Root Diseases of Snapbean and Southern Pea in Intensive Cropping Systems

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ABSTRACT

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Root diseases of snapbean and southern pea were studied in whole plots of cropping systems of snapbean-soybean-cabbage, turnip-corn-snapbean, turnip-peanut-snapbean, and turnip-cucumber-southern pea-turnip. Each cropping system was repeated each year for 4 yr. Subplots were treated with a nematicide, *O*-ethyl *S*, *S* dipropyl phosphorodithioate (ethoprop), or nontreated, and sub-subplots were treated with herbicides, ααα-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine + 2-*sec*-butyl-4,6-dinitrophenol (trifluralin + dinoseb) or nontreated. *Pythium* spp. (primarily *P. irregulare*) were isolated more frequently than other fungi from spring snapbean, and *Rhizoctonia solani* and cultures of *Fusarium solani* were isolated more frequently than other fungi from fall snapbean. The fungus most frequently isolated from southern pea was *R. solani*. Root diseases of snapbean were more severe in the fall than in the spring, but there were no differences between the two cropping systems in the amount of root disease in fall snapbean. Root diseases of southern pea were most severe, and southern pea yields were the lowest in the 4th yr of the study. Treating soil with ethoprop resulted in a significant ($P = 0.05$) increase in root disease severity in three spring crops of snapbean and one crop of southern pea, but treating soil with ethoprop did not influence severity of root disease in fall snapbean. Herbicide treatments occasionally reduced but never increased root disease severity. Soil populations of total *F. solani* increased in the snapbean-soybean-cabbage system and soil populations of *Pythium* spp. increased in the turnip-peanut-snapbean system. Total populations of *F. solani* and *Pythium* spp. frequently were the lowest in herbicide-treated soils, but treating soil with ethoprop rarely influenced populations of the soil fungi measured.

Additional key words: *Phaseolus vulgaris*, *Vigna unguiculata*.

Snapbean (*Phaseolus vulgaris* L.) and southern pea (protopea, cowpea) [*Vigna unguiculata* (L.) Walp.] are grown widely as food crops in the southeastern USA. Frequently they are grown in mono- or double-cropping systems in the spring or fall, but with the long growing season and mild winters in the southeast, three or four crops per year can be grown on the same land. Most disease control information has been developed in annual mono-crop systems (12, 13, 23), and may not be applicable to multiple cropping where diseases can be severe (24).

An additional factor in multiple-cropping systems is the increased use of soil pesticides, since pest control may be more difficult than in mono-cropping systems (26). Soil pesticides may increase root diseases of snapbean (20, 25, 28, 29), and herbicides and nematicides may influence root disease severity in other crops (6, 7, 19). The purpose of this investigation was to determine the influence of cropping systems, herbicides, and a nematicide on root disease severity in snapbean and southern pea.

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MATERIALS AND METHODS

Experimental design.—A 2-hectare (ha) experimental area was established at the Coastal Plain Station on Tifton, Carnegie, and Dothan loamy sand soils (approximately 75% sand, 16% silt, and 9% clay). A split split-plot experiment with a randomized complete-block design of five replications was used. Three replicates were entirely on Tifton loamy sand, but small areas of Dothan or Carnegie loamy sands were on the edges of the other two replicates. Whole plots were crops grown each year in the following sequences: (i) turnip-corn-snapbean, (ii) turnip-peanut-snapbean, (iii) snapbean-soybean-cabbage, and (iv) turnip-cucumber-southern pea-turnip. Crops in each sequence were grown in the same plots for four complete cycles in 4 consecutive years from February 1971 through March 1975. The first crop of each sequence was planted in February (turnip) or March (snapbean); peanut, cucumber, and corn were planted in April; southern pea was planted in June; fall crops of snapbean and turnip were planted in September; and cabbage was transplanted in November. Subplots were nematicide vs. no nematicide and sub-subplots were herbicides vs. only cultivation. Whole plots, subplots, and sub-subplots were 16.2 × 21.3 m, 9.1 × 16.2 m, and 8.1 × 9.1 m, respectively. Each sub-subplot contained five beds of 1.6 × 9.1 m. The

center bed was harvested for yield. Plant and soil samples were taken from the two beds adjacent to the middle bed.

