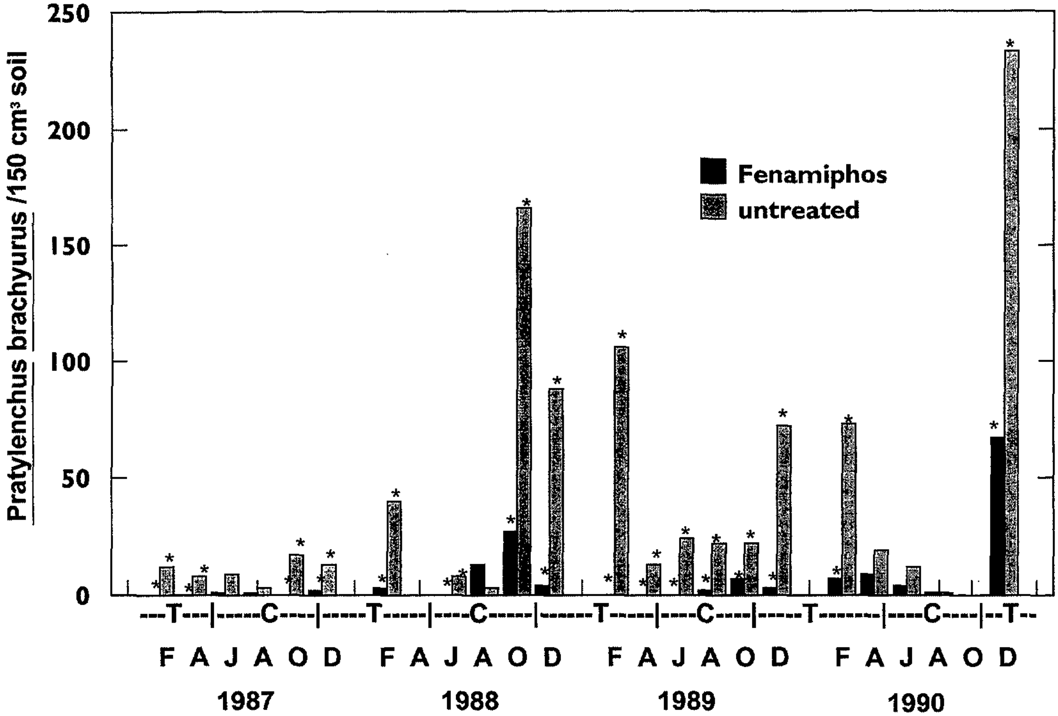

FIG. 3. Population densities of *Pratylenchus brachyurus* in soil as influenced by fenamiphos (6.7 kg a.i./ha) in a triticale (T)-cotton (C)-T-C cropping sequence 1987–1990. Asterisks for a given month indicate numbers were different ($P < 0.05$) between treated and untreated plots.

