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AGRONOMY AND SOILS

Effects of Potassium Rates and Timing on Cotton Yield and Fiber Quality

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ABSTRACT

Ensuring potassium (K) is readily available for plant uptake during all stages of growth, especially during reproductive growth, is critical for cotton production. While improvements in cotton genetics and production have led to significant yield improvements, observations of K deficiencies are still common. Re-evaluating the current cotton K fertility recommendations is necessary. The objective of this research was to predict the effect of variable timings and rates of K on cotton yield and fiber quality. Field trials in North Carolina were conducted at two locations in 2017 and three locations in 2018. Treatments included three rates (1, 1.5, and 2 times the soil test analysis recommended rate) applied using three timing combinations (planting, planting and layby, and planting, layby, and three wk after layby) compared to a non-treated control. Layby applications occurred between 45 and 62 d after planting. Treatments were applied as a broadcast granular and the source was muriate of potash. Growth and maturity measurements were recorded throughout the growing season. Petiole samples were collected at five weeks after layby for analysis of K concentration. Yield and fiber quality were also measured. Neither K rate nor application timing had a significant effect on lint yield and fiber quality in any environment. The concentration of tissue K did respond positively to K rates and timings in soil with low potassium availability.

Cotton is more sensitive to K deficiencies than most other crops (Kerby and Adams, 1985; Khalifa et al., 2012). The amount of K absorbed by plants is second only to nitrogen (N) (Havlin et al., 2005). Potassium's role in fruit development is more significant than its role in vegetative growth (Kerby and Adams, 1985; Pettigrew and Meredith, 1997). In 2015, 64% of cotton field soil samples submitted to the North Carolina Department of Agriculture (NCDA) were high or very high in K (Crozier and Hardy, 2018). Applications of K fertilizer usually occur as a single pre-plant application (Oosterhuis, 2002), but in areas with high leaching potential, a split soil-applied K application, with half applied pre-plant, and half applied at first bloom, has been reported as beneficial (Abaye, 1998). Choice of K fertilizer source does not seem to change efficacy (Howard et al., 1998; Makhdum et al., 2007). Management of K begins with consideration and knowledge of the amount of K in the soil and the soil type in question.

Maturity is delayed in cotton that has access to very high levels of K in the soil (Gwathmey and Howard, 1998; Kerby and Adams, 1985) and is cut short by deficiency (Kerby and Adams, 1985). Boll growth requires sugar accumulation at high rates which must be transported using energy from adenosine triphosphate that is synthesized using K (Havlin et al., 2005). Bennett et al. (1965) reported increased boll weights as a result of increased K rates. Potassium deficiencies can cause low lint yield (Pettigrew, 2003; Pettigrew and Meredith, 1997; Read et al., 2006), low boll weight (Pettigrew and Meredith, 1997; Read et al., 2006), boll shedding (Kerby and Adams, 1985), and leaf shedding (Read et al., 2006). Much of the research suggests that lint and seed yield exhibit a response to K rates (Bennett et al., 1965; Cassman et al., 1989; Clement-Bailey and Gwathmey, 2007; Gormus, 2002; Kerby and Adams, 1985; Khalifa et al., 2012; Mapkhdum et al., 2007).

Potassium deficiencies can limit fiber quality (Pettigrew and Meredith, 1997) by decreasing strength (Read et al., 2006), producing short staple fibers (Bennett et al., 1965), and reducing micronaire (Bennett et al., 1965; Read et al., 2006) only when severely deficient for an extended amount of time. Potassium at high or very high levels does not seem to affect cotton yield and is only occasionally a concern for fiber quality (Marcus-Wyner

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and Rains, 1982). Bennett et al. (1965) reported no changes in elongation at any K rates but did report a decrease in fiber strength at rates above 140 kg K ha^{-1}.

Cotton can exhibit K deficiency symptoms in fields with sufficient K (Cassman et al., 1989). Cotton retains high concentrations of K in leaves before reproductive growth begins to supply sufficient K to fruiting structures. In cases where the boll load is too much for the plant to adequately supply K, the deficiency symptoms will appear in the upper leaves (Reedy et al., 2000). According to a study done by Rosolem and Mikkelsen (1991), cotton can tolerate a K deficient environment late in the season for up to 30 d without experiencing yield loss.

