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Cotton Yield and Fiber Quality Response to Green Manures and Nitrogen

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ABSTRACT

The quantity and availability of N from green manures will considerably affect the N management of a succeeding cotton (*Gossypium hirsutum* L.) crop. This study was conducted to determine the N supplying capacity of crimson clover (*Trifolium incarnatum* L.), Austrian winter pea [*Pisum sativum* subsp. *arvense* (L.) Poir.], and rye (*Secale cereale* L.) to cotton and their influence on cotton yield and fiber properties. Green manure treatments (and a fallow check) with fertilizer N levels of 0, 56, 112, and 168 kg ha^{-1} were compared for 3 yr on a Norfolk loamy sand (fine-loamy, siliceous, thermic Typic Kandiudult). Soil moisture at planting was similar among the four green manure treatments. At the 0 N level, the legumes generally had higher soil NO_3–N than rye or fallow. Cotton grown following clover and pea with 0 kg ha^{-1} added N had petiole NO_3–N levels similar to those of rye and fallow with 56 kg N ha^{-1}. Fertilizer N had no influence on cotton yield in the pea winter cover treatment. A quadratic regression equation best described the lint yield response following clover. For both rye and fallow treatments, yield plateaued at 56 kg N ha^{-1}. Green manures had little influence on fiber properties. The results indicate that legumes supply adequate but not excessive N for modern cotton production and that incorporation of rye into the production system does not affect N fertilization requirements.

THE VALUE OF WINTER CROPS as erosion control agents, as sources of nutrients, and for improving soil physical and chemical conditions has long been known (Pieters and McKee, 1938). National interest in the development of systems that rely less on commercial fertilizers has resulted in a renewed interest in using green manures for crop production. Early investigations of green manures as N sources for cotton (Hale, 1936; Lewis and Hunter, 1940) may no longer be applicable, since breeders have improved cotton yield by increasing earliness (Bridge and Meredith, 1983; Bridge et al., 1971; Culp and Green, 1992), which may affect the efficiency by which modern cultivars use N from green manures.

Legume green manures can provide substantial N to the subsequent crop. Legumes such as crimson clover and Austrian winter pea can supply up to 100 kg N ha^{-1} to a summer crop (Hoyt and Hargrove, 1986). Touchton et al. (1984), using the cotton cultivars DPL 61 and DPL 41, concluded that winter annual legumes can provide adequate N for cotton production on a sandy soil with a low N content.

High rates of N uptake by cotton begin at about first flower, ≈8 wk after planting (Mullins and Burmester, 1990). For optimum N utilization from green manures by cotton, mineralization must occur in time to meet this N demand. Conversely, if mineralization occurs too early, NO_3–N in the soil will be vulnerable to leaching. Wilson and Hargrove (1986) found that only 48% of the original N in crimson clover remained in buried residue after 2 wk in the field in a conventional tillage system. Nitrogen availability from winter annuals as surface mulches depends on crop species, moisture, temperature, and maturity of the winter annual when it is desiccated (Ranells and Wagger, 1992; Wagger, 1989).

Cotton maturity can be delayed with the use of legume green manures (Bauer et al., 1991), so fiber quality may be affected. Fiber strength, length, micronaire reading, and elongation all affect spinning of fiber and the quality of the yarn. Information is lacking on the response of these fiber characteristics to green manures.

We conducted this study to evaluate winter annual cover crop species as green manures for cotton production. The objectives were to (i) compare the plant and soil NO_3–N status of a modern cotton cultivar grown following the green manures of Austrian winter pea, crimson clover, and rye and (ii) determine the effect of green manures on cotton yield and fiber properties.

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MATERIALS AND METHODS

The study was conducted at the Clemson University Pee Dee Research and Education Center near Florence, SC (34° 11′ N, 79° 43′ W) in 1989, 1990, and 1991. Each year the experiment was planted on a new site on Norfolk loamy sand, with cotton as the previous crop.

