Winter Cover and Tillage Influences on Coastal Plain Cotton Production

Philip J. Bauer and Warren J. Busscher

Research Question

Surface residues are important in conservation tillage systems. After cotton harvest, there are few residues for soil protection or improvement. Using winter annual cover crops to increase surface residues in conservation tillage cotton production has been proposed. Our objectives were to evaluate two legume and one cereal species as cover crops for a cotton conservation tillage production system and to determine if soil strength increased with time for continuous conservation tillage cotton produced without cover crops.

Literature Summary

Successful conservation tillage production of sorghum and soybean in the humid southeastern USA was dependent on doublecropping winter and summer crops to provide large amounts of residues. Since doublecropping cotton is economically risky in much of the region, winter annual cover crops can provide residues for a conservation tillage system. Cotton yields following winter cover crops in conservation tillage systems are somewhat dependent on cover crop species. Conservation tillage cotton following a rye winter cover crop yielded higher than conservation tillage cotton following fallow and the same as conventional tillage cotton. Fiber property data for conservation tillage cotton following cover crops are needed.

Study Description

A cotton conservation tillage system (in-row subsoiling only) was compared with conventional tillage for 2 yr on a Norfolk loamy sand soil at Florence, SC.

Experimental design:

Main plots:	Winter covers of rye, vetch, crimson clover, and fallow.
Sub plots:	Conservation and conventional tillage.
Sub-subplots:	Winter covers desiccated or incorporated at 15 or 5 d before planting.

Applied Questions

Which cover crops produced the most residue?

Rye was superior to the legumes for biomass production both years of the study. It provided about 2200 lb/acre of residues each year. Crimson clover and vetch yielded 1600 lb/acre or less each year, with the clover being about the same as winter weeds in 1991.

Did conservation tillage increase soil strength?

Two years of conservation tillage did not influence soil strength. Soil strength of the surface 12 in. in conservation tillage during the second spring was about the same as for the first year.

Did cover crops and tillage systems affect cotton yield and fiber properties?

Fiber properties were not substantially affected by either winter cover or tillage. With conventional tillage, lint yield was the same for all winter cover treat-

Full scientific article from which this summary was written begins on page 50 of this issue.

ments (Fig. 1). With conservation tillage, cotton following rye had greater yield than cotton following the legumes and fallow winter covers. The results of this study suggest that when converting to a conservation tillage system for continuous cotton, using a rye winter cover crop may help production on these Coastal Plain soils.

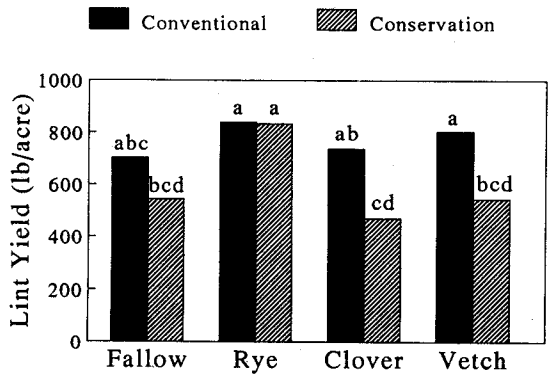

Fig. 1. Influence of winter cover and tillage on cotton lint yield at Florence, SC. Bars with common letters are not different by LSD (*P* = 0.05).

Reprinted from the *Journal of Production Agriculture*
Volume 9, no. 1, January–March 1996
677 South Segoe Rd., Madison, WI 53711 USA