Pesticide treatments.—A nematicide, *O*-ethyl *S*, *S* dipropyl phosphorodithioate (ethoprop) was applied as a granule (10% active) at 8.96 kg active ingredient (a.i.)/ha once each spring before planting the crop most susceptible to nematode injury in each system (snapbean or cucumber). Ethoprop was broadcast on the soil surface and immediately incorporated into the top 15-cm soil layer with a tractor-mounted, power-driven rototiller. Herbicides used on snapbean and southern pea were $\alpha\alpha\alpha$-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine (trifluralin) and 2-*sec*-butyl-4,6-dinitrophenol (dinoseb). Trifluralin at 0.56 kg a.i./ha was incorporated 5 cm deep with a tractor-mounted, power-driven rototiller just before planting. Dinoseb was sprayed on the surface at 1.68 kg a.i./ha as the plants were emerging. Recommended herbicides were used on the other crops within each annual cropping system for maximum weed control, as follows: (with kg a.i./ha); DCPA (8.96) on turnip and cabbage; nitralin (0.84) on cucumber; benefin (1.4), vernolate (2.24), and dinoseb (0.56) on peanut; vernolate (2.24), chloroxuron (1.12), linuron (1.12), and dinoseb (0.56) on soybean; and butylate (3.36), atrazine + oil (1.68), and ametryne (1.12) on corn. Each pesticide treatment and cropping sequence was maintained on the same sub-subplot for the duration of the experiment. The possible residual effects of pesticides on subsequent crops was not investigated.

Cultural practices.—The soil was disk-harrowed, then turned 25-30 cm deep with a mold-board plow after each crop was harvested. The next crop was planted as soon as possible. Snapbean or southern pea was planted within 2 to 7 days after incorporating green, succulent corn, cabbage, or cucumber foliage. Peanut plants were green when they were mechanically dug, but the vines were dried 3 to 7 days before the peanuts were threshed and the residues incorporated into the soil. An NPK fertilizer (5-10-15) was applied to each crop as necessary for optimum production based on soil tests. Dolomitic limestone (6,729 kg/ha) was applied in April 1971 and again in February 1972. Soil pH was maintained between 6.0 and 6.7 as measured in a saturated paste. The soils contained approximately 1.0% organic matter (wet oxidation) and had a bulk density of 1.5-1.6 g/ml. Crops were irrigated as needed to maintain soil moisture near field capacity. Rainfall was 113-135 cm/year, but varied from 1 to 27 cm/month.

RESULTS

Fungi isolated from seedlings.—In the spring crop of snapbean *Pythium* spp. (primarily *P. irregulare* Buis.) were isolated more frequently than other fungi from roots and hypocotyls of seedlings, but in the fall crops of snapbean *Rhizoctonia solani* and total cultures *Fusarium solani* were isolated more frequently than other fungi (Fig. 1). However, *P. aphanidermatum* (Edson) Fitzp. and *P. myriotylum* Drechs. were isolated frequently from fall snapbean seedlings during the last two years of the study. *Rhizoctonia solani* was isolated more frequently from fall snapbean following peanut than from fall snapbean following corn, but total cultures of *Fusarium solani* were isolated more frequently from snapbean following corn than from snapbean following peanut.

The fungi most frequently isolated from southern pea, in descending order, were: *Rhizoctonia solani*, *F. oxysporum*, and *Pythium* spp. Frequently more than one fungus was isolated from a section of tissue in both snapbean and southern pea.

