

Nematode Population and Community Dynamics in Soybean-Wheat Cropping and Tillage Regimes¹

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Abstract: The nematode community structures of various soybean-wheat regimes and of a single-cropped, conventionally tilled soybean regime were studied at two sites in Tennessee. Each of the 100 nematode species identified in the study was placed in one of five trophic groups, the most diverse being plant parasites (31 species), followed by Dorylaimida (26 species), bacterivores (23 species), fungivores (15 species), and predators (5 species). No significant differences in overall diversity and dominance among treatments and trophic groups were found. Densities of *Heterodera glycines* Ichinohe infective juveniles were significantly higher in single-cropped, conventionally tilled soybeans in July. When data were subjected to ordination analysis, it was shown that plant-parasitic nematode communities produced an aggregation of conventionally tilled, single-cropped soybean plots when compared to all double-cropped treatments. Ordination of overall nematode communities yielded similar results.

Key words: community ordination techniques, ecology, *Filenchus* species, *Glycine max*, *Heterodera glycines*, soybean cyst nematode, no-till, *Triticum aestivum*, trophic groups.

Mounting concern with soil erosion, water pollution, and land and pest management has increased utilization of minimum or no-tillage planting techniques in the United States (15) and in other countries (4). Conservation tillage practices reduce soil erosion (15) and water pollution (19) and may increase crop yields (8).

Previous studies of nematode populations in various conservation tillage systems have yielded widely varied results (4,17,18). Populations of plant-parasitic nematodes were greater in conventionally tilled field plots than in no-till plots of grain sorghum followed by winter rye in Georgia (17). In Nigeria, numbers of *Helicotylenchus pseudorobustus* (Steiner) Golden and *Meloidogyne incognita* (Kofoid and White) Chitwood juveniles were greater in no-till plantings than in conventionally tilled plantings of maize in rotation with several crops (4). In Indiana, *Pratylenchus scribneri* Steiner was more evenly distributed in no-till plots than in conventional tillage plots (1).

The present study was undertaken to characterize the nematode community structure of no-till soybean-wheat fields and to assess the effects of various cropping

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TABLE 1. Soybean-wheat cropping and tillage regimes at Spring Hill and Milan.*

Treatment	Row width (cm)	Rows per plot	Cropping and tillage regime
Spring Hill			
1	96	8	Soybean conventional tillage, no wheat
2	96	8	Soybean drilled in killed green wheat
3	96	8	Soybean drilled in green wheat
4	96	8	Soybean no-till after wheat harvest
5	96	8	Soybean conventional tillage after wheat harvest
Milan			
1	96	4	Soybean conventional tillage, no wheat
2	96	4	Soybean after wheat, both conventional tillage
3	96	4	Soybean conventional tillage after aerially seeded wheat
4	48	8	Soybean no-till after conventional tillage wheat
5	48	8	Soybean no-till after aerially seeded wheat

* Indicated row widths and rows per plot apply to the soybean crop.

and tillage regimes on nematode community and population dynamics.

MATERIALS AND METHODS

Field plots established at the Middle Tennessee Experiment Station at Spring Hill and the Milan Experiment Station, Milan, Tennessee, were sampled. Treatments at each station included various combinations of wheat (*Triticum aestivum* L. cv. Arthur) and soybean (*Glycine max* L. Merr. cv. Essex) cropping and tillage regimes (Table 1). Treatments were arranged in a randomized block design and replicated four times at Spring Hill and six times at Milan. The Milan site was infested with *H. glycines*. Soil samples consisting of a composite of 10 soil cores (ca. 500 cm³) were taken from the center rows of each plot in May, July, and October 1982. Nematodes were extracted from 100-cm³ subsamples by sugar flotation-centrifugation methods (5,9).

Nematodes were identified to genus, when possible, with a dissecting microscope or grouped by body shape and gross morphology when such generic identification was not possible. Ten percent of each group was hand-picked from the samples, killed and fixed in hot 4% formalin, processed to glycerin (16), and mounted on glass slides. All mounted nematodes were identified to species using a compound interference-contrast microscope. Nematodes not identifiable to species were assigned to species-level taxa within their proper genera. When juvenile nematodes

within a genus could not be identified to species, they were assigned to species on a proportional basis dependent on species-level identification of adult nematodes in that sample. Vulval cones of *H. glycines* females were mounted in glycerin jelly for species confirmation. Voucher specimens of adult nematodes were deposited in the permanent nematological slide collection at the University of Tennessee, Knoxville.