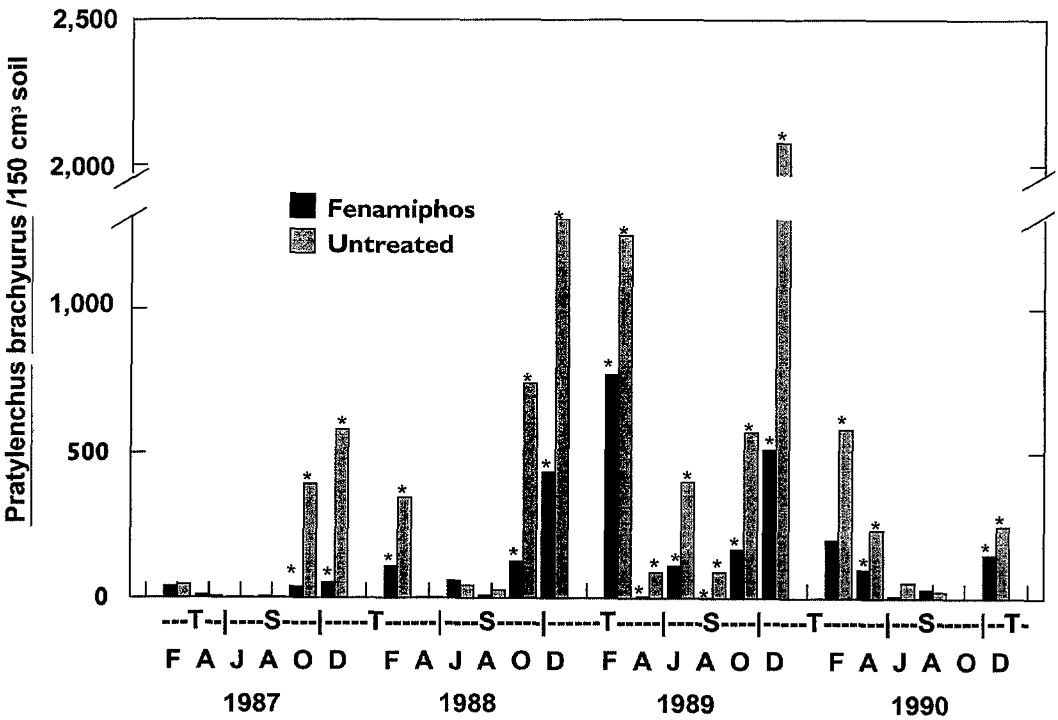

FIG. 4. Population densities of *Pratylenchus brachyurus* in soil as influenced by fenamiphos (6.7 kg a.i./ha) in a triticale (T)-soybean (S)-T-S cropping sequence 1987–1990. Asterisks for a given month indicate numbers were different ($P \leqslant 0.05$) between treated and untreated plots.

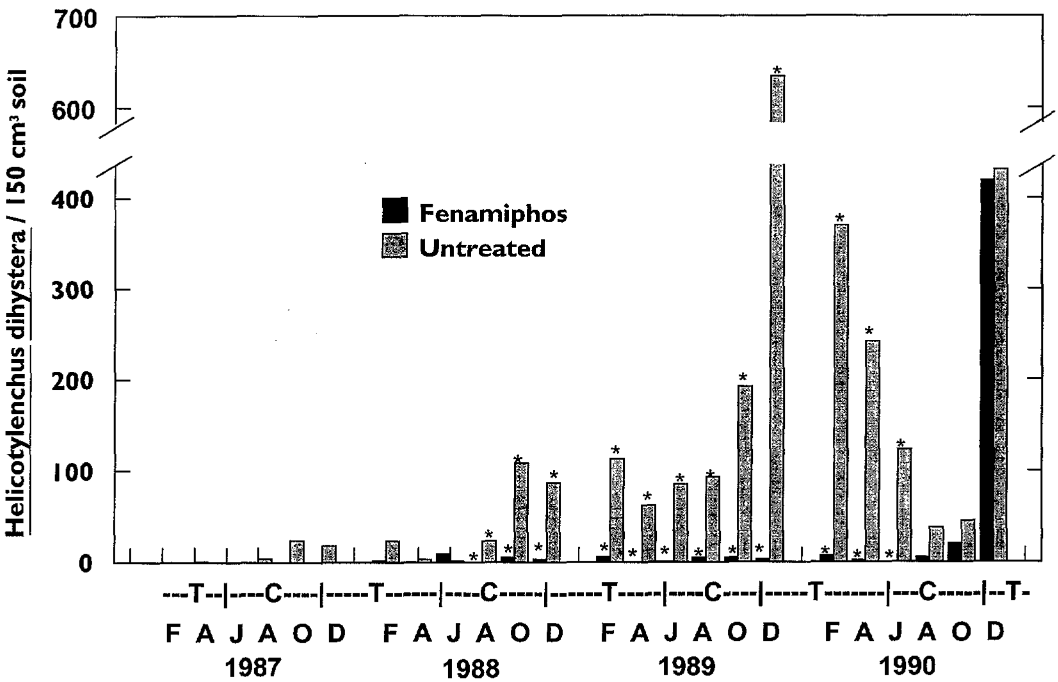

FIG. 5. Population densities of *Helicotylenchus dihystera* in soil as influenced by fenamiphos (6.7 kg a.i./ha) in a triticale (T)-cotton (C)-T-C cropping sequence 1987–1990. Asterisks for a given month indicate numbers were different ($P \leq 0.05$) between treated and untreated plots.

(Table 1). The cotton yield increase was related to lower numbers of *H. dihystera* (r = −0.68) in the T-C-T-C sequence and fewer *M. incognita* (r = −0.60) in the T-C-T-S sequence in fenamiphos-treated plots compared with untreated plots. After the first year, cotton yield was not affected by the cropping sequences.