Pathogenicity.—In greenhouse tests with cultures isolated from plant tissues, *R. solani* caused the most severe root and hypocotyl rot and pre- and postemergence damping-off in snapbean, but *P. myriotylum*, *P. aphanidermatum*, *P. irregulare*, and *S. rolfsii* also caused severe root rot. Cultures of *Fusarium solani* f. sp. *phaseoli* and *F. oxysporum* were less virulent. The most virulent root-rot pathogen on southern pea was *R. solani*, but *P. aphanidermatum*, *F. solani* f. sp. *phaseoli*, and *F. oxysporum* also were pathogenic. Isolates of *F. oxysporum* caused discoloration and decay of secondary roots, but not vascular wilt, in both bean and southern pea.

Snapbeans and southern peas were planted 2-5 cm apart and 2-5 cm deep in rows 0.9 m apart. Snapbean cultivar GV50 and southern pea cultivar Purple Hull Pinkeye were used throughout the test. Snapbean seeds were treated with tetramethylthiuram disulfide (thiram)

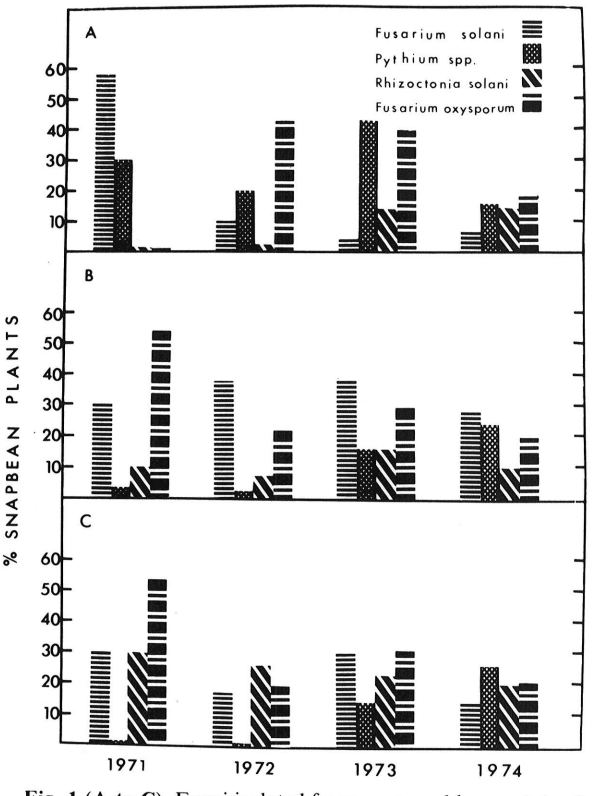

Fig. 1-(A to C). Fungi isolated from roots and hypocotyls of snapbean seedlings in three cropping systems grown each year from 1971-1974. Cropping systems and planting dates were: A = snapbean (March) - soybean - (June) - cabbage (November); B = turnip (February) - corn (April) - snapbean (September); and C = turnip (February) - peanut (April) - snapbean (September).

at 1.4 g/kg, with hexachloro-epoxy octahydroendo, exo-dimethanonaphthalene (dieldrin) at 0.4 g/kg, and with 1,4-dichloro-2,5-dimethoxy benzene (chloroneb) at 2.5 g/kg. In the fall crop of snapbean an in-furrow spray of chloroneb, 104 g/km of row, was applied at planting. No in-furrow fungicide was used with the spring crop of snapbean, or with southern pea. An insecticide, *O*, *O*-diethyl *O*-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate (diazionon), was used to control soil insects in southern pea and fall crops of snapbean.

