THE INFLUENCE OF MINIMUM TILLAGE ON POPULATIONS OF SOILBORNE FUNGI, ENDOMYCORRHIZAL FUNGI, AND NEMATODES IN OATS AND VETCH

D. J. MITCHELL, N. C. SCHENCK, D. W. DICKSON, AND R. N. GALLAHER

Advantages of minimum tillage over conventional tillage, which may include improved soil and water conservation, increased yields, more efficient time and labor utilization, and reduced energy input, may be augmented or compromised by the effects of tillage operations on the development of plant diseases. Few detailed studies have been conducted on the influences of minimum tillage on populations of plant pathogens or on diseases caused by viruses, fungi, and nematodes (1,2,4,5,6,8, 12,14).

Stalk rot of grain sorghum caused by Fusarium spp. was reduced and grain yield was increased under minimum tillage as compared to conventional tillage in each of 3 years of a study by Doupnik et al. (6). The incidences in wheat take-all, caused by Gaeumannomyces graminis, and of eyespot or footrot, caused by Cercosporella herpotrichoides, were lower after several years under minimum tillage as compared to conventional tillage (2,4). Although differences were not statistically significant, there were trends of higher incidences of maize chlorotic dwarf and maize dwarf mosaic viruses, greater disease severity, and lower yield in minimum tillage than in conventional tillage plots (1). Examples of diseases that have been observed to be problems in minimum tillage, include gray leaf spot of corn, caused by Cercospora zeae-maydis, and anthracnose of corn, caused by Colletotrichum graminicola (8). Information is not available on the effects of minimum tillage on the development of plant diseases caused by nematodes; however, great differences in populations of plant pathogenic nematodes have not been associated with tillage practices (1,5,12,14). With one exception (l), these studies have only considered an individual or closely related plant pathogens.

Since populations of microorganisms interact in soil and tillage practices will have direct and indirect effects on any given plant pathogenic microorganism, it is important to monitor as many of these interactants as possible and to determine their influences on each other and on crop production. This study was initiated to evaluate the effects of minimum tillage on populations of fungi and nematodes in vetch, which was grown after sorghum, and oats, which were grown after soybeans. It is intended to provide background information for more detailed studies on the effects of multicropping and minimum tillage on plant pathogenic fungi and nematodes as well as on beneficial organisms such as endomycorrhizal fungi (ll), actinomycetes, and bacteria.

D. J. Mitchell and N. C. Schenck are Associate Professor and Professor of Plant Pathology, D. W. Dickson is Professor of Nematology, and R. N. Gallaher is Associate Professor of Agronomy; University of Florida, Gainesville, FL 32611.

METHODS AND MATERIALS

The fields assayed in this study were maintained on the Green Acres

Gainesville. Populations of the microorganisms were followed in vetch (*Vicia villosa*) in the fourth year of a vetch-grain sorghum (*Sorghum bicolor* "DeKalb BR64") rotation and in oats (*Avena sativa* "Florida 501") in the fourth year of an oats-soybean (*Glycine max* "Cobb") rotation. Plots consisted of four repetitionsof minimum or conventional tillage of each crop in randomized complete block designs.

In studies on vetch, grain sorghum residue was harrowed three times and 30 pounds/acre of hairy vetch were planted with a drill in rows spaced 7 inches apart on 7 November 1979. Conventional tillage for the preceeding grain sorghum consisted of two rototill passes before planting in April 1979; grain sorghum was planted directly in the vetch stubble in the minimum tillage treatments. The vetch was topdressed with 18-14-85-4-2 pounds/acre of N-P-K-Mg-S plus 30 pounds/ton of Frit 503 trace elements on 28 December 1979. Vetch dry matter yield was determined on 3 April 1980 by collecting growth on a 25 ft^2 area at random near the center of each 1125 ft^2 plot.

In the studies on oats, soybean residue was left undisturbed on minimum-tillage oat-soybean sucession plots; conventional tillage plots were prepared by two passes with a harrow on 7 November 1979. Oats were planted in all plots with a drill in rows spaced 7 inches apart at 144 pounds/acre on 7 November 1979. One pint of 2-4 D/acre was broadcast over the oats on 27 December 1979 to control winter annual broadleaf weeds. The oats received the same fertilization as the vetch in December but an additional application of 66 pounds of N/acre was made on 28 January 1980. Oat grain yield was determined by harvesting a 300 ft^2 area from the center of each 1125 ft^2 plot in mid May 1980.