Soybean yield was greater following fenamiphos treatment compared with the untreated control only in the 1988 in the T-S-T-S sequence (Table 1). The yield increase was related to fewer *P. brachyurus* (r = −0.79) in fenamiphos-treated than in untreated plots. In 1988, yield of soybean following triticale in the T-S-T-S sequence was greater than yield in the T-C-T-S sequence. There were no other consistent correlations between crop yields and numbers of nematodes in the soil or root-gall indices in all treatments.

Discussion

Cotton and soybean were grown successfully with little suppression in yields caused by nematodes in conservation tillage following triticale harvested for grain. Similar results probably could be expected with other winter crops grown for grain, but nematode population densities might be different if the grain crop were planted during September or October, when the soil temperatures are more favorable for development and maturation of *M. incognita*. In previous research at the Coastal Plain Experiment Station, more *M. incognita* J2 and egg-producing adults were found in roots of rye (*Secale cereale* cv. Wren Abruzzi) planted on 1 October than on rye planted on 1 November (Johnson and Motsinger, 1990). The researchers involved suggested that reproduction of *M. incognita* might be avoided by delaying planting dates of cereal crops until soil temperature declined below the nematode penetration threshold (18 °C) (Roberts et al., 1981), but that no long-term benefits could be expected. The rapid decline in *M. incognita* J2 population densities in the T-C-T-C and T-C-T-S sequences demonstrates that triticale is a poor host of *M. incognita*

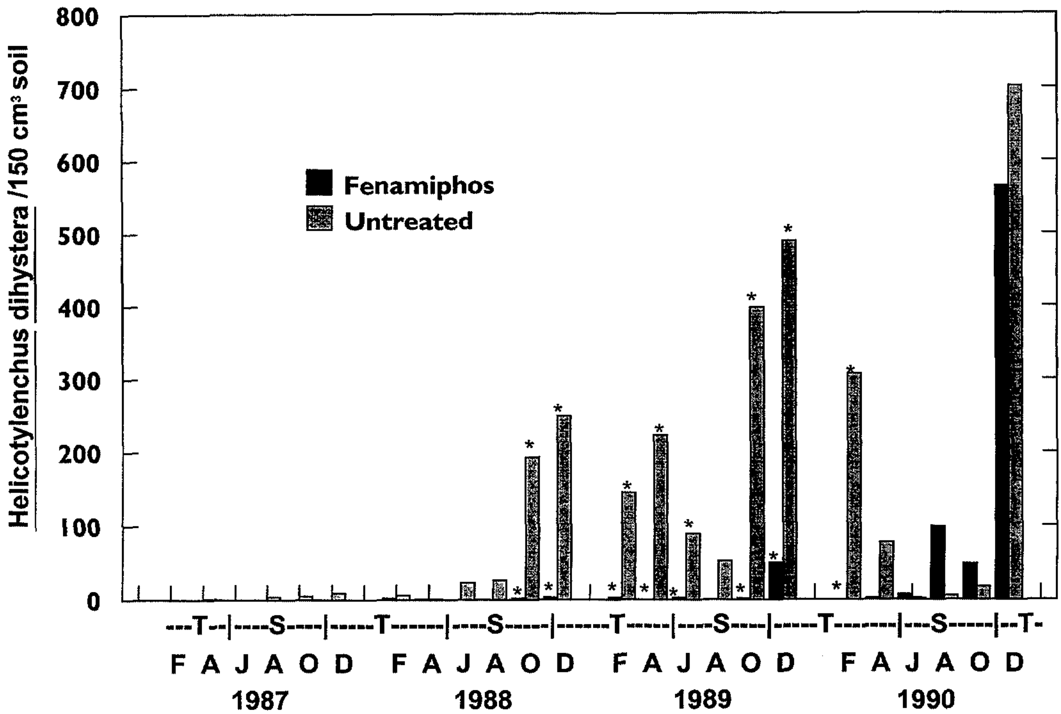

FIG. 6. Population densities of *Helicotylenchus dihystera* in soil as influenced by fenamiphos (6.7 kg a.i./ha) in a triticale (T)-soybean (S)-T-S cropping sequence 1987–1990. Asterisks for a given month indicate numbers were different ($P \leq 0.05$) between treated and untreated plots.

