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Planting Date and Potassium Fertility Effects on Cotton Yield and Fiber Properties

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Late planting causes cotton (*Gossypium hirsutum* L.) to flower later in the season so boll development occurs at lower temperatures. Potassium deficiency elicits some of the same responses in cotton that delayed planting does. Together, these stresses may affect the yield and fiber quality beyond the individual effects of late planting and K deficiency. Our objective was to determine the effect of K fertilization on normal- and late-planted cotton. In 1991, 1992, and 1993, three cotton genotypes (PD 5286, PD 5358, and PD 5472) were seeded in late April and late May on a Hornsville loamy sand (clayey, kaolinitic, thermic Aquic Hapludult) soil with and without annual applications of 100 lb K_2O/acre. Soil K in the upper 6-in. was 95 lb/acre at the initiation of the experiment. Soil K did not differ between the two K fertilizer treatments after the 1991 growing season. After the 1992 and 1993 seasons, K in the 0- to 6- and 6- to 12-in. soil layers was greater in the 100 lb K_2O/acre treatment than in the 0 lb K_2O/acre treatment, but no differences occurred at greater depths. Potassium fertilization did not affect flower production in either planting date in any year. Potassium deficiency reduced the lint yield and fiber length of PD 5286 and PD 5358 but not that of PD 5472. Besides yield and fiber length, fiber perimeter was the only parameter reduced by K deficiency. Late planting caused reduced yield in only 1 of the 3 yr, and for only two of the three genotypes. In general, cotton planted in late May had higher yarn strength, elongation, and fiber length, but lower micronaire and fiber maturity than cotton planted in late April. No interactions that included both K and planting date were significant for lint yield, yarn strength, or any of the fiber properties. This indicates that additional attention to K fertility is not needed in production systems where the boll maturation period is delayed.

DOUBLE-CROPPING soybean [*Glycine max* (L.) Merr.] with wheat (*Triticum aestivum* L.) is a common practice in the Southeast Coastal Plain, but attempts to double-crop cotton behind a small grain crop have not always been successful (Baker, 1987; Smith and Varvel, 1982; Hunt et al., 1997). However, recent advances in conservation tillage, and especially interseeding of cotton with wheat (Khalilian et al., 1995), are providing optimism that this practice will be feasible. May and Bridges (1995) found that selection factors for development of genotypes for short-season production are the same as for full-season genotypes. Therefore, cultivar development for double-cropping should be rapid, provided that sufficient genetic diversity exists within the species for maturity.

In the southeastern USA, delaying initiation of cotton flowering and the boll maturation period causes boll set, fiber elongation, and fiber thickening to occur when average temperatures are lower and declining faster than temperatures for current production strategies. Numerous studies, which are the basis for extension recommendations for optimum planting date windows, document the effect of planting date on lint yield. The temperature regime that occurs as bolls are developing affects the physical properties of the fibers (Ramey, 1985). Bilbro and Ray (1973) found that, as planting was delayed, fiber length and micronaire declined while fiber strength increased. Recently, Porter et al. (1996) planted six modern cultivars varying in maturity at planting dates ranging from very early to very late for the Coastal Plain in South Carolina. They reported that as planting was delayed, fiber strength and elongation increased while micronaire decreased. They found no effect of planting date on fiber length.

Potassium deficiency elicits some of the same effects on cotton fiber properties as delayed planting does. Cassman et al. (1990) reported that fiber length, strength, elongation, micronaire, and uniformity were all positively related to fiber K concentration at maturity but the relationship between fiber traits and K concentration was genotype dependent. Pettigrew et al. (1996) reported that K deficiency reduced fiber elongation, 50% span length, uniformity, micronaire, fiber maturity, and fiber perimeter, but genotype × K interactions did not occur in that study for yield or fiber properties among Midsouth-adapted cultivars. Nelson (1949) reported that reduced spinning quality of K-deficient cotton was caused by higher immature fiber content.

During the time when secondary wall development is occurring in the cotton fibers, cellulose synthesis in the bolls is reduced by low temperature (Gipson and Joham, 1968). Potassium deficiency reduces the translocation of photosyn-

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thates from the leaves of cotton (Ashley and Goodson, 1972). Thus, should double-cropping cotton with small grain be implemented on K deficient soils, together these stresses may affect the yield and quality of the crop more than the individual effects of low temperature and K deficiency. The objective of this research was to determine the effect of K fertilization on normal- and late-planted cotton genotypes of different maturity levels.