Forty random soil samples from each plot were bulked to provide approximately 2 kg of soil. After thorough mixing, portions of each sample were assayed for various microorganisms. For soilborne fungi, dilutions of soil in water of 1:5,000 (wt:vol) were dilution-plated in potato dextrose agar containing 1 ml of Turgitol NPX, 100 mg of streptomycin sulfate and 40 mg of chlortetracycline HC1 per liter of medium (13). *Pythium* spp. from 1:25 dilutions of soil in water were isolated on Difco cornmeal agar containing 10 mg pimaricin, 250 mg ampicillin, 10 mg rifampicin, and 100 mg pentachloronitrobenzene per liter of medium (9). Bacteria and actinomycetes were isolated from 1:1,000,000 dilutions of soil in water dilution-plated in 0.3% tryptic-soy agar (10). Endomycorrhizal fungi were assayed by wet-sieving 40g subsamples of soil to collect spores and debris as described by Gerdemann and Nicolson (7); the sievings were then centrifuged in a 0.5 M sucrose solution and the supernatant was poured over a 230 mesh sieve (63% opening) to further free spores from soil debris. Spores were then washed onto a 15-cm Petri plate in 10-15 ml of water and examined under a dissecting microscope (20 to 70X) to count and identify spore numbers for each species of mycorrhizal fungus present. Nematodes were counted after extraction from soil by the centrifugal-flotation method of Caveness and Jensen (3).

RESULTS AND DISCUSSION

Although populations of soil fungi, bacteria, and actinomycetes were higher at harvest than at planting and also, except with Pythium spp. or actinomycetes, were higher in vetch than in oats, no significant differences appeared between populations in soils under minimum or conventional tillage (Table 1). Information is not available on the influence of minimum tillage on populations of bacteria and actinomycetes in soil, but they generally are of benefit to crop plants and it is significant in this study that they were not depressed by minimum tillage practices. Of the 1,658 soilborne fungi isolated and identified in a comparison of the mycoflora of soils under minimum or conventional tillage, Wacha and Tiffany (15) found only two species, Penicillium velutinum and Rhizopus oligosporus, that varied significantly with tillage treatments following the second year of soybeans in a corn-soybean rotation. The predominant fungi reported in their study were similar to those observed in this study. It is of significance that Trichoderma spp., which are considered beneficial because of their role in the decomposition of organic matter and possible biological control of plant pathogens, maintained higher populations under minimum than conventional tillage in this study.

There were qualitative and quantitative differences in species of mycorrhizal fungi present on each sample date for the various crop and tillage treatments (Table 2). There were consistently higher spore numbers associated with oats after soybeans than with vetch after sorghum. Immediately after crop harvest (November sample), spore numbers were higher in conventional than in minimum tillage plots, but these differences did not persist in later samples. Most spores recovered were from species in the genus Gigaspora; oats had three times as many Gigaspora spores as did vetch (Table 3). However, spores from species in the genus Acaulospora were more abundant from vetch than oat samples. Generally there were more spores from each genus in the conventional tillage than in the minimum tillage treatments. However, there was consistently higher root infection in the minimum tillage than the conventional tillage plots (Table 3). This would indicate that factors favoring root infection occur more with minimum than the conventional tillage practices. The importance of the positive effects of minimum tillage on beneficial organisms such as endomycorrhizal fungi and organisms antagonistic to plant pathogens is obvious. Research is needed on artificial infestation of plant debris under minimal tillage systems with organisms that will protect the host plants.

Populations of most of the five nematodes examined in this study behaved similarly under minimum tillage and conventional tillage (Table 4). Because of extreme variations in numbers of nematodes within replicate samples, statistical differences were not observed. Ring nematodes appeared to occur in lower numbers in vetch under minimum tillage than under conventional tillage, but populations appeared to be slightly higher in oats under minimum as compared to conventional tillage. Root lesion nematodes also generally were slightly more numerous in oats under minimum as compared to conventional tillage. The total numbers of nematodes were influenced by the high populations of ring nematodes in vetch and of ring plus lesion nematodes in oats. Populations of lesion nematodes, Pratylenchus zeae and of spiral nematodes, *Helicotylenchus* spp., in corn were not influenced by methods of tillage (1), but Corbett and Webb (5) found that populations of Pratylenchus minyus and other migratory plant parasitic nematodes were reduced in wheat under minimum tillage when compared to conventional tillage. Southards (12) and Thomas (14) have demonstrated the significance of multiple seasons of study and variation of tillage treatments, respectively, in the evaluation of the effects of tillage on nematode populations. Direct plant damage by nematodes, as well as indirect damage due to interactions with other microorganisms, will be important factors in the future development of minimum tillage; it is important that disease and not just population dynamics be evaluated critically over multiple seasons in diversified soils and climates.