Green manure treatments in the study were Austrian winter pea, 'Tibbee' crimson clover, 'Vita-graze' rye, and winter fallow.[1] Nitrogen treatments were 0, 56, 112, and 168 kg N ha^{-1}. The experimental design was randomized complete block in split-plot arrangement with green manures as main plots and N levels as subplots. Subplot size was six rows (10.64 by 0.97 m) in 1989 and 1990 and eight rows (9.12 by 0.97 m) rows in 1991. The experiment had four replicates each year.

Prior to planting winter annuals, cotton stalks were shredded and the field was conventionally prepared by disking and harrowing. Green manures were planted with a grain drill on 19 and 20 Oct. 1988, 9 Nov. 1989, and 22 Oct. 1990. Seeding rates were 22, 45, and 133 kg seed ha^{-1} for clover, pea, and rye, respectively. Biomass production of the green manures and of winter weeds (weeds were sampled in 1991 only) was determined by taking a 1.0-m^2 sample from two areas of each main plot on 17 Apr. 1989 and 23 Apr. 1990 and 1991. Samples were air-dried in a greenhouse (1989 and 1990) or dried in a forced-air oven at 70 °C (1991) and weighed.

After biomass samples were collected, all plots were disked twice and rows were formed with a bedder. 'Coker 315' cotton was seeded after in-row subsoiling on 12 May 1989, 7 May 1990, and 8 May 1991. Coker 315 was a popular cultivar in South Carolina in 1989 (USDA, 1989), comprising an estimated 37.7% of the state's total area planted to cotton. Weed control was accomplished with a combination of herbicides, cultivation, and handweeding. Pyrethroid and organophosphate insecticides were applied as insect infestations warranted.

[1] Mention of a trade name or vendor is for information only and does not constitute an endorsement by the USDA or Clemson University.

Table 1. Winter annual cover crop aboveground biomass production.

Cover crop	Year		
	1989	1990	1991
	kg ha^{-1}		
Fallow†	—	—	660 (78)‡
Rye	4644 (726)	1630 (59)	4228 (183)
Clover	5824 (280)	4386 (270)	1914 (429)
Pea	4587 (554)	2673 (597)	2920 (173)

† Biomass production of winter weeds.
‡ Values in parenthesis are standard errors of means.

On the subplots, N as NH_4NO_3 was hand-applied to the soil surface in a band ≈13 cm to the side of each row. Half of each N level was applied at planting and the other half was applied when the plants had six fully expanded true leaves.

Cotton was chemically defoliated prior to harvest in 1990 and 1991. In 1989, high winds from Hurricane Hugo caused extensive plant stress, and chemical defoliation was not necessary. Two interior rows were harvested with a two-row spindle picker for yield determinations each year. Plants in those two rows were counted shortly after harvest. Lint percent and fiber analysis were determined on a 25-boll handpicked sample in 1989 and on a grab sample from the harvest bags in the other 2 yr of the study. Samples were saw-ginned, and micronaire reading, 2.5 and 50% span length, elongation, and fiber strength were determined by standard procedures by Starlab, Inc. (Knoxville, TN).

Petioles from uppermost fully expanded leaves in all plots were collected at biweekly intervals from late June through August each year. Beginning ≈2 wk after planting in 1990 and 1991, Nitrate–N was measured in soil samples collected to a 20-cm depth in the 0 kg N ha^{-1} level for all cover treatments and the 112 kg N ha^{-1} level for the rye and fallow winter covers. The 112 kg N ha^{-1} level was chosen for soil NO_3–N analysis, since it is a common level for cotton grown without legumes in South Carolina. Also, soil samples were collected in 15-cm increments to a depth of 90 cm shortly after planting and after harvest in those 2 yr. Gravimetric soil moisture (for samples collected at planting only) and NO_3–N were determined.

Petioles were dried and ground to pass a 100 mesh screen. Petiole NO_3–N was measured with an ion-specific electrode after extraction with $Al_2(SO_4)_3$ solution (Baker and Thompson, 1992). Soil NO_3–N was determined on a TRAACS 800 AutoAnalyzer (Bran & Luebbe, Buffalo Grove, IL) after extraction with deionized water.