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Winter cover crops and conservation tillage can be used by southeastern Coastal Plain cotton (*Gossypium hirsutum* L.) growers to meet soil erosion control requirements of the 1985 Food Security Act. Our objective was to determine whether these production practices influence cotton productivity and quality. The study was conducted on a Norfolk loamy sand soil (fine-loamy, siliceous, thermic Typic Kandiudult) near Florence, SC, in 1991 and 1992. Treatments were winter annual cover crops, tillage, and timing of cover crop incorporation or desiccation before cotton planting. Cover crop treatments were crimson clover (*Trifolium incarnatum* L.), hairy vetch (*Vicia villosa* Roth.), rye (*Secale cereale* L.), and winter fallow. Tillage systems were conventional (annual disking and bedding with in-row subsoiling) and conservation (in-row subsoiling only). Soil strength was measured during the spring in the fallow plots in both tillage systems. Incorporation (conventional tillage) or desiccation (conservation tillage) of the winter cover was done 5 or 15 d before cotton planting. Winter legume dry matter production was <1800 lb/acre per yr. Rye dry matter production was approximately 2200 lb/acre per year. Soil and crop variables studied were not affected by timing of the cover crop incorporation or desiccation. Soil strength was lower in the top 12 in. with conventional tillage. In conservation tillage, soil strength was the same both years. Conservation tillage had lower lint yield than conventional tillage by 267 lb/acre following clover and by 259 lb/acre following vetch [$LSD_{(0.05)}$ = 221 lb/acre]. Within winter cover treatments following fallow and rye, tillage systems did not differ in yield, but lint yield for conservation tillage following rye was 292 lb/acre greater than yield for that tillage system following fallow. Fiber properties were not greatly influenced by tillage system or winter cover, but micronaire was 0.1 units lower for cotton following rye than cotton following legumes. Including a rye winter cover crop may better insure successful conversion to conservation tillage cotton production systems on Coastal Plain soils.

CONVENTIONAL TILLAGE (burying of all crop residues) is the predominant method of land preparation for cotton. Although successful conservation tillage systems have been developed for the southeastern USA (Patterson and Burtmester, 1993), improvements in this technology are needed for greater grower acceptance (Crawford, 1993). One area of need is the development of systems to attain and manage surface residues.

USDA-ARS Coastal Plains Soil, Water, and Plant Res. Cent., 2611 W. Lucas St., Florence, SC 29501-1241. In cooperation with the South Carolina Agric. Exp. Stn., Clemson Univ., Clemson, SC. Received 16 Mar. 1995. *Corresponding author (bauer@florence.ars.usda.gov).

Published in J. Prod. Agric. 9:50–54.

Crop residues left on the surface reduce soil erosion potential and improve rainfall infiltration. Langdale et al. (1990) concluded that a cropping system that included both cool- and warm-season annual crops was needed for successful conservation tillage sorghum [*Sorghum bicolor* (L.) Moench] and soybean [*Glycine max* (L.) Merrill] production on Piedmont sandy loam soils. In continuous monocropped cotton, previous cotton residues are often insufficient for erosion protection and soil improvement. Because of the long cotton growing season, doublecropping with a winter small grain is impossible for much of the Coastal Plain region. Winter annual cover crops, seeded in the fall and terminated before cotton planting in the spring, have the potential to increase the amount of residues left on the soil surface in conservation tillage cotton production systems.

Touchton et al. (1984) reported that on a Coastal Plain soil low in N, no-tillage cotton yield did not increase with additional N fertilizer when crimson clover and common vetch (*Vicia sativa* L.) were used as cover crops. On a Decatur silt loam soil (clayey, Kaolinitic, thermic Rhodic Paleudult) in the Tennessee Valley of Alabama, Brown et al. (1985) reported that conservation tillage cotton yields were decreased (compared with disk tillage) for crimson clover and winter fallow in every year of a 3-yr study. Conservation tillage cotton yield following vetch was lower only one of the years. The conservation tillage system that included rye had similar yield to conventional tillage yield each year.

Information is needed on fiber properties of cotton grown with conservation tillage techniques, both with and without cover crops. Baker (1987) and Smith and Varvil (1982) reported no difference in fiber properties between conservation and conventional tillage cotton that was doublecropped with wheat (*Triticum aestivum* L.). However, boll size and distribution within the canopy have been reported to differ between conventional and conservation tillage cotton in full season planting (Hoskinson and Howard, 1992). Further, Stevens et al. (1992) reported fewer squares were formed on main stem nodes five through eight on cotton planted into a wheat cover crop stubble than in conventional tillage cotton. Changes in the size and distribution of bolls within the canopy due to tillage systems and surface residues may alter fiber properties and, ultimately, the spinning and dyeing quality of a bale of cotton.