Soil pH, percentage of organic carbon, and percentage of organic matter were determined (3; R. Miles, pers. comm.).

The Milan and Spring Hill data sets were analyzed separately in all instances, as variation in treatments, plot layouts, and community composition were too great to allow comparison between these locations. The computer program WORM was used to obtain values for species diversity and species dominance and to perform a community ordination procedure. Species diversity (H') was computed for each sample by a modified Shannon-Weiner formula (13):

$$H' = \frac{c}{N} (N \log_{10} N - \sum n_i \log_{10} n_i)$$

where $c = \log$ base conversion factor (1), $N =$ total number of individuals, and $n_i =$ number of individuals per species. Species dominance (d) was calculated for each sample by a modification of Simpson's formula (14):

$$d = \sum \left(\frac{n_i}{N} \right)^2$$

where n_i = number of individuals per species and N = total number of individuals.

A community ordination technique (2) was used to compare communities of plant-parasitic, bacterivorous, fungivorous, predaceous, and dorylaimid nematodes, as well as total nematode community, within plots at each station.

With the aid of the SAS-79 computer program system, Friedman's distribution-free two-way analysis for block designs with mean separation by the Waller-Duncan K -ratio t -test was performed to determine differences in species dominance, species diversity, and densities of individual species recovered from at least half of the plots at each station. Soil pH and percentage of organic matter data were also analyzed and correlated with treatments.

RESULTS

Nematode community structure: Of the 100 nematode species identified in this study, 74 were present at Spring Hill and 69 at Milan (Table 2). Percentages of the communities comprised by plant-parasites, Dorylaimida, bacterivores, fungivores, and predators are presented in Table 3.

At Spring Hill, predator numbers in May and October did not differ among treatments, but July treatments 1 and 5, both conventionally tilled, had significantly more predators than did the no-till treatments. Predaceous nematode densities at Spring Hill were higher in May than in July and October in all treatments. Numbers of bacterivores, Dorylaimida, fungivores, and plant parasites, as well as total numbers of nematodes did not differ among treatments on any of the sample dates.

Numbers of predaceous nematodes at Milan were not different among treatments in May and July, but were significantly greater in the October treatment 5 samples. In May, plant parasites at the Milan site were significantly fewer in treatment 1 and 5 plots (Table 4). Numbers of bacterivores, dorylaimids, fungivores, and total nematodes, as well as the July and October numbers of plant parasites were not different among treatments.

No significant differences in species dominance and species diversity occurred for plant parasites, bacterivores, fungivores, Dorylaimida, or predators at either Spring Hill or Milan on any sampling date.

Nematode population dynamics: Of those species at Spring Hill occurring in 50 percent or more of the plots, densities varied significantly only for *Clarkus papillatus*. Densities of this species in July treatment 5 samples were significantly greater than those of other treatments.

In July, densities of *Heterodera glycines* infective juveniles were significantly greater in conventional till, single-crop soybeans than in the other treatments at the Milan site (Fig. 1A). No treatment differences were detected for infective juveniles in May and October, and cyst counts were not different among treatments on any of the sample dates (Fig. 1B).

Densities of *Filenchus* sp. B at Milan were significantly lower in treatment 1 than in other treatments in July but not in May or October. *Helicotylenchus pseudorobustus* densities at Milan varied significantly among replicates as well as among treatments in May and October but not in July.

Ordination of nematode communities: When treatment-replicate plots for Milan plant parasites were ordinated, those of treatment 1 aggregated on the left side of the graph and were distinctly set off from the points representing the other treatment plots (Fig. 2A). Ordination of all species for all dates at Milan also shows distinct aggregation of treatment 1 plots (Fig. 2C).

Ordinations of bacterivores, Dorylaimida, fungivores, and predators at both Spring Hill and Milan, and of Spring Hill plant parasites and total community yielded inconclusive results. The points representing treatment-replicate plots did not aggregate in any way that could be related to cropping and tillage regimes.

Soil analyses: No significant differences among treatments or sites were detected in soil pH or percentage of organic matter.