MATERIALS AND METHODS

The experiment was conducted in 1991, 1992, and 1993 at Clemson University's Pee Dee Research and Education Center near Florence, SC, on a Hornsville loamy sand. Daily maximum and minimum temperatures and precipitation data were collected by a weather station located within 0.5 mi of the experiment. Prior to establishing the plots in 1991, the soil test K level of the surface 6 in. was 95 lb extractable K/acre (soil test rating of medium-low; Anonymous, 1982). Treatments consisted of planting date (late April and late May), K rate (0 and 100 lb K_2O/acre), and genotype (PD 5246, PD 5358, and PD 5472).

Experimental design was split-plot with main plots in a randomized block. Main plots were the planting date × K combinations, and subplots were the genotypes. In the establishment year of the study (1991), eight other genotypes were studied with the three reported here. In that year, subplot size was two 38-in.-wide by 50-ft-long rows. Each main plot was bordered by two rows that were seeded at the appropriate date for that main plot (total 26 rows per main plot). In 1992 and 1993, the other eight genotypes were discarded from the experiment and subplot size was increased to four 50-ft-long rows. Main plot size was maintained throughout the 3 yr of the study by planting cotton cultivar DES 119 in the extra rows in 1992 and 1993. The 0 and 100 lb K_2O/acre application rates were assigned to plots in 1991 that remained the same throughout the 2 yr of the experiment, while both planting date and genotype were re-randomized each year. The experiment had three replicates.

The three genotypes chosen for this study have similar genetic backgrounds but differ in maturity. They are released germplasm lines that were derived from crosses between Pee Dee lines and Midsouth Delta-type cottons. PD 5286 is an early maturity genotype that yielded well in a short-season production system (Green et al., 1991b). PD 5358 is a full-season genotype (Green et al., 1991a), and PD 5472 was released as a germplasm line that performed well in both short- and full-season production systems (Green et al., 1991c). The fiber properties and yarn strength of these lines are equal to or better than a commercial genotype (PD-3) (Green et al., 1991a, b, c).

Lime, P, S, B, and Mn were broadcast based on soil test results and recommendations of Clemson University Cooperative Extension Service for rainfed cotton (Anonymous, 1982). In the plots receiving K, 167 lb/acre of a 0-0-60 fertilizer was broadcast approximately 1 wk before the plots were disked each year. Before planting each year, the field was disked, harrowed, in-row subsoiled to a depth of 14 in, and bedded. For the normal planting date, cotton was planted on 27 Apr. 1991, 29 Apr. 1992, and 29 Apr. 1993. For the late planting date, planting occurred on 29 May 1991, 27 May 1992, and 28 May 1993. Ammonium nitrate was sidedress applied each year to provide 35 lb N/acre at planting and another 35 lb N/acre about 4 wk after planting. Weeds were controlled with a combination of herbicides and handweeding. Herbicides used at recommended rates and times were trifluralin, fluometuron, monosodium methanearsonate, and cyanazine. Aldicarb [2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime] (0.38 lb ai/acre) was applied at planting. Tobacco budworms (*Heliothis virescens*) and cotton bollworms (*Helicoverpa zea*) were controlled with organophosphate and pyrethroid insecticides at recommended rates when insect pressures reached economic thresholds (Roof et al., 1994).

Flowering rates were monitored in all 3 yr of the study. Since open cotton flowers are white only on the day of anthesis, determinations were made by marking a section of row near the middle of each plot and counting all open white flowers within that section daily (Monday through Friday, excluding holidays). In 1991, a 3.25-ft section of row was selected in each subplot for flower counts. In the other 2 yr, a 6.5-ft section of row was monitored.

Soil K was measured in 6-in. increments throughout the upper 36 in. of the soil profile in each main plot before the second growing season (spring 1992), after the second growing season (fall 1992), and after the third growing season (fall 1993). Six to eight 2-in. diameter soil cores were collected from each main plot, separated by depth, and blended to provide the sample. After collection, samples were placed on a greenhouse bench until dry and K was determined by the Clemson University Extension Agricultural Service Lab (Anonymous, 1983). An estimate of plant K was made by collecting 15 to 20 uppermost fully expanded leaves from border rows of the late April planting date on 11 July, 29 July, 16 August, and 9 September in 1993. The blades and petioles were separated from each other when collected and then dried for 3 d at 150°F, ground, and K was determined by the lab.