Potassium deficiencies in cotton have begun to appear in the latter part of the growing season where soil reports suggest K levels are sufficient (Oosterhuis, 2002; Weir et al., 1986). This phenomenon has been called K deficiency syndrome by some. Proposed reasoning behind these occurrences include infection from *Verticillum* wilt (Weir et al., 1986), root knot nematode (*Meloidohyne incognita*) damage (Oosterhuis, 2002), and that cotton is a poor K absorber (Rosolem and Mikkelsen, 1991). While pest pressure can be minimized with pesticides, increasing K absorption by the roots is not as easily resolved. As mentioned previously, bolls are a major K sink (Halevy, 1976; Leffler and Tubertini, 1976; Weir et al., 1986) and genotypes have been developed with root systems that are more efficient K absorbers than others (Brouder and Cassman, 1990; Halevy, 1976). Foliar applications of K have been used effectively to proactively or retroactively relieve K deficiency that occurs during the boll fill period (Oosterhuis, 2002). Bolls receive a portion of K from leaves and other vegetative structures during the boll fill period (Reedy et al., 2000). Cotton accumulates K at elevated rates before reproductive growth when there is more than enough available in the soil (Bennett et al., 1965). Therefore, maintaining a high amount of K in the soil for luxury consumption may benefit cotton yield. However, since K is leachable but also requires water for plant uptake, considering the timing of application(s) is critical for profitability. The objective of the current experiment was to evaluate the effect of K application rates and timings on yield and fiber quality in modern cotton cultivars.

MATERIALS AND METHODS

Experiments were conducted in 2017 and 2018 at the Peanut Belt Research Station (PBRS) in Lewiston, NC, and the Sandhills Research Station (SRS) in Candor, NC. In 2018, a location was added at the Upper Coastal Plain Research Station (UCPRS) in Rocky Mount, NC. Soil series, soil pH, soil cation exchange capacity (CEC), planting date, seeding rate, and irrigation for each location are described in Table 1. Monthly and cumulative precipitation for each growing environment is illustrated in Table 2 (Cardinal, 2023). The cultivar used at all locations in 2017 and 2018 was ST 4848 GLT™ (Stoneville®, BASF Corporation, Research Triangle Park, NC), except for the SRS location in 2017, which was planted with ST 5115 GLT™ (Stoneville®, BASF Corporation, Research Triangle Park, NC) due to issues with availability of ST 4848 GLT™. Both cultivars' average performance over four years in the official variety test at SRS is similar according to the NC Cotton Variety Performance Calculator (NC State Extension, 2017). The experiment was conducted as a randomized complete block design with four replications at each location. Experimental units at UCPRS and PBRS consisted of four 12.2 m long rows spaced 0.91 m apart. Experimental units at SRS consisted of four 12.2 m long rows spaced 0.97 m apart.

Potassium was broadcast applied with a chest-mounted fertilizer spreader using a granular 0-0-60 (potassium chloride) fertilizer to achieve total rates of 1 (1x), 1.5 (1.5x), and 2 times (2x) the recommended potash rate (Table 1), based on soil samples analyzed at the North Carolina Department of Agriculture and Consumer Services agronomic lab using the Mehlich-3 analytical method. Treatments were applied either 1) at planting, 2) at planting and layby, or 3) at planting, at layby, and three wk after layby. If two or three timings were used, half or a third of the total rate was applied at each timing, respectively. Layby occurred between 45 and 62 d after planting. Treatments, application rates, and application timings are illustrated in Table 3. Mepiquat chloride (Mepex®, DuPont, Wilmington, DE.) and other growth regulators were not applied to any plots due to the difference in K rate and foliar growth between individual plots. All other management procedures were conducted according to the NCDA soil test recommendations.