DISCUSSION

The number of species occurring at our locations was considerably greater than the 12-21 species identified from soybean fields in Indiana and Illinois (7). The percentages of Dorylaimida recovered from our samples more closely approximate the natural

TABLE 2. Composition of nematode communities at the Milan (M) and Spring Hill (S) sampling sites.

Site	Species	Site	Species
Plant parasites (31 species)			
M	<i>Anguina</i> sp.	S	<i>Hoplolaimus galeatus</i> (Cobb, 1913)
M S	<i>Bastliophora</i> sp.		Filipjev and Schuurmans
M S	<i>Basiria</i> sp. A		Stekhoven, 1941
M S	<i>B.</i> sp. B	S	<i>Macroposthonia xenoplax</i> (Raski, 1952) deGrisse and Loof, 1965
M	<i>Basiroides</i> sp.		
M S	<i>Boleodorus</i> sp.	M	<i>Malenchus exiguus</i> (Massey, 1969) Andrassy, 1980
	<i>Costlenchus costatus</i> (de Man, 1921) Siddiqi, 1978	S	<i>Merlinius brevidens</i> (Allen, 1955) Siddiqi, 1970
M S	<i>Filenchus</i> sp. A		
M S	<i>F.</i> sp. B	M S	<i>Paratylenchus projectus</i> Jenkins, 1956
M S	<i>F.</i> sp. C		
M S	<i>F.</i> sp. D	S	<i>Pratylenchus neglectus</i> (Rensch, 1924) Filipjev and Schuurmans Stekhoven, 1941
	<i>F.</i> sp. E		
	<i>F.</i> sp. F	M	<i>Pseudhalenchus</i> sp.
	<i>F.</i> sp. G	S	<i>Quimiculcius acutus</i> (Allen, 1955) Siddiqi, 1971
M	<i>F.</i> sp. H		
M	<i>F.</i> sp. I	M S	<i>Tylenchus davainei</i> Bastian, 1865
M	<i>Helicotylenchus platyurus</i> Perry, 1959	M S	<i>T. hamatus</i> Thorne and Malek, 1968
M S	<i>H. pseudorobustus</i> (Steiner, 1914) Golden, 1956	S	<i>T.</i> sp. A
M S	<i>Heterodera glycines</i> Ichinohe, 1952	S	<i>Xiphinema americanum</i> Cobb, 1913
Predators (five species)			
M S	<i>Clarkus papillatus</i> (Bastian, 1865) Jairajpuri, 1970	S	<i>Tobrilus</i> sp.
M S	<i>Mylonchulus brachyuris</i> (Bütschli, 1873) Altherr, 1954	M	<i>Tripyla</i> sp.
		M	<i>Trischistoma</i> sp.
Bacterivores (23 species)			
M S	<i>Acrobeles complexus</i> Thorne, 1925	M S	<i>Eucephalobus oxyuroides</i> (de Man, 1876) Steiner, 1936
M S	<i>Acrobeloides buetschlii</i> (de Man, 1884) Steiner and Burher, 1933	M	<i>Eumonhystera</i> sp.
M	<i>A. setosus</i> Brzeski, 1962	M	<i>Heterocephalobus elongatus</i> (de Man, 1876) Steiner, 1936
S	<i>Alaimus</i> sp. A	S	<i>H. latus</i> (Cobb, 1906) Andrassy, 1967
M S	<i>A.</i> sp. B		
S	<i>Anaplectus granulatus</i> (Bastian, 1865) deConinck and Schuurmans Stekhoven, 1933	M S	<i>Mesodiplogaster lheritieri</i> (Maupas, 1919) Goodey, 1963
M S	<i>Cervidellus</i> sp.	M S	<i>Mesorhabditis</i> sp.
M S	<i>Chiloplacus trilineatus</i> Steiner, 1940	M	<i>Panagrolaimus</i> sp.
		M	<i>Plectus armatus</i> Bütschli, 1873
S	<i>C.</i> sp. A	S	<i>P. elongatus</i> Maggenti, 1961
M	<i>C.</i> sp. B	M S	<i>P. parietinus</i> Bastian, 1865
M	<i>Diploscapter coronata</i> (Cobb, 1893) Cobb, 1913	M S	<i>P. varians</i> Maggenti, 1961
		S	<i>Prismatolaimus</i> sp.
Fungivores (15 species)			
M S	<i>Aphelenchoides bicaudatus</i> (Imamura, 1931) Filipjev and Schuurmans Stekhoven, 1941	S	<i>Diphtherophora perplexans</i> (Cobb, 1913) Micoletzky, 1922
		M S	<i>Ditylenchus</i> sp.
S	<i>A.</i> sp. A	M	<i>Hexatylus</i> sp.
M S	<i>A.</i> sp. B	S	<i>Neopsilenchus</i> sp. A
M S	<i>A.</i> sp. C	M	<i>N.</i> sp. B
M S	<i>A.</i> sp. D	M S	<i>Nothotylenchus</i> sp. A
M	<i>A.</i> sp. E	M	<i>N.</i> sp. B
M S	<i>Aphelenchus avenae</i> Bastian, 1865	M S	<i>Psilenchus hilarulus</i> de Man, 1921
Dorylaimida (26 species)			
S	<i>Aporcelaimellus adoxus</i> Tjepkema, Ferris, and Ferris, 1971	M S	<i>Eudorylaimus meridionalis</i> Tjepkema, Ferris, and Ferris, 1971

