Conservation Tillage and Seedling Diseases in Cotton and Soybean Double-Cropped with Triticale

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ABSTRACT

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A double-crop rotation of cotton-triticale-soybean-triticale was grown for 4–5 yr in three experiments on loamy sand soil. Tillage treatments were conventional (moldboard plowing 20–25 cm deep after burning triticale residues), no-till, row-till, and ridge-plant. Triticale residues were managed by burning or cutting the straw short (20 cm) or tall (60 cm) at harvest. Population densities of *Rhizoctonia solani* anastomosis group (AG)-4 in soil after triticale were low to moderate and similar among treatments. Population densities of *Pythium* spp. in soil were high and variable among treatments. Root and hypocotyl disease severity in cotton and soybean seedlings was low to moderate each year. In most years and crops, tillage and residue management treatments did not influence seedling disease or inoculum densities of pathogens. When there were differences, burning triticale residues and moldboard plowing improved seedling health.

In Georgia, *Rhizoctonia solani* Kühn anastomosis group (AG)-4 causes seedling diseases on numerous crops including cotton (*Gossypium hirsutum* L.) and soybean (*Glycine max* (L.) Merr.) (3,11,19). *Pythium irregulare* Buisman and other *Pythium* spp. may incite seed rot, feeder root necrosis, and stunting (15). Seedling and root diseases in multiple-cropping systems are influenced by tillage practices and previous crops (12,21–23). Moldboard plowing reduces the inoculum density of *R. solani* AG-4 in topsoil and Rhizoctonia root and hypocotyl rot but has less influence on inoculum densities of *Pythium* and *Fusarium* spp. compared to conservation tillage practices (21). Traditionally, most plant pathologists have recommended that plant debris be destroyed or buried (10). However, soil is more subject to wind and water erosion if conservation tillage practices are not used to maintain some plant residues on the soil surface.

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No-till increased the incidence of southern stem canker of soybean in the Georgia Piedmont and Tennessee (16,24), as well as the frequency of isolation of *F. oxysporum* Schlechtend.:Fr. from soybean in Delaware compared with conventional tillage (4). Seedling diseases in soybean in Arkansas were increased by double-cropping compared with conventionally planted soybean (7). Emergence and survival of cotton were reduced, and infestation of soil with *Rhizoctonia* (estimated by colonization of cotton petiole segments) was increased with conservation tillage following winter legumes compared with fallow in Alabama (14). In the Georgia coastal plain, population densities of *R. solani* were frequently lower following corn and rye than following legumes and vegetables (21,23). Populations of *R. solani* AG-4 were influenced by the presence or absence of susceptible hosts (soybean or rye) in Florida (13) but not by tillage methods.

In previous research in Georgia, full-season cotton produced higher lint yields than did cotton double-cropped with wheat, and burning wheat residues increased lint yield compared with planting cotton in no-till wheat residues (2). The objective of our research was to determine whether alternating cotton and soybean with the winter small grain triticale (*Triticosecale*) in a double-crop system with conservation tillage and residue management would suppress seedling losses to soilborne pathogenic fungi in cotton and soybean.

MATERIALS AND METHODS

The research was done on two fields of Tifton loamy sand (fine-loamy, siliceous, thermic Plinthic Kandiudults) under center-pivot sprinkler irrigation at the Coastal Plain Experiment Station, Tifton, GA. Crops were planted for 4–5 yr in a 2-yr rotation of cotton-triticale-soybean-triticale. In one field, a randomized complete-block design was used with four replications of tillage treatments. The four tillage treatments were moldboard plow, ridge-plant, row-till, and no-till. In a second experiment, the same four tillage treatments were applied in a stripped split-plot, and three residue management treatments were applied in strips to the tillage treatments. The residue management treatments were triticale straw burned after harvest, straw cut short (20 cm), or straw cut tall (60 cm) at harvest. The straw in all moldboard-plowed plots was burned before plowing, eliminating two disc-harrow tillage operations before plowing. Data for residue management treatments were compared among the three conservation tillage treatments. In tillage treatments where residues were burned, the harmonic mean was calculated to determine a least significant difference that could be used for the Duncan's multiple range test.