Root disease evaluation.—Plants were examined for root diseases 2-4 wk after seeding. Plants were removed from three 30-cm-long sections of row in the inside row of each of the two beds adjacent to the center bed. The six subsamples were combined, the roots washed under running tap water, and the plants rated for root disease where 1 = <2%, 2 = 2-10%, 3 = 11-50%, 4 = > 50% discoloration or decay of roots and hypocotyls, and 5 = dead plants. Individual samples from sub-subplots ranged from 8 to 66 plants during the test. In each sub-subplot 1- to 2-cm-long tissue sections were removed from the hypocotyl and adjacent primary root of eight to 20 plants, selected at random. If there was decay on the hypocotyls, sections were removed from the margins of necrotic tissues. Tissues were washed 30-60 min under running tap water, surface disinfested for 15-30 sec in 0.5% NaOCl, blotted dry on sterile filter paper, and incubated on petri plates of water agar at 20-30 C. Fungi growing from the tissues were transferred to potato-dextrose agar and identified. Two or three cultures of each fungus were grown 2-3 wk on 3% cornmeal-sand (w/w) and this inoculum was used to infest soil for pathogenicity tests on snapbean and southern pea in a greenhouse. Tests were run in 15-cm diameter clay pots, and soil was watered twice each day to approximately 1/3 bar to prevent moisture stress. Soil temperatures 2-3 cm deep varied from 16.5 to 32 C during the tests. A Tifton loamy sand treated with methyl bromide in a closed tank (112 g/m^3) was used in each test.

Populations of soilborne fungi.—Soil samples were assayed on gallic acid agar (pH 6.25) for *Pythium* spp. (3), on modified PCNB agar (14) for *Fusarium solani* (Mart.) Appel & Wr., and *F. oxysporum* Schlecht., and on tannic-acid agar (2) for *Rhizoctonia solani* Kuehn. Soils were collected from the snapbean-soybean-cabbage system in January 1972, and in all systems in June 1972; February and July 1973; February and July 1974; and August 1975. Ten cores of soil (2.5-cm diameter) were taken 15-cm deep in each sub-subplot and combined. Cores were taken within the row when crops were present. In July 1974, 20 colonies of *F. solani* were selected at random from soil dilutions on modified PCNB agar from either the herbicide or nematicide-herbicide sub-subplots from each system. The selected isolates were transferred to water agar, then to test tubes of PDA and stored under mineral oil. The following winter the isolates were grown in flasks of 3% cornmeal-sand (w/w) and this inoculum was used to test for pathogenicity on GV50 snapbean, Purple Hull Pinkeye southern pea, and soybean (*Glycine max* L. Merr. 'Davis') in a greenhouse. Colonies of *Pythium* spp., and *F. oxysporum* from soil dilution plates were not tested for pathogenicity.

Differences in cropping seasons (spring vs. fall).—Soil temperatures 10 cm deep ranged from 10 to 26 C in the spring crop and from 25 to 37 C in the fall crops during the week after planting, according to Coastal Plain Station meterological records. Postemergence damping-off was greater in the fall crops of snapbean than in the spring crop (Table 1). After the first year, root diseases were slighlty more severe in the fall crops of snapbean than in the spring crop, even though an in-furrow chloroneb spray was used in the fall crops (Table 2). There were no significant differences ($P = 0.05$) between the two fall crops in plant stands 3 to 5 wk after planting. Root disease severity did not increase from year to year in any system; nevertheless, yields of snapbean decreased each year in the spring system (Table 2). In the fall crops, there were no differences in yield among the cropping systems. Root diseases in southern pea were the most severe in the 2nd and 4th yr of the study (Table 3).

Decaying mature and immature plant residues (i.e., corn stalks and roots, peanut pods and stems, cabbage roots and stems) were frequently observed in contact with, or a few millimeters from hypocotyls or primary roots of both snapbean and southern pea seedlings, even though the soil was turned with a mold-board plow before planting. However, no data were taken on the amount of

TABLE 1. Root diseases indices, post-emergence damping-off, and yields in snapbean or southern pea grown in intensive cropping systems for 4 successive years[a]

Cropping system and planting date	RDI[b]	Post-emergence damping-off (%)	Yield[c] (kg/ha)
Snapbean (March) - soybean (July) - cabbage (Nov.)	1.86	1.8	3,228
Turnip (Feb.) - corn (April) - snapbean (Sept.)	1.96	3.5	2,206
Turnip (Feb.) - peanut (April) - snapbean (Sept.)	2.05	5.6	2,994
Turnip (Feb.) - cucumber (April) - southern pea (July) - turnip (Sept.)	2.06	1.3	1,928

[a]Data are averages of 4 yr.

