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AGRONOMY AND SOILS

Soil Potassium Effects on Cotton Lint Yield and Fiber Quality on the Texas High Plains

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ABSTRACT

When comparing soil potassium (K) levels common in West Texas to the current Mehlich III-K critical levels for cotton (*Gossypium hirsutum* L.), fertilizer K applications are seldom recommended. However, when soil K is applied, positive responses in cotton yield have been reported. Studies were conducted in Lamesa and New Deal, TX to: 1) determine K effects on leaf K concentrations; 2) evaluate whether K application increases crop growth, yield, and fiber quality in sufficient K soils; and 3) evaluate whether K application under water deficit conditions also increases growth, yield, and fiber quality. In Lamesa, muriate of potash (KCl) was applied using two methods, knife-injected (0-0-15) and broadcast (0-0-60); and at New Deal, KCl was applied using knife injection. Potassium application rates included 0, 45, 90, 135, and 180 kg ha^{-1} with both high (90% ET) and low (30% ET) irrigation levels. At Lamesa in 2016 at 90% ET irrigation, lint yield was greater when 90 kg K ha^{-1} was broadcast (2,153 kg ha^{-1} lint) compared to the 180 kg K ha^{-1} treatment, and all K treatments with 30% ET irrigation. There were no lint yield differences in 2017 at Lamesa. At New Deal, lint yield was similar amongst all K application rates in both years. Although K application increased yield with the 90% ET irrigation level with broadcast application, no differences were observed in water-deficit cotton suggesting further research is needed to better understand the dynamics of K on lint yield in semiarid cotton production systems.

Potassium (K) is a macronutrient that impacts cotton (*Gossypium hirsutum* L.) growth and development, lint yield, and fiber quality (Cassman et al., 1990). Potassium deficiency in cotton is occurring more often across the U.S. possibly due to modern faster-fruiting and higher-yielding cotton cultivars (Pabuayon et al., 2020), reduced root growth and ion uptake during reproductive development, and reduced levels of plant-available soil K (Oosterhuis, 1995). Cotton is more sensitive to low availability of K than other crops, and deficiency symptoms have appeared in soil not considered deficient in K (Cassman et al., 1990; Gulick et al., 1989; Hons et al., 1990), thus K fertilizer is used when the soil is unable to supply an adequate amount of K required for crop yield goals. Potash or potassium chloride (KCl) accounts for more than 90% of the K fertilizer used globally for plant nutrition (IPNI, 2011). Potassium, a single-charged cation in soils (IPNI, 2011), is a vital macronutrient involved in many chemical and physical plant processes necessary for plant growth and development (Yang et al., 2014).

Cotton bolls are a major sink for K, and K uptake by roots can be limited by dry soils due to reduced diffusion (Gulick et al., 1989; Hake et al., 1991). In addition, K increases boll set later in the growing season allowing more bolls and higher yields (Kerby and Adams, 1985). Conversely, K deficiency decreases leaf area expansion and canopy photosynthesis, which reduces cotton growth and development (Reddy and Zhao, 2005). Cassman et al. (1990) and Pettigrew et al. (1996) determined that K fertilization had a positive effect on cotton lint yield with the addition of K increasing yield compared to no K application or K deficiency reducing yield. Potassium deficiency decreases the translocation of photosynthetic assimilates out of the cotton leaves and into the developing boll, reducing plant growth and development (Ashley and Goodson, 1972). In addition to photosynthesis, K is involved in the maintenance of water pressure in the plant, enzyme activation, pH balance, and other physiological processes (Clarkson and Hanson, 1980; Hake et al., 1991).

Cotton has an indeterminate growth habit. Therefore, changing plant nutritional content can have a

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significant impact on the development of individual cotton bolls produced in the field (Wanjura and Barker, 1985). Potassium can affect fiber quality because it has a direct impact on the osmotic potential of the fiber cell (Harmon and Ramey, 1986). Dhindsa et al. (1975) determined that during the highest growth rate of a cotton fiber, K concentration also reaches its highest level, which accounts for 55% of the total osmotic potential. Their results also demonstrated that K is an osmoregulatory solute during fiber development. Cassman et al. (1990) found that limited, water-soluble K in soil at a 40-cm depth at maturity and early bloom reduced fiber quality parameters. Bennett et al. (1965) reported that fiber length and micronaire were increased with the application of K when irrigated, whereas Nelson and Ware (1932) and Pettiet (1973) determined that with dryland conditions K had no effect on fiber quality.

Water availability is often the most limiting factor in the Texas High Plains, where high temperatures, low rainfall, and high evapotranspiration (ET) potential during the growing season result in moisture stress in cotton (Feng et al., 2010; Ritchie at al., 2009). Potassium has been reported to mitigate drought stress due to K regulating the opening and closing of the stomates to prevent water loss (Bednarz et al., 1998; Griffin and Danner, 1998). Potassium is a main factor involved in the fixation of photosynthetic carbon dioxide (CO_2), whereas drought stress decreases CO_2 fixation due to stomatal closure (Cakmak, 2005). Berkowitz and Whalen (1985) determined that when K is deficient, the osmotic potential of K in the leaf cells is reduced due to a decrease in turgor pressure. Low soil water decreases the availability of K to the plant due to the low soil mobility of K (Hu and Schmidhalter, 2005). Our hypothesis was that with added K, we would observe a greater response in the lower irrigation due to K's involvement in osmotic regulation.