TABLE 2. Continued.

Site	Species	Site	Species
M S	<i>A. hylophilus</i> Tjepkema, Ferris, and Ferris, 1971	M S	<i>E. sabulophilus</i> Tjepkema, Ferris, and Ferris, 1971
M S	<i>A. obscurus</i> (Thorne and Swanger, 1936) Heyns, 1966	S	<i>E. sp. A</i>
M S	<i>A. simplex</i> (Thorne and Swanger, 1936) Loof and Coomans, 1970	S	<i>E. sp. B</i>
S	<i>A. sp. A</i>	M	<i>Labronema ferox</i> Thorne, 1939
M S	<i>Aquatides christei</i> (Heyns, 1968) Thorne, 1974	M S	<i>L. sp. A</i>
M	<i>Axonchium crassum</i> Thorne, 1939	M	<i>Mesodorylaimus sp.</i>
S	<i>Belondira sp.</i>	S	<i>Nygolaimus sp.</i>
M S	<i>Discolaimium sp.</i>	S	<i>Prodorylaimus sp.</i>
M	<i>Discolaimus brevis</i> Siddiqi, 1964	M S	<i>Pungentus angulosus</i> Thorne, 1939
M S	<i>Ecumenicus monohystera</i> (de Man, 1880) Thorne, 1974	M	<i>P. obscurus</i> Thorne, 1939
		M	<i>Sectonema ventralis</i> Thorne, 1930
		S	<i>Thonus sp.</i>
		M	<i>Thorneella sp.</i>
		S	<i>Tylencholaimellus sayi</i> Goseco, Ferris, and Ferris, 1975

woodlands than the soybean fields of the Indiana study. The greater densities of nematodes detected in our study probably resulted from differences in cropping practices, soil types, climate, and nematode extraction efficiencies.

The greater predator densities in the July samples of conventionally tilled plots at Spring Hill may be caused by microenvironmental factors not measured in this study. These factors include temperature, moisture, and soil compaction. Differences in densities of *Clarkus papillatus*, the predominant predator at Spring Hill in July, may also be explained by these factors.

Replicate differences reflect the clumped distribution of predaceous nematodes in the Milan field. This uneven distribution may be responsible for the apparent treatment differences among the October samples.

The lower densities of plant parasites in the May samples from Milan treatment 1

TABLE 3. Distribution (%) of nematodes among trophic groups at Milan and Spring Hill.

	Milan species	Spring Hill species
Plant parasites	27.5	32.4
Dorylaimida	24.6	27.0
Bacterivores	24.6	21.6
Fungivores	17.5	15.0
Predators	5.8	4.0

may be due to lack of potential host plants on those plots. Treatment 1 lacked a winter wheat crop. At the May sampling, wheat in the other plots had not yet been harvested and there were few weeds in the treatment 1 plots.

The lack of treatment-dependent variation in species dominance and species diversity for trophic groups, and for the entire community, suggests that single season changes in cropping and tillage regimes have little effect on nematode communities.

Possible explanations for the reduction in densities of *H. glycines*-infective juveniles in treatments where wheat preceded soybeans include climatic or edaphic factors,

TABLE 4. Mean densities of plant-parasitic nematodes at Milan on three sample dates.

