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Impact of Conservation Tillage on Nematode Populations[1]

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Abstract: Literature reporting the development of conservation tillage and the research that has been conducted on nematode control in crops grown in conservation tillage systems is reviewed. Effects of different types of conservation tillage on population densities of various nematode species in monocropping and multicropping systems, effects of tillage on nematode distribution in the soil profile, effects of conservation tillage on nematode control, and the role of nematology in conservation tillage research are discussed.
Key words: conservation tillage, conventional tillage, monocropping, multicropping, nematicide, nematode distribution, nematode population density, no-till, tillage.

American farmers are changing the ways they till the soil. During the past decade, a shift has been occurring from almost complete reliance on the moldboard plow and disk harrow (conventional tillage) that incorporated the residue of the preceding crop with the soil to conservation tillage practices that disturb the soil less and leave more residue on the soil surface (8).

Conservation tillage, a combination of ancient and modern agricultural practices, has been described as 1) any tillage sequence that reduces loss of soil or water relative to conventional tillage (4) and 2) any tillage and planting system that retains at least 30 percent residue cover on the soil surface after planting (5). Conservation tillage methods may include no-till or slot planting, ridge-till, strip-till, mulch-till, stubble-till, and other tillage and planting systems that meet the 30 percent surface residue requirements. Residue may be from meadow, winter cover crop, small grain, or row crops.

In 1984, 39.2 million hectares were conservation tilled in the United States and Puerto Rico (5): corn, 12.2 million; small grain, 13.8 million; soybean, 8.7 million; cotton, 0.1 million; grain sorghum, 2.3 million; vegetable and truck crops, 0.1 million; forage crops, 1.3 million; and other crops, 0.8 million. By the year 2000, it is

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estimated 65 percent of the crop hectarage in the United States will be grown under some type of conservation tillage system (17).

Little is known about the impact of conservation tillage on plant pathogen populations, including nematodes, and their management. A workshop group on development of conservation production systems at a conference, "Changing Agricultural Production Systems and the Fate of Agricultural Chemicals" sponsored by the Agricultural Research Institute in February 1984, reached this conclusion:

> No-till is a radical change in the ecology of soils, the crops grown there, and the organisms that live on or with these crops. There are few long-term plots where scientists can assess the changes that are occurring as a new steady-state is approached. Neither are techniques available to extrapolate observations on insects or diseases from experimental plots or individual fields to assess what would happen with wide-scale adoption of no-till or other practices. The development and use of predictive models for making such assessments are critically needed (12).

Corn and soybean were the principal crops studied, and research reported was limited to a few locations and soil types and was conducted over short periods of time.

Tillage Effects on Nematodes in Monocropping

A South Carolina study showed that population densities of *Meloidogyne incognita* and *Paratrichodorus christiei* did not differ significantly in minimum tilled and conventional tilled corn plots (9). However, population densities of *Scutellonema brachyurum* were highest in April 1981 and 1982 in minimum tillage treatments where crop debris was not removed. In contrast, *S. brachyurum* populations were lowest during the same period in minimum tillage plots where 90% of previous crop debris had been removed or where residues were incorporated with conventional tillage. Populations of *Pratylenchus scribneri* were lowest in minimum tillage plots during August 1981 and April 1982. Regardless of tillage system, corn yields in all nonirrigated plots were increased by application of carbofuran.

The varied response of different nematodes to tillage has also been observed by others. Thomas (20) monitored population densities of plant-parasitic nematodes on corn growing under tillage regimes of chisel plow, offset disk, till-plant, no-till flat, no-till ridge, fall plow, and spring plow in Iowa. He found that the highest population densities of *Helicotylenchus pseudorobustus*, *Pratylenchus* spp., and *Xiphinema americanum* occurred in no-till ridged plots and lowest densities in spring-plowed and fall-plowed plots. Population densities of *Aphelenchus* spp., *Aphelenchoides* spp., *Hoplolaimus galeatus*, *Tylenchorhynchus nudus*, and members of the Psilenchinae and Mononchidae and non-stylet-bearing nematodes were not affected by tillage treatments.