Table 1. Soil series, soil pH, available potassium, recommended potash value, planting date, seeding rate, and irrigation at Peanut Belt (PBRS), Upper Coastal Plain (UCPRS), and Sandhills (SRS) research stations in 2017 and 2018.

Environment		Soil Series	Soil pH[z]	Available Potassium	Recommended Potash Value[z]	CEC[z]	Planting Date	Seeding Rate	Irrigation
Location	Year			-- mg kg^{-1} soil --	----- kg ha^{-1} -----			--- Seeds meter^{-1} ---	
PBRS	2017	Lynchburg sandy loam *Fine-loamy, siliceous, semiactive, thermic Aeric Pleaquults*	6.2	91.9	67	4.5	May 11	13.1	Irrigated
SRS	2017	Candor sand *Sandy, kaolinitic, thermic Grossarenic Kandiudults*	6.6	50.8	112	4.2	May 1	9.8	Irrigated
PBRS	2018	Goldsboro sandy loam *Fine-loamy, siliceous, subactive, thermic Aquic Paleudults*	5.7	74.3	79	4.2	May 15	13.1	Dryland
UCPRS	2018	Norfolk loamy sand *Fine-loamy, kaolinitic, thermic Typic Kandiudults*	5.8	101.7	56	3.3	May 14	13.1	Irrigated
SRS	2018	Candor sand *Sandy, kaolinitic, thermic Grossarenic Kandiudults*	6.1	41.1	123	4.3	May 4	9.8	Irrigated

[z] Soil samples were analyzed at the North Carolina Department of Agriculture and Consumer Services Agronomic Lab using the Mehlich-3 Analytical Method.

Table 2. Monthly and cumulative precipitation at Peanut Belt (PBRS), Upper Coastal Plain (UCPRS), and Sandhills (SRS) research stations in 2017 and 2018.

Month	PBRS 2017	SRS 2017	PBRS 2018	UCPRS 2018	SRS 2018
	------ cm ------				
April	14.4	12	11.7	10.7	11.7
May	14.8	16.1	24.8	16.6	4.6
June	14.2	9.5	14.1	7.3	3.9
July	18.8	9.4	29.2	18.1	12.8
August	12.8	7.5	15.8	9.4	22.5
September	8.2	6.4	14.8	13	48.4
October	6.9	8.8	7.7	4.9	16.1
Total	90.1	69.7	118.1	80	120

Table 3. Potassium treatments with rates and timings for split applications.

Treatment[z]	Potassium Rate[y]	% K at Planting	% K at Layby	% K at 3 wk After Layby
UTC	None	0	0	0
1x, P	1x	100	0	0
1x, P, L	1x	50	50	0
1x, P, L, +3	1x	33	33	33
1.5x, P	1.5x	150	0	0
1.5x, P, L	1.5x	75	75	0
1.5x, P, L, +3	1.5x	50	50	50
2x, P	2x	200	0	0
2x, P, L	2x	100	100	0
2x, P, L, +3	2x	67	67	67

[z] Treatments – UTC: Untreated Check; 1X: Recommended rate; 1.5X: 1.5 x Recommended rate; 2X: 2 x Recommended rate; P: Application at planting; L: Application at lay-by; +3: Application at lay-by plus 3 weeks

[y] Recommended value based on soil analysis by the North Carolina Department of Agriculture and Consumer Services Agronomic Lab using the Mehlich-3 Analytical Method.

Stand counts were recorded within three wk of planting. Plant height and nodes above white flower (NAWF) for five plants on the two center rows were recorded at first bloom, three wk after layby, and five wk after layby. Petiole samples were collected five wk after layby and sent to Water's Agricultural Laboratories, Incorporated (Warsaw, NC) for analysis of K concentrations using acetic acid extraction and inductively coupled plasma (ICP) analysis. End-of-season plant growth measures were collected on five plants on the two center rows when 50-60% of bolls were open on average throughout the field. End-of-season plant growth measures were collected by recording height, nodes to the first fruiting branch (NFFB), nodes to the uppermost cracked boll (NUCB), nodes to the uppermost harvestable boll (NUHB), and total nodes. Nodes to the uppermost cracked boll recorded on a specific date can be used to signify differences in maturity between treatments (Whitaker et al., 2008). A visual defoliation rating was recorded at harvest which captured the percentage of bolls open, the percentage of defoliation, and the percentage of desiccation. Desiccation was determined by the amount of dried, stuck leaves appearing on the plant.