No significant differences were observed in the frequency of isolation of fungi from roots of vetch or oats grown under minimum or conventional tillage (Table 5). Plant disease symptoms were not apparent under either tillage system. No significant differences occurred in yields of vetch from minimum tillage (1975 pounds/acre) and conventional tillage (2095 pounds/acre) plots. Although data for the yield of oats were not available at the time of writing, yields were significantly greater (P=0.05) in 1979 under minimum tillage (62 bushels/acre) than under conventional tillage (53 bushels/acre).

The results of this preliminary investigation indicate that after 3 years of multicropping vetch-grain sorghum and oats-soybeans, plant diseases did not become serious hindrances to vetch or oat production under minimum tillage in north Florida. Future studies must develop a comprehensive understanding of the interactions of various organisms in crop development under minimum tillage.

LITERATURE CITED

1. All, J. N., C. W. Kuhn, R. N. Gallaher, M. D. Jellum, and R. S. Hussey. 1977. Influence of no-tillage-cropping, carbofuran, and hybrid resistance on dynamics of maize chlorotic dwarf and maize dwarf mosaic diseases of corn. J. Econ. Entomol. 70:221-225.
2. Brooks, D. H., and M. G. Dawson. 1968. Influence of direct-drilling of winter wheat on incidence of take-all and eyespot. Ann. Appl. Biol. 61:57-64.
3. Caveness, F. E., and H. J. Jensen. 1955. Modification of the centrifugal-flotation technique for the isolation and concentration of nematodes and their eggs from soil and plant tissue. Proc. Helminthol. Soc. Wash. 22:87-89.
4. Cook, R. J., and J. T. Waldher. 1977. Influence of stubble-mulch residue management on Cercosporella foot rot and yields of winter wheat. Plant Dis. Reptr. 61:96-100.
5. Corbett, D. C. M., and R. M. Webb. 1970. Plant and soil nematode population changes in wheat grown continuously in ploughed and in unploughed soil. Ann. Appl. Biol. 65:327-335.
6. Doupnik, Jr., B., M. G. Boosalis, G. Wicks, and D. Smika. 1975. Ecofallow reduces stalk rot in grain sorghum. Phytopathology 65: 1021-1022.

7. Gerdemann, J. W., and T. H. Nicolson. 1965. Spores of mycorrhizal Endogone species extracted from soil by wet sieving and decanting. Trans. Brit. Mycol Soc. 46:235-244.
8. Hardison, J. R. 1976. Fire and flame for plant disease control. Annu. Rev. Plant Pathol. 14:355-376.
9. Kannwischer, M. E., and D. J. Mitchell. 1978. The influence of a fungicide on the epidemiology of black shank of tobacco. Phytopathology 68:1760-1765.
10. Martin, J. K. 1975. Comparison of agar media for counts of viable soil bacteria. Soil Biol. Biochem. 7:401-402.
11. Schenck, N. C., and M. K. Kellam. 1978. The influence of vesicular arbuscular mycorrhizae on disease development. Fla. Agr. Exp. Sta. Bull. 798. 16 p.
12. Southards, C. J. 1971. Effect of fall tillage and selected hosts on the population density of Meloidogyne incognita and Pratylenchus zeae. Plant Dis. Reptr. 55:41-44.
13. Steiner, G. W., and R. D. Watson. 1965. Use of surfactants in the soil dilution and plate count method. Phytopathology 55:728-730.
14. Thomas, S. H. 1978. Population densities of nematodes under seven tillage regimes. J. Nematol. 10:24-27.
15. Wacha, A. G., and L. H. Tiffany. 1979. Soil fungi isolated from fields under different tillages and weed-control regimes. Mycologia 71:1215-1226.

TABLE 1. Populations of soilborne fungi in soil planted with vetch or oats under minimum or conventional tillage.[z/]

Organism	Propagules of Microorganism/g of soil							
	Vetch				Oats			
	Oct. 1979		April 1980		Oct. 1979		April 1980	
	Min.	Con.	Min.	Con.	Min.	Con.	Min.	Con.
Pythium spp.	104	105	116	140	56	59	160	159
Fusarium spp. x 10^3	3.9	3.2	17.8	14.3	1.9	1.6	2.3	3.1
Trichoderma spp. x 10^3	1.7	1.0	9.0	6.1	0.8	1.3	3.3	1.7
Penicillium spp. x 10^3	3.2	4.1	6.3	4.0	1.4	0.7	3.3	4.1
Other fungi x 10^3	16.8	17.4	4.8	20.0	11.8	13.3	1.6	1.7
Total fungi x 10^3	26.3	26.8	83.4	81.0	16.3	17.1	74.0	80.0
Total bacteria x 10^6	13.1	8.7	32.8	32.1	7.3	9.2	15.0	16.4
Total Actinomycetes x 10^6	0.7	0.8	1.5	1.6	1.9	1.2	2.8	2.9

[z/] Minimum and conventional tillage plots were maintained for 3 years of multicropping; vetch followed grain sorghum and oats followed soybeans.

