Impact of Stale Seedbed Production on Seedling Diseases in Cotton

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ABSTRACT

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Cotton production using conservation tillage practices has increased in the past decade. Most studies involving reduced tillage have shown a reduction in plant populations, which has been attributed to seedling diseases. Although most of these studies have focused on no-till production, cotton planted in the mid-south is often planted using stale seedbeds. The objective of this research was to compare the effect of stale seedbed production and conventional tillage with and without in-furrow fungicides on the incidence and severity of seedling diseases. Tillage systems were established in the fall to focus on the effect of tillage on inoculum density and distribution and to minimize differences in the soil environment between tillage treatments. From 1998 to 2001, cotton was planted and seedling disease was evaluated by counting surviving plant populations, estimating stand uniformity, and conducting root and hypocotyl disease indices. Soil populations of *Pythium* spp. and *Rhizoctonia* spp. were also estimated. Plant populations were significantly different between tillage treatments in 1998 and between in-furrow treatments in 2000. Skip variables were not different in any year. Soil populations of *Rhizoctonia* spp. were highly variable and not significantly different among treatments in any year. Populations of *Pythium* spp. were higher in stale seedbed plots in 2000 and 2001. There were no differences in seed cotton yield in any year. In this study, stale seedbed production increased the incidence and severity of seedling diseases of cotton in only one of four years, but the disease was effectively managed with the application of in-furrow fungicides. These results indicate that the potential for an increase in seedling diseases associated with stale seedbed production is minimal and is not sufficient to overlook the potential benefits of this tillage system.

Additional keywords: *Rhizoctonia solani*

Cotton has traditionally been produced using extensive tillage operations that include disking prior to forming beds. Forming the beds often involved the use of an implement (ripper/hipper) that subsoiled (ripper) and formed beds (hipper) in the same operation. In recent years, there has been an increase in reduced tillage practices for cotton production. Conservation tillage is defined as any tillage and planting system that retains greater than 30% of crop residue on the soil surface after planting (12). There are many different approaches to conservation tillage that include no-till, mulch till, strip till, ridge till, and stale seedbed planting (25). The benefits of conservation tillage include reductions in soil erosion and in labor and energy inputs for production.

Although the benefits of reduced tillage are obvious, these practices have an impact on the physical and biological characteris-

tics of the soil that may directly or indirectly influence the development of plant diseases (5,6,16,19,30). In some crops, reduced tillage resulted in an increase in foliar diseases (4,15,26,29) and in root and lower stem diseases (31,34,35).

Seedling diseases in cotton are caused by *Rhizoctonia solani*, *Pythium* spp., *Fusarium* spp., and in some areas *Thielaviopsis basicola*, and these pathogens continue to cause significant disease losses (13). Several studies involving reduced tillage production in cotton have observed reductions in plant population, which have been attributed to seedling diseases (2,8,11,28,33). Most of these studies with cotton involved no-till practices and the use of winter cover crops.

One popular form of reduced tillage on clay soils in the mid-south is stale seedbed production. Under this system, the beds are formed in the fall over the old beds without disking and left idle until spring. When the new beds are formed, cotton stalks and other residue from the previous crop are concentrated in the bed and often are visible on top of the old bed. A cover crop may or may not be planted. The advantages of stale seedbeds are that they allow producers to reduce the number of field operations in the spring, which permits larger areas of land to be planted in less time and does not delay planting while preparing the beds. The role of this debris in the estab-

lished bed on the development of seedling diseases in the subsequent crop is not known.

The objective of this research was to compare the effects of stale seedbed production and conventional tillage with and without in-furrow fungicides on the incidence and severity of seedling diseases. Populations of *Rhizoctonia* spp. and *Pythium* spp. were also determined in each tillage treatment. Since tillage affects the density and distribution of inoculum and soil environmental factors, all tillage operations were conducted in the fall to minimize differences in the soil environment between tillage treatments. Minimizing soil environmental effects and the application of in-furrow fungicides assisted in discerning the impact of tillage on inoculum density and concentration.