The center two rows of the plots were harvested with a two-row John Deere 9910 spindle-type picker (John Deere, Moline, IL). Total seed cotton yield was recorded for each plot and a 200 g sub-sample was collected for seed weight, lint weight, lint percentage, and High Volume Instrumentation (HVI) analysis. Seed weight, lint weight, and lint percentage were collected by ginning samples with a continental 12-saw cotton gin (Continental Eagle Corporation, Prattville, AL). High Volume Instrumentation analysis was conducted at Cotton Inc. (Cary, NC). The HVI data included micronaire, fiber length (upper half mean length), length uniformity, fiber strength, elongation, and short fiber content.

Site-year and replications were treated as a random effect while treatment and environment were fixed. All data were subjected to analysis of variance using PROC GLIMMIX (GLIMMIX procedure) in SAS version 9.4 (SAS Institute Inc. SAS® 9.4. Cary, NC). Means of significant main effects and interactions were separated using Tukey-Kramer's test at $p \leq 0.05$.

RESULTS AND CONCLUSIONS

No difference was observed between treatments for NAWF (Table 4). The only significant difference K rate and timing had on plant heights in all environments is at three wk after layby where the treatment of 1.5x recommended K rate applied at planting, layby, and three wk after layby was significantly taller, at 89 cm, than the 2x recommended K rate applied at planting and layby treatment, at 83 cm (Table 4). Potassium's role in fruit development is more significant than its role in vegetative growth (Kerby and Adams, 1985; Pettigrew and Meredith, 1997), therefore a response in plant height might not be the strongest indicator for differences in K rate and application timing.

Table 4. Nodes above white flower and plant height as influenced by potassium rate and timing across environments.

Treatment[z]	Nodes Above White Flower			Plant Height			
	Time of Measurement						
	FB[y]	3 WAL	5 WAL	FB	3 WAL	5 WAL	EOS
	no.			cm			
UTC	5a[x]	2.7a	1.9a	75.2a	83.2ab	99.3a	87.2a
1x,P	4.7a	2.9a	2a	73.9a	85.8ab	101.3a	90.4a
1x,P,L	4.9a	2.7a	1.9a	75.4a	84.7ab	101.3a	90.4a
1x,P,L,+3	4.8a	2.7a	1.9a	43.6a	82.8ab	100.8a	87.9a
1.5x,P	5.2a	2.8a	2.2a	74.2a	84.3ab	102.5a	88.8a
1.5x,P,L	5a	2.8a	1.9a	75.6a	83.8ab	100.6a	90.7a
1.5x,P,L,+3	4.7a	2.9a	2.2a	76.3a	89.2a	103.2a	90.4a
2x,P	4.9a	2.6a	1.9a	76.8a	85.9ab	101.6a	89a
2x,P,L	5a	2.9a	2a	75.4a	82.5b	100.5a	89.4a
2x,P,L,+3	5.1a	2.8a	2a	76.9a	85.6ab	99.3a	91.3a

[z] Treatments – UTC: Untreated Check; 1X: Recommended rate; 1.5X: 1.5 x Recommended rate; 2X: 2 x Recommended rate; P: Application at planting; L: Application at lay-by; +3: Application at lay-by plus 3 weeks.

[y] FB, 3WAL, 5WAL and EOS designate first bloom, 3 weeks after layby, 5 weeks after layby, respectively.

[x] Means with the same letter are not significantly different based on Tukey-Kramer's test ($p > 0.05$).