Thomas and Saunders (21) found that during the seventh and eighth cropping cycles no quantitative differences in nematodes occurred between plowed and no-tilled corn plots in Costa Rica. However, where crop residues were removed, numbers of total soil nematodes and *Helicotylenchus* spp. declined whereas *Pratylenchus* spp. increased.

Pratylenchus spp. were four and five times more numerous on maize in conventionally tilled than in no-tilled soil after 7 and 13 consecutive cropping seasons in Nigeria (7). *Helicotylenchus pseudorobustus* and *M. incognita* juveniles were more numerous in no-tilled than in tilled soil. Application of DD reduced the population of *Pratylenchus* spp. to very low levels in both tilled and no-tilled soil.

Alby et al. (1) in Indiana found that *Pratylenchus scribneri* attained greater population densities in conventional tillage soybean plots than in zero tillage plots which resulted in a more dramatic expression of nematode patchiness (lack of uniformity of distribution) in the conventional tillage plots. They attributed the greater population densities to larger and more robust roots in the conventional tillage plots. Treatment with carbofuran reduced the patchiness (or increased the dispersion) for *H. galeatus*.

The average number of soybean cyst nematodes, *Heterodera glycines*, in soybean in no-tilled plots was significantly less than in plots that were disked, chiseled, subsoiled under-row, and subsoiled between-row in Tennessee (22). Cyst population densities in moldboard plowed plots did not differ from those in any tillage treatment except subsoiled between row. Numbers of cysts were greater in plots subsoiled between rows than in moldboard plow prepared plots.

Tillage Effects on Nematodes in Multicropping

Baird and Bernard (6) characterized the nematode community structure of no-tilled soybean–wheat fields to assess the effects of various cropping and tillage regimes (conventional and no-tillage) on nematode community and population dynamics at two sites in Tennessee. One hundred nematode species were identified and placed in five trophic groups: 1) plant parasites, 31 species; 2) Dorylaimida, 26 species; 3) bacterivores, 23 species; 4) fungivores, 15 species; and 5) predators, 5 species. No significant differences in overall diversity and dominance among treatments and trophic groups were found. Population densities of *H. glycines* infective juveniles were significantly higher in single-cropped, conventionally tilled soybean in July. When data were subjected to ordination analysis, plant-parasitic nematode communities produced an aggregation of single-cropped, conventionally tilled soybean plots when compared to all double-cropped treatments. Ordination of overall nematode communities yielded similar results. The authors concluded that the major factor influencing nematode communities appeared to be presence or absence of wheat rather than the tillage system. In addition, they suggested that long-term cropping and tillage regimes would likely have greater effects on nematode communities than occurred in their short-term study.

In a double-cropped corn–soybean experiment in Georgia, Parker et al. (16) found that population densities of *Meloidogyne arenaria* and *P. christiei* remained relatively low for 3 years. Population densities under soybean were not significantly different among tillage treatments (moldboard plow, subsoil-plant, and no-tillage). Also, the relative population densities did not change in these plots under corn planted by the no-tillage system.

In a second Georgia experiment (14), *M. incognita, Paratrichodorus minor,* and *Belonolaimus longicaudatus* increased under rip-plant corn in a 3-year double-cropped corn–soybean rotation (Table 1). Ethylene dibromide, phenamiphos, and aldicarb reduced *M. incognita* and *B. longicaudatus* population densities and increased corn yields (yield data not shown). Nematicides also increased yields of soybean planted after corn in a moldboard plow prepared seed bed (yield data not shown).

TABLE 1. Number of *Meloidogyne incognita* juveniles, *Paratrichodorus christiei,* and *Belonolaimus longicaudatus* in rip-plant corn in a double-cropped corn–soybean rotation, 1982.*

	Number nematodes per 150 cm³ soil			
	February		July	
Nematode	Control	Nematicides†	Control	Nematicides†
M. incognita	108 a	128 a	840 a	193 b
P. minor	18 a	17 a	44 a	44 a
B. longicaudatus	5 a	2 a	16 a	4 b

Data followed by the same letter in rows within dates are not significantly ($P = 0.05$) different according to Duncan's multiple-range test.