MATERIALS AND METHODS

Experimental design and plot maintenance. Experiments were conducted on a Moreland clay soil located at the Red River Research Station in Bossier City, LA, from 1998 to 2001. Tests were arranged in a randomized complete block with a split-plot design of treatments with four replications. Main plots were tillage practices and split plots were with or without an in-furrow fungicide treatment. Main plots consisted of 16 rows that were 1.01 m wide and 135.7 m long. Split plots were eight rows by 135.7 m. The two tillage practices evaluated were reduced tillage (stale seedbed) and conventional tillage. To reduce any delays in planting and reduce the effects of tillage on soil temperature and moisture in the spring, all tillage operations were conducted in the fall. For the reduced tillage operation, beds were formed in the fall after harvest and stalk shredding without any disking. Under conventional tillage, the field was disked prior to forming beds. All treatments were fallow in the winter and maintained in the same plots in each of the 4 years of the experiment. Plots were sprayed with paraquat dichloride (Gramoxone Extra, Zeneca Ag Products, Wilmington, DE) approximately 2 weeks prior to planting to kill winter annuals. The in-furrow fungicide treatment was PCNB + etridiazole at 7.28 kg/ha (Terraclor Super X 18.8G, Crompton Co., Middlebury, CT).

Cotton was planted on 17, 17, 19, and 20 April in 1998, 1999, 2000, and 2001, respectively. Cotton cultivars were Paymaster 1220 BG/RR in 1998 and Deltapine 451B/RR (Delta Pine and Land Co., Scott, MS) in 1999 through 2001. All cotton seed

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were commercially treated with triadimenol, thiram, and metalaxyl (RTU-Baytan-Thiram and Apron FL, Gustafson Inc., Plano, TX). All plots were treated with aldicarb at 3.7 kg/ha (Temik 15G, Bayer CropScience, Research Triangle Park, NC) to control nematodes and early season insects. Plots were side-dressed with 32% liquid N at 67.7 to 78.4 kg N/ha approximately 4 to 6 weeks after planting. Weeds and insects were controlled according to Louisiana Cooperative Extension Service guidelines. Yield was determined by harvesting the two center rows of each plot with a mechanical harvester.

Disease incidence and severity. Seedling disease was assessed by counting surviving plant populations and rating the roots and hypocotyls of surviving plants. Plant populations were counted from a 30.5-m section from the fourth or fifth row in each plot at approximately 21 and 42 days after planting (DAP). At 42 DAP, stand uniformity was estimated by counting the number of skips and determining the average length per skip. A skip is defined as a distance greater than 30.5 cm between seedlings. A skip index was calculated by assigning a value of 1 for every 30.5-cm skip and adding one for every 15 cm greater than 30.5 cm (10). Root and hypocotyl disease indices were determined by arbitrarily removing 10 plants from each plot and estimating the extent of root and hypocotyl necrosis. The root disease severity index was based on a scale of 1 to 6, where 1 = no root discoloration, 2 = 1 to 19%, 3 = 20 to 40%, 4 = 41 to 60%, 5 = 61 to 80%, and 6 = >80% of the root system discolored. The hypocotyl disease severity index was based on a scale of 1 to 3, where 1 = no symptoms, 2 = nongirdling lesion, and 3 = girdling lesion.

Fungal populations. Soil samples were collected from each tillage plot prior to planting to a depth of 20 cm using a 2.5-cm-diameter sampling tube. Approximately 25 soil cores per plot were arbitrarily collected from the center of the planting bed from the two center rows. Soil samples were refrigerated at 2 to 5°C and assayed within 3 weeks of collection, except in 1999. In 1999, the soil samples were refrigerated for 6 weeks before assaying. Populations of *Pythium* spp. were quantified by dilution plating on P₅ARP medium (24). Twenty-five grams of soil were suspended in 250 ml of 0.2% water agar and shaken on an orbital shaker for 20 to 30 min prior to dilution plating.