In an adjacent field under the same center-pivot irrigation system, a third experiment was conducted. The four tillage treatments were no-till or row-till with triticale residues and row-till or moldboard plowing after residues were burned. Plots in all experiments were six rows wide (5.5 m) and 7.6 m long. Cotton, soybean, and triticale were seeded at 11, 67, and 101 kg/ha, respectively. Cotton and soybean were planted 2.5 cm deep in rows 91 cm apart, and triticale was planted 1–2 cm deep in rows 15 cm apart. Cotton seeds were treated commercially with fungicides (carboxin, pentachloronitrobenzene, and metalaxyl; approximately 0.8, 0.8, and 0.3 g a.i./kg of seed, respectively), but soybean seeds were not treated with fungicides. Cultivars used were Beagle 82, triticale; Tifcot 56, cotton; and Twiggs, soybean, except that McNair 235 cotton was planted in field one in 1989. Rye (*Secale cereale* L. 'Wrens Albruzzi') was planted instead of triticale the first winter in field two, but triticale was used from 1988 through 1991 in all experiments. In 1988, cotton and soybean were planted in fields one and two, respectively, and the two crops were planted alternately for 4 yr.

In all years, triticale was planted during November or December and harvested for grain during late May. Soybean and cotton were planted during June, and harvested during October and November, respectively. Immediately after harvesting triticale, the row- and no-till plots were subsoiled before planting cotton or soybean. Paraquat was applied with a tractor-mounted sprayer before planting either cotton or soybean to kill existing vegetation. Fluometuron (1.68 kg a.i./ha) and fomesafen (0.42 kg a.i./ha) were applied through the irrigation water for preemergence weed control in cotton, and methazole (0.84 kg a.i./ha) and methylarsonic acid monosodium salt (2.24 kg a.i./ha) were applied with a tractor-mounted sprayer for postemergence weed control approximately 2 wk after planting. For soybean, metribuzin (0.42 kg a.i./ha) and chlorimuron (0.009 kg a.i./ha) were applied for preemergence weed control, and fluazifop (0.21 kg a.i./ha) and lactofen (0.22 kg a.i./ha) were applied for postemergence weed control.

After harvest, cotton stalks were lifted from the soil with a mechanical puller and chopped with a flail mower, and soybean residues were mowed. Before planting triticale, paraquat was applied by a tractor-mounted sprayer to kill existing vegetation. Fertilization materials and methods and other pesticides used in growing the crops were described previously (1). Most chemicals applied in crop production were metered through the irrigation water in the center-pivot sprinklers.

Soil cores (10 samples, 2.5 cm diameter, 15 cm deep) were collected in each plot during July and December 1987, and from mid-June to early July 1988–1991. All samples were assayed on tannic acid-benomyl medium (19) with a multiple-pellet soil sampler (8) for *R. solani*, *Rhizoctonia* spp., and other basidiomycetous fungi (20). Soil collected during July in 1987 and 1991 was assayed for *Pythium* spp. on P5ARP medium (9). Population densities of *R. solani* AG-4 were considered low, moderate, or high at <10, 10–20, and >20 cfu/100 g of oven-dried soil, respectively.

Each year 2- to 3-wk-old seedlings were dug in 0.3–0.5 m of row in four locations in the second and fifth rows in each plot and combined. Seedlings were washed and rated for root and hypocotyl discoloration as follows: none = <2%, slight = 2–10%, moderate = 11–50%, severe = >50%, and seedlings dead or dying from disease. Each sample ranged from 16 to 200 seedlings in soybeans and from five to 41 seedlings in cotton. Disease levels were considered very slight, slight, moderate, or severe if <5, 5–10, 11–50, and >50% of the seedlings had >50% discoloration and decay, respectively. In each crop, a 5- to 10-mm section of tissue was removed from a root or hypocotyl of five to 10 seedlings in all replications of each tillage treatment, and four or more replications of each residue management treatment (except in 1988). Tissues were surface-disinfested 0.5–1 min in 70% ethanol, rinsed in tap water, blotted dry on sterile filter paper, and incubated on petri plates of water agar. Hyphae growing from tissues were transferred to potato dextrose agar and identified. Isolations were made from a total of 1,063 cotton seedlings and 680 soybean seedlings. Selected isolates of *R. solani* AG-4 from seedlings and soil were tested for pathogenicity in a greenhouse. Plants in the two center rows of each plot (15.24 m of row) were counted 6–8 wk after planting.