Standard errors were calculated for the biomass means from the cover crop treatments. All other data collected were subjected to analysis of variance. Yield, stand, fiber properties, and petiole NO_3–N data were analyzed over years. Since *F*-values for the year × cover crop × N interactions for yield and stand and the year × cover crop × N × sampling date interaction for petiole NO_3–N were not significant, means over years are presented. Soil NO_3–N data were analyzed by year because of different sampling times during the season. Means separations were made with an LSD at $P = 0.05$.

RESULTS AND DISCUSSION

Aboveground biomass production of the green manures is given in Table 1. Clover production was considerably less in 1991 compared with the other 2 yr, because of selective feeding by white-tailed deer (*Odocoileus virginianus* Zimmermann). Winter weed biomass production was less than the green manures in 1991. Although weed biomass measurements were not made in the other 2 yr, weed production did not appear to differ among years.

Table 2. Monthly rainfall totals at Florence, SC, from April through September. Thirty-year average is from 1951 to 1980.

Month	Year			30-yr average
	1989	1990	1991	
	mm			
April	142	28	22	79
May	76	82	77	94
June	109	25	86	124
July	131	135	152	143
August	161	170	146	139
September	159	25	42	105
Total	778	465	525	684

Total monthly rainfall amounts through the cotton growing season for the 3 yr are given in Table 2. Distribution of precipitation through the growing season was good for cotton production in all 3 yr, except for very low precipitation in June 1990.

Ebelhar et al. (1984) found soil moisture to be decreased at the 7.5- to 15-cm and 15- to 30-cm depths under a hairy vetch (*Vicia villosa* L.) cover crop com-

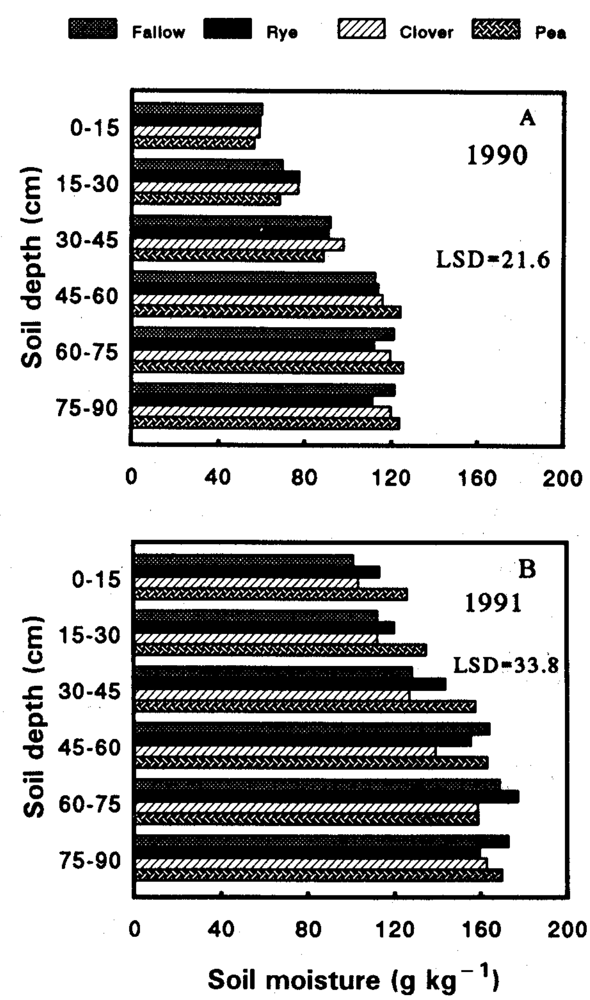

Fig. 1. Gravimetric soil moisture levels following winter cover crops at Florence, SC; (A) 1990 and (B) 1991.

pared with corn (*Zea mays* L.) stubble in a conservation tillage system. In our study using conventional tillage, soil moisture at planting to a depth of 90 cm was not affected by green manures in 1990 or 1991 (Fig. 1). In both years, soil moisture (averaged over all green manures) increased with depth to 45 cm. Soil moisture levels at planting were considerably higher in 1991 than in 1990 (Fig. 1).