Cotton was chemically defoliated when all the harvestable bolls in the row sections used for flower counts were open. A 75-boll sample was then randomly hand-harvested from throughout the two middle rows of each plot each year. Yield was determined by harvesting with a spindle picker. Cotton harvest dates for the late April planting dates were 4 Oct. 1991, 19 Oct. 1992, and 4 Oct. 1993. For the late May planting dates, cotton was harvested on 6 Nov. 1991, 10 Nov. 1992, and 21 Oct. 1993. The 75-boll samples were saw-ginned, and the lint was sent for determination of fiber and spinning properties to Starlab Inc.[1] in Knoxville, TN. Properties evaluated were 2.5% and 50% span length, fiber strength, fiber elongation, micronaire, yarn strength, maturity, and fiber perimeter.

Only the three genotypes that were in each year of the study were included in the statistical analysis of all data. Analysis of variance (ANOVA) was performed on the soils and flower tagging data collected in this experiment for each year of the study. A combined ANOVA over years was conducted on the yield, yarn strength, and fiber property data.

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

Table 1. Monthly heat units and precipitation accumulations at Florence, SC, in 1991, 1992, and 1993. Inclusive dates are through 6 Nov. 1991, 20 Nov. 1992, and 21 Oct. 1993. Thirty-year average is from 1951–1980.

	Year							
	1991		1992		1993		30-yr average	
Month	Heat units†	Precip.	Heat units	Precip.	Heat units	Precip.	Heat units	Precip.
	°F	in.	°F	in.	°F	in.	°F	in.
May	446	3.0	247	3.7	371	1.6	346	3.7
June	545	3.4	442	6.0	604	1.0	511	4.9
July	694	6.0	733	1.0	802	2.2	623	5.6
Aug.	602	5.7	558	14.0	632	2.8	597	5.5
Sept.	422	1.7	424	2.2	499	6.8	427	4.1
Oct.	149	0.9	87	4.1	122	1.5	162	2.7
Nov.	0	0.0	35	1.7	--	--	--	--

† Heat units were calculated as Σ([daily high temperature + daily low temperature]/2) – 60°F. Negative values of daily heat units were set equal to 0 for the calculations.

Sources of variation were considered significant when probability of a greater F value was ≤0.05. Mean separations of main effects and interactions were made by calculating an LSD ($\alpha = 0.05$) when ANOVA F values were significant.

RESULTS AND DISCUSSION

Monthly total rainfall and heat unit accumulations are given in Table 1 for the 3 yr of the study. For comparison, also included are the average monthly rainfall and heat unit accumulations for the years between 1951 and 1980. In 1991, early season heat unit accumulation was high and the seasonal rainfall distribution was good, especially during flowering and early boll development for both planting dates. In that year, 6 in. of precipitation fell in July and 5.7 in. of precipitation fell in August. In 1992, May was cold and the cool weather delayed stand establishment and early growth of the normal planting date. There was an extended dry period during July and early August when only 1 in. of precipitation occurred. A prolonged period of heavy rains followed the dry period that year with 13 of the 14-in. total for the month occurring between 13 and 21 August. The 1993 growing season was hot and dry with only 7.6 in. of precipitation occurring between 1 May and 1 September.

Growing conditions were much better in 1991 than in the other 2 yr of the study, and daily bloom counts reflected the more vigorous growth that year (Fig. 1). In 1991, bloom counts were two to three times higher during peak bloom than either 1992 or 1993. With the more vigorous growth, yield in 1991 was more than twice as much as the yield in the other 2 yr. Average yields were 1022 lb lint/acre in 1991, 423 lb lint/acre in 1992, and 397 lb lint/acre in 1993. Neither K fertilization nor genotypes were significant sources of variation for flower production in any year. The cool May temperatures in 1992 (Table 1) delayed emergence and early growth of the crop. This delay was apparent in the flowering rates as cotton from the late-April planting date began flowering just prior to cotton seeded in late-May. In the other 2 yr of the study, flower production in the late-April planting date began much earlier in the season (Fig. 1).