[b]The abbreviation RDI = root disease index where 1 = <2%, 2 = 2-10%, 3 = 11-50%, 4 = >50% discoloration or decay of roots and hypocotyls, and 5 = dead plants.

[c]Yield in green pods and shelled peas in snapbean and southern pea, respectively. Fall snapbean yields are an average of 3 yr because the plants were killed by an early freeze in the 4th yr.

residue incorporated into the soil, or the number of plants growing in contact with decaying residues.

Soil pesticides and root diseases.—Root disease severity was increased significantly by ethoprop in the spring crop of snapbean in 3 of the 4 yr and in the 2nd yr the yield was reduced significantly by ethoprop in the spring crop (Table 2). The isolation of *Pythium* spp. from roots and hypocotyls was correlated significantly ($P = 0.05$) with root disease severity ($r = 0.53$). Ethoprop did not affect root disease severity in the fall crops.

Significantly less root disease occurred in the spring snapbean crop in the 1st yr in herbicide-treated plots than in nontreated plots, but there were no differences in later spring crops (Table 2).

Root disease severity was increased in southern pea in ethoprop-treated plots in the 2nd and 4th yr (Table 3).

Cropping systems and soil-pesticide interactions.—Root disease severity in snapbean was

TABLE 2. Root disease severity and yield in snapbean plants grown in soil treated with a nematicide and herbicides in three annual cropping systems

		Year							
		1971		1972		1973		1974	
Cropping[w] system	Soil[x] treatment	RDI[y]	Yield (kg/ha)[z]	RDI	Yield (kg/ha)	RDI	Yield (kg/ha)	RDI	Yield (kg ha)
Spring crop SSbCa	C	2.1 a	5,613	1.9	3,870 a	1.8 ab	2,043 b	1.4 a	939 ab
	H	1.6 b	5,704	1.5	3,833 a	1.6 b	4,147 a	1.8 a	1,933 a
	NC	2.5 a	4,588	2.0	2,234 b	1.9 a	1,951 b	1.6 a	481 b
	NH	2.0 b	5,320	1.9	2,704 b	1.9 a	4,482 a	2.4 b	1,756 a
Fall crop TCoS	C	2.0	2,410	1.9	3,321	1.7	1,067	2.3	
	H	1.9	2,538	1.7	2,948	1.9	1,189	1.9	
	NC	1.9	2,257	2.0	3,247	1.8	884	2.3	
	NH	2.1	2,544	1.9	2,869	1.9	1,201	2.1	
TPS	C	1.6 b	2,355	1.8 b	3,998 a	2.0	1,667	1.8	
	H	1.9 b	2,581	2.5 a	2,448 b	1.9	1,330	2.4	
	NC	2.4 a	2,391	2.0 b	4,077 a	2.0	1,744	2.0	
	NH	2.0 b	2,324	2.5 a	2,667 b	2.0	1,141	2.1	

[w]Abbreviations for cropping systems: SSbCa = snapbean (March)- soybean (June) - cabbage (November); TCoS = turnip (February)- corn (April) - snapbean (September); TPS = turnip (February) - peanut (April) - snapbean (September).

[x]Abbreviations for soil treatments: C = cultivated, no pesticides for nematode or weed control; H = herbicides, trifluralin + dinoseb; N = nematicide, ethoprop. Ethoprop was applied in each system each year before planting snapbean. Trifluralin + dinoseb was used on each crop of snapbean; other herbicides were used on other crops in each system.

[y]The abbreviation RDI = root disease index where 1 = <2%, 2 = 2-10%, 3 = 10-50%, 4 = >50% discoloration or decay of roots and hypocotyls, and 5 = dead plants.

[z]Yield of green pods. The fall crops were killed by an early freeze in 1974, and no yield data were taken. Numbers within a column in each cropping system followed by the same letter are not significantly different according to Duncan's multiple range test, $P = 0.05$. No letters indicate no differences.