Rhizoctonia spp. populations were determined using a beet seed assay (27). Fifty autoclaved red beet seeds were mixed with 100 g of soil in a 9-cm petri dish and incubated for 48 h. The seed were recovered on a 1.41-mm screen, washed under running water, and placed on 2% water agar. After 24 to 36 h, hyphal tips were transferred to potato carrot agar acidified with 50% lactic acid (PCAL) and identified. Starting in 1999, isolates identified as *Rhizoctonia* species were stained to determine the nuclear condition (1), and the anastomosis group (AG) of the *R. solani* isolates was determined by pairing isolates with known tester isolates on cellophane (9).

Environmental data. From 1998 to 2001, soil temperature was measured using an Onset Hobo soil temperature probe programmed to record soil temperature every 30 min. The probes were buried at 10 cm in the row in a stale seedbed plot. Rainfall data were recorded at a weather station less than 500 m from the field.

Statistical analysis. Since cotton seedling diseases are influenced by soil tem-

perature and moisture, and these parameters were highly variable among years, the data were analyzed by year. All experimental data were analyzed using analysis of variance for split plots using the general linear model (GLM) procedures of SAS (SAS Institute, Cary, NC). The hypocotyl disease index was square root transformed ($\sqrt{(X + 0.05)}$) prior to analysis. The root disease index was converted to the midpoint of the percentage range for each rating prior to analysis. Only main effects (tillage and fungicide application) means are presented in data tables, unless there was a significant interaction for any year.

RESULTS

Disease incidence and severity. There was a trend toward higher plant populations in the conventional tillage plots than in the stale seedbed plots in most years, but only in 1998 were plant populations at 21 and 42 DAP significantly higher with conventional tillage (Table 1). There were no significant differences in plant populations between tillage and in-furrow treatments in 1999 and 2001. The interaction between fungicide application and tillage was significant in 2000. Fungicides improved plant populations in the stale seedbed plots, but there was no difference between fungicide treatments in the conventional tillage plots.

None of the skip parameters were significantly different in any year (Table 2). Since plant populations were significantly different among tillage treatments in 1999, it would be expected that some or all of the skip parameters might be different, but skip index, average skip length, and number of skips were insignificant at $P = 0.08$, 0.07, and 0.07, respectively.

Table 1. Effect of tillage and in-furrow fungicide application on plant populations at 21 and 42 days after planting (DAP)

Tillage ^x	Plant population ^w					
	21 DAP			42 DAP		
	With fungicide ^y	Without fungicide	Mean ^z	With fungicide	Without fungicide	Mean
1998						
Conventional	220	211	215 *	188	188	188 *
Stale seedbed	178	175	177 *	144	143	144 *
Mean	199	193		166	166	
1999						
Conventional	201	197	199	200	195	198
Stale seedbed	212	198	204	211	198	205
Mean	206	197		207	197	
2000						
Conventional	316	320	318	322	325	323
Stale seedbed	311 *	277 *	294	325 *	285 *	305
Mean	314	299		323	305	
2001						
Conventional	303	302	303	281	295	288
Stale seedbed	281	297	289	256	277	267
Mean	292	300		269	286	

^w Plants per 30.5 m.

^x Conventional = plots are disked before forming beds; stale seedbed = plots are not disked before forming beds.

^y The fungicide was PCNB plus etridiazole (Terraclor Super X 18.8G) applied at 7.28 kg/ha.

^z Means down a column or across a row within a year designated with an asterisk indicate that tillage or fungicide effect was significantly different ($P \leq 0.05$). Interaction between fungicide and tillage was significant in 2000.

Disease indices were significantly different between in-furrow fungicide treatments only in 1999 (Table 3). The application of in-furrow fungicide lowered both root and hypocotyl ratings. Tillage had no effect on disease indices in any year.

Fungal populations. Soil populations of *Pythium* spp. at planting were significantly different among tillage treatments in 2000 and 2001 (Table 4). In both years, populations were higher in the stale seedbed plots than in the conventionally tilled plots. Overall soil populations were lower

in 1999 than in the other years. Soil samples in 1999 were stored for a longer period and may have resulted in a reduction in populations.