Our objective was to determine the impact of cover crops and tillage systems on cotton yield and field properties. Because of the costs and increased management associated with cover crops, a conservation tillage system without cover crops may be most cost effective. A particular concern for this system is that soil strength may increase if the surface layer is not stirred (Bloodworth and Johnson, 1995). Therefore, a second objective of this study was to compare conservation

Table 1. Winter cover crop biomass production at Florence, SC, in 1991 and 1992.

Winter cover	Year 1991	Year 1992
	lb/acre	
Fallow	490 (72)†	900 (248)
Rye	2275 (158)	2200 (190)
Clover	638 (158)	1605 (206)
Vetch	1137 (98)	1494 (243)

† Values in parentheses are standard errors of means.

tillage to conventional tillage for soil strength when no winter cover crops are grown.

MATERIALS AND METHODS

The experiment was conducted in 1991 and 1992 at the Clemson University Pee Dee Research and Education Center near Florence, SC. Treatments consisted of winter cover (rye, clover, hairy vetch, and fallow), tillage (conventional and conservation), and winter cover desiccation or incorporation date (5 and 15 d before planting). The soil type was Norfolk loamy sand. Conventional tillage corn (*Zea mays* L.) was grown prior to this experiment in 1990.

The experimental design was randomized complete block with treatments in split-split plot arrangement. Main plots were winter cover, subplots were tillage system, and sub-subplots were the incorporation or desiccation dates. The experiment had four replicates. Sub-subplot size was four cotton rows that were 50 ft long and 38 in. wide.

In October 1990, the field was disked and bedded (bed elevation was two to four in. above midrows) before planting the cover crops. After the cotton stalks were shredded in the fall of 1991, disk bedders were used to place a small amount of soil (about an inch) onto the existing beds of all plots before seeding the cover crops. All cover crops were seeded with a grain drill (John Deere Model 8200[1]) on 22 Oct. 1990 and 16 Oct. 1991. Drill spacing was 7 in. Seeding rates were 110 lb/acre for rye, 20 lb/acre for clover, and 25 lb/acre for vetch.

Winter cover aboveground dry matter (including winter weeds in the fallow plots) was determined by drying a 10.8-sq-ft sample from two areas of each main plot in mid-April of each year. Cotton planting dates were 8 May 1991 and 11 May 1992. At 15 or 5 d before these planting dates each year, the conventional tillage plots were disked 6 to 8 in. deep and beds were reformed with disk bedders. On these same dates, the conservation tillage plots were desiccated with paraquat. All plots were in-row subsoiled (Kelly Manufacturing Co.) immediately prior to planting. Cotton (cultivar Coker 315) was seeded with a four-row planter (Case-IH 900 Series) at approximately four seeds/ft of row.

Cotton plant populations were determined 4 wk after planting in 1991 and 3 wk after planting in 1992. Counts were made in 60 ft of row in 1991 and 30 ft of row in 1992.

Nitrogen (70 lb N/acre) as ammonium nitrate was side-dressed 4 wk after planting in the rye and fallow plots. No fertilizer N was applied in the legume cover crop plots. Lime, P, K, S, B, and Mn were applied to meet Clemson University Extension recommendations. The herbicides applied to all plots in 1991 (at recommended rates) were fluometuron, disodium methanearsonate, fluazifop, and sethoxydim. In 1992, the herbicides applied were fluometuron, monosodium methanearsonate, and cyanazine. Paraquat was applied with a directed sprayer, equipped with shields to protect the cotton, to the midrows of the conservation tillage plots when cultivation was used in the conventional tillage treatment. Hand-weeding was also used in all plots. The plots were last hand-