TABLE 3. Root disease severity and yield in southern pea grown in soil treated with a nematicide and herbicide in a turnip-cucumber-southern pea-turnip annual cropping system

	Year							
	1971		1972		1973		1974	
Soil Treatment[w]	RDI[x]	Yield[y] (kg/ha)	RDI	Yield (kg/ha)	RDI	Yield (kg/ha)	RDI	Yield (kg ha)
C	1.5	3,874 ab[z]	2.2 b	1,093	1.5	1,904	2.5 b	835
H	1.4	4,466 a	2.2 b	1,147	1.6	1,897	2.6 ab	848
NC	1.4	3,691 b	2.8 a	1,471	1.8	1,806	3.0 a	847
NH	1.5	4,093 ab	2.5 a	1,349	1.7	1,607	2.8 ab	780

[w]Abbreviations for soil treatments: C = cultivated, no pesticides for nematode or weed control; H = herbicides, trifluralin + dinoseb, and N = nematicide, ethoprop. Ethoprop was applied once each year before planting cucumber. Trifluralin + dinoseb was used on each crop of southern pea; other herbicides were used on cucumber and turnip.

[x]The abbreviation RDI = root disease index where 1 = <2%, 2 = 2-10%, 3 = 11-50%, 4 = >50% discoloration or decay of roots and hypocotyls, and 5 = dead plants.

[y]Yield of shelled peas for processing.

[z]Numbers within a column followed by the same letter are not significantly different according to Duncan's multiple range test, $P = 0.05$. No letters indicate no differences.

influenced differently by herbicide-nematicide treatment combinations in different years (Table 2). In the 2nd yr, herbicides increased root disease severity in the turnip-peanut-snapbean system, but not in the turnip-corn-snapbean system, and yields of snapbean were reduced significantly in the turnip-peanut-snapbean system from 4,038 kg/ha in cultivated plots to 2,558 kg/ha in plots receiving herbicides. Root disease severity was correlated significantly ($P = 0.05$) with the isolation of *Pythium* spp. from seedlings ($r = 0.49$).

Root disease severity was also greater in the herbicide-treated plots of the turnip-peanut-snapbean system in the last year of the study, but then root disease severity was significantly correlated ($P = 0.05$) with the frequency of isolation of *R. solani* from seedlings ($r = 0.48$).

Populations of soilborne fungi.—In the snapbean-soybean-cabbage system, populations of total *F. solani* increased to significantly higher levels than in the other systems (Table 4). Populations frequently were higher in nontreated soils than in herbicide-treated soils, especially in the snapbean-soybean-cabbage system. Populations of *F. solani* increased significantly in plots treated with ethoprop [2,640 vs. 1,540 propagules/g of oven-dry soil (p/g) in the control] in January 1972, in the snapbean-soybean-cabbage system, but the nematicide treatment had no effect on populations of *F. solani* in other cropping systems. In greenhouse tests, 24, 5, and 1% of the isolates of *F. solani* were pathogenic [*F. solani* (Mart.) Appel & Wr. f. sp. *phaseoli* (Burk.) Snyd. & Hans.] on GV50 snapbean, Purple Hull Pinkeye southern pea, and Davis soybean, respectively. None of the isolates was pathogenic on all three crops. The isolates from soil in the turnip-peanut-snapbean system were more virulent on the three crops than the isolates from soil in the turnip-corn-snapbean system, but there were no differences in the numbers of pathogenic isolates from soils from the different systems.

The turnip-peanut-snapbean system increased populations of *Pythium* spp. in soil compared with the other systems in February 1973 and in 1974 (Table 5); populations were always lowest in the turnip-cucumber-southern pea-turnip system.

Herbicide treatments frequently decreased populations, especially in the snapbean-soybean-cabbage system (Table 5). Treatment with ethoprop significantly increased populations in the turnip-peanut-snapbean system in August 1973 compared with nontreated soil (49 vs. 33 p/g), but the nematicide had no influence at other times. Most propagules of *Pythium* spp. on soil dilution plates were *P. irregulare*, but *P. aphanidermatum* and several nonidentified species were also common.