The site for this experiment was chosen because it had a medium-low soil test level for K prior to conducting the study. Before initiating this experiment, the area was in a corn (*Zea mays* L.)-winter wheat-soybean rotation with K fertilizer added based on soil test results and recommendations of Clemson University Cooperative Extension Service for each crop (Anonymous, 1982). When soil samples were collected in the spring of 1992 after the first year of the treatments, there was no difference in soil K at any depth between treatments with and without K fertilizer (Table 2). Soil K levels were highest in the 0- to 6-in. depth (mean of 111 lb/acre) after the 1991 growing season. Below that layer, soil K ranged from 42 to 64 lb K/acre and it was evenly distributed through the remainder of the profile. After the 1992 and 1993 growing seasons, the 100 lb K_2O/acre treatment had higher soil K levels at both the 0- to 6- and 6- to 12-in. depths than the 0 lb K_2O/acre treatment, but soil K levels were similar at lower soil depths (Table 2). An indi-

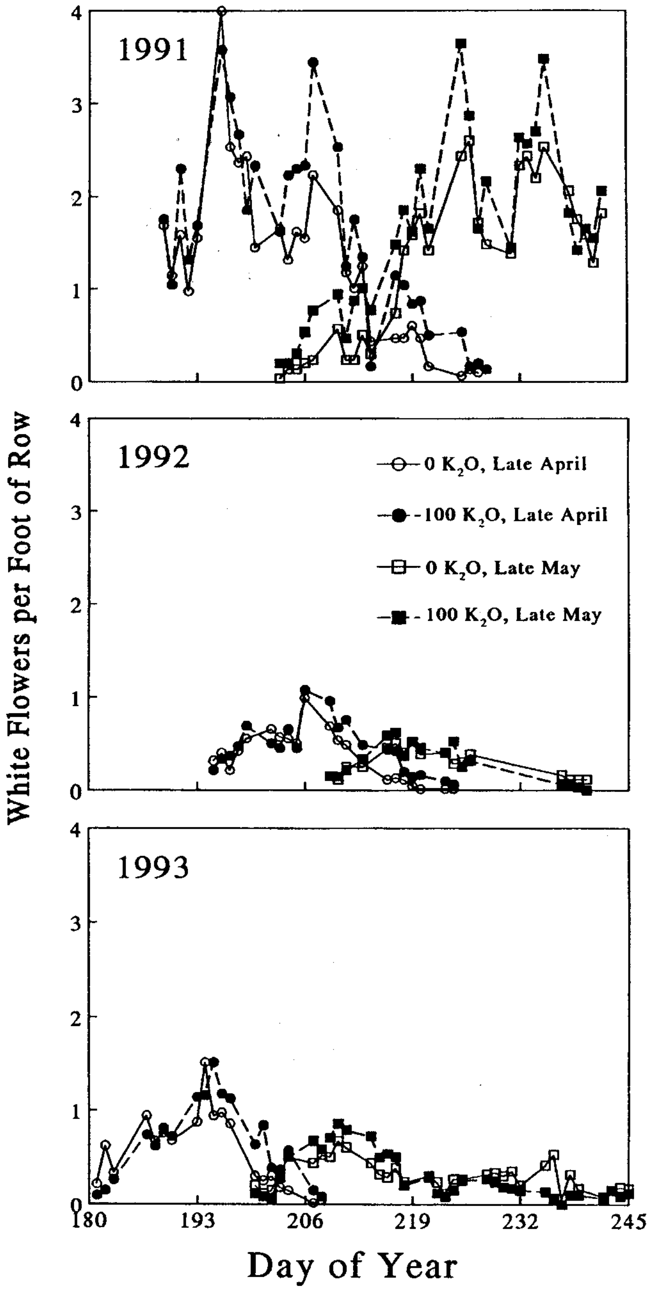

Fig. 1. Effect of planting date and K fertility on white flower counts in 1991, 1992, and 1993 at Florence, SC. Values are averaged over all three genotypes.

Table 2. Soil test K levels at different depths in the profile at different times as influenced by K fertility.