Cotton stand establishment was lower in the legume and fallow plots than in the rye plots. Averaged over all 3 yr, the cotton grown following rye had 8.0 plants m^{-2}, in comparison with 6.7, 6.9, and 7.2 plants m^{-2} in the clover, pea, and fallow plots, respectively (LSD [0.05] = 0.5 plant m^{-2}). In a previous study, stands of this variety were reduced following green manured crimson clover (in comparison with winter fallow) in 1 yr of 2 (Bauer et al., 1991) but yield was not affected. Thus, the stand differences found in this study probably did not affect yield.

Soil NO_3–N was greater following pea than following rye and fallow in the 0 kg N ha^{-1} plots in 1990 (Fig. 2A). Levels following clover were intermediate. Mean soil NO_3–N of the surface soil in the 0 added N plots in 1990 (averaged over all sampling times) was 5.74 mg kg^{-1} for fallow, 4.59 mg kg^{-1} for rye, 9.54 mg kg^{-1} for clover, and 13.24 mg kg^{-1} for pea (LSD [0.05] = 4.34 mg kg^{-1}).

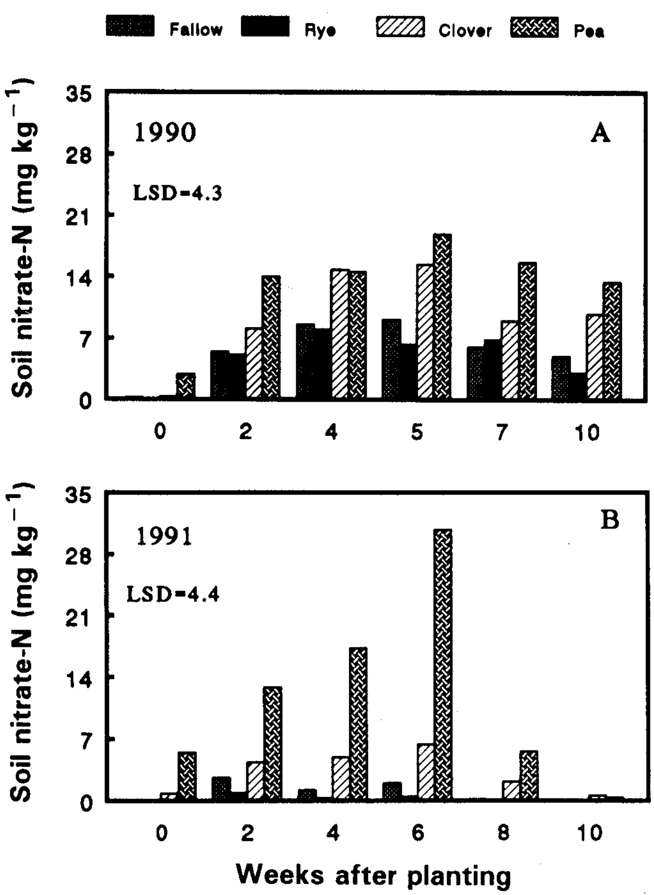

Fig. 2. Effect of winter cover crops with 0 added N fertilizer on soil NO_3–N level in the upper 20 cm of soil at Florence, SC; (A) 1990 and (B) 1991. Measurements were from the upper 15 cm of soil at the at-planting sampling time each year.