Soils were assayed only for *R. solani* in February 1973, and populations ranged from 1.6-2.6 p/g. There were no differences in populations among cropping systems or pesticide treatments.

DISCUSSION

Root disease severity in snapbean and southern pea appeared to be related to complex interactions of propagule densities of pathogens, soil pesticides, and decomposing plant residues that increased inoculum

TABLE 4. Populations of total *Fuarium solani* in soils treated with herbicides or nontreated in four cropping systems

Cropping[w] system	Soil[x] treatment	Year						
		1972		1973		1974		1975
		Jan	June	Feb	August	Feb	July	August
TCoS	C		2,420[y]	1,880	1,880	1,480	1,010 a	1,960
	H		3,100	1,620	1,710	1,534	750 b	1,530
TPS	C		2,630	3,050	2,560	2,890	1,960 a	2,974
	H		3,190	3,180	3,060	2,210	1,640 b	2,714
SSbCa	C	1,900	2,630	3,080	3,560 a	3,790	4,640 a	3,980
	H	2,300	2,410	2,340	2,960 b	2,750	2,010 b	2,930
TCuSpT	C		1,580	1,810	1,300	1,910	1,850 a	1,460
	H		1,870	1,980	1,520	1,820	1,170 b	1,160
System avg.								
TCoS			2,760 a[z]	1,750 b	1,820 b	1,560 c	880 b	1,750 b
TPS			2,900 a	3,110 a	2,800 a	2,580 b	1,800 b	2,840 ab
SSbCa		2,050	2,520 a	2,710 a	3,260 a	3,270 a	3,330 a	3,450 a
TCuSpT			1,900 b	1,890 b	1,410 b	1,860 c	1,510 b	1,310 c

[w]Cropping systems abbreviations: TCoS = turnip-corn-snapbean; TPS = turnip-peanut-snapbean; SSbCa = snapbean-soybean-cabbage; and TCuSpT = turnip-cucumber-southern pea-turnip. The 4-yr experiment was completed when snapbean and turnip were harvested in November 1974, and cabbage was harvested in March 1975. The experimental area was fallow the remainder of 1975.

[x]Soil treatment abbreviations: C = cultivated, no herbicides; H = trifluralin + dinoseb on snapbean and southern pea, other herbicides on other crops in each system.

[y]Numbers within a cropping system (cultivated vs. herbicide) followed by different letters are significantly different according to Duncan's multiple range test, $P = 0.05$. No letters indicate no significant differences.

[z]Numbers for different cropping systems followed by different letters are significantly different, $P = 0.05$.

potential. Snapbean yields were low (1 to 5 metric tonnes/ha) in all cropping systems, even when weed and nematode populations were reduced and chloroneb was used as an in-furrow drench for partially controlling root diseases. With optimum irrigation, nitrogen fertilization, and plant populations, 10 to 13 tonnes/ha of snapbean can be produced in the Georgia Coastal Plain (22). *Rhizoctonia solani* (10) and *Pythium myriotylum* (4) were reported previously to be limiting factors in fall snapbean production, but our research shows that these and other pathogenic soil fungi also can cause root diseases in spring snapbean in Georgia. Yields of southern pea were satisfactory in the first year of the test, but were lowered dramatically in the 4th yr when root diseases were devastating and numerous wilted plants were observed in all soil treatments.

Recent research with a snapbean-snapbean-rye rotation showed that inoculum densities of *Rhizoctonia solani* (15) and *Pythium* spp. (9) were related directly to root disease severity in snapbean. However, the incidence of bean root rot is not necessarily related to inoculum levels, as a barley rotation increased inoculum density of *F. solani* f. sp. *phaseoli* but still reduced root rot (18).