The objectives of this research were to: (1) determine K fertilizer application rate effects on leaf K concentrations; (2) evaluate whether K fertilizer application increases yield and fiber quality in soils with sufficient tested K; and (3) evaluate whether K fertilizer application in the presence of water deficit conditions also increases yield and fiber quality.

MATERIALS AND METHODS

Field studies were conducted in 2016 and 2017 at the Agricultural Complex for Advanced Research and Extension Systems (Ag-CARES) located in Lamesa, TX (32.7643°N, - 101.9486°W) and at the Texas Tech University Department of Plant and Soil Science New Deal Research Farm located near New Deal, TX (33.4441°N, -101.4337°W). The soil series at Lamesa is an Amarillo fine sandy loam (fine-loamy, mixed, superactive, thermic Aridic Paleustalfs), which is classified as a very deep, well drained, and moderately permeable soil (USDA NRCS, 2017a). At New Deal the soil is classified as a Pullman clay loam (fine, mixed, superactive, thermic Torrertic Paleustolls), which is a very deep, well drained, and slowly permeable soil (USDA NRCS, 2017b).

The cotton variety Deltapine 1522 Bollgard II® XtendFlex® (DP 1522 B2XF) (Bayer CropScience, Research Triangle Park, NC) was planted at 131,000 seeds ha^{-1} on 24 May 2016 at Lamesa and 7 June 2016 and 16 May 2017 at New Deal. Cotton was replanted on 7 June 2017 in Lamesa at 117,084 seeds ha^{-1} due to poor germination from unfavorable weather conditions of high temperature, strong wind, and limited rainfall. There was a hail event on 5 July 2016 in Lamesa that caused plant damage but not plant loss. Both locations were managed using conventional tillage, which included bed prepping prior to planting and three in-season cultivations using sweeps to control weeds. Manual hoeing was used at all locations and years to control weeds. DP 1522 B2XF is considered early to mid-maturing with a semi-smooth leaf that is adaptable to different growing environments (DeltaPine, 2020).

The experimental design in both locations was a randomized complete block design with irrigation (main) and K rate (subplot) arranged as a split plot. At Lamesa, fertilizer rate and application method were arranged in a randomized complete block design replicated four times within each irrigation rate. There were two main effects at New Deal: K fertilizer application rate and irrigation amount. Treatments were replicated four times for a total of 40 plots. Plots at both locations were four rows wide (1-m spacing) by 12.2 m in length for a total plot area of 50 m^2.

Potassium Treatments. Potassium fertilizer was applied 2 to 4 wk before planting at rates of 0, 45, 90, 135, and 180 kg K ha^{-1}. Fertilizer K was applied at Lamesa on 2 May 2016 and 8 May 2017 as dry potassium chloride (KCl; 0-0-60) broadcast applied and liquid form KCl (0-0-15) knife-injected. Liquid KCl (0-0-15) was knife-injected at New Deal on 6 June 2016 and 6 May 2017. After broadcast application of 0-0-60, a rolling cultivator was used to incorporate fertilizer to a 10-cm depth at the Lamesa location. For liquid knife-injection application of 0-0-15, a four-row side-dress applicator with four injection knives mounted behind coulters was used with knives set 10 cm off the top center of the bed and at a depth of 15 to 20 cm below the soil surface at both locations.

Irrigation Treatments. Cotton at both locations was planted on a subsurface drip field with drip tape placed underneath the center of each row (1.01-m row spacing). High (80% ET at New Deal and 90% ET at Lamesa) and low (30% ET at New Deal and 30% ET at Lamesa) irrigation levels were used in 2016. New Deal had high (80% ET) and low (30% ET) irrigation levels and Lamesa had a base (60% ET) irrigation level due to irrigation controller programming errors in 2017.

Rainfall received in Lamesa during the 2016 season starting 24 May was 349 mm (Fig. 1). Accumulated growing degree days (GDD$_{15.6}$), calculated as the mean of the daily maximum and minimum air temperatures minus 15.6 °C (Peng et al. 1989) during the season was 1,403 (Fig. 2). Irrigation of 160 mm was applied in the 90% ET treatment and 109 mm in the 30% ET treatment in 2016. Irrigation was initiated at squaring on 28 June 2016 with 24 mm of irrigation applied in the 90% ET treatment and 13 mm applied in the 30% ET treatment. After flowering, 136 mm of irrigation was applied in the 90% ET treatment and 96 mm in the 30% ET treatment. Rainfall received at the same site during the 2017 growing season starting 7 June was 254 mm with the majority occurring later in the season (Fig. 1). Accumulated GDD$_{15.6}$ at Lamesa in 2017 was 1,282 (Fig. 2). Irrigation at Lamesa in 2017 was applied at 165 mm in the 60% ET treatment. Irrigation was initiated preplant through emergence in the amount of 101 mm and then from squaring through boll opening in the amount of 64 mm.

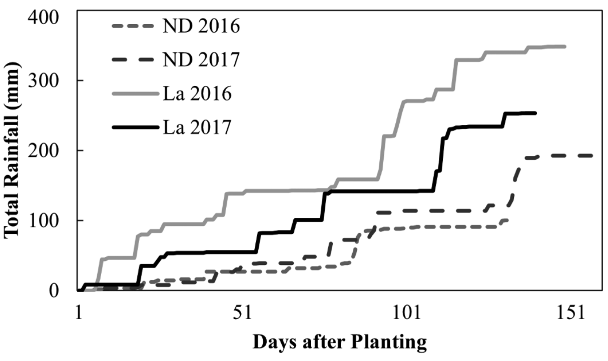

Figure 1. Total rainfall (mm) at Lamesa (La) and New Deal (ND) in 2016 and 2017.

