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Evaluation of F_2 Genotypes of Cotton for Conservation Tillage

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ABSTRACT

Reduced plant populations often occur when cotton (*Gossypium hirsutum* L.) is grown in conservation tillage systems. Our objectives were to determine the potential of exploiting hybrid vigor in F_2 cotton to improve stand establishment and yield in conservation tillage systems and to compare the expression of heterosis in this system with that in a conventional tillage system. This field study was conducted in 1991, 1992, and 1994 on a Norfolk loamy sand soil (fine-loamy, silicious, thermic, Typic Kandiudult) near Florence, SC. Five cotton cultivars were crossed in a half-diallel design to generate 10 F_2 generation genotypes. The parent and F_2 generations were planted into conservation tillage plots that had desiccated crimson clover (*Trifolium incarnatum* L.) as a surface mulch and into conventional tillage plots. Cotton stands were similar for both generations in both tillage systems in 1991. At 2 wk after planting in 1992, a tillage × (Parent vs. F_2) interaction ($P \leq 0.05$) occurred for plant population as stands in conventional tillage were 7.5 and 8.4 plants m^{-1} for the parent and F_2 generations, respectively, while stands in conservation tillage were 4.1 plants m^{-1} for the parents and 4.2 plants m^{-1} for the F_2 generation. At 2 wk after planting in 1994, stands of the F_2 generation were 1.3 plants m^{-1} greater than the parents averaged over both tillage systems. Yield differences occurred only in 1992, when the F_2 generation had greater lint yield than the parents in both tillage systems. The results suggest that growing F_2 genotypes may improve cotton stand establishment and yield under certain conditions in conservation tillage systems, but the amount of improvement will be similar to that found in conventional tillage.

Reduced stands are a major disadvantage of using conservation tillage for cotton production (Bryson and Keeley, 1992). Bradley (1992) reported that cotton stands in conservation tillage were 75% of those in conventional tillage in 8 yr of research in Tennessee. Growing legume winter cover crops prior to cotton planting with conservation tillage can further increase stand establishment problems (Grisso et al., 1985; Brown et al., 1985; Hutchinson and Sharpe, 1989; Rickerl et al., 1989).

Improvements in seedling vigor and early plant growth can be achieved through the use of heterosis or hybrid vigor. As early as 1927, Brown (1927) observed that the F_1 generation from intraspecific hybrids was frequently larger, more vigorous, and more productive than the parents. In a study on growth and leaf area partitioning in cotton hybrids, Wells and Meredith (1986) attributed increased vegetative productivity of F_1 cotton to more rapid early growth. Hybrids in that study had a higher percentage of yield at first harvest than parents.

Commercial production of F_1 hybrid cotton seed is currently not economically feasible; however, heterosis has been reported in F_2 generation cotton (Meredith, 1990; Meredith and Bridge, 1972) and commercial F_2 seed is currently being marketed with reported vigor advantages. Tang et al. (1993) found environment × general combining ability and environment × specific combining ability interaction effects for lint yield heterosis of F_2 cotton. They suggested that F_2 populations be evaluated separately in each environment in which they are to be grown. This study was conducted to determine the potential for using hybrid vigor expression in the F_2 generation to improve cotton productivity in a conservation tillage system that included crimson clover as a winter cover crop.

MATERIALS AND METHODS

Five cotton cultivars, DPL Acala 90, DES 119, PD 3, Paymaster 145, and Coker 315, were crossed in a half-diallel design during the summer of 1989 to produce 10 hybrid combinations. The cultivars were chosen because they were developed in four different regions of the Cotton Belt (California, Texas, Mississippi, and South Carolina). All cultivars except Paymaster 145 were commercially grown in the southeastern USA at the time of the study. In 1990, the parents and F_1 plants were grown at Florence, SC, to produce the seed for this study.

The study was conducted at the Clemson University Pee

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Dee Research and Education Center near Florence, SC, (34° 11′ N latitude, 79° 43′ W longitude) in 1991, 1992, and 1994. Corn (*Zea mays* L.) was grown during the summer of 1990 in the field used in 1991. Winter wheat (*Triticum aestivum* L.)/summer fallow was the previous year's cropping history on the field used in 1992. Corn was the previous crop for the 1994 trial. The soil type of all fields was Norfolk loamy sand.

The entire experimental area was disked and harrowed before establishing the plots in the fall each year. 'Tibbee' crimson clover was planted with a grain drill in the conservation tillage plots on 21 October 1990, 22 October 1991, and 19 October 1993. Seeding rate of the clover was 22 kg ha^{-1}. Dry matter production of the crimson clover averaged about 1900 kg ha^{-1} in 1991, 2250 kg ha^{-1} in 1992, and 4100 kg ha^{-1} in 1994.