An interaction between environment and treatment was observed for tissue K concentration (Table 5). Potassium rate had a significant effect on tissue K concentration in all environments (Table 6). Potassium rate and timing had a significant effect on tissue K concentration at PBRS 2018, SRS 2017, and SRS 2018 (Table 7). At PBRS 2018 the untreated check had a lower tissue K concentration than the 1x, 1.5x, and 2x recommended K rate applied at planting and the 2x recommended K rate applied at planting and layby. At SRS 2017 the untreated check had a lower tissue K concentration than the 1.5x and 2x recommended K rate applied at planting and layby and at planting, layby, and three wk after layby. At SRS 2017 the 2x recommended K rate applied at planting, layby, and three wk after layby had a significantly higher tissue K concentration than all 1x recommended K rate treatments and the 1.5x recommended K rate treatment applied at planting. The untreated check at SRS 2018 had a significantly lower tissue K concentration than the 2x recommended K rate treatment applied at planting and at planting and layby. The data from this study suggest that in an environment with low soil available K, a single application of 2x recommended K rate, or split applications of at least a 1x rate may be necessary to produce a significant increase in tissue K concentration. The increased concentration of tissue K did not increase lint yield, however. Deficiency symptoms were observed in the untreated plots at SRS 2017 and were widespread at varying degrees of severity at SRS 2018 and UCPRS 2018.

Potassium rate and timing main effect for all plant mapping measurements in all environments were not significant (Table 8). Nodes to the first fruiting branch, NUHB, and total nodes measurements were higher overall in 2017 than in 2018 (Data not shown). The range of total nodes by treatment in 2017 was from 17.3 to 18.6 nodes, while the range of total nodes by treatment in 2018 was from 15.2 to 16.6 nodes. Other studies concluded higher K rates cause delayed maturity (Gwathmey and Howard, 1998; Kerby and Adams, 1985), lower K rates can hasten maturity (Kerby and Adams, 1985), and that higher K rates produced more growth in cotton (Bennett et al., 1965).

There was no difference in any defoliation rating measurements among any treatments due to K rate and timings in any environment (Data not shown). All treatments had at least 85% defoliation, at least 90% open bolls, no more than 7% desiccation, and no more than 2% regrowth.

Table 5. An analysis of variance *p*-values for cotton growth parameters, lint yield, and fiber quality as affected by environment and treatment.

Source	NAWF 5WAL[z]	EOS Plant Height[y]	Tissue Sample Potassium Content	Nodes to 1st Fruiting Branch	Nodes Above Uppermost Cracked Boll	Nodes to Uppermost Harvestable Boll	Total Nodes	Lint Yield	Micronaire
Environment	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.001
Treatment	0.8956	0.7751	<0.001	0.1180	0.2185	0.3334	0.4223	0.5196	0.0042
Environment x Treatment	0.9604	0.3997	0.0002	0.9102	0.4243	0.1935	0.9095	0.0155	<0.001

[z] Nodes above white flower 5 wk after layby.

[y] End of season plant height.

Table 6. An analysis of variance *p*-values for cotton growth parameters, lint yield, and fiber quality as affected by potassium rate and timing.

Source	NAWF 5WAL[z]	EOS Plant Height[y]	Tissue Sample Potassium Content	Nodes to 1st Fruiting Branch	Nodes Above Uppermost Cracked Boll	Nodes to Uppermost Harvestable Boll	Total Nodes	Lint Yield	Micronaire
Rate	0.4506	0.9634	<0.001	0.5168	0.7485	0.7090	0.8334	0.8196	0.2605
Timing	0.7019	0.8584	0.3359	0.0343	0.9046	0.4262	0.7364	0.7916	0.2337
Rate x Timing	0.6022	0.5917	0.7781	0.1255	0.0146	0.7937	0.6028	0.5509	0.9745

[z] Nodes above white flower 5 wk after layby.

[y] End of season plant height.

Table 7. Tissue sample content of potassium as influenced by potassium rate and timing at Peanut Belt (PBRS), Upper Coastal Plain (UCPRS), and Sandhills (SRS) research stations in 2017 and 2018.