Populations of *Rhizoctonia* spp. were highly variable among plots, and there were no significant differences between tillage treatments. Fifty percent of the isolates were binucleate *Rhizoctonia* species. Most of the *R. solani* isolates were AG4, but there were four AG7 isolates. Two were recovered from a conventional tillage plot in 1999, and one each was recovered from a conventional tillage plot and a stale seedbed plot in 2000.

Seed cotton yield. There were no differences in yield between tillage treatments or between in-furrow treatments in any of the years (Table 5). There was an interaction between tillage and in-furrow application in 1999. For both stale seedbed and conventional tillage, yields were significantly different between application and no application of an in-furrow fungicide. Seed cotton yields were very low in 1998, presumably due to drought conditions. In 1998, from 1 June to 1 August, total rainfall was only 70.4 mm, and average air temperatures were 36.2 and 38.3°C in June and July, respectively.

DISCUSSION

Prior research has indicated that tillage affects diseases by either influencing physical properties of the soil, or through the survival of pathogens in plant debris and distribution of plant debris (5,30,32). Tillage operations for both tillage regimes were conducted in the fall to limit the differences in soil temperature, moisture, and other physical soil properties that might occur with spring versus fall soil disturbance. Under stale seedbed production, cotton debris is concentrated in the seed bed, while under conventional tillage disking tends to spread the debris over the entire plot area. The results of other research on the effects of reduced tillage on cotton seedling diseases have been variable, but most have reported a reduction in plant populations. In a 10-year study in Tennessee, plant populations were often reduced in no-till plots and often improved by the application of in-furrow fungicide at planting (11). In Alabama, plant populations were lower in conservation tillage plots than in conventional tillage, and in plots planted to a legume winter cover crop than in fallow soils (28). Batson and Caceres (2) did not observe any differences in plant populations between stale seedbed and conventional production systems. In a cotton-triticale double-cropping system over a 4- or 5-year period, cotton populations were reduced in the no-till plots compared with moldboard plowing (33).

Providing conditions for rapid seed germination and seedling emergence are often recommended for the management of seedling diseases. This includes delaying

Table 2. Effect of tillage and in-furrow fungicide application on mean skip index, average skip length, and number of skips

	1998	1999	2000	2001
Skip index ^v				
Tillage ^w				
Conventional	27.4	24.8	7.5	16.0
Stale seedbed	48.8	24.0	8.8	17.5
Fungicide ^x				
With	38.3	26.5	7.5	19.9
Without	37.9	22.4	8.8	13.6
Skip length (cm) ^y				
Tillage				
Conventional	43.2	39.9	38.9	49.5
Stale seedbed	52.3	40.6	35.5	42.7
Fungicide				
With	47.0	40.6	34.0	48.2
Without	48.5	39.9	39.9	43.9
Number of skips ^z				
Tillage				
Conventional	19.3	19.8	6.4	10.0
Stale seedbed	24.9	18.8	6.5	11.3
Fungicide				
With	22.8	21.4	6.3	11.6
Without	21.4	17.1	6.6	9.6

^v Mean sum of skip indices within a plot where 0 = no skips greater than 30.5 cm, 1 = skip 30.5 to 45.7 cm in length, and 1 for each additional 15.2 cm per skip. Means of tillage and fungicide treatments were not significantly different ($P \leq 0.05$) in any year.

^w Conventional = plots are disked before forming beds; stale seedbed = plots are not disked before forming beds.

^x The fungicide was PCNB plus etridiazole (Terraclor Super X 18.8G) applied at 7.28 kg/ha.

^y Average length (cm) of all skips within a plot. Means of tillage and fungicide treatments were not significantly different ($P \leq 0.05$) in any year.

^z Total number of skips per plot. A skip is defined as a distance of 30.5 cm or greater between plants. Means of tillage and fungicide treatments were not significantly different ($P \leq 0.05$) in any year.