Depths, in.	Spring 1992		Fall 1992		Fall 1993	
	Sampling time					
	K rate, lb K_2O /acre					
	0	100	0	100	0	100
	lb/acre					
0–6	102	120	49	84	52	122
6–12	50	64	4	54	28	64
12–18	55	60	48	47	39	53
18–24	0	55	43	46	43	41
24–30	54	46	36	38	37	32
30–36	47	42	29	34	31	27
Total	368	387	239	303	230	339
†$LSD_{0.05}$	ns		18.2		15.8	

†LSD is for comparing K fertilizer rates within a soil depth.

cation of the amount of K stress throughout the season in the third year of the study is shown by the leaf blade and petiole K levels from the normal planting date in Fig. 2. The leaves in the 100 lb K_2O/acre treatment had twice the K concentration of the leaves in the 0 lb K_2O/acre treatment at all sampling times. Averaged across sampling times, the 100 lb K_2O /acre treatment had 4.4% K in the petioles and 2.1% K in the blades while the 0 lb K_2O /acre treatment had 2.0% K in the petioles and 1.0% K in the blades. In South Carolina, cotton is considered K deficient when leaf blade K concentrations are below 1.5% (Parks, 1989).

Planting date did not influence the response of cotton to K fertilization in this study. The K × planting date, K × planting date × genotype, and year × K × planting date × genotype interactions were not significant for lint yield, yarn strength, or any of the fiber properties. Similarly, differences in weather among years did not influence the K fertilization response as none of the ANOVA sources of variation that included both year and K rate were significant for any of the parameters measured.

Unlike environmental conditions (year and planting date), genetic background did influence the K fertilization response for yield and fiber length. Lint yield of all three genotypes was the same at the 0 lb K_2O/acre level. Adding K increased the yield of PD 5286 and PD 5358, but not that of PD 5472 (Table 3). There was also a significant K × genotype interaction for fiber length, and this interaction was similar to the one that occurred for lint yield. Adding K increased 2.5% and 50% span length of the two genotypes that had higher yield with added K, but did not affect fiber length of PD 5472.

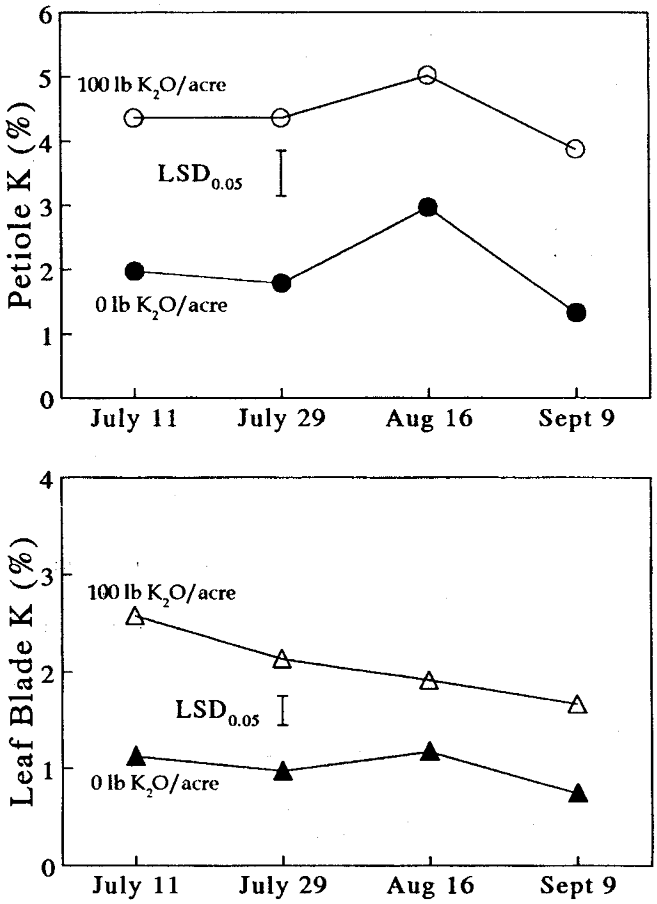

Fig. 2. Effect of K fertility on leaf petiole K (top) and leaf blade K (bottom) in the early planting date in 1993 at Florence, SC.

The only other parameter that was affected by K fertilization was fiber perimeter (Table 3). The 100 lb K_2O /acre treatment had slightly higher perimeter than the 0 lb K_2O /acre level. Previously, K deficiency was reported to reduce yarn strength (Nelson, 1949). Evidently, the level of K deficiency in this study, though great enough to reduce the yield of two of the three genotypes, was not enough to influence yarn strength.