Treatment[z]	PBRS 2017	SRS 2017	PBRS 2018	UCPRS 2018	SRS 2018
	%				
UTC	1.02a[y]	0.65c	1.14b	1.53a	0.57b
1x, P	1.09a	0.83bc	1.41ab	1.52a	0.95ab
1x, P, L	0.93a	0.86bc	1.64a	1.52a	0.81ab
1x, P, L, +3	1.03a	0.88bc	1.70a	1.44a	0.90ab
1.5x, P	1.06a	0.86bc	1.50ab	1.77a	1.00ab
1.5x, P, L	1.06a	1.00ab	1.64a	1.60a	0.93ab
1.5x, P, L, +3	1.13a	0.97ab	1.75a	1.26a	1.04ab
2x, P	0.93a	0.95abc	1.54ab	1.72a	1.27a
2x, P, L	1.05a	1.11ab	1.58ab	1.56a	1.14a
2x, P, L, +3	1.14a	1.23a	1.85a	1.64a	1.02ab

[z] Treatments – UTC: Untreated Check; 1X: Recommended rate; 1.5X: 1.5 x Recommended rate; 2X: 2 x Recommended rate; P: Application at planting; L: Application at lay-by; +3: Application at lay-by plus 3 weeks.

[y] Means with the same letter are not significantly different based on Tukey-Kramer's test ($p > 0.05$).

Table 8. Plant mapping measurements as influenced by potassium rate and timing across environments.

Treatment	Plant Mapping Measurement			
	Nodes to 1st Fruiting Branch	Nodes Above Uppermost Cracked Boll	Nodes to Uppermost Harvestable Boll	Total Nodes
	no.			
UTC[z]	6.1a[y]	9.8a	12.4a	16.3a
1x,P	6.2a	9.8a	13.4a	17a
1x,P,L	6.5a	9.9a	12.9a	16.9a
1x,P,L,+3	6a	10.1a	12.9a	16.8a
1.5x,P	6.1a	9.9a	13.4a	17a
1.5x,P,L	6.4a	10.5a	13.4a	17.3a
1.5x,P,L,+3	6a	9.7a	13.1a	16.7a
2x,P	6.1a	10.4a	13.4a	16.8a
2x,P,L	6.1a	9.6a	12.8a	16.8a
2x,P,L,+3	6.2a	10.1a	13.3a	17.1a

[z] Treatments – UTC: Untreated Check; 1X: Recommended rate; 1.5X: 1.5 x Recommended rate; 2X: 2 x Recommended rate; P: Application at planting; L: Application at lay-by; +3: Application at lay-by plus 3 weeks.

[y] Means with the same letter are not significantly different based on Tukey-Kramer's test ($p > 0.05$).

Potassium rate and application timing main effect for lint yield were not significant regardless of environment (Table 9). In individual environments, K rate, and the application timing main effect on lint yield were only significant at SRS 2018 where the untreated check produced a lower yield than the 1x and 2x recommended K rate applied at planting (Table 10). Two environments, PBRS 2017 and UCPRS 2018, had a soil available K concentration of 91.2 ppm and 101.7 ppm, respectively (Table 1). A soil available K concentration around 100 ppm would typically recommend a K application primarily for maintenance and would not necessarily be expected to produce a yield response. Lower K available soils, such as the ones at SRS 2017, SRS 2018, and PBRS 2018 would be considered sub-optimal, and a yield response would typically be expected from a K application. At SRS 2018, increasing the K rate from the untreated check and applying exclusively at pre-plant, increased lint yield with the exception of the 1.5x recommended K rate treatments. Separated by years, higher lint yields were produced in 2017 than in 2018 (Table 11). The range of average lint yields by treatment in 2017 was from 1,081 kg ha^{-1} to 1,202 kg ha^{-1}, while the range of average lint yields by treatment in 2018 was from 500 kg ha^{-1} to 664 kg ha^{-1}. The overall low yields in 2018, largely due to excessive rainfall, are likely why no yield response was observed between treatments that year.