Table 2. Effect of minimum and conventional tillage practices on the spore numbers of vesicular-arbuscular mycorrhizal fungi per gram of soil at five month sample dates.

Crop and Tillage[y]	Spores/g of soil at sample date					
	1979		1980			
	November	December	January	February	March	
Oats-soybean						Mean
Minimum	2.36[z]	2.98	4.01	3.72	2.24	3.06
Conventional	4.48	2.53	3.69	3.02	3.31	3.49
Vetch-sorghum						
Minimum	1.52	1.38	1.55	1.75	1.29	1.50
Conventional	2.21	0.99	1.12	1.65	1.25	1.44
Mean	2.64	1.97	2.59	2.54	2.02	

[y]Minimum and conventional tillage plots were maintained for 3 years of multicropping; vetch followed grain sorghum and oats followed soybeans.
[z]Mean numbers of spores per gram of soil from four replicate samples.

Table 3. Effect of minimum and conventional tillage practices on the incidence of vesicular-arbuscular mycorrhizal fungi in soil and in roots of vetch and oats.

Crop and Tillage[y]	Mean numbers of spores/kg of soil of four genera of mycorrhizal fungi				Root colonization by mycorrhizal fungi
	Gigaspora	Acaulospora	Glomus	Sclerocystis	
Oats					(%)
Minimum	388[z]	35	53	7	9
Conventional	480	88	27	8	2
Vetch					
Minimum	104	129	20	2	38
Conventional	91	124	26	3	18

[y]Minimum and conventional tillage plots were maintained for 3 years of multicropping; vetch followed grain sorghum and oats followed soybeans.
[z]Mean numbers of spores from five monthly samples of 4 replicates per treatment.

TABLE 4. Populations of plant pathogenic nematodes in soil planted with vetch or oats under minimal or conventional tillage in north Florida.

			Number of Nematodes[Y]/250 cm^3 of Soil											
			Root lesion		Stubby Root		Root knot		Ring		Dagger		Total	
Sampling	Date	Crop	Min.[z]	Con.	Min.	Con.	Min.	Con.	Min.	Con.	Min.	Con.	Min.	Con.
October	1979	Vetch	12	3	9	9	4	4	9	6	3	3	37	25
November	1979	Vetch	8	9	20	21	1	17	144	297	30	16	173	360
January	1980	Vetch	11	11	4	9	9	6	60	107	4	11	88	144
February	1980	Vetch	3	2	2	3	0	0	59	86	0	0	64	91
March	1980	Vetch	2	0	18	12	0	0	30	132	3	8	53	152
October	1979	Oats	74	36	10	6	3	0	0	2	1	4	88	48
November	1979	Oats	44	28	24	11	3	1	64	17	7	4	142	61
January	1980	Oats	47	25	18	16	0	0	40	27	10	10	115	78
February	1980	Oats	2	9	1	1	0	0	11	9	2	0	16	19
March	1980	Oats	16	9	5	10	0	0	26	9	6	2	53	30

[Y] Root lesion nematode = *Pratylenchus brachyurus*, stubby root nematode = *Paratrichodorus christiei*, root knot nematodes = *Meloidogyne* spp., ring nematode = *Macroposthonia ornata*, dagger nematode = *Xiphinema* spp.

[z] Minimum and conventional tillage plots were maintained for 3 years of multicropping; vetch followed grain sorghum and oats followed soybeans.

Table 5. Frequency of isolation of fungi from roots of vetch or oats grown under minimum or conventional tillage.

	Frequency of isolation (% of plants)[z/]			
	Vetch		Oats	
Fungus	Minimum Tillage	Conventional Tillage	Minimum Tillage	Conventional Tillage
Pythium spp.	100	100	100	100
Pusarium spp.	85	74	aa	90
Trichoderma spp.	65	63	63	60
Penicillum spp.	68	50	60	55
Aspergillus spp.	3	3	5	5
Curvularia spp.	5	10	0	3
Rhizopus sp.	3	15	5	0

[z/]Surface disinfested roots were plated on potato dextrose agar containing 200 mg of streptomycin/liter of medium; data presented as % of plants with roots infected (20 root systems/plot collected).