Table 3. Effect of tillage and in-furrow fungicide application on root and hypocotyl disease indices

	1998	1999	2000	2001
Hypocotyl disease index ^w				
Tillage ^x				
Conventional	2.3	1.5	2.1	2.0
Stale seedbed	2.3	1.6	1.8	1.9
Fungicide ^y				
With	2.3	1.4 *	1.9	2.0
Without	2.2	1.7 *	2.0	1.9
Root disease index ^z				
Tillage				
Conventional	3.1	2.6	3.2	2.7
Stale seedbed	3.1	2.9	2.8	2.9
Fungicide				
With	3.2	2.4 *	2.8	2.8
Without	3.1	3.1 *	3.2	2.8

^w Hypocotyl disease index on a scale of 1 to 3, where 1 = no visible lesions, 2 = nongirdling lesions, and 3 = girdling lesion. Means down a column designated with an asterisk indicate that tillage or fungicide effect was significantly different ($P \leq 0.05$). Actual index values are shown, but the means were square root transformed ($\sqrt{X + 0.5}$) prior to analysis.

^x Conventional = plots are disked before forming beds; stale = plots are not disked before forming beds.

^y The fungicide was PCNB plus etridiazole (Terraclor Super X 18.8G) applied at 7.28 kg/ha.

^z Root disease index on a scale of 1 to 6, where 1 = no damaged roots, and 6 = between 80 and 100% of the roots damaged. Means down a column designated with an asterisk indicate that tillage or fungicide effect was significantly different ($P \leq 0.05$). Actual means are shown, but index values were converted to the midpoint of the percentage range for each rating prior to analysis.

planting until average soil temperatures are at least 18°C (14). In every year of this study, there were several days during the first 2 weeks after planting in which soil temperatures were below 18°C (Fig. 1). These conditions should have slowed seed germination and seedling emergence, and provided sufficient levels of seedling disease in the test for evaluation of treatment effects.

In this study, only in 1998 was tillage a significant factor on plant populations. Since there was no significant difference between no fungicide and in-furrow fungicide application this year, some factor other than seedling disease may have been responsible for the stand failure. With reduced tillage, others have observed an increase in cutworms (18,23) and poor seed bed preparation that results in reduced seed contact with the soil (23), which reduced stands. Although attempts were made in this study to control early season insects, rainfall after seedling emergence in 1998 delayed the application of insecticides to control cutworms. Extensive cutworm damage was observed in the plots, which most likely contributed to reduced plant populations.

In 2000, plant populations at 14 and 42 DAP were not different between in-furrow treatments in the conventional tillage, but were improved with a fungicide application in the stale seedbed plots. Nearly 250 mm of rainfall during the first 21 days after planting in 2000 resulted in extremely wet conditions. These wet soils and cool soil temperatures (Fig. 1) are conducive to seedling infection by *Pythium* spp. (21,22). Populations of *Pythium* spp. in the soil were significantly higher in the stale seedbed plots in 2000, and probably contributed to the increase in seedling disease in these plots. Populations were also higher in 2001 in the stale seedbed plots, but only 19 mm of rainfall occurred the first 21 days after planting.

None of the skip indices were significantly different, even in 1998 when tillage effects were significant and in 2000 when fungicide effects were significant. In 1998, all three skip indices were nearly significant. The lack of significance is most likely related to the high coefficient of variation (27.4 for the index; 36.3 for average length; 19.9 for number of skips) among the plots. In 2000, surviving plant populations exceeded nine plants per meter. At this high density of plants, skips longer than 30.5 cm are uncommon.