Increasing K rates in this experiment only resulted in significantly greater lint yield at SRS 2018 where the untreated check produced a lower yield than the 1x and 2x recommended K rate applied at planting (Table 10). In other similar studies, K rate was found to increase lint yield (Bennett et al., 1965; Cassman et al., 1989; Clement-Bailey and Gwathmey, 2007; Gormus, 2002; Kerby and Adams, 1985; Khalifa et al., 2012; Makhdum et al., 2007), while others observed no effect on lint yield from K fertilization rates (Girma et al, 2007). Reasons for this discrepancy could be that the soil available K may have been at sufficient levels at PBRS 2017 and UCPRS 2018, or because the excessive rainfall at PBRS 2018 and SRS 2018 may have stressed the crop. At SRS the coarse soils have a very low water holding capacity which, along with causing drought stress, can significantly limit K uptake if soil water availability is low. This may help explain the results from SRS 2017. Results noted here are similar to those observed by Marcus-Wyner and Rains (1982), high K rates did not negatively affect lint yield.

Table 9. Fiber yield and quality as influenced by potassium rate and timing across environments.

Treatment[z]	Lint Yield	Micronaire	Uniformity	Strength	Short Fiber Content
	------- kg ha^{-1} -------	-------- Units --------	---------- % ----------	------- g tex^{-1} -------	---------- % ----------
UTC	688a[y]	4.56b	82.71a	29.29a	8.67a
1x, P	758a	4.78a	82.96a	29.94a	8.46a
1x, P, L	764a	4.83a	82.35a	29.61a	8.76a
1x, P, L, +3	742a	4.74ab	82.64a	29.97a	8.77a
1.5x, P	740a	4.73ab	82.55a	29.27a	8.72a
1.5x, P, L	734a	4.73ab	82.99a	29.71a	8.48a
1.5x, P, L, +3	761a	4.69ab	82.75a	29.42a	8.47a
2x, P	758a	4.77a	82.49a	29.67a	8.59a
2x, P, L	743a	4.78a	83.06a	29.34a	8.46a
2x, P, L, +3	709a	4.7ab	82.57a	29.36a	8.72a

[z] Treatments – UTC: Untreated Check; 1X: Recommended rate; 1.5X: 1.5 x Recommended rate; 2X: 2 x Recommended rate; P: Application at planting; L: Application at lay-by; +3: Application at lay-by plus 3 weeks.

[y] Means with the same letter are not significantly different based on Tukey-Kramer's test ($p > 0.05$).

Table 10. Fiber yield as influenced by potassium rate and timing at Peanut Belt (PBRS), Upper Coastal Plain (UCPRS), and Sandhills (SRS) research stations in 2017 and 2018.

Treatment[z]	PBRS 2017	SRS 2017	PBRS 2018	UCPRS 2018	SRS 2018
	kg ha^{-1}				
UTC	1745a[y]	612a	620a	562a	318b
1x, P	1673a	647a	584a	559a	784a
1x, P, L	1607a	683a	633a	630a	729ab
1x, P, L, +3	1575a	737a	613a	533a	700ab
1.5x, P	1635a	652a	615a	624a	624ab
1.5x, P, L	1510a	743a	617a	552a	693ab
1.5x, P, L, +3	1618a	785a	632a	553a	674ab
2x, P	1628a	658a	636a	511a	814a
2x, P, L	1637a	712a	632a	632a	554ab
2x, P, L, +3	1487a	676a	598a	618a	596ab

[z] Treatments – UTC: Untreated Check; 1X: Recommended rate; 1.5X: 1.5 x Recommended rate; 2X: 2 x Recommended rate; P: Application at planting; L: Application at lay-by; +3: Application at lay-by plus 3 weeks.

[y] Means with the same letter are not significantly different based on Tukey-Kramer's test ($p > 0.05$).

Table 11. Fiber yield as influenced by potassium rate and timing years separate.

Treatment[z]	Lint Yield	
	2017	2018
	------------------- kg ha^{-1} -------------------	
UTC	1178a[y]	500a
1x, P	1160a	642a
1x, P, L	1146a	663a
1x, P, L, +3	1157a	615a
1.5x, P	1143a	621a
1.5x, P, L	1127a	621a
1.5x, P, L, +3	1202a	620a
2x, P	1143a	654a
2x, P, L	1127a	605a
2x, P, L, +3	1081a	603a

[z] Treatments – UTC: Untreated Check; 1X: Recommended rate; 1.5X: 1.5 x Recommended rate; 2X: 2 x Recommended rate; P: Application at planting; L: Application at lay-by; +3: Application at lay-by plus 3 weeks.