The experimental design was randomized complete block with treatments in a split-plot arrangement. Main plots were tillage system. The subplots were genotypes. Subplot size was two 0.97-m-wide × 10.7-m-long rows. There were four replicates each year.

Before seeding cotton, the conventional tillage treatment was disked and harrowed on 13 May 1991, 15 May 1992, and 3 May 1994. On the same days, paraquat dichloride (1,1′dimethyl-4,4′-bypridinium dichloride) was applied to desiccate all vegetation in the conservation tillage treatment. The plots were in-row subsoiled and then cotton was seeded with a four-row Case-IH 900[1] series planter at a rate of approximately 14 seeds m^{-1} of row. Seeding dates were 17 May 1991, 20 May 1992, and 25 May 1994. Seeds were treated with carboxin (5,6-dihydro-2-methyl-*N*-phenyl-1,4-oxathiin-3-carboxamide) and PCNB (pentachloronitrobenzene) before planting.

Emerged cotton plants were counted at 1 and 2 wk after planting in 1991. In 1992, counts were made at 1, 2, and 4 wk after planting; and, in 1994, we determined plant stands at 1, 2, and 3 wk after planting. Additional counts were made in 1992 and 1994 because stand establishment was slower than in 1991. Seedlings were counted as emerged if any part of the plant (including hypocotyl) was above the soil surface.

Plant nutrients (other than N) and lime were surface-applied in the spring before the clover was desiccated and the conventional tillage plots were disked. Application amounts were based on soil test results and recommendations of the Clemson University Extension Service (Clemson University Cooperative Extension Service, 1982). A N fertilizer application (as NH_4NO_3) of 78 kg N ha^{-1} was sidedress-applied at about 4 wk after planting in the conventional tillage plots in 1991 and 1992. In 1994, the conventional tillage plots received 45 kg N ha^{-1} at planting and another 45 kg N ha^{-1} at about 30 d after planting. Since clover was grown on the conservation tillage plots, no N fertilizer was applied to these plots in 1991 and 1994 and only 39 kg N ha^{-1} was applied in 1992. In 1991 and 1992, all N fertilizer was applied with a four-row applicator that placed the fertilizer on the soil surface about 15 cm to the side of the row. In 1994, this same applicator was equipped with fertilizer coulters (Yetter Manufacturing Co., Colchester, IL. Model No. 2975), and the NH_4NO_3 was placed approximately 10 cm below the soil surface and 15 cm to the side of the row.

Weed control in all plots was accomplished with a combination of herbicides and hand-weeding. Herbicides used at recommended rates and times were fluometuron [1,1dimethyl-3-(a,a,a-trifluoro-*m*-tolyl)urea], MSMA (monosodium acid methanearsonate), cyanazine {2[[4-chloro-6-(ethylamino)-s-triazin-2-yl]amino]-2-methylpropionitrile}, and fluazifop-P-butyl {butyl(*R*)-2-[4-[5-(trifluoromethyl)-2-pyridinylloxy] phenoxylpropanoate}. In addition, a shielded sprayer was used to apply paraquat dichloride to the row middles of the conservation tillage plots in early July of 1991. Between row cultivation was also used for weed control in the conventional tillage plots. Aldicarb [2-methyl-2(methylthio)propionaldehyde *O*-(methylcarbamoyl) oxime] was applied in-furrow at planting for early season insect control. Several different pyrethroid and organophosphate insecticides were applied during each season as insect infestations warranted.

Cotton was defoliated with a combination of thidiazuron (*N*-phenyl-*N*′-1,2,3-9 thiadiazol-5-ylurea) and *S,S,S*-tributyl phosphorotrithioate prior to harvest in 1991. These two chemicals plus ethephon [(2-chloroethyl)phosphonic acid] were used prior to harvest in 1992. In 1994, plots were defoliated with *S,S,S*-tributyl phosphorotrithioate and ethephon. Plots were harvested with a two-row spindle picker on 10 October 1991, 9 November 1992, and 23 November 1994. Lint percent was determined by calculation after saw-ginning a sample of seedcotton from each harvest bag.

A weather station at the Pee Dee Research and Education Center provided the daily maximum and minimum temperature and total precipitation. Heat units (DD60s) were calculated as Σ {[(maximum temperature − minimum temperature)/2] − 15.6°C}.

All data were subjected to analysis of variance. Single degree of freedom contrasts were made to compare parent and F_2 means and interactions with production systems.

RESULTS AND DISCUSSION

Heat unit accumulations and precipitation for the three years of this study are shown in Table 1. Growing conditions in 1991 were good, and average lint yield for the experiment was 1318 kg ha^{-1}. The 1992 growing season had low temperatures after planting and an extended dry period from late June through early August (Table 1), which resulted in low cotton yield that year (478 kg ha^{-1}). Rainfall was plentiful in 1994, but cool temperatures, especially during July and September, delayed crop development (Table 1). Mean lint yield that year was 849 kg ha^{-1}.

