Vertical Distribution of Soil Microorganisms Following Subsoiling in a Cotton Management System

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ABSTRACT

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Soil in cotton plots was sampled at four depths (0-18, 19-38, 39-53, and 54-70 cm) to determine the influence of continued subsoiling on the vertical distribution of selected soil microorganisms. Subsoiling under the planting row for three consecutive years had little influence on the vertical distribution of soil microorganisms as sampled during the 3rd yr. It increased the population density of *Fusarium* spp. at the 39-53 cm level, but had no effect on them at other levels nor on *Rhizoctonia solani, Pythium* spp., or plant-parasitic nematodes at any levels of the soil profile. Spores of vesicular-arbuscular mycorrhizal fungi decreased at the 54-70 cm level after subsoiling, but were not changed at the other levels. Populations of plant-parasitic nematodes, *Pythium* spp., *Fusarium* spp., Endogonaceae spores, and *R. solani* were greatest in the top 18 cm of soil. Significant changes in population densities occurred between soil samples collected before planting and at harvest. Population densities of *Hoplolaimus columbus* increased at all depths and *Helicotylenchus* spp. increased within the top 53 cm of soil during the growing season. The populations of *Helicotylenchus* spp. were uniformly distributed throughout the 70 cm of soil sampled. Populations of *Pythium* spp. and *Fusarium* spp. remained stable and mycorrhizal fungi spores increased within the surface 18 cm of soil.

Subsoiling is rapidly becoming a popular tillage practice used by cotton growers in the southeastern United States where soil compaction is a problem. Use of this treatment under the planting row is beneficial for cotton growth, primarily by increasing root growth and promoting root penetration to lower depths of the soil profile (1, 2, 7). Without subsoiling, cotton root systems are restricted to the first 20 cm of the soil profile. Tap roots usually penetrate to and grow horizontally along the surface of the plow pan (2, 7). Following subsoiling, however, the depth of cotton root penetration may be as great as 68 to 70 cm (2).

The vertical distribution of plant-parasitic nematodes is correlated with root distribution, although physical characteristics of the soil also may influence their distribution (15).

Populations of soil fungi generally are greatest near plant roots, but other factors such as organic matter, pH, season, and soil type may influence the abundance of these microorganisms in the soil (12, 14). Subsoiling reduced damage to bean caused by *Fusarium solani* f. sp. *phaseoli* by promoting development of a more vigorous root system and promoting root penetration into the subsoil where low levels of inoculum occurred (4, 5).

The objectives of this study were to determine the vertical distribution of soil microorganisms in the cotton root zone following 3 yr of subsoiling and to compare the preplant and harvest population densities of soil microorganisms in the cotton root zone. Emphasis was placed on organisms parasitic on cotton.

MATERIALS AND METHODS

The study was conducted at Midville, Georgia, on Marlboro loamy sand soil consisting of approximately 20-25 cm of a loamy sand topsoil, a 5- to 8-cm sand-textured plow-pan-layer, and a sandy clay subsoil (7). The physical characteristics and nutrient status of the soil are shown in Table 1. The data are means for the treatments as they did not differ significantly.

Field plots from an investigation on the effects of subsoiling on cotton yield (7) were used in this study. To study the influence of subsoiling on the vertical distribution of soil microorganisms, two treatments with four replications were selected. Treatments were: (i) bedding (standard-tillage check) and (ii) subsoiling and bedding. The soil was disked twice to a depth of 10 cm prior to bedding, and subsoiling and bedding. Plots were subsoiled to a depth of 35 cm under the planting row and bedded in the same pattern for three consecutive years. Each plot consisted of four 15.2-m rows spaced 95 cm apart. Beds 20-25 cm high were made with lister-bedders directly over the subsoil furrow. During the third year, plots were planted 29 May 1975 with cotton (*Gossypium hirsutum* L. 'Coker 310', 13.4 kg seed/ha) and were maintained throughout the growing season under recommended cultural practices.