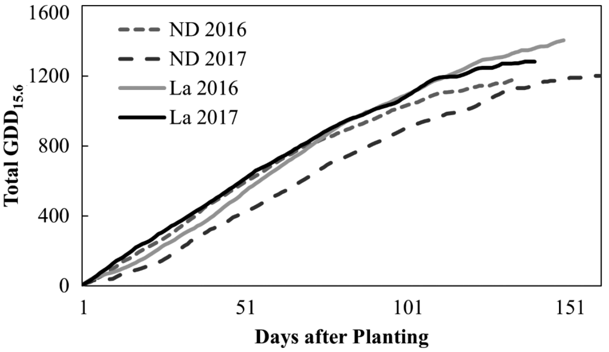

Figure 2. Total growing degree days (GDD$_{15.6}$) at Lamesa (La) and New Deal (ND) in 2016 and 2017.

Rainfall received in New Deal during the season in 2016 starting 7 June was 100 mm (Fig. 1). Accumulated GDD$_{15.6}$ during the season in 2016 was 1,176 (Fig. 2). New Deal irrigation levels at 80% ET and 30% ET were initiated at flowering on 15 July 2016. Prior to flowering, 172 mm of irrigation was applied. Once flowering began, 91 mm of irrigation was applied in the 80% ET treatment and 3.8 mm in the 30% ET treatment. Seasonal rainfall in 2017 starting 16 May was 193 mm (Fig. 1) and GDD$_{15.6}$ was 1,200 (Fig. 2). Irrigation treatments were initiated at flowering on 12 July 2017. Prior to flowering, 132 mm of irrigation was applied. Once flowering began 76 mm of irrigation was applied in the 80% ET treatment and no irrigation was applied in the 30% ET treatment.

Soil Nutrient and Plant Mineral Characterization. Soil samples were collected using a Giddings hydraulic probe (5.3-cm diameter). Three cores were composited by replication and irrigation zone prior to fertilizer application at 0-to-15-, 15-to-30-, and 30-to-60-cm depths to determine soil K levels on 15 April 2016 and 10 April 2017 in Lamesa and on 27 May 2016 and 12 April 2017 in New Deal. Soil collected from both sites was air dried, ground to pass a 2-mm mesh sieve, and mixed thoroughly prior to analysis at the Texas A&M AgriLife Soil, Water, and Forage Testing Lab in College Station, TX. Extractable soil nutrients including P, K, Ca, Mg, Na, and S were extracted using a procedure adapted from Mehlich III (Mehlich, 1984) and measured using inductively coupled plasma (ICP) spectroscopy. Nitrate-N (NO_3^--N) was determined by cadmium reduction following extraction with 2 N KCl using a 1:5 soil-to-extractant ratio (5-g soil:25-ml 2 N KCl), followed by analysis using flow-injection spectrometry (FIAlab 2600; FIAlab Instruments Inc., Bellevue, WA) (Keeney and Nelson, 1982).

Electrical conductivity and soil pH was determined in a 1:2 ratio of soil to deionized water, with actual determination made using a conductivity (Rhoades, 1996) and pH probe (Thomas, 1996).

The youngest fully expanded leaf (typically four to five nodes below the terminal) was collected 2 wk after first bloom to determine leaf tissue K. Thirty leaf samples from each plot at Lamesa were collected on 26 July 2016 and 11 August 2017, and on 15 August 2016 and 4 August 2017 at New Deal. Leaf samples were oven dried (60 °C), ground to pass a 2-mm mesh sieve using a Thomas Wiley universal mill, and shipped to Texas A&M AgriLife Soil, Water, and Forage Testing Lab in College Station for mineral (B, Ca, Cu, Fe, K, Mg, Mn, Na, P, S, and Zn) analysis using the ICP method of a nitric acid digest, which is reported on a dry plant basis (Havlin and Soltanpour, 1980; Isaac and Johnson, 1975).

Agronomic Measurements. A Case International Harvester 1400 cotton stripper was used for mechanical harvest at both locations except at Lamesa in 2017. The cotton stripper was not fitted with a bur extractor, thus bur cotton and not seed cotton was collected at harvest. The Lamesa location was harvested on 18 November 2016, and the New Deal location was harvested on 8 November 2016 and on 3 November 2017. The center two rows were harvested, and bur cotton weights were collected. Plots were harvested 27 November 2017 in Lamesa by hand due to uneven stands resulting from early-season unfavorable weather conditions. Two rows from each plot that had a continuous 1.8-m length were hand harvested by stripping the whole cotton bolls off the plant. Following harvest, approximately 650-g samples of bur cotton from each plot were ginned, with bur extraction included as part of the ginning process at the Texas A&M AgriLife Research and Extension Center research gin in Lubbock, TX. Lint from New Deal was sent to the Texas Tech University Fiber and Biopolymer Research Institute (FBRI) in Lubbock, and lint from Lamesa was sent to Cotton Incorporated in Cary, NC, for classing and HVI analysis, which included micronaire, length, uniformity, strength, elongation, yellowness (+b), and reflectance (Rd).

Statistical Analysis. Statistical analyses were performed using SAS version 9.3 software (SAS Institute Inc., Cary, NC). Analysis of variance for all parameters was calculated using two irrigation treatments in a split plot design with four replications (PROC GLIMMIX) at $p < 0.1$. Means of treatment effects were compared within sample using Fisher's least significant difference (LSD) at $p < 0.1$. Main effects of K fertilizer application rate and application method and their interactions with irrigation on cotton lint yield, leaf tissue K, and fiber quality parameters were analyzed. Fixed effects included treatment, irrigation, and application (rate and method), whereas the random effect was replication. Year and location were analyzed separately due to significance.