In all experiments, data were analyzed by a PROC GLM SAS statistical analysis program (17). Duncan's multiple range test was used as a mean separation test. Data were transformed as necessary (square root transformations for small numbers [<100], $\log^{10}$ for large numbers [>100], or arcsine transformations for percents) for statistical analyses (18), but all data are reported as nontransformed values.

RESULTS

In the tillage experiment there were no differences ($P = 0.05$) in root and hypocotyl disease severity or in population densities of *R. solani* AG-4 in soil in any year (data not shown). Plants with severe root and hypocotyl rot averaged 9.6%, and population densities of *R. solani* AG-4 averaged 7.1 cfu/100 g of oven-dried soil. Population densities of *R. solani* AG-4 in soil were low to moderate in the tillage-residue management experiment and were similar among tillage systems. However, there were significant ($P = 0.05$) tillage × residue management × year interactions, among conservation tillage treatments (Table 1).

Table 1. Population densities of *Rhizoctonia solani* anastomosis group (AG)-4 and root diseases in cotton and soybean double-cropped alternately with triticale using different tillage and residue management practices

Tillage treatment	Triticale residue management	*R. solani* AG-4 (cfu/100 g)[w] Cotton 1987	Soybean 1988	Cotton 1989	Soybean 1990	Cotton 1991	Percent root and hypocotyl disease[x] Soybean 1988	Cotton 1989	Soybean 1990	Cotton 1991
Ridge-plant	Burn	0 aB[y]	3.3 aA	0 aA	3.3 aA	3.8 aA	0 bA	22 bA	26 aBC	13 aAB
	SS[z]	1.4 a	0 a	2.0 a	0 a	0 b	11 a	18 b	30 a	10 a
	TS[z]	0 a	2.2 a	1.6 a	0 a	0 b	0 b	56 a	19 a	9 a
Row-till	Burn	8.4 aA	1.1 aA	0 aA	17.9 aA	0 aB	0 aA	54 aA	54 aA	20 aA
	SS	0 b	0 a	2.0 a	11.4 a	0 a	4 a	30 a	28 b	16 a
	TS	0 b	4.4 a	0 a	32.5 a	0 a	1 a	29 a	48 ab	15 a
No-till	Burn	1.4 aB	0 bA	0 aA	17.9 aA	0 aB	3 aA	34 aA	40 aAB	15 aAB
	SS	0 a	1.1 b	2.0 a	6.5 a	0 a	2 a	58 a	25 a	16 a
	TS	0 a	8.8 a	1.6 a	3.3 a	1.9 a	6 a	26 a	27 a	19 a
SE		2.2	2.1	1.7	9.0	1.2	1.8	12.3	8.3	3.1
Moldboard plow	Burn	0 B	1.8 A	1.6 A	7.0 A	0 B	0 A	34 A	10 C	8 B

[w] Colony forming units per 100 g of oven-dried soil collected from mid-June to mid-July each year.
[x] Seedlings with more than 50% root and hypocotyl discoloration and decay 2–3 wk after planting.
[y] Numbers in columns of different triticale residue management treatments followed by different small letters and tillage-burn treatments followed by different large letters are different according to Duncan's multiple range test, $P = 0.05$.
[z] SS = stubble cut short, 20 cm; TS = stubble cut tall, 60 cm.

Table 2. Population densities of *Rhizoctonia solani* anastomosis group (AG)-4 and root diseases in cotton and soybean double-crops alternated with winter cereals using different tillage systems with and without burning triticale residues[v]

	R. solani AG-4 (cfu/100 g)[w]				Percent root and hypocotyl disease[x]			
Tillage	Cotton 1988	Soybean 1989	Cotton 1990	Soybean 1991	Cotton 1988	Soybean 1989	Cotton 1990	Soybean 1991
No-till	5.2	9.8	21.1	3.7	4 ab[y]	0	59	1
Row-till	2.6	3.9	29.2	0.0	5 a	1	26	1
Row-till (burn)[z]	2.6	3.9	11.4	5.5	0 b	1	27	1
Moldboard plow (burn)[z]	9.2	2.0	1.6	1.8	5 a	0	21	1
SE	3.3	2.2	10.8	1.9	1.5	1.0	10.9	0.3

[v] Cotton followed rye in 1988, but triticale was the winter cereal from 1989 through 1991.
[w] Colony-forming units per 100 g of oven-dried soil. Soil was collected from mid-June to early July each year.
[x] Seedlings with more than 50% root and hypocotyl discoloration and decay 2–3 wk after planting.
[y] Numbers in columns of tillage treatments followed by different letters are different according to Duncan's multiple range test, $P = 0.05$. No letter(s) indicates no significant differences.
[z] Triticale residues were burned before the tillage treatments.