The mean squares from analysis of variance for plant stands for the three years of the study are shown in

Table 1. Heat unit accumulation (DD60s) and precipitation from planting to harvest in 1991, 1992, and 1994. Data were collected by a weather station at the Pee Dee Research and Education Center near Florence, SC.

	Heat units†			Precipitation		
Month‡	1991	1992	1994	1991	1992	1994
	°C			cm		
May	133	56	57	0.9	2.9	0.9
June	301	244	315	8.6	15.3	16.7
July	384	406	365	15.2	2.6	13.5
August	333	309	303	14.6	35.7	26.0
September	233	234	200	4.2	5.5	17.3
October	37	52	41	1.9	10.5	11.5
November	–	19	6	–	4.4	6.6
Total	1421	1320	1287	45.4	76.9	92.5

† Heat units were calculated as Σ {[(max temp − min temp)/2] − 15.6°C}.
‡ Inclusive dates for data are 17 May through 10 Oct. 1991, 20 May through 11 Nov. 1992, and 25 May through 23 Nov. 1994.

[1] Mention of a trademark, proprietary product, or vendor is for information only and does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

Table 2. Mean squares from analysis of variance for plant populations determined at one and two weeks after planting at Florence, SC, in 1991, 1992, and 1994.

	Week after planting					
	1991		1992		1994	
Source	1	2	1	2	1	2
	mean square					
Rep	15.2*	8.4	10.1	28.7	25.5	2.3
Tillage (T)	0.6	5.4	–‡	415.0*	102.3*	16.9*
Error A	0.8	1.0	–	34.7	9.4	1.1
Genotype	5.2*	5.7**	5.4†	3.2**	6.9*	7.7*
Parent vs F_2	1.3	0.6	10.9	5.1*	14.5*	42.6*
T × Genotype	0.4	1.1	–	2.0*	2.3	3.6
T × (Parent vs F_2)	0.2	0.5	–	5.9*	0.6	0.1
Error B	1.4	2.0	3.2	1.1	3.7	3.5

†, *, and ** Indicate significant effect at $P = 0.10$, 0.05, and 0.01, respectively.
‡ Plants in conservation tillage plots had not emerged by 1 wk after planting in 1992.

Table 2. Stands were established in all plots by 7 d after planting in 1991 and averaged 9.2 plants m^{-1} of row (Table 3). Timely precipitation and warm temperatures around planting combined with the low amount of clover present as a surface mulch in the conservation tillage plots resulted in similar stands for the two tillage systems. At planting in 1992, we noticed some soil water was present in the seedbeds of the conventional tillage plots but the seedbed of the conservation tillage plots was dry. Evidently, there was not enough soil water for germination in the conservation tillage plots in that year because seedling emergence was delayed in those plots until after it rained at 10 d after planting. At 2 wk after planting, plant stands were still lower in the conservation tillage plots than in the conventional tillage (Table 3). At about 30 d after planting, plant stands did not differ between tillage systems; average plant population across all plots in 1992 was 7.4 plants m^{-1} of row. In 1994, there was about double the surface mulch from the clover than the other 2 yr. Plant populations were lower for conservation tillage cotton than for conventional tillage at both one and 2 wk after planting (Table 3). Plant population counts at 3 wk after planting were the same as for 2 wk after planting (data not shown).

Table 3. Cotton plant populations at one and two weeks after planting at Florence, SC, in 1991, 1992, and 1994.

		Week after planting					
		One			Two		
Year	Generation	Conventional tillage	Conservation tillage	Mean	Conventional tillage	Conservation tillage	Mean
		Plants m^{-1}					
1991	Parent	9.5	9.4	9.5	9.3	8.9	9.1
	F_2	9.3	9.3	9.3	9.2	8.9	9.1
	Mean	9.4	9.3		9.2	8.9	
1992	Parent	6.2	–†	–	7.5‡	4.1	5.8*
	F_2	6.8	–	–	8.4	4.2	6.3
	Mean	6.6	–		8.1*	4.2	
1994	Parent	5.2	3.5	4.4*	5.4	4.6	5.0**
	F_2	6.1	4.1	5.1	6.7	5.9	6.3
	Mean	5.8*	3.9		6.3*	5.5	

*, ** Indicate means within a column (parent mean vs F_2 mean over tillage systems) or row (conventional tillage mean vs conservation tillage mean over generation) are different at $P = 0.05$, 0.01, respectively.
† Plants in conservation tillage had not emerged by 1 wk after planting in 1992.
‡ Indicates significant ($P = 0.05$) tillage system × generation interaction in week two of 1992 from contrasts.