Pearson's correlation (PROC CORR) was used to evaluate relationships between lint yield, leaf tissue K, and fiber quality parameters. Pearson's stepwise regression (PROC REG) was used to evaluate the response of yield and fiber quality to leaf tissue minerals within irrigation levels and to build a model to describe the response. Stepwise regression is a sequence of steps that adds or removes an independent variable to the regression equation based on the variable screening procedure. The variables were considered at slentry = 0.1 and slstay = 0.1 for yield and slstay = 0.1 for the fiber quality parameters. The model was considered significant at $p < 0.1$.

RESULTS AND DISCUSSION

Soil Nutrient and Plant Mineral Characterization. Soil K results for all site years indicated soil test levels greater than the established Mehlich III soil test critical level (125-150 mg kg^{-1}). Because K is relatively immobile within the soil, K was greater at shallower depths and decreased as soil depth increased. This could also be the result of plant uptake and redeposition from previous years (Franzluebbers and Hons, 1996; Wright et al., 2007). Soil test results in 2016 at the Lamesa location revealed high K, Mg, and Ca levels, whereas P and S levels were low, and Na was very low (Table 1).

Potassium ranged from 287 mg kg^{-1} at the 0-to-15-cm soil depth to 240 mg kg^{-1} at the 30-to-60–cm depth. Pullman soil in New Deal was rated as very high in K, Ca, Mg, and S levels, whereas P and Na levels were very low (Table 1). Potassium ranged from 522 mg kg^{-1} at the 0-to-15-cm depth to 314 mg kg^{-1} at the 30-to-60-cm depth. Potassium was not considered deficient with levels greater than the Mehlich III K critical level 150 mg kg^{-1} (Mehlich, 1978, 1984). However, cotton has been reported to show deficiency symptoms on soil with K concentrations greater than the critical level (Cassman et al., 1989; Hons et al., 1990).

Table 1. Soil characterization of samples collected at three depths (0-15, 15-30, and 30-60 cm) prior to fertilizer application in 2016 and 2017 at Lamesa and New Deal

Location	Year	Depth	pH	EC[z]	NO_3^--N[y]	P	K	Ca	Mg	S	Na
		---- cm ----		--- umhos cm^{-1} ---	mg kg^{-1}						
Lamesa	2016	0-15	7.4	111	3	29	287	959	250	3	2
		15-30	7.5	116	2	25	270	1091	278	6	6
		30-60	7.7	179	0	8	240	1618	365	13	15
	2017	0-15	7.4	140	1	79	261	1402	275	6	4
		15-30	7.7	109	0	11	236	1768	364	5	10
		30-60	7.9	143	0	7	246	2426	439	9	29
New Deal	2016	0-15	8.0	317	8	16	522	2942	699	13	54
		15-30	8.0	313	3	6	370	4626	766	11	78
		30-60	8.2	349	2	4	314	8972	709	17	87
	2017	0-15	8.0	332	4	13	605	3938	853	13	65
		15-30	8.0	328	1	5	407	5114	919	18	86
		30-60	8.2	316	1	4	370	9588	762	19	87

[z] EC, Electrical Conductivity

[y] NO_3^--N, nitrate-N

Soil results in 2017 at the Lamesa location were also high in K, Ca, and Mg levels, whereas P levels for the 0-to-15-cm depth were rated high then decreased to very low at the deeper depths (Table 1). The soil was rated low in S and very low in Na. Potassium ranged from 261 mg kg^{-1} at the 0-to-15-cm depth to 236 mg kg^{-1} at 15-to-30-cm depth, possibly due to crop uptake, whereas the lowest depth K level (30-60 cm) was at 246 mg kg^{-1}. The increase in P was most likely due to the field variability and plots being moved to a new location in 2017. Soil results in 2017 at the New Deal location revealed very high K, Ca, Mg, and S, whereas P and Na levels were rated very low at the 0-to-15-cm depth (Table 1). Potassium ranged from 605 mg kg^{-1} at the top depth to 370 mg kg^{-1} at the lowest depth, which was a 39% decrease at New Deal.

Stratification of K was more apparent at the New Deal location compared to the Lamesa location. Many factors can influence stratification, including soil type and structure, crop uptake and cycling, fertilizer placement, and tillage (Dinkins et al., 2014; Zayas et al., 2018). Stratification can be influenced also by the amount of time subsurface drip irrigation has been in place due to an increase in soil moisture increasing K uptake near the irrigation tape in the soil (Gath et al., 1989; Grimme and Von Braunschweig, 1974; Kuchenbuch et al., 1986). The drip irrigation at New Deal was installed in 2005, which is 11 years longer than the drip irrigation at Lamesa, possibly causing a larger decrease of K between the shallow and deeper depths at New Deal compared to Lamesa.