Treatment*	Non-parametric ranking	May	July	October
1	1.5	382 c	606 a	329 a
2	3.2	585 ab	532 a	346 a
3	4.2	822 a	562 a	599 a
4	3.8	744 ab	544 a	454 a
5	2.3	628 bc	443 a	348 a

Since numerical means and letters of significance are not in the same order, non-parametric ranking means have been included in the table to facilitate better understanding.

Means within columns followed by a common letter are not significantly ($P = 0.01$) different, according to the Waller-Duncan K -ratio t -test.

* Treatment 1, conventional tillage, no wheat; treatments 2-5, various soybean-wheat systems (see Table 1).

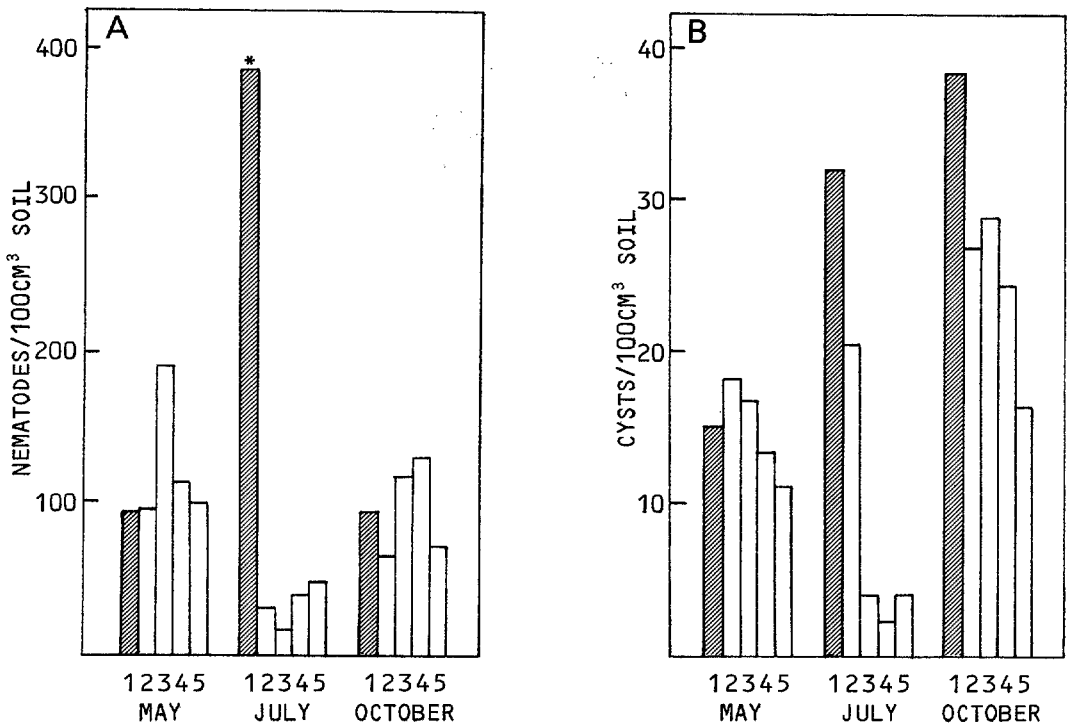


FIG. 1. Mean numbers of *Heterodera glycines* infective juveniles (A) and cysts (B) from the Milan sampling site on three sample dates. The column over which an asterisk appears is significantly different ($P = 0.01$) from other columns within that date, according to the Waller-Duncan K -ratio t -test. Shaded columns represent single-cropped conventionally tilled soybeans; those not shaded represent treatments having double-cropped soybeans and wheat (see Table 1).

as well as possible toxicity of root exudates or metabolic products of wheat to *H. glycines* eggs, juveniles, or fecund females. Although this toxicity of wheat to *H. glycines* has not been proven, various crop residues, including oat straw, have been shown to reduce the severity of *Meloidogyne* sp. infection on tomatoes (10,11). The attractiveness to growers of soybean-wheat cropping regimes would be enhanced if wheat could be proven to have specific inhibitory effects on cyst nematodes.

Because *Filenchus* sp. B seemed to be evenly distributed at the Milan site, the July population decrease in treatment 1 may also be a treatment effect. No evidence exists that cropping and tillage systems were responsible for density differences of *H. pseudorobustus*; rather, they resulted from replicate variation. Our data and the data of others (6) suggest that *H. pseudorobustus* is not very sensitive to changes in cropping sequences.