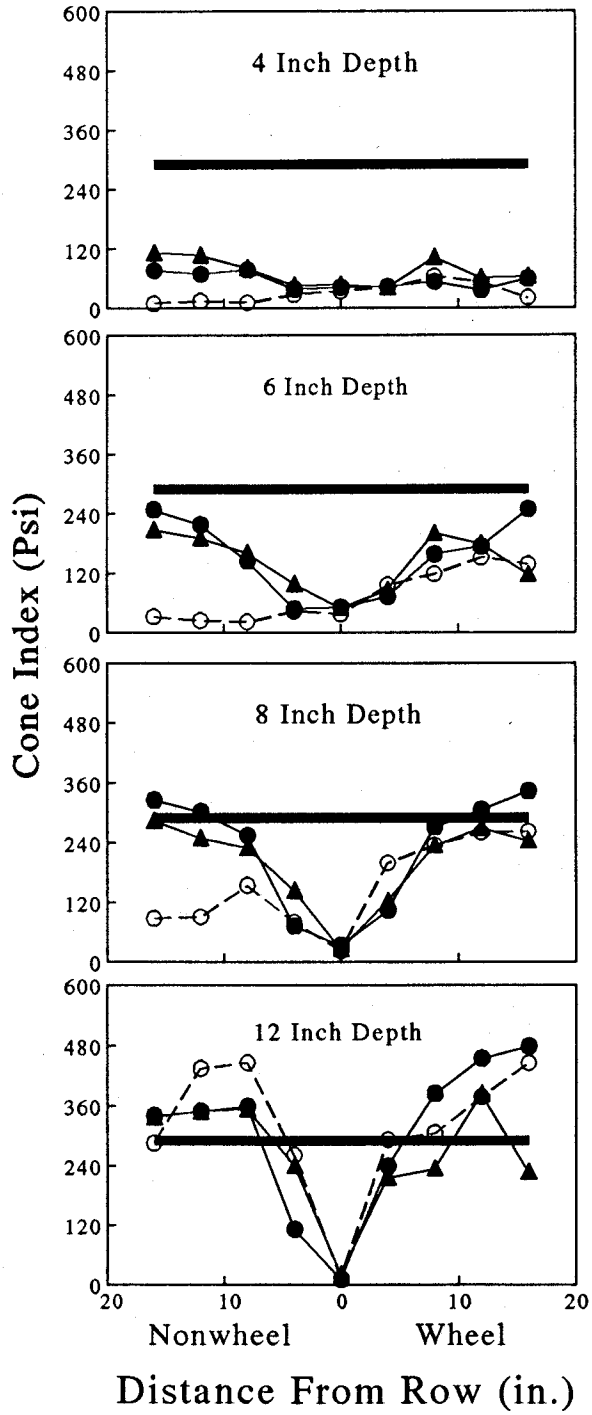

Fig. 1. Soil strength at selected depths across a 38-in.-wide cotton row for conventional tillage in 1992 (○), conservation tillage in 1991 (▲), and conservation tillage in 1992 (●). Horizontal line indicates root restricting soil strength (290 PSI). The $LSD_{(0.05)}$ for comparing means is 22.3 PSI.

[1] Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

weeded in late July 1991 and early August 1992. Aldicarb (2-methyl-2-(methylthio)propanal 0-[(methylamino)carbonyl]-omine) was applied in furrow at planting, and pyrethroid and organophosphate insecticides were applied as needed to control insect pests.

Soil strength and gravimetric water content were measured in the fallow plots for both tillage treatments at the beginning of each cotton growing season. Soil strength was determined with a 0.5-in. diameter, 30° solid angle cone tip, hand-operated, recording penetrometer (Carter, 1967). Strength readings were made to a depth of 24 in. at nine positions across one row (from a nontraffic midrow to a traffic mid-row). These measurements were made at three locations within each plot and digitized into the computer as in Busscher et al. (1986b). Data were log transformed before analysis for normalization (Cassel and Nelson, 1979). Soil water content was determined for soil samples that were collected at 4-in. increments to the 24-in. depth at two positions, in the row and in the nontraffic midrow. Soil water content in the upper 24 in. of the profile when strength measurements were taken was 10.14% in 1991 and 9.99% in 1992.

Cotton was chemically defoliated on 25 Sept. 1991 and 30 Sept. 1992. Shortly before harvest, plant height was measured on five plants in each plot. The two interior rows were harvested with a two-row spindle picker on 9 Oct. 1991 and 22 Oct. 1992. Lint percentage was calculated by saw-ginning a sample of seedcotton from each harvest bag. Lint yield was estimated by multiplying seedcotton yield by lint percentage. Samples of the lint were sent to Star-Lab in Knoxville, TN, for fiber property analysis.