[y] Means with the same letter are not significantly different based on Tukey-Kramer's test ($p > 0.05$).

Potassium application timing also had no effect on lint yield. In contrast, Gormus (2002) observed a reduction in yield following split applications of K, and others observed a yield increase following split applications of K (Yang et al., 2016). Kusi et al. (2021) reported inconsistent lint yield response from split and single-season K applications. Like these previously mentioned studies, soil type and climate could largely influence the results found in this study.

An interaction between environment and treatment was observed for micronaire (Table 5). Micronaire was significantly affected by K rate at SRS 2018 but not for any of the other environments (Table 12). At SRS 2018 the untreated check produced a micronaire value lower than all other treatments. No clear relationship between K rate and timing and micronaire was found. Potassium rate and application timing main effect for all other fiber quality measurements, including upper half mean length (UHM), uniformity, strength, elongation, and short fiber content, in all environments was not significant. None of these fiber quality measurements fell in the discount range for any of the treatments at any environment.

The data suggest that K rate and timing do not have a significant effect on micronaire, which can be supported by the findings in Gormus (2002) but is in contrast to findings by Bennett et al. (1965) and Cassman et al. (1990), who found a response to micronaire from K rate. All other fiber quality measures including UHM, uniformity, strength, elongation, and short fiber content did not respond to K rate or timing. In other studies fiber strength (Gormus, 2002) and fiber length (Cassman et al., 1990; Gormus, 2002) responded positively to increasing K rate. Still, other experiments (Pettigrew et al., 1996) show no change in fiber strength due to K rate. The previously mentioned studies suggest that the interaction of K rate and timing and fiber quality is inconsistent.

Table 12. Micronaire as influenced by potassium rate and timing at Peanut Belt (PBRS), Upper Coastal Plain (UCPRS), and Sandhills (SRS) research stations in 2017 and 2018.

Treatment[z]	PBRS 2017	SRS 2017	PBRS 2018	UCPRS 2018	SRS 2018
	------------------------ Units ------------------------				
UTC	4.41ab[y]	4.55a	5.11a	4.82a	3.93b
1x, P	4.66a	4.58a	4.94a	4.81a	4.92a
1x, P, L	4.59ab	4.62a	5.20a	4.95a	4.77a
1x, P, L, +3	4.44ab	4.87a	5.10a	4.78a	4.54a
1.5x, P	4.35ab	4.62a	5.15a	4.80a	4.72a
1.5x, P, L	4.56ab	4.58a	5.05a	4.84a	4.64a
1.5x, P, L, +3	4.41ab	4.56a	4.99a	4.92a	4.60a
2x, P	4.45ab	4.62a	5.10a	4.84a	4.83a
2x, P, L	4.32ab	4.84a	5.17a	4.82a	4.75a
2x, P, L, +3	4.38b	4.56a	5.15a	4.87a	4.56a

[z] Treatments – UTC: Untreated Check; 1X: Recommended rate; 1.5X: 1.5 x Recommended rate; 2X: 2 x Recommended rate; P: Application at planting; L: Application at lay-by; +3: Application at lay-by plus 3 weeks.

[y] Means with the same letter are not significantly different based on Tukey-Kramer's test ($p > 0.05$).

This study found that the effect K rate and application timing has on lint yield and fiber quality is complex. Potassium rate and application timing main effects for lint yield were not significant in all environments, which could be explained by the influence of factors, such as climate conditions, soil textures, and soil fertility. With a yield increase observed at SRS 2018 when K was applied at 1x and 2x recommended K rate as compared to the untreated check, there is reason to believe that a yield response can be achieved with a K application in certain environments. More research is needed to understand the impact environmental conditions have on K rates and timing effect on lint yield.

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