Dorylaimid nematodes have long been

considered good indicators of ecosystem stability (12), but changes in their populations may not be good indicators of single-year changes in agroecosystems. Dorylaimida identified in this study showed no clear response to cropping and tillage regimes. This apparent lack of reaction to changes in the ecosystem may be explained by the fact that although no-till plots are not disturbed as much as conventional-till plots, they are still subjected to disturbances during planting and harvesting. Had the fields been left in these cropping and tillage regimes for several years, detectable changes in nematode communities might be more likely.

Ordinations of Milan plant parasites for all dates (Fig. 2A) and for July only (Fig. 2B) illustrate the dominating influence of *H. glycines* and *Filenchus* sp. B on the plant-parasitic nematode community. The aggregation of treatment 1 plots in the ordination of all Milan species on all dates is again due to the heavy influence of *H. gly-*

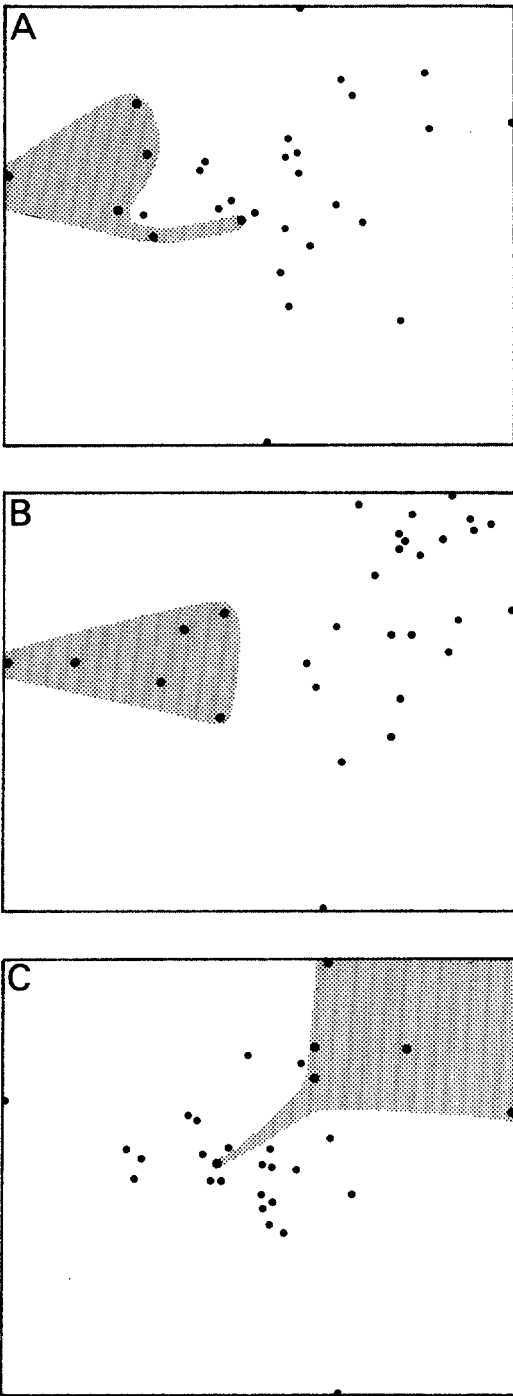


FIG. 2. Ordination of plant parasites at Milan for all sample dates (A), and for July (B), and of the entire Milan nematode community for all sample dates (C). Points within the shaded areas represent single-cropped, conventionally tilled soybean plots. Points outside the shaded areas represent plots of treatments having double-cropped soybeans and wheat.

cines and *Filenchus* sp. B in the July samples (Fig. 2C). The ordinations of data from the Milan and Spring Hill sites generally show little or no aggregation. This low rate of aggregation is due largely to the fact that community structure does not vary widely among plots within a field. Thus, differences in plots are usually species density differences which apparently carry less weight in the ordination process than does community composition. Although community ordination techniques can be useful in nematological research, the current techniques are of little help in defining single-year changes in nematode communities within a single field.

The major treatment factor influencing nematode communities, especially the plant-parasitic ones, at Spring Hill and Milan appears to be presence or absence of wheat rather than the tillage system. More research is needed on the effects of crop rotations on nematode communities and the application of these systems to nematode management.

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