Analysis of variance was performed on all data. Except for the soil physical measurements, the sums of squares for main effect of cover crop, the interaction with tillage, and the three-way interaction between cover crops, tillage, and years were partitioned with single degree of freedom contrasts. We compared (i) fallow and rye, (ii) fallow and legumes, and (iii) rye and legumes with these contrasts. Mean comparisons were made by computing a least significant difference (LSD). The level for significance used for all statistical tests was $P = 0.05$.

RESULTS AND DISCUSSION

Previous work has shown that rye is easier to establish than legumes, making it less risky to use as a cover crop (Reeves, 1994). This was evident in our study. Rye produced more dry matter than the legumes each year (Table 1), and variation between years was less for rye than for the legumes. Part of the reason for the poor dry matter production of the legumes may have been our inability to get accurate seed placement both on the beds and in the row middles with the conventional tillage grain drill that we used. Although plant population counts of the winter covers were not made, it appeared that the rye tolerated the variable seeding depth better than the legumes.

Timing of desiccation or incorporation of winter cover had little effect on any of the variables we measured during the cotton growing season either year. Therefore, results were averaged over the incorporation or desiccation dates.

Soil strength is root restrictive at cone index levels of about 290 to 360 lb/sq in. (PSI) (Busscher et al., 1986a) in the structureless loamy sand surface horizons of the Coastal Plains. Busscher et al. (1988) found that soils that were disk-tilled had an average lower soil strength than conservation-tilled soils throughout the upper 24 in. of the profile. They attributed the lower soil strength in conventional tillage to loosening of the surface layer by disking and to higher soil moisture content. Soil strength is shown in Fig. 1 for different surface horizon depths in the fallow conservation tillage plots both years and the conventional plots in 1992 in this study.

The tillage × row position × soil depth × year interaction was significant for soil strength. In-row subsoiling reduced cone index values to near 0 PSI directly under each row throughout the upper foot both years (Fig. 1). In the nontraffic midrows, strength was greater for conservation tillage than for conventional tillage to the 8-in. depth. As Busscher et al. (1988) previously reported, the disking and harrowing of the soil reduced soil compaction in these row positions. In the wheel track midrows, driving equipment over the conventionally tilled plots to seed the cotton and apply herbicides caused soil strength of conventional tillage to be similar to conservation tillage through the upper 8 in. (Fig. 1). Although differences between tillage systems occurred, most soil strength values in the surface 8 in. were below root restricting levels. In the wheel track midrow at the 12-in. depth, soil strength in 1991 was considerably less than in 1992 and less than directly in the row middle in that year. We cannot explain these low values. The plots in this experiment were subsoiled to approximately 16 in. At the 18-in. depth and deeper, soil strength was greater than 360 PSI across the entire row in both tillage systems both years (data not shown). However, the soil at these depths contains a high percentage of clay and

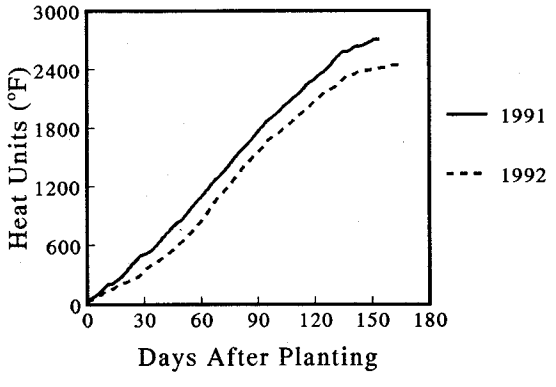

Fig. 2. Heat unit accumulations at Florence, SC, during the 1991 and 1992 growing seasons. Heat units were calculated as the sum of [(daily maximum temperature − daily minimum temperature)/2 − 60°F].