* Data for 1981 and 1983 were similar.

† Averages of three nematicides (ethylene dibromide, phenamiphos, and aldicarb).

Recent research by Minton and Parker (unpubl.) showed that rye suppressed population densities of *M. incognita,* but not *P. christiei,* compared to winter weed cover in double-cropped rye–soybean plots (Table 2). Population densities of both nematodes were lower in rip-plant plots than in moldboard plow prepared plots. Nematicide application (ethylene dibromide, phenamiphos, and aldicarb) reduced population densities of *M. incognita.* Rye, rip-plant, and nematicides increased yields over those of weed, moldboard plow, and no nematicide plots, respectively.

Population densities of *M. arenaria* and *Criconemella ornata* were not significantly different in rip-plant and moldboard plow prepared peanut plots planted after wheat in Georgia (Minton et al., unpubl.) (Table 3). However, peanut yields were greatest in moldboard plow prepared plots. Nematicides reduced *M. arenaria* population densities but did not increase yields.

Nematode population densities in no-tilled and disk-plowed double-cropped sorghum–rye varied with crop and season of the year in Georgia (19). Plant-parasitic nematodes (*Meloidogyne* spp., *Paratrichodo-*

TABLE 2. Effects of the preceding crop, soil preparation, and nematicides on nematode population densities, 1982–83.

Treatment	Number nematodes per 150 cm³ soil							
	Meloidogyne incognita				*Paratrichodorus minor*			
	April		September*		April		September*	
Rye vs. weed	110 b	471 a	594 a	653 a	67 a	51 a	116 a	77 b
Moldboard plow vs. rip-plant	429 a	151 b	779 a	469 b	65 a	52 a	110 a	83 b
Control vs. nematicides†	522 a	213 b	908 a	529 b	53 a	61 a	106 a	93 a

Data followed by the same letter in rows within dates are not significantly ($P = 0.05$) different as tested by orthogonal comparison.
* Nematode numbers in September were adjusted by covariant analysis of variance using nematode numbers obtained in August which are not included.
† Averages for three nematicides (ethylene dibromide, phenamiphos, and aldicarb).

rus spp., *Belonolaimus* spp., *Criconemella* spp., *Xiphinema* spp., *Rotylenchus* spp., and *Helicotylenchus* spp.) were more numerous in the grain sorghum no-tilled plots than in disk-plowed plots in summer, but in rye in winter they were more numerous in disk-plowed plots. Tillage had no effect on population densities of free-living nematodes.

Population densities of *Helicotylenchus* spp. and *P. zeae* were compared in no-tillage and conventional tillage corn planted after oats in Georgia (3). Population densities of these nematodes did not differ significantly in the two tillage systems, and carbofuran application did not significantly reduce population densities. In a second corn–rye double-cropped experiment (2), population densities of *Hoplolaimus columbus* and *Criconemella* spp. were compared in corn planted by the no-tillage and coulter-in-row chiseling methods. In the no-tillage plots, corn was planted directly in standing rye or after it had been mowed. The coulter-in-row chiseled plots were plowed once and harrowed 2–4 times to prepare a smooth seedbed. Tillage treatments did not affect nematode population densities. Carbofuran and terbufos suppressed nematode population densities in only 1 of 5 years.

Effects of Tillage on Soil Profile Nematode Distribution

Differences in population densities among types of tillage may, in some instances, reflect differences in nematode distribution in the soil profile. Such nematode distribution has been shown to occur after in-row subsoiling in conventional tilled soil with hard pans where root distribution in the soil profile was altered.