Leaf tissue K differences in 2016 at Lamesa were present due to K fertilizer application rate with the 0 kg K ha^{-1} application rate resulting in greater leaf tissue K than the 90 and 180 kg K ha^{-1} treatments, but no differences were determined for the three-way interactive effect (K rate x application method x irrigation level). The interactive effect of rate by irrigation within the broadcast application was significant, but not within the liquid application, which may be due to the broadcast application of K being more common in sandy soil as K is only moderately mobile within the soil; whereas liquid banding is a better choice in clay soil due to the possibility that K fixation can occur (Mahler and McDole, 1985; Malvi, 2011). The greatest leaf tissue K concentration was observed following 0 and 135 kg K ha^{-1} rates with 30% ET irrigation, whereas the 90 and 180 kg K ha^{-1} application rates with the 30% ET irrigation and the 135 and 180 kg K ha^{-1} application rates with the 90% ET irrigation resulted in the lowest leaf tissue K concentrations within the broadcast application method (Fig. 3). A similar pattern was observed following the injection application with 30% ET irrigation. The control (0 kg K ha^{-1}) had a leaf tissue K level of 23.4 g kg^{-1}, which decreased with the K fertilizer treatments to 21.6 g kg^{-1} when 135 kg K ha^{-1} was applied (Fig. 3). The 0 kg K ha^{-1} application rate resulted in the greatest leaf tissue K levels in 2016 at Lamesa. Bolls are major sinks for K, so K might have been partitioned from the leaves and to the reproductive structure (Hake et al., 1991; Kusi et al., 2021). Similarly, Kusi et al. (2021) observed that in some cases the control was greater than the K treatments on an Amarillo fine sandy loam soil in Lamesa. There were no differences in leaf tissue K at Lamesa in 2017 (Fig. 4). No differences existed for leaf tissue K in 2016 or 2017 at New Deal (Fig. 5). The 30% ET irrigation treatment resulted in greater leaf tissue K concentrations in 2017 at New Deal (Fig. 5). Lewis et al. (2021), Kusi et al. (2021), Bednarz et al. (1999), and Tsialtas et al. (2016) observed either no K fertilizer treatment effects for leaf tissue K or that the untreated plots had greater K concentrations than the treated plots which is similar to the results from this research.

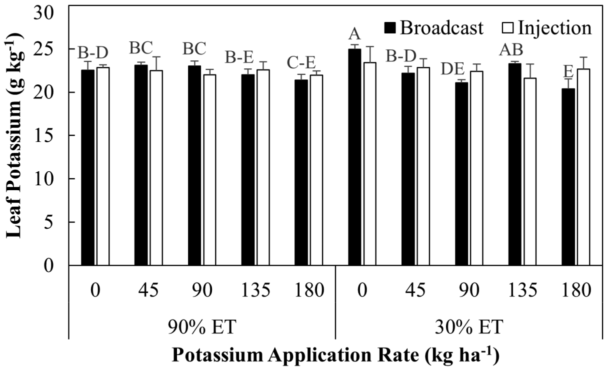

Figure 3. Leaf tissue K concentration of samples collected after first bloom in 2016 at the Lamesa location with 90% ET and 30% ET irrigation levels. The same letters within the broadcast application method are not different at $p < 0.1$ by Fisher's protected LSD. The vertical bars represent the standard error of the mean. Where mean comparison letters are not present differences were not determined.

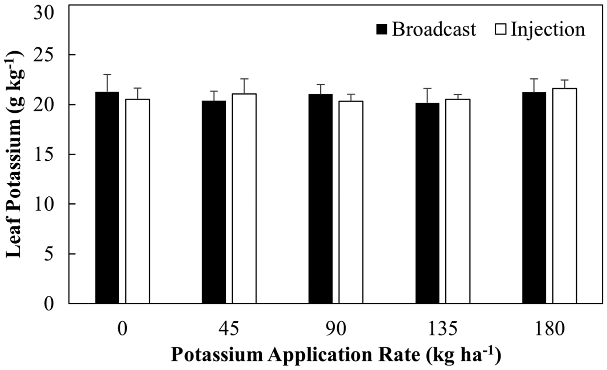

Figure 4. Leaf tissue K concentration after first bloom in 2017 at the Lamesa location. The vertical bars represent the standard error of the mean. Where mean comparison letters are not present differences were not determined.

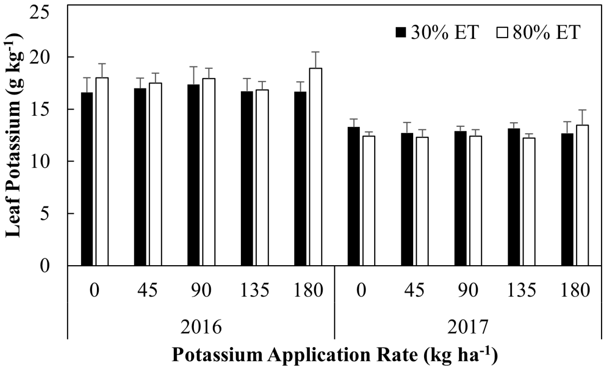

Figure 5. Leaf tissue K concentration after first bloom in 2016 and 2017 at the New Deal location with 80% ET and 30% ET irrigation levels. The vertical bars represent the standard error of the mean. Where mean comparison letters are not present differences were not determined.

Cotton is deficient in K when leaf tissue concentrations drop below 15.0 g kg^{-1} during early bloom (Kerby and Adams, 1985; Pettiet, 1994; Plank, 1989; Reeves and Mullins, 1993). Potassium deficiency can affect reproductive or fiber development due to the relationship between K and osmotic potential within the cell (Harmon and Ramey, 1986). Leaf tissue K in 2017 at New Deal indicated deficiencies with all treatment combinations. This could be due to not sampling until 2 wk after first bloom (approximately 80 d after planting due to K being used for early boll set and growth (Reddy et al., 2000). Leaf tissue K was greater in 2016 than in 2017 most likely due to greater rainfall in 2016 when the plant was partitioning K to vegetative growth (Fig. 5). Although soil K is greater than the established Mehlich III soil test level in Texas, it is generally not translating to adequate K in the plant based on leaf tissue levels. This has also been reported by Lewis et al. (2021), who determined that K rates had no effect on leaf tissue K in the Texas High Plains. Hons et al. (1990) determined that added K had no influence on the K concentration in the plant parts of the seed hulls and whole seeds.