Table 3. Effect of genotype and K rate on cotton lint yield, fiber properties, and yarn strength at Florence, SC. Data are averages of 3 yr (1991, 1992, and 1993).

Genotype	Lint yield		Elongation		50% span length		2.5% span length		Fiber strength		Micronaire		Fiber maturity		Perimeter		Yarn strength	
	K rate, lb K_2O /acre																	
	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100
	— lb/acre —		— % —		— in. —				— g/tex —		— units —		— % —		in. (X 1000)		— g/tex —	
PD 5286	562	686	7.4	7.6	0.55	0.57	1.11	1.13	21.5	21.3	4.6	4.5	88.8	86.7	1.83	1.87	137.6	137.3
PD 5358	552	706	7.7	7.8	0.57	0.58	1.14	1.15	21.9	21.9	4.6	4.6	87.8	86.3	1.85	1.92	142.4	140.8
PD 5472	564	614	7.5	7.5	0.56	0.56	1.14	1.13	21.8	21.6	4.5	4.5	86.4	85.2	1.87	1.89	139.6	137.3
$LSD_{(0.05)}$	56†		ns		0.01		0.01		ns		ns		ns		ns		ns	
Mean	560	669‡	7.5	7.6	0.563	0.570	1.131	1.140	21.7	21.6	4.6	4.5	87.7	86.1	1.85	1.90‡	139.9	138.4

† LSD is for comparing K means within genotypes. ns indicates the genotype × K interaction was not significant.
‡ Indicates K rates were different averaged over all genotypes.

Table 4. **Effect of planting date and genotype on lint yield at Florence, SC. Data are averaged over both K rates.**

Genotype	1991 Late-April	1991 Late-May	1992 Late-April	1992 Late-May	1993 Late-April	1993 Late-May
	lb/acre					
PD 5286	1122†	905	342	526	359	490
PD 5358	1216	920	371	456	359	455
PD 5472	999	975	391	450	331	386

† LSD for comparing genotype means within a planting date and year is 97 lb/acre.

Yield differences between the planting dates were not typical (Porter et al., 1996) as there were very low yields for the late-April planting dates in 1992 and 1993. A significant year × planting date × genotype interaction occurred for lint yield (Table 4). In 1991, PD 5286 and PD 5358 had higher yield when planted in late-April than when planted in late-May, but planting date did not affect the yield of PD 5472. In the other 2 yr of the study, the genotype selected for short season production (PD 5286) yielded higher when planted in late-May than when planted in late-April, while differences between the planting dates were not significant for the other two genotypes.

Planting date had a much greater impact on fiber properties than did K fertilization. Averaged over all 3 yr, fiber elongation was slightly greater for the late-May planting date than for the late-April (Table 5). In 1991, fiber from the normal and late planting date treatments did not differ in span length. In 1992 and 1993, both 50% and 2.5% span length were higher for the late-May planting date than for the late-April (Table 5). Fiber cell expansion occurs for about 20 d after anthesis and secondary wall development occurs for another 20 d (Ramey, 1985). Gipson and Joham (1968) reported that fiber length was temperature dependent with maximum length occurring when night temperatures were between 59 and 70°F. In 1991 (when length differences did not occur between planting date treatments), the difference in total heat units between July (when the majority of the bolls in the late-April planting date were in bloom) and August (when the second planting date was flowering) was less than for the other 2 yr (Table 1). Micronaire was lower for the late-May planting date than the late-April in all 3 yr. This is consistent with findings of Porter et al. (1996). The lower micronaire in the late planting date was associated with lower maturity but not fiber perimeter.

Fiber strength was greater for the late-May planting date than for the late-April planting date only in 1993, but yarn strength from cotton in the late-May planting date was greater than for the late-April in 1991 and 1993 (Table 5). Higher yarn strength with late planting was reported previously (May and Bridges, 1995). Absence of differences between planting dates in yarn strength in 1992 may have been due to similar environmental conditions during secondary wall development arising from the proximity of peak bloom in planting dates (Fig. 2). Even though differences in fiber length occurred, indicating a different environment during cell expansion, micronaire and maturity differences (secondary wall characteristics) between planting dates in that year were smaller than for 1991 and 1993 (Table 5).