Table 4. Mean squares from analysis of variance for lint yield at Florence, SC, in 1991, 1992, and 1994.

Source	1991	1992	1994
	mean square (× 10^{-4})		
Replicate	4.8	13.0	2.5
Tillage (T)	58.5	138.2*	8.6
Error A	13.2	4.1	6.3
Genotype	6.6	2.3*	4.3
Parent vs F_2	0.0	13.0**	3.2
T × Genotype	7.3	1.6	4.1
T × (Parent vs F_2)	3.6	2.1	1.2
Error B	4.9	1.3	3.8

*, ** Indicate significant F value at $P \leq 0.05$ and 0.01, respectively.

The F_2 generation gave no advantage in stand establishment rate or final populations in either tillage system when conditions were favorable for rapid germination and early seedling growth in 1991. With both water and temperature stress after planting in 1992, the F_2 generation had higher stands at one and 2 wk after planting in conventional tillage, but not in conservation tillage (Table 2). At about 30 d after seeding in that year, the F_2 generation had 0.3 more plants m^{-1} than the parents (difference between generations was significant at $P = 0.10$) in both tillage systems. In 1994, the F_2 generation had higher plant populations than the parents at 1, 2 (Table 3), and 3 (not shown) wk after planting in both tillage systems.

Tillage systems did not differ in yield in 1991 or 1994 (Tables 4 and 5). The 2-to-3-wk delay in crop emergence in conservation tillage in 1992 resulted in lower yield for that tillage treatment than for conventional tillage.

Lint yield of the F_2 generation did not differ from the parents in either tillage system in 1991 or 1994 (Tables 4 and 5). In 1992 when yields were lowest of the three years, the F_2 generation had higher yield than the parent generation in both tillage systems. Similar to our results, Hawkins et al. (1965) found the most high-parent heterosis of F_1 hybrids in the year that the parent generation had the lowest yield.

Table 5. Cotton lint yield for the parent and F_2 generations in conventional and conservation tillage systems at Florence, SC, in 1991, 1992, and 1994.

		Tillage system		
Year	Generation	Conventional	Conservation	Mean
		kg ha^{-1}		
1991	Parent	1368	1282	1324
	F_2	1407	1241	1325
	Mean	1395	1254	
1992	Parent	526	337	429**
	F_2	620	383	499
	Mean	589*	368	
1994	Parent	812	838	825
	F_2	826	894	860
	Mean	822	875	

* Indicates tillage means within year, averaged over generations, were different at $P = 0.05$.
** Indicates generation means within year, averaged over tillage systems, were different at $P = 0.01$.

Tang et al. (1993) found that the heterosis for yield of F_2 cotton was due to increased boll number and boll weight, and Meredith and Bridge (1972) found F_1 heterosis to be due mainly to increased boll number. Wells and Meredith (1986) found that seedling growth rate of F_1 hybrids was faster than parent generation genotypes. The faster seedling growth rate resulted in greater leaf area and more canopy photosynthesis early in the season (Wells and Meredith, 1988). As leaf area approached maximum later in the season, differences between hybrids and parents in canopy photosynthesis disappeared (Wells and Meredith, 1988). Additionally, Marani and Avieli (1973) found greater heterosis in F_1 hybrids when cooler temperatures occurred after planting. In our study, total accumulated heat units in the 21 d after planting were 190°C in 1991 and 188°C in 1994, but only 118°C in 1992. Also, a low temperature of 7°C occurred during the second night after planting in 1992. This may partially explain why expression of yield heterosis in the F_2 generation was found only in 1992. With good temperature conditions after planting in 1991 and 1994, perhaps early season growth was rapid enough in the parent lines so that early season vegetative production was not a limiting factor for yield in those years.

Even though we found a yield advantage for F_2 cotton in only 1 of 3 yr, their use in conservation tillage systems may offer other agronomic advantages over pure line cultivars that we did not address. For example, cotton is relatively slow growing after emergence. Practices that lead to a faster growing crop and more uniform stands will improve the competitiveness of the crop with weeds. Since the F_2 generation genotypes had higher plant stands in 2 of the 3 yr of our study, using F_2 generation genotypes may aid in weed management in commercial production systems.

Expression of yield heterosis by F_2 cotton has been found to be dependent on environmental conditions (Tang et al., 1993). The soil and microclimate differences between conventional and conservation tillage did not influence the yield heterosis of the F_2 generation genotypes in our study. The results suggest that growing F_2 genotypes may improve cotton stand establishment and yield under certain conditions in conservation tillage systems, but the amount of improvement will be similar to that found in conventional tillage.

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