Lint Yield and Fiber Quality. Lint yield differences existed in 2016 at Lamesa resulting from the interactive effect of K fertilizer application rate by irrigation for both application methods, but no differences were determined for the three-way interactive effect (K fertilizer application rate x application method x irrigation level). The 0, 45, 90, and 135 kg K ha^{-1} broadcast applied treatment with 90% ET irrigation produced greater lint yield than the 45, 90, 135, and 180 kg K ha^{-1} treatment with the 30% ET irrigation (Fig. 6). Greater lint yield following the broadcast application method was achieved with the 90% ET irrigation level at 90 kg K ha^{-1} (2,153 kg lint ha^{-1}), which was

193 kg lint ha^{-1} greater than lint yield following 180 kg K fertilizer ha^{-1} treatment with the 90% ET irrigation level. However, the lint yield following the 90 kg K ha^{-1} application rate with the 90% ET irrigation treatment was not different from that following the 0, 45, and 135 kg K ha^{-1} application rates with the 90% ET irrigation treatment. The 90 kg K ha^{-1} rate in the 30% ET irrigation treatment resulted in the lowest lint yield of 1,694 kg ha^{-1}. Yield increased up to 90 kg K ha^{-1} and then decreased following greater K fertilizer application rates at Lamesa in 2016, most likely due to luxury consumption or cotton's inefficiency of K uptake from the soil at the greater rates of K (Bartholomew and Janssen, 1929; Cassman et al., 1989) (Fig.6). With the injection application method, the 90, 135, and 180 kg K ha^{-1} rates with 90% ET irrigation yielded greater than all K treatments irrigated at 30% ET replacement at Lamesa in 2016 (Fig. 6). There was a positive correlation between lint yield and leaf tissue K (as leaf tissue increased, lint yield also increased) with Pearson's correlation of $R^2 = 0.32$ and $p = 0.004$ at Lamesa in 2016 (Fig. 7); however, it was a weak relationship and there was no relationship for other site years.

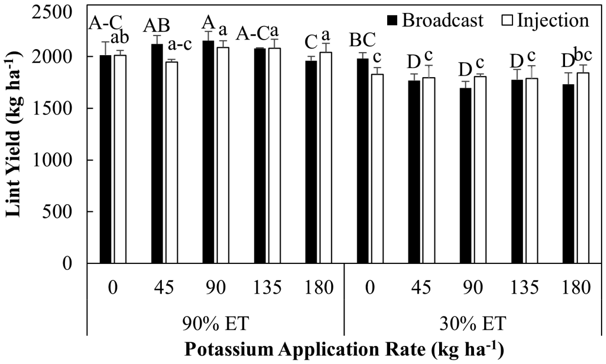

Figure 6. Cotton lint yield determined in 2016 at the Lamesa location with 90% ET and 30% ET irrigation levels. The same letters within the broadcast and injection application method are not different at p < 0.1 by Fisher's protected LSD. The vertical bars represent the standard error of the mean.

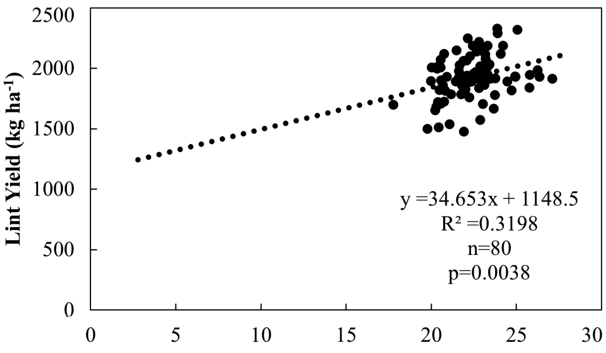

Figure 7. Leaf tissue K vs. lint yield in 2016 at the Lamesa location.

In 2017 at the Lamesa location, no lint yield differences were present. When the broadcast fertilizer application method was used, the average lint yield was 1,703 kg ha^{-1}, whereas yield following the injection application method averaged 1,780 kg ha^{-1} (Fig. 8). Similarly, Kusi et al. (2021) observed no response to added fertilizer K at the Lamesa location in 2017.

Hons et al. (1990) determined that when 63 kg K ha^{-1} was applied there was an 8% increase in lint yield in 1981; in 1982 when 167 kg K ha^{-1} treatment was applied, there was a 9% increase in lint yield on a Pullman clay loam soil with 550 mg K kg^{-1}. An interaction between K rate and irrigation on lint yield on a Pullman soil in New Deal was observed in 2016 and 2017, with all the 80% ET irrigation treatments yielding greater than the 30% ET irrigation treatments. The 80% ET at New Deal in 2016 produced double the lint yield (2,000 kg ha^{-1}) compared to the 30% ET irrigation level (1,000 kg ha^{-1}) (Fig. 9). At New Deal in 2017, the lint yield difference between 80% ET and 30% ET irrigation was, on average, 425 kg ha^{-1}. No lint yield differences existed between K fertilizer treatments within irrigation levels (Fig. 9).