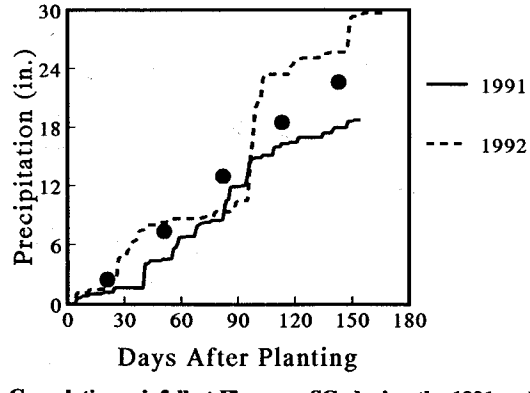

Fig. 3. Cumulative rainfall at Florence, SC, during the 1991 and 1992 growing seasons. Filled circles indicate cumulative 30-yr average (1951–1980) from 10 May through 30 September.

better structure than the surface horizons (Doty et al., 1975).

Except in the wheel track midrow at the 12-in. depth, differences in soil strength between 1991 and 1992 in conservation tillage were not great at any depth (Fig. 1). Also, soil strength was not at root restrictive levels in the 0- to 8-in. depth in either tillage system either year. Although additional research is needed, this may indicate that for the surface horizon, little additional increase in soil strength beyond that found in the first year may be expected when converting to this conservation tillage system on these soils.

Cotton plant population was not influenced by tillage or cover crops in either year. Cotton plant populations averaged 3.0 plants/ft in 1991 and 2.8 plants/ft in 1992. Campbell et al. (1984) found that corn plant population and yield were lower with conservation tillage than conventional tillage when overwintering plants dried out the upper part of the soil profile. In our study, rainfall (1.5 in. in 1991 and 1.0 in. in 1992) before planting provided adequate moisture for germination and early growth of the cotton.

Previous studies have shown that soil incorporated legumes produce toxic ammonia (Megie et al., 1967) and organic volatiles (Bradow and Connick, 1988 and 1990) and increase plant pathogenic fungi (Rickerl et al., 1988). When left as surface mulches (as in conservation tillage), deleterious effects of the legumes on cotton are reduced or eliminated (Rickerl et al., 1989; White and Worsham, 1989). Dry matter production of the legume cover crops in our study may have been too low (all <2000 lb/acre, Table 1) to cause cotton plant population reductions with conventional tillage. When Coker 315 was planted into plots that had almost 3500 lb/acre green-manured clover in a previous study (Bauer et al., 1991), plant populations were 30% lower than those following winter fallow. Hicks et al. (1989) reported that incorporated wheat stubble inhibited cotton germination and seedling growth when the cotton seed contacted the straw, but we did not find lower stands with the incorporated rye in our study.

For plant height, the rye vs. legumes and tillage × rye vs. legumes contrasts were significant. In conventional tillage, cotton plant height (mean = 29 in., data not shown) at harvest was similar following all four winter covers. In conservation tillage, the low dry matter production of the winter weeds, clover, and vetch provided little surface mulch compared with the rye winter cover crop. The presence of the rye mulch appears to have benefitted the cotton crop throughout both growing seasons since cotton was taller following rye (31 in.) than following legumes (23 in.). Though contrasts were not

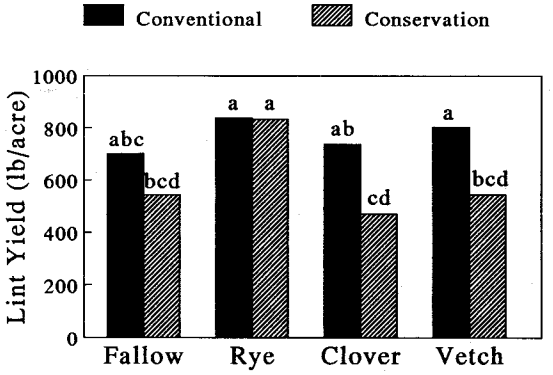

Fig. 4. Influence of winter cover and tillage on cotton lint yield at Florence, SC. Bars with common letters are not different by LSD (*P* = 0.05).

Table 2. Effect of cover crops and tillage on lint percentage and cotton fiber properties at Florence, SC.