Soil samples were collected at depths of 0-18, 19-38, 39-53, and 54-70 cm from two rows of each plot on 15 May 1975 (preplant) and on 10 October 1975 (harvest) with an 8.1-cm diameter bucket auger. Six cores (three per row) from each depth of each plot were mixed thoroughly and a 500-cm^3 subsample was withdrawn for the assays.

Nematodes and spores of vesicular-arbuscular mycorrhizal fungi were extracted from a 100-cm^3 aliquant of each sample by the centrifugal-flotation method (8). Dilution plate methods were used for isolating *Pythium* spp. (6), and *Fusarium* spp. (10) from the soil. The method and selective medium of Ko and Hora were used for the isolation of *Rhizoctonia solani* Kuehn (9).

RESULTS AND DISCUSSION

Subsoiling had little influence on the occurrence or vertical distribution of plant-parasitic nematodes or selected soil fungi. Subsoiling the plots in the same pattern for 3 yr increased the population density of *Fusarium* spp. at the 39-53 soil depth, but had no effect on *Fusarium* spp. at other depths, or on *R. solani, Pythium* spp., or plant-parasitic nematodes at any depth of the soil profile. Subsoiling caused a decrease in counts of mycorrhizal fungi at the 54-70 cm level, but had no effect at other levels. Similar results were obtained in another field in which *M. incognita* was the principal plant-parasitic nematode (Hussey, *unpublished*). These findings are contrary to recent research involving soybean where *Hoplolaimus columbus* populations increased significantly in the 33- to 46-cm zone following subsoiling (11). Soybean yields did not increase in response to subsoiling the 2nd yr unless the soil was fumigated with a nematicide, whereas during the first year subsoiling alone increased soybean yields equal to that of fumigation alone. In a similar study with cotton, however, the combination of subsoiling and a nematicide did not significantly increase seed cotton yields over subsoiling alone during the 3 yr the study was conducted (7). Subsoiling and bedding resulted in a doubling of plant height and enhanced seed cotton yields by more than 200% over that of plants that received bedding treatment alone (7). We believe the different results with soybean and cotton occurred because soybean supports much higher populations of *H. columbus* than does cotton.

Vertical distribution of soil fungi is related primarily to the distribution of plant roots and soil organic matter (14). The percentage of organic matter in the soil at the deeper levels (Table 1) should increase over a period of time since subsoiling promotes greater penetration of roots into the subsoil (2). Root sections were present in all samples at all depths from subsoiled plots and only in the shallow samples from nonsubsoiled plots. Whether an increase in organic matter will be sufficient to support greater populations of soil fungi is unknown. However, other conditions (e.g., pH, soil type, O_2 levels) at the lower depths may be unfavorable for growth of microorganisms even in the presence of organic matter. In a study involving root rot of bean, propagules of *F. solani* f. sp. *phaseoli* were confined principally to plowed soil layers (4).

The population densities of some soil microorganisms were influenced by season. This effect is apparent in Tables 2 and 3 in which data from both treatments were

TABLE 1. Characteristics of soil in field plots at Midville, Georgia, used to study the influence of subsoiling on the vertical distribution of microorganisms[a]

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Organic matter (%)	pH	P (μg/g)	K (μg/g)	Ca (μg/g)	Mg (μg/g)
0-18	73.2	9.1	17.7	0.73	6.2	56	95	406	56
19-38	69.1	9.6	21.3	0.53	5.7	30	69	292	48
39-53	52.5	8.3	39.2	0.61	5.1	5	84	346	66
54-70	49.3	9.7	41.0	0.37	5.1	3	49	342	60

[a]Soil samples were collected November 1974. Analyses were made by the Soil and Plant Analytical Laboratory, University of Georgia, Athens.