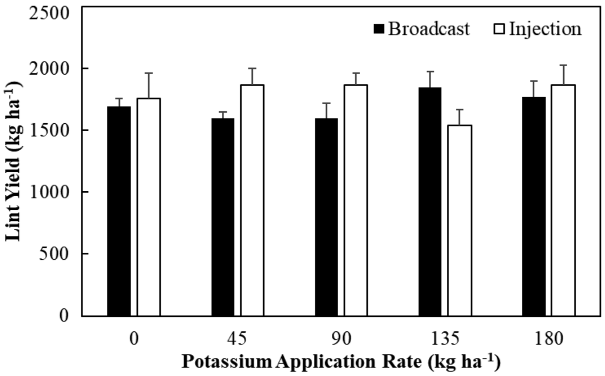

Figure 8. Cotton lint yield determined in 2017 at the Lamesa location. The vertical bars represent the standard error of the mean.

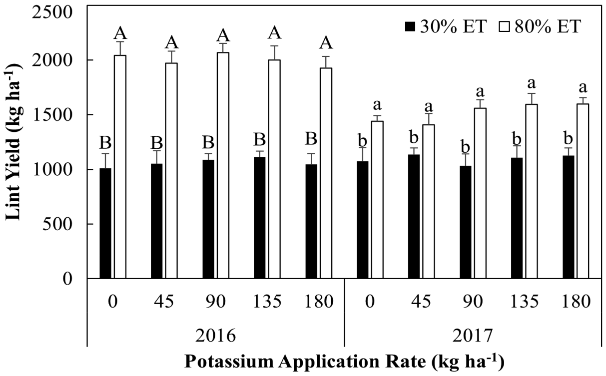

Figure 9. Cotton lint yield determined in 2016 and 2017 at the New Deal location with 80% ET and 30% ET irrigation levels. The same letters within the year are not different at p < 0.1 by Fisher's protected LSD. The vertical bars represent the standard error of the mean.

An interaction between irrigation and K fertilizer application rate was present for all fiber quality parameters at both years and locations. At Lamesa in 2016, micronaire, uniformity, strength, elongation, and +b were influenced by the interaction of K rate and irrigation (Table 2). Within the K fertilizer broadcast application method, micronaire was greater following 30% ET irrigation compared to 90% ET irrigation, although micronaire from the 30% ET irrigation was in the base range (4.3-4.9) and from the 90% ET was in the premium range (3.7-4.2) (Table 3) (Cotton Inc., 2013). For uniformity, the 180 kg K ha^{-1} rate with the 30% ET irrigation resulted in greater uniformity than the 0, 45, 135, and 180 kg K ha^{-1} application rates with the 90% ET irrigation treatments. However, all the degrees of uniformity were in the intermediate range between 80 and 82% (Cotton Inc., 2013).

An irrigation-by-K-rate interaction existed at Lamesa in 2016 for the fiber quality parameters of elongation, uniformity, micronaire, and strength following K fertilizer applied using the injection application method. Micronaire, uniformity, and strength values had approximately the same pattern with the 30% ET irrigation level K treatments producing greater values than the 90% ET irrigation level K treatments. Elongation was greater following the 45 kg K ha^{-1} application rate at the 30% ET irrigation level compared to the 135 kg K ha^{-1} with the 30% ET irrigation levels. Uniformity was greater following the 180 kg K ha^{-1} rate at the 30% ET irrigation level compared to the 0 kg K ha^{-1} rate at 30% ET and the 0, 45, 90, and 135 kg K ha^{-1} application rates with the 90% ET irrigation level. Micronaire was greater following application of 180 kg K ha^{-1} with the 30% ET irrigation, which was greater than all micronaire values from the 90% ET irrigation K rates within the injection application method. However, the 90% ET irrigation treatments resulted in micronaire values in the premium range (3.7-4.2), whereas the 30% ET irrigation treatment rates produced values in the base range (4.3-4.9) (Cotton Inc., 2013). Strength was greater when 45 and 90 kg K ha^{-1} application rates were used with the 30% ET irrigation level compared to the 45, 135, and 180 kg K ha^{-1} application rates with the 90% ET irrigation level.

Table 2. ANOVA *p*-values determined for lint yield, leaf tissue K, and fiber quality parameters in 2016 and 2017 at New Deal and Lamesa