Winter cover	Lint percentage		Micronaire		Elongation		50% span length		2.5% span length		Fiber strength	
	CV†	CS	CV	CS	CV	CS	CV	CS	CV	CS	CV	CS
	%		units		%		in.		in.		gm/tex	
Fallow	41	42	4.45	4.43	7.30	7.28	0.56	0.55	1.16	1.15	20.4	20.0
Rye	41	42	4.40	4.36	7.42	7.22	0.56	0.56	1.16	1.16	20.0	20.5
Clover	41	42	4.50	4.49	7.23	7.42	0.56	0.56	1.15	1.15	20.5	20.1
Vetch	41	42	4.53	4.51	7.42	7.30	0.55	0.55	1.15	1.14	20.2	19.9
LSD (P = 0.05)	ns‡		ns		0.16		ns		ns		ns	

† CV = Conventional tillage, CS = conservation tillage.
‡ ns indicates winter cover × tillage interactions were not significant.

significant between rye and fallow, mean plant height for the cotton following fallow in conservation tillage was nearer the height of the cotton following the legumes (25 in.).

Lint yield averaged 970 lb/acre in 1991 and 413 lb/acre in 1992. A cool spring (Fig. 2) and prolonged dry period from late-June through early-August 1992 (from about 40 through 80 d after planting) (Fig. 3) reduced yield. Despite the large yield difference between years, cotton yield response to cover crop and tillage was similar both years (cover × tillage × year interactions and all contrasts computed from this interaction sums of squares were not significant). Therefore, data presented are averaged over years (Fig. 4). The winter cover and tillage main effects and the single degree-of-freedom contrasts rye vs. fallow, rye vs. legumes, and tillage × rye vs. legumes were significant for lint yield.

Lint yield was greater following rye than the three other winter covers with conservation tillage (Fig. 4). Gallaher (1977) reported that soil remained wetter when rye was left as a surface mulch than when aboveground parts of the rye were removed in a conservation tillage system. It is possible that the rye residues improved soil water status during the cotton growing season compared with the soil water status in the fallow and legume treatments that had few residues. For conventional tillage cotton, lint yield following the four winter covers did not differ (Fig. 4).

For the fallow and legume treatments, cotton yield within tillage systems did not differ in this study (Fig. 4). The low dry matter production by the legumes in 1991 suggested that N-deficiency should have occurred in the clover and vetch winter cover plots in both tillage systems since they did not receive any fertilizer N. Using previously reported N concentration levels of 2.27% for clover and 3.90% for vetch (Brown et al., 1985), the estimated amount of N in the legumes in 1991 was only 17 lb/acre for clover and 44 lb/acre for vetch. However, corn grain yield in this field the previous year was low (the South Carolina nonirrigated field corn hybrid test averaged only 967 lb/acre at the Pee Dee Research and Education Center [Barefield and Chrestman, 1990]); and, though not measured, residual N-levels in the soil were probably high in 1991. In 1992, N in the legumes was estimated to be 43 lb/acre for clover and 58 lb/acre for vetch. The N from both legumes was probably sufficient for the succeeding cotton crop since the long period with little precipitation limited growth and productivity in that year.

The tillage main effect was significant for lint percentage. Lint percentage was greater (1%) for conservation tillage than for conventional tillage, regardless of cover crop (Table 2). Our fiber property results generally agree with those found by

Baker (1987) and Smith and Varvel (1982) (Table 2). Cover crops and tillage did not influence 50% span length, 2.5% span length, or fiber strength. For micronaire, the rye vs. legumes contrast was significant. Micronaire was more than 0.1 units lower following rye than following the legumes, regardless of tillage. Micronaire of cotton following winter fallow was intermediate between rye and the legumes and did not differ from either. For elongation, differences occurred due to winter cover and/or tillage (the tillage × rye vs. legumes contrast was significant), but these differences were small (Table 2).

Our results provide further evidence of the risk involved with using legumes for winter cover crops (Reeves, 1994). Lack of surface mulch because of low legume dry matter production probably contributed to cotton yields following the legumes being similar to the yields following winter weeds in both tillage systems. Conservation tillage cotton yield was greatest following the rye winter cover, and that yield equaled all conventional tillage yields. Also, fiber quality was not adversely affected. This suggests that including a rye winter cover crop may better insure successful conversion to conservation tillage production systems for cotton on these Coastal Plain soils.

ACKNOWLEDGMENT

We thank B.J. Fisher, S.A. Godwin, and E.E. Strickland for technical support.

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