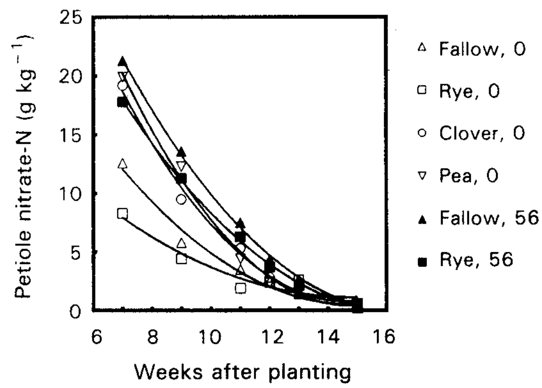

Fig. 3. Effect of winter cover crops and fertilizer N on cotton petiole NO_3–N levels averaged over 3 yr (1989–1991) at Florence, SC. Regression equations are given in Table 3.

In 1991, a green manure × week interaction occurred (Fig. 2B). In that year, clover dry matter production was less than pea, and soil NO_3–N levels reflected the reduced biomass yield. Soil NO_3–N levels in the pea plots without added N decreased substantially between 6 and 8 wk after planting (Fig. 2B). The dramatic decline was probably due to leaching of NO_3–N below 20 cm in response to 70 mm of rain during the 6th wk after planting, with 62 mm falling in 1 d. However, plant uptake and denitrification may have removed some NO_3–N from the soil. Statistical analysis did not detect a difference in soil NO_3–N levels in the top 20 cm of soil between the fallow and rye treatments either year at the 0 (Fig. 2) and the 112 (data not shown) kg N ha^{-1} levels.

Residual NO_3–N at the end of the season was measured to a depth of 90 cm in select treatments; the 0 and 112 kg N ha^{-1} rye and fallow plots and the zero N added legume plots. Little residual NO_3–N was found following the cotton crop either year and it was not affected by green manures (data not shown).

For cotton grown following pea and clover without fertilizer N, the petiole NO_3–N levels at 7 wk after planting were the same as those for the fallow and rye treatments with 56 kg N ha^{-1} (Fig. 3; Table 3). Also, the rate of decline with crop development was similar between these four treatment combinations. Without added N, the cotton grown following the rye and fallow green manures had reduced petiole NO_3–N levels until levels for all plots were low (Fig. 3). The rye and fallow treatments (without added N) were the only treatment combinations that were N deficient, according to petiole NO_3–N monitoring criteria developed at the University of Arkansas (Maples et al., 1992).

Table 3. Regression equations and R^2 values for petiole NO_3–N results presented in Fig. 3.

Green manure	Fertilizer N	Equation	R^2
	kg ha^{-1}		
Fallow	0	$Y = 18.8 - 3.7X + 0.19X^2$	0.98
Rye	0	$Y = 11.9 - 2.2X + 0.11X^2$	0.92
Clover	0	$Y = 29.4 - 5.9X + 0.31X^2$	0.99
Pea	0	$Y = 31.9 - 6.5X + 0.33X^2$	0.99
Fallow	56	$Y = 31.6 - 5.5X + 0.24X^2$	0.99
Rye	56	$Y = 26.6 - 4.6X + 0.20X^2$	0.99

Table 4. Mean squares from analysis of variance and coefficients of variation for cotton lint yield and fiber properties.

Source	Lint yield	Lint %	Elongation	Span Length 50%	Span Length 2.5%	Fiber strength	Micronaire
	× 10⁵†	× 10⁻⁴†		— × 10⁻³† —			× 10⁻²†
Year (Y)	16.5**	12.1**	4.3*	620**	86**	1.7	790**
Cover Crop (C)	1.6	3.4	0.1	0.6	2.3	0.8	0.1
Y × C	0.2	1.4	0.3	0.3	3.4*	1.5	12.5*
Nitrogen (N)	7.9**	22.7**	0.2	0.4	1.0	7.5**	9.1
Y × N	1.2	1.1	0.3	0.4	1.4	0.5	8.4
C × N	1.3*	1.8	0.2	0.5	0.5	0.5	3.8
Y × C × N	0.4	1.2	0.4*	0.4	0.8	1.1	5.3
CV, %	20.1	2.8	5.0	1.7	1.0	2.8	4.4

*, ** Significant F-value at the 0.05 and 0.01 probability level, respectively.
† To get actual values, multiply reported values by the factor shown.