Loc.	Year	Effect	Yield	Leaf Tissue K	Length	Strength	Mic.	Uniformity	Elong.	Rd^{z}	+b^{y}
			------------	------------	------------	------------	p-value	------------	------------	------------	------------
New Deal	2016	Treatment	0.8091	0.3360	0.2174	0.0632	0.8773	0.7598	0.0936	0.5699	0.1331
		Treatment*Irr^{x}	<.0001	0.1093	<.0001	0.0153	<.0001	0.0145	0.0026	<.0001	0.0394
		Within Irr- 90%	0.3000	0.1648	0.3766	0.1475	0.4202	0.9890	0.5482	0.5303	0.0860
		Within Irr- 30%	0.8122	0.8301	0.4566	0.6773	0.1628	0.6333	0.0332	0.7279	0.0610
	2017	Treatment	0.4602	0.9283	0.1916	0.6443	0.6169	0.7183	0.3986	0.9967	0.3771
		Treatment*Irr	<.0001	0.6901	0.5197	0.7148	0.0289	0.7478	0.0022	0.2206	0.0022
		Within Irr- 90%	0.1958	0.6359	0.1798	0.6585	0.6987	0.6285	0.2993	0.7605	0.2912
		Within Irr- 30%	0.7685	0.9605	0.8719	0.8127	0.839	0.7309	0.4948	0.3206	0.7638
Lamesa	2016	Treatment	0.5674	0.0351	0.4005	0.6927	0.9459	0.4888	0.905	0.7873	0.5656
		Application	0.8443	0.8095	0.8529	0.8797	0.5578	0.5384	0.1294	0.8935	0.9312
		Treatment*Irr	<.0001	0.4927	0.3058	<.0001	<.0001	0.0010	0.023	0.7343	<.0001
		Treatment*App^{w}	0.1954	0.3773	0.7745	0.3880	0.4993	0.5138	0.9589	0.6243	0.2048
		Treatment*Irr*App	0.2425	0.2401	0.4534	0.8775	0.7941	0.7081	0.5848	0.9505	0.0899
	2017	Treatment	0.8578	0.8568	0.8724	0.9656	0.6634	0.149	0.3678	0.5025	0.4419
		Application	0.7331	0.2978	0.8016	0.3417	0.2465	0.8002	0.6057	0.6076	0.2059
		Treatment*App	0.853	0.1061	0.6935	0.3025	0.1003	0.2123	0.0383	0.4562	0.0348
		Within App- Broadcast	0.9723	0.2865	0.4866	0.5221	0.4036	0.02	0.276	0.8631	0.3187
		Within App- Injection	0.4671	0.3740	0.9916	0.5947	0.2379	0.8279	0.0684	0.1076	0.0711

[z] **Rd, Reflectance**

[y] **+b, Yellowness**

[x] **Irr, Irrigation**

[w] **App, Application**

Table 3. Simple mean fiber quality values in 2016 and 2017 at the Lamesa location

Year	Irr. Level	App. Method	K Rate (kg ha^{-1})	Length (in)	Strength (g tex^{-1})	Mic.	Uniformity (%)	Elong. (%)	Rd^z	+b^y
2016	High (90% ET)	Broadcast	0	1.16	29.0 b-c^x	4.1 ab	81.5 b	8.7	73.7	9.1 AB^w
			45	1.17	28.7 cd	4.0 b	81.4 b	8.4	73.4	9.1 AB
			90	1.17	28.8 cd	4.0 b	81.6 ab	8.5	73.5	8.9 B
			135	1.17	29.1 a-d	4.0 b	81.4 b	8.7	73.9	9.2 AB
			180	1.16	28.6 d	3.9 b	81.4 b	8.4	73.2	9.2 AB
	Low (30% ET)		0	1.17	29.9 a	4.3 a	82.4 a	8.5	74.1	8.4 C
			45	1.17	29.8 ab	4.4 a	82.0 ab	8.7	73.3	8.3 CD
			90	1.15	29.4 a-d	4.4 a	82.0 ab	8.5	74.3	8.5 C
			135	1.17	29.5 a-c	4.3 a	81.9 ab	8.5	74.1	8.4 CD
			180	1.17	29.7 ab	4.3 a	82.3 a	8.5	73.3	8.0 D
	High (90% ET)	Injection	0	1.16	29.0 a-d	4.0 c	81.5 bc	8.5 ab	73.6	9.0 AB
			45	1.16	28.8 b-d	4.0 c	81.2 c	8.5 ab	74.1	9.3 A
			90	1.16	29.3 a-d	3.8 c	81.4 bc	8.6 ab	73.4	9.3 A
			135	1.17	28.6 d	3.9 c	81.5 bc	8.7 ab	73.6	9.0 AB
			180	1.16	28.7 cd	4.1 bc	81.8 a-c	8.5 ab	73.7	9.0 B
	Low (30% ET)		0	1.16	29.6 ab	4.4 ab	81.6 bc	8.7 ab	74.1	8.2 CD
			45	1.17	29.8 a	4.4 ab	81.8 a-c	8.8 a	73.3	8.4 C
			90	1.16	29.8 a	4.4 ab	81.9 a-c	8.6 ab	73.6	8.3 CD
			135	1.16	29.5 a-c	4.4 ab	82.1 ab	8.5 b	73.7	8.3 CD
			180	1.17	29.3 a-d	4.4 a	82.3 a	8.7 ab	73.8	8.3 CD
2017	Base (60% ET)	Broadcast	0	1.15	28.8	3.9 C^v	81.9 ab^u	8.8 C	81.1	8.0 C
			45	1.15	29.0	4.3 A-C	82.5 a	9.3 A-C	81.5	8.0 C
			90	1.17	29.5	4.2 A-C	82.6 a	9.3 A-C	81.7	8.2 A-C
			135	1.16	28.6	4.4 A-C	81.6 b	9.4 AB	81.7	8.3 A-C
			180	1.14	28.7	4.2 A-C	81.3 b	9.4 AB	81.5	8.1 BC
		Injection	0	1.15	29.0	4.5 A	82.0	9.6 A	81.9	8.0 C
			45	1.15	28.9	4.0 BC	81.9	9.0 BC	81.6	8.4 A
			90	1.15	28.7	4.4 AB	82.0	9.2 A-C	81.8	8.1 A-C
			135	1.15	29.6	4.4 A-C	81.5	9.6 A	81.7	8.1 BC
			180	1.16	29.3	4.3 A-C	82.1	9.1 BC	80.9	8.4 AB

[z] Rd, Reflectance

[y] +b, Yellowness

[x] Means separation was performed using Fisher's LSD at $\alpha = 0.1