race 3, contrary to results reported by Ibrahim et al. (1993) in greenhouse experiments. Different isolates of *M. incognita* race 3 may respond differently on triticale as reported for different isolates of *M. arenaria* race 2 (Ibrahim et al., 1993). The level of resistance in cotton cv. McNair 235 and soybean cv. Twiggs is adequate to prevent large increases of *M. incognita* and damage to crop yields during most years without the use of fenamiphos. The efficacy of fenamiphos was more consistent in suppressing populations of *P. brachyurus* and *H. dihystera* than *M. incognita.*

TABLE 1. Yield (kg/ha) of triticale, cotton (lint), and soybean as influenced by cropping sequence and fenamiphos.

Cropping sequence	1987		1988		1989		1990	
	Fenamiphos[a]	Control	Fenamiphos	Control	Fenamiphos	Control	Fenamiphos	Control
Triticale-	3,181 b	2,822 ab	2,042	1,937	1,490 B	1,638 A	1,785 b	1,732 b
cotton	977 aB	1,042 aA	838	916	954 A	746 B	789	840
Triticale-	2,861 b	2,621 b	2,484	2,508	1,567	1,517	2,321 a	2,325 a
soybean	1,760 B	1,972 A	2,447 aA	2,083 B	2,129	1,979	1,754	1,575
Triticale-	3,724 aA	3,364 aB	—	—	1,516	1,541	—	—
cotton	795 b	844 b	—	—	956 A	772 B	—	—
Triticale-	—	—	2,366	2,428	—	—	1,870 b	1,630 b
soybean	—	—	1,908 bB	2,221 A	—	—	1,604	1,481

Data are means of six replications. Means followed by the same letter are not different ($P \leq 0.05$) according to Duncan's multiple-range test (lowercase letters for crops in columns; uppercase letters for treatment in rows). No letters indicate no difference ($P \leq 0.05$).

[a] Fenamiphos 3SC applied broadcast at 6.7 kg a.i./ha via irrigation immediately after each crop was planted.

Our results showed that soybean is a more favorable host of *P. brachyurus* than cotton. Also, the results agree with reports that showed large numbers of *Pratylenchus* spp. in soil during the fall when roots of soybean and cotton decomposed (Good, 1961; Johnson et al., 1974, 1975).

Seasonal fluctuations of *H. dihystera* on cotton and soybean agree with other reports (Johnson et al., 1974, 1975). The large numbers of *H. dihystera* in untreated plots of triticale from November through May demonstrate that triticale is a good host for this nematode species. The low numbers of *H. dihystera* in T-C-T-C and T-S-T-S plots during the first 2 years of the study and the increases in both cropping sequences during the third year were similar to those reported for monocultured cotton and soybean (Johnson et al., 1975). Also, the low numbers of *H. dihystera* in the T-C-T-S sequence throughout the study were similar to those reported on multicropping systems including cotton and soybean (Johnson et al., 1975). The pathogenicity of *H. dihystera* to these crops is unknown.

The lower yields of triticale from 1988 through 1990 compared with those in 1987 were related to cold damage, especially when the air temperature ranged from −2 °C to −5 °C from 23 to 26 February 1989. One problem with growing triticale in Georgia is the danger of winter and spring cold damage. Triticale is planted in November or December and harvested in May, and fits well with cotton and soybean in cropping sequences. Because there is currently no cultivar available with cold hardiness, triticale is better grown in southern Georgia and Florida.

Triticale yield increased as a result of soil treatment with fenamiphos only in the T-C-T-S sequence in 1987. At that time, triticale yield was correlated only with population densities of *P. brachyurus*. Because triticale grew well and produced acceptable yields in soil with large population densities of *M. incognita, P. brachyurus*, and *H. dihystera*, and there were no significant inverse correlation coefficients between yield and nematode population densities on most sampling dates, the data indicate that triticale is tolerant to these nematode species.

The lack of consistent correlations between crop yields and nematode population densities on most sampling dates indicates that nematode population densities were below damaging levels. Based on root-gall indices, numbers of nematodes in the soil on all sampling dates, and response from fenamiphos soil treatment, the level of resistance to *M. incognita* in cotton cv. McNair and soybean cv. Twiggs and the nematode tolerance in triticale are adequate to produce acceptable yields without the use of a nematicide.

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