Cotton responds to N by increasing vegetative growth. Higher yield with N fertilizer (optimal vs. deficient) is generally a function of more bolls on the N sufficient plants (Joham, 1986). Although we did not measure maturity in this study, we noticed that plants in the rye and fallow plots without added N reached cutout (cessation of vegetative growth) earlier and were ready for harvest before the other plots. Also, since nutrient status of plants (especially N) affects defoliation efficiency (Cathey, 1986), it might be suspected that high N treatments (especially following legumes) would be more difficult to defoliate. However, we did not experience problems defoliating any plots in either 1990 or 1991. The lack of rainfall in September of those two years (Table 2) and adequate night temperatures for chemical activity following application may have facilitated defoliation.

Cotton lint production varied considerably among years, averaging 604, 1147, and 1663 kg ha^{-1} in 1989, 1990, and 1991, respectively. High winds from Hurricane Hugo in September 1989 contributed to the reduced yield in that year.

As expected, a green manure × N interaction occurred for lint yield (Table 4). Even though cover crop growth and cotton yield level varied considerably between years, no year × green manure × N interaction occurred (Table 4). Cotton lint yield was independent of fertilizer N level following pea (Fig. 4). In the fallow and rye plots, cotton lint yield increased by >450 kg ha^{-1} with 56 kg N ha^{-1}, but there was no yield response with additional N (Fig. 4). These yield responses were

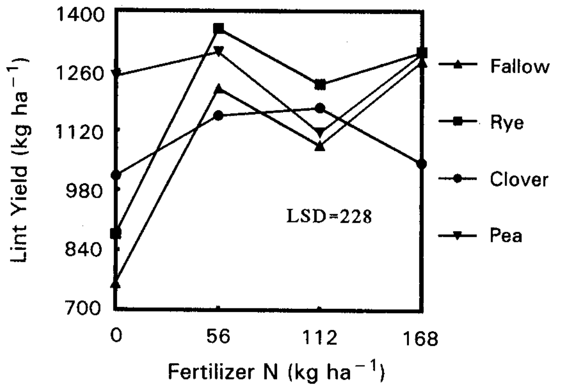

Fig. 4. Effect of winter cover crop and N fertilization on cotton lint yield averaged over 3 yr (1989–1991) at Florence, SC.

as predicted from the petiole NO_3–N analysis. A quadratic equation best described the yield response to increasing N following clover ($Y = 1011.75 + 3.83N - 0.02N^2$; $R^2 = 0.99$).

The influence of green manures on fiber properties was small and inconsistent from year to year. Green manures had no impact on lint percent, elongation, 50% span length, or fiber strength (Table 4). Significant year × green manure interactions occurred for 2.5% span length and micronaire. For these two variables, ranking of the green manures changed each year, but the range of means across N levels was small. For micronaire reading, the range was 0.2, 0.14, and 0.16 micronaire units in 1989, 1990, and 1991, respectively. The range of means for 2.5% span length was 0.09 cm in 1989, 0.03 cm in 1990, and 0.02 cm in 1991.

At current prices, cotton producers may not be able to economically justify growing legumes simply for N. Costs for establishing a pea or clover crop are higher for most growers than fertilizer N costs. However, residues in cotton fields after harvest are often insufficient for adequate soil protection with conservation tillage (Mutchler et al., 1985). Thus, in addition to the potential N fertilizer savings when using legumes, these winter crops can be used for soil cover to meet federal regulations for soil conservation on highly erodible land.

These data agree with Touchton et al. (1984) that legumes can supply adequate N for modern cotton production. They also suggest that nitrate availability following a rye green manure is not reduced enough by microbial immobilization to warrant increased N fertilization recommendations for cotton in the U.S. Southeastern Coastal Plain. Finally, our results suggest that the use of legumes or nonlegumes for soil protection or improvement will not alter lint quality.

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