Seed cotton yield was not affected by in-furrow fungicide application or tillage treatment in any year, although plant populations were significantly different between tillage treatments in 1998 and between in-furrow treatments in 2000. Other researchers have failed to observe yield differences over a range of plant populations (3,7,17). The failure to observe yield differences despite differences in plant

Table 4. Effect of tillage practices on soil populations of *Pythium* spp. and *Rhizoctonia* spp. at planting

Tillage	1998	1999	2000	2001
<i>Pythium</i> spp. (propagules/g soil) ^y				
Conventional	583 a	89 a	497 a	452 a
Stale seedbed	628 a	90 a	557 b	876 b
<i>Rhizoctonia</i> spp. ^z				
Conventional	—	6.3 a	4.3 a	1.5 a
Stale seedbed	—	5.5 a	6.0 a	6.5 a

^y Means followed by the same letter within a year are not significantly different according to ANOVA ($P \leq 0.05$). Data based on the mean of five dilution plates for each replication. There were four replications.

^z Means followed by the same letter within a year are not significantly different according to ANOVA ($P \leq 0.05$). Based on the number of 50 beet seeds mixed with 100 g of soil that were colonized. Data were not collected in 1998.

Table 5. Effect of tillage and in-furrow fungicide application on seed cotton yield

Tillage ^y	Seed cotton (kg/ha) ^x		
	With fungicide ^z	Without fungicide	Mean
1998			
Conventional	710	771	740
Stale seedbed	750	720	735
Mean	730	745	
1999			
Conventional	2,069 *	1,962 *	2,015
Stale seedbed	1,962 *	2,071 *	2,016
Mean	2,015	2,016	
2000			
Conventional	1,719	1,719	1,719
Stale seedbed	1,842	1,847	1,845
Mean	1,781	1,783	
2001			
Conventional	1,519	1,513	1,517
Stale seedbed	1,391	1,556	1,473
Mean	1,455	1,538	

^x Tillage and fungicide effects were not significant in any year. There was a significant interaction in 1999. For both stale seedbed and conventional tillage, yields were significantly different between application and no application of an in-furrow fungicide.

^y Conventional = plots are disked before forming beds; stale = plots are not disked before forming beds.

^z Fungicide was PCNB plus etridiazole (Terraclor Super X 18.8G) applied at 7.28 kg/ha.

Fig. 1. Soil temperature at 10 cm from 1998 to 2001 for the first 30 days after planting.

populations is most likely related to the ability of the cotton plant to adapt its shape to compensate for reduced plant populations (17,20). Plants at lower populations have more mainstem nodes and monopodial branches (3,17) and greater fruit retention (3) and larger bolls (3,7). These components all contribute to yield and allow the plant to compensate for reduced plant populations.

In this study, plant populations were reduced by stale seedbed production in only one of four years. Since fungicides did not result in higher populations, the reduced plant populations were most likely associated with greater cutworm damage. In one year, the application of an in-furrow fungicide improved plant populations in the stale seedbed plots, but not the conventionally tilled plots. This demonstrates the potential for greater seedling disease in stale seedbed production, but it also demonstrates ability to manage seedling diseases with fungicide applications. Bockus and Shroyer (5) discuss the significance of fungicides to control diseases in reduced tillage production systems. Based on these results, stale seedbed production does not appear to present a significantly greater potential for the development of seedling diseases.

Previous studies frequently observed a stand response associated with no or reduced tillage (2,8,11). Although the response was attributed to pathogens, the means by which this response occurred was not always determined. The decrease in stand could be due to an increase in pathogen populations or concentration of pathogen inoculum in the row, which would warrant changes in tillage practices or in fungicide recommendations. Data from this study do not support an increase in pathogen populations or the concentration of inoculum in the row. The other reason for a reduction in plant populations associated with no or reduced tillage would be a change in soil environment. In this study, differences in the soil environment between tillage treatments were minimized by establishing the beds for all treatments in the fall. The lack of tillage response in this study compared with the other studies cited would indicate that changes in the soil environment were more important to stand establishment than inoculum levels. No or reduced tillage would increase the incidence and severity of seedling diseases and reduce plant stands by creating cooler or wetter soil environment for the same planting date. If environment is the critical factor in determining the incidence of cotton seedling

diseases in conservation tillage systems, the impact of tillage on seedling diseases could be diminished by changing the decision to plant from a calendar-based decision to one based on soil temperature.

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