Table 3. Plant stands in cotton and soybean following triticale with different tillage practices[y]

Tillage	Cotton 1987	Soybean 1988	Cotton 1989	Soybean 1990	Cotton 1991
Ridge plant	50 c[z]	248	54 b	317	123
Row-till	129 a	387	92 a	396	124
No-till	88 b	384	50 b	374	121
Moldboard plow	146 a	455	118 a	394	174

[y] Plants per plot (15.24 m of row) 6–8 wk after planting.
[z] Numbers followed by the same letter are not significantly different according to Duncan's multiple range test, $P = 0.05$. Absence of letters indicates no significant differences.

Also, when all tillage treatments combined with burning were compared, there was variation among years (Table 1). Root and hypocotyl discoloration and decay were very slight in soybean the first year and moderate in both cotton and soybean in subsequent years, and there were significant tillage × residue management × year interactions (Table 1). The moldboard plowing plus burning treatment reduced the severity of root diseases compared with some conservation tillage plus burning treatments in the last 2 yr of the investigation (Table 1).

In the second tillage-residue management experiment, population densities of *R. solani* AG-4 in soil and root and hypocotyl disease severity in cotton in 1990 increased following soybean-triticale in 1989 but were low in soybean in 1991 following cotton-triticale in 1990 (Table 2). There were no differences ($P = 0.05$) in population densities of AG-4 among tillage-residue management systems. Root and hypocotyl disease incidence was very low in cotton the first year, but burning triticale residues before row-till planting resulted in significantly reduced disease levels compared to treatments with row-till planting without burning or burning before plowing. Disease severity was very low in soybean during both years but moderate to high in cotton during the third year (Table 2).

Population densities of *Pythium* spp. in soil were high (760 cfu/g) and not different ($P = 0.05$) among treatments in cotton in the tillage experiment in 1987. In the tillage experiment in cotton in 1991, population densities in soil increased in no-till (285 cfu/g) compared to the other tillage treatments (113–156 cfu/g) ($P = 0.05$). Population densities averaged 761 cfu/g in the tillage-residue management experiment in 1987. Populations of *Pythium* spp. in 1991 were greater in the moldboard plowed-burn plots (1,082 cfu/g) than in the row-till–burn (538 cfu/g) and no-till–burn plots (732 cfu/g) and lowest in the ridge-plant–burn plots (291 cfu/g) ($P = 0.05$). No differences were found among residue management treatments in conservation tillage plots. In 1991 in row-till tillage treatments, burning residues reduced population densities (25 cfu/g) compared with cutting straw tall (224 cfu/g), but cutting straw short (96 cfu/g) was not different from burning or cutting straw tall treatments. There were no differences among residue management treatments in ridge-plant or no-till tillage treatments nor among tillage treatments with burning (68–160 cfu/g) ($P = 0.05$). A few of the colonies selected at random from P5ARP medium in 1987 were *P. irregulare* and *P. spinosum*, but most of the colonies were not identified to species. In 1991, five of 10 colonies selected at random were identified as *P. irregulare*.

There were significant differences in variances among years in inoculum densities of *R. solani* AG-4 and in root and hypocotyl disease severities. There were more root and hypocotyl diseases in both cotton and soybean in the third year than in the other years, and population densities in soil were higher the third year than in other years (Tables 1 and 2).

Plant stands 6–8 wk after planting were frequently improved by moldboard plowing before planting cotton but not before planting soybean in the tillage experiment (Table 3). Seeds were sometimes not covered with soil uniformly during planting in conservation tillage treatments during the first two years of the experiments. Thus, physical factors probably influenced final stand more than seedling diseases. In the tillage-burn experiment there were no differences ($P = 0.05$) in final stand among the no-till, row-till, row-till (burn), or moldboard plow (burn) treatments (data not shown).