TABLE 2. Effect of soil depth and sampling time on distribution of populations of specific plant-parasitic nematode species within soil beneath cotton plants

	Nematodes (per 100 cm^3 of soil)					
	Hoplolaimus columbus		*Meloidogyne incognita*		*Helicotylenchus* spp.	
Depth (cm)	Preplant[y] sample	Harvest sample	Preplant sample	Harvest sample	Preplant sample	Harvest sample
0-18	109 a[z]	590 a	3 a	105 a	29 a	174 a
19-38	10 b	125 b	9 a	54 ab	26 a	235 a
39-53	11 b	35 b	14 a	41 ab	50 a	166 a
54-70	4 b	20 b	1 a	12 b	41 a	147 a

[y]Samples were taken 15 May (preplant) and 10 October (harvest), 1975. Data are means from two treatments.

[z]Column means followed by a common letter are not significantly different. Paired means within each nematode species differ from each other if one of the two is underlined ($P = 0.05$, Duncan's new multiple range test).

TABLE 3. Effect of soil depth and sampling time on distribution of specific soil fungi under cotton plants

Depth (cm)	Fungus populations					
	Pythium spp. (ppg)[x]		*Fusarium* spp. (ppg)		Endogonaceae (Spores/100 cm^3 soil)	
	Preplant[y] sample	Harvest sample	Preplant sample	Harvest sample	Preplant sample	Harvest sample
0-18	76 a[z]	62 a	2,137 a	1,528 a	2.6 a	38.4 a
19-38	7 b	12 b	423 b	721 b	0.3 a	16.4 b
39-53	8 b	9 b	600 b	291 b	0.3 a	0.5 c
54-70	3 b	6 b	356 b	387 b	1.5 a	0.1 c

[x]ppg = Propagules per gram of oven dry soil.
[y]Samples were taken 15 May (preplant) and 10 October (harvest), 1975. Data are means from two treatments.
[z]Column means followed by a common letter are not significantly different. Paired means within each fungal species differ from each other if one of the two is underlined ($P = 0.05$, Duncan's new multiple range test).

combined. Populations of *H. columbus* increased at all depths and *Helicotylenchus* spp. increased within the top 53-cm of the soil during the growing season (Table 2). Endogonaceae spores increased significantly during the growing season in the top 18-cm of the soil (Table 3). This seasonal variation corresponds with that reported by Sutton and Barron (13). *Pythium* spp. and *Fusarium* spp. essentially remained the same throughout the season (Table 3). These fungi, which maintain a high population with little fluctuation, may be good saprophytes or competitors, whereas microorganisms that have developed a high degree of parasitism, such as plant-parasitic nematodes and the endomycorrhizal fungi, are dependent upon the presence of plant roots to increase their populations and reach a maximum at the end of the growing season.

Reductions in populations of plant-parasitic nematodes and fungi generally were noted with increasing soil depth (Tables 2 and 3). *Hoplolaimus columbus* Sher, *M. incognita* (Kofoid and White) Chitwood and *Helicotylenchus* spp. were the predominant plant-parasitic nematodes present in the soil (Table 2). Both *H. columbus* and *M. incognita* were most abundant in the upper 18-cm of the soil profile. *Helicotylenchus* spp. were distributed uniformly within all four depths. Populations of *Pythium* spp., *Fusarium* spp., and the mycorrhizal fungi were reduced greatly below 18 cm (Table 3).

Rhizoctonia solani was detected in less than 1% of the soil samples assayed and occurred primarily in the upper 18-cm of the soil. The restricted distribution of *R. solani* within the upper soil surface was not unexpected since it is primarily a seedling pathogen which attacks cotton near the soil line (3). The *R. solani* populations were low and seasonal or treatment effects were not detected.

The top 18-cm of the soil was biologically the most active; this was reflected in greater microorganism population densities. These data suggest that the development of a deeper root system as a result of subsoiling (2) may be beneficial not only by increasing moisture and nutrient availability to the plants, but also by promoting root penetration into the subsoil where population densities of pathogenic microorganisms are low. Therefore, cotton plants with roots reaching to greater depths in the soil profile possess a distinct growth and survival advantage over shallow-rooted plants.

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