In summary, applied K increased the lint yield of two of the three genotypes in this study. However, the detrimental effects of K deficiency appear to be the same for these genotypes since yield of all three genotypes was the same at 0 lb K_2O /acre. When peak bloom dates differed markedly in 2 of the 3 yr of this study, late planting decreased the micronaire and the fiber maturity, even though yield levels were not very different between the planting dates within each year. Efforts are needed to ensure adequate micronaire and fiber maturity levels in production systems in which bolls mature later in the season. Adequate K nutrition will be needed for late-maturing production systems; however, the lack of planting date × K interactions for yield and fiber properties in this study indicates that the effects of K deficiency will be the same for both normal- and late-developing cropping systems.

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Table 5. **Effect of planting date on yarn strength and fiber properties at Florence SC. Data are averaged over both K rates.**

Variable	1991 Late-April	1991 Late-May	1992 Late-April	1992 Late-May	1993 Late-April	1993 Late-May	$LSD_{(0.05)}$
Elongation, %	7.4	7.8	7.6	7.9	7.2	7.5	ns†
50% span length, in.	0.55	0.55	0.58	0.61	0.54	0.56	0.01
2.5% span length, in.	1.13	1.13	1.11	1.18	1.10	1.15	0.03
Fiber strength, g/tex	20.8	20.5	22.6	22.1	21.4	22.7	0.8
Micronaire, units	4.5	3.8	5.0	4.7	5.1	4.3	0.3
Maturity, %	90.5	80.1	93.8	90.7	88.3	77.8	4.5
Perimeter, in. × 1000	1.76	1.81	1.80	1.81	2.02	2.06	ns
Yarn strength, g/tex	134	140	141	140	130	151	4.2

†LSD is for comparing planting date means within a year. ns indicates the year × planting date interaction was not significant.

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Research Question

Production systems with late plantings, like double-cropping cotton with small grain, causes cotton boll growth and development to occur later in the season and lower temperatures during this time can influence yield and fiber properties. Potassium deficiency also reduces yield and affects fiber properties. Should production systems that delay boll development be adopted on K-deficient soils, the yield and fiber quality may be compromised beyond the individual effects of low temperature stress and K deficiency. This study was conducted to compare the effects of K deficiency on yield, fiber properties, and yarn strength on early- and late-planted cotton.

Literature Summary

Both low temperature stress during boll development and K deficiency affect the yield and fiber properties of cotton. Studies have been conducted to determine the optimum planting time for highest yield with acceptable fiber properties. As planting is delayed beyond the optimum date, yield and micronaire generally decline while elongation, fiber strength, and yarn strength increase. Recently, K deficiency was reported to be widespread throughout the cotton growing region of the USA. Potassium deficiency reduces micronaire, elongation, fiber length, fiber uniformity, and fiber maturity. There are conflicting reports about the role of cultivar selection in reducing the effect of K deficiency.

Study Description

A 3-yr (1991–1993) study was conducted at Clemson University's Pee Dee Research and Education Center near Florence, SC, on a Hornsville loamy sand soil. Initial soil K rating at the beginning of the experiment was medium (95 lb K/acre), indicating a yield response to K fertilizer 50% of the time.

Treatments:
- a) Seeding dates of late April and late May.
- b) K levels of 0 and 100 lb K_2O/acre applied annually.
- c) Three cotton germplasm lines (PD 5286, PD 5358, and PD 5472) chosen because of their differential yield response to early and late production systems in previous studies.

Applied Questions

How did planting date and K fertilization affect cotton yield and fiber properties?

Cotton in both planting dates had similar responses to K deficiency in this study. Averaged over all 3 yr, lint yield was increased for two of the three genotypes by applying 100 lb K_2O/acre. Fiber length was slightly higher with added K for those two genotypes that responded with higher yield to the K fertilizer.

Full scientific article from which this summary was written begins on page 415 of this issue.

Other fiber properties and yarn strength were not substantially affected by K, regardless of genotype or planting date. Late planting reduced yield in only 1 of the 3 yr, and then only for only two of the three genotypes. In general, cotton planted in late May had higher yarn strength, elongation, and fiber length, but lower micronaire and fiber maturity than cotton planted in late-April. The data from this study indicate that K fertility strategies developed for full-season cotton production systems do not have to be modified for short-season systems.