Parker et al. (15) found that population densities of *H. columbus* were greater in the 20–33-cm-deep and 33–46-cm-deep soil zones in subsoiled soybean plots than in conventional tilled plots in Georgia, but total numbers of nematodes in the two tillage treatments did not differ. In a similar study, subsoiling suppressed the root-knot index of soybean roots when compared to conventional tillage (13). Also, population densities of *M. incognita* were greater at the 33–46-cm soil zone in subsoiled DBCP-treated plots than in nonsubsoiled DBCP-treated plots.

Subsoiling bedded cotton plots in Georgia did not influence the occurrence or vertical distribution of *H. columbus* and *Helicotylenchus* spp. compared to bedded plots that were not subsoiled (11), but, in a second cotton experiment, in-row subsoiling reduced numbers of *H. columbus* in the top 20 cm of soil (10).

A Florida study showed that in-row subsoiling of corn significantly increased total numbers of *M. incognita* and *Criconemella* spp. when compared to nonsubsoiled plots (18); however, *Pratylenchus* spp. were not affected. Higher population densities of *M. incognita*, *Criconemella* spp., and total numbers of nematodes were found below the tillage pan (15–20 cm deep) in subsoiled than in nonsubsoiled plots.

Role of Nematology in Conservation Tillage

The limited research on conservation tillage indicates that its use may result in nematode problems never before encountered. Also the research has not been extensive and definitive enough to fully assess the impact of conservation tillage on nema-

TABLE 3. Effects of tillage treatments and nematicides on nematode population densities, root-knot indices, and yield of peanut planted in wheat stubble, 1984.

	Number nematodes per 150 cm³ soil					
	Meloidogyne arenaria		*Criconemella ornata*			
Treatment	June*	October	June*	October	Root-knot index†	Yield (kg/ha)
Moldboard plow	79 a	177 a	36 a	189 a	1.8 a	5,106 a
Rip-plant	7 a	179 a	31 a	323 a	2.1 a	4,679 b
Nematicide‡	45 a	93 b	38 a	248 a	1.4 b	4,876 a
No nematicide	40 a	348 a	25 a	267 a	3.1 a	4,926 a

Data within columns and within tillage and nematicide treatments followed by the same letter are not significantly (P = 0.05) different according to Duncan's multiple-range test.
* Soil was sampled in June before nematicides were applied.
† Root-knot index based on rating 1–5: 1 = no galling, 2 = 1–25, 3 = 26–50, 4 = 51–75, and 5 = 76–100% of roots and pods galled.
‡ Data in nematicide-treated plots are averages for two nematicides (phenamiphos and aldicarb).

tode management. Because of the rapid acceptance of conservation tillage, it is imperative that new and improved nematode control methodologies be developed (17).

Several inherent conditions in conservation tillage systems may modify nematode problems: 1) Reduced tillage may limit the soil volume available to roots and the depth of root penetration, especially in compacted soil, and resultant moisture stress may intensify nematode damage. 2) Multiple cropping, if practiced in conservation tillage, may either decrease or increase nematode problems depending on the crops in the rotation. 3) Optimum placement of nematicides may be restricted in some conservation tillage systems. 4) Plant roots left in the soil and not exposed to drying at the soil surface may harbor greater population densities of nematodes than occur in conventional tillage. 5) Soil is not cultivated to maintain clean fallow that usually reduces nematode population densities. 6) Crop residue left on the soil surface rather than incorporated in the soil may alter the populations of soil microorganisms that affect nematodes, thus increasing or decreasing nematode problems. 7) Crop residue on the soil surface may alter soil temperature, moisture, etc., affecting both soil microorganisms and nematodes. 8) Reduced cultivation may slow nematode spread.

Nematologists face a great challenge. Integrating effective nematode management into conservation tillage systems will require close cooperation among disciplines involved in crop production, including engineers, agronomists, horticulturists, plant pathologists, entomologists, microbiologists, plant breeders, mathematicians, and statisticians. It will involve the consideration of every management method available and the development of new ones. Standard management methods, such as crop rotation and resistant varieties, will play a major role. Biological control agents, if they become available, could also become important. The use of nematicides may be restricted in many situations unless new nematicides that do not require soil incorporation are developed or new methods, such as chemigation, are further developed.

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