TABLE 5. Populations of *Pythium* spp. in soils treated with herbicides or nontreated in four annual cropping systems

		Propagules/g of oven-dry soil				
		1973		1974		1975
Cropping[w] system	Soil[x] treatment	Feb.	August	Feb.	July	August
TCoS	C	85[y]	54	102	90	78
	H	81	46	112	64	61
TPS	C	159	49 a	185	152	98
	H	182	33 b	197	133	84
SSbCa	C	100 a	105 a	106	101 a	81 a
	H	48 b	44 b	84	34 b	43 b
TCuSpT	C	58	48 a	63	148 a	31
	H	79	22 b	56	48 b	41
System avg.						
TCoS		83 b[z]	50 ab	108 b	77 b	69
TPS		171 a	41 b	191 a	150 a	91
SSbCa		74 b	75 a	95 b	97 b	62
TCuSpT		68 b	35 b	60 b	64 b	36

[w]Cropping system abbreviations: TCoS = turnip-corn-snapbean, TPS = turnip-peanut-snapbean, SSbCa = snapbean-soybean-cabbage, and TCuSpT = turnip-cucumber-southern pea-turnip. The 4 yr experiment was completed when snapbean and turnip were harvested in November 1974, and cabbage was harvested in March 1975. The experimental area was fallow the remainder of 1975.

[x]Soil treatment abbreviations: C = cultivated, no herbicides; H = trifluralin + dinoseb on snapbean and southern pea, other herbicides on other crops in each system.

[y]Numbers within a cropping system (cultivated vs. herbicide) followed by different letters are significantly different according to Duncan's multiple range test, $P = 0.05$. No letters indicate no significant differences.

[z]Numbers for different cropping systems followed by different letters are significantly different, $P = 0.05$.

Research in other crops also suggests that inoculum density of *Pythium* spp. is not related to root disease severity caused by *Pythium* spp. (21). In our study, root disease was associated with increased populations of total *F. solani*, total *F. oxysporum*, and *Pythium* spp., but in a stepwide-regression analysis populations of soil fungi frequently did not explain the variability in root disease severity.

In other bean production areas, trifluralin and dinoseb increased root disease of snapbean caused by *R. solani* (20) and trifluralin increased root disease of navy bean caused by *F. solani* (28). In contrast, we observed increased root disease in herbicide-treated plots in only 3 of 12 snapbean crops, and herbicides had no effect on root diseases in southern pea. In greenhouse tests with Dothan loamy sand, trifluralin increased root disease caused by *P. myriotylum*, but reduced root disease caused by *P. irregulare* (25).

In our tests herbicides frequently reduced populations of *F. solani* and *Pythium* spp., especially in the snapbean-soybean-cabbage system. It is not known if differences were caused by a direct effect of the herbicides on the pathogens in soil or in the root lesions on crop hosts, by an indirect effect through reduction of weedy hosts in herbicide-treated plots, or by the influence of the pesticides on the soil microflora. In greenhouse tests trifluralin + dinoseb had no influence on soil populations of *R. solani* or *Pythium* spp. 4 wk after treatment (25).

In earlier greenhouse tests ethoprop treatments increased root disease caused by *P. myriotylum* but not that caused by *P. irregulare*, and consistently reduced growth of snapbean but not that of southern pea (25). In the current study under field conditions, root disease severity also was increased frequently in spring snapbean crops treated with ethoprop, and root disease severity was associated with increased injury by *Pythium* spp. In other tests, under field conditions, ethoprop significantly increased yields of snapbean (8) and southern pea (5), but the influence of the chemical on root disease severity was not measured. The chemical inhibited growth of *R. solani* in vitro and in petri plates of field soil (19). Nevertheless, we frequently isolated more cultures of *R. solani* from roots of snapbean seedlings grown in soil treated with ethoprop than from nontreated soil.

In our study, root diseases may have been increased by phytotoxins from decomposing plant residues, as has been reported in other investigations (27), but plant residues may have either detrimental or beneficial effects on root diseases (18). Green corn (16), mature corn (1, 11, 13), green cabbage (17), and snapbean (16) residues have reduced root rot of snapbean in greenhouse and field tests. However, residues were usually incorporated 8-28 days before planting in those tests, in contrast to 2 to 7 days before planting in our study.

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