Fungi isolated most frequently from cotton seedlings were *F. oxysporum*, *F. solani* (Mart.) Sacc., *Fusarium* spp., *R. solani* AG-4, and other unidentified *Rhizoctonia* spp.: 7, 6, 5, 4, and 3%, respectively. No fungi were isolated from 52% of the plants. In the second year more unidentified *Fusarium* spp. were isolated from seedlings in the plowed (28%) than in the ridge-plant (10%), row-till (10%), and no-till (0%) plots. There were no differences ($P = 0.05$) in other years among tillage or residue management treatments in the frequency of isolation of any fungus.

Fungi were isolated more frequently from root and hypocotyl tissues in soybean than in cotton, and there were occasionally small differences among treatments. The fungi isolated most frequently from soybean were *F. solani*, *F. oxysporum*, *Fusarium* spp., *Rhizoctonia* spp., and *R. solani* AG-4: 13, 13, 5, 4, and 3%, respectively. *Marasimus* (= sterile white basidiomycete) and *Pythium* spp. were isolated only in one year, and then from <1% of the seedlings. In the third year *F. oxysporum* was isolated from more seedlings in the ridge-plant (30%) than in the row-till (5%), plowed (5%), or no-till (0%) plots ($P = 0.05$). In the last year of the second tillage residue management experiment, more *R. solani* AG-4 was isolated from seedlings in no-till (15%) than in row-till (0%), row-till (burned) (5%), or plowed (burned) (0%) plots ($P = 0.05$). In other years there were no differences among tillage or residue management treatments.

In pathogenicity tests in a greenhouse, *R. solani* AG-4 was the most virulent pathogen of seedling cotton, causing both pre- and postemergence damping-off. Other isolates from these experiments were not tested, but isolates of *F. oxysporum*, *F. solani*, *Pythium* spp., and unidentified *Rhizoctonia* spp. from soil collected in other fields on the station caused slight to moderate root and hypocotyl discoloration and decay in both crops. Some isolates of *Marasimus* spp. caused moderate to severe root and hypocotyl rot on soybean, but cotton was resistant to the *Marasimus* fungal complex.

DISCUSSION

Cotton and soybean were grown successfully with low levels of seedling diseases in conservation tillage following triticale harvested for grain. Similar results probably could be expected with other winter cereals grown for grain, but seedling disease intensity might be different if cotton or soybean were planted during late April or early May before the small grain matured. In previous research at the Coastal Plain Experiment Station, lint yields were increased by planting a full-season cotton after fallow compared with planting double-cropped cotton after wheat (2).

In continuous cropping of cotton with winter fallow, seedling diseases were increased, and plant stands were reduced with conservation tillage in Louisiana and Tennessee, and in-furrow treatment with soil fungicides at planting was beneficial (5,6). However, with the low levels of seedling disease observed in the triticale-cotton-triticale-soybean rotation, treatment with in-furrow fungicides will probably be unnecessary and not economically feasible. Cotton was planted after soil temperatures were above levels where seedling diseases caused by *Pythium* spp. usually occur (15), and population densities of *R. solani* AG-4 in soil were suppressed to low to moderate levels by including triticale in the rotation.

In Arkansas, planting double-cropped soybean into wheat stubble reduced seedling diseases compared with plowing and discing. However, burning wheat residues and discing before planting reduced seedling diseases (7). In our research in most years and crops, tillage and residue management treatments did not influence seedling disease or inoculum densities of pathogens. When there were differences, burning and moldboard plowing improved seedling health. Burning eliminates two disc-harrow tillage operations and kills weeds but causes air pollution and removes organic matter necessary to reduce soil erosion and improve soil tilth. Tillage 15-cm deep did not result in reduced propagule densities of *R. solani* AG-4 compared with no-till in double-cropped rye-soybean in Florida. In contrast, there were decreased propagule densities of *Rhizoctonia* spp., *Pythium* spp., and *P. irregulare* when tillage was compared with no-till (13).

Though burning and moldboard-plowing treatments reduced seedling diseases in some experiments and years, those management practices also reduced the food base for various basidiomycetes and other fleshy fungi (1). The saprophytic activity of those and other fungi in colonizing small grain residues may be beneficial in suppressing the inoculum potential of pathogens to low levels for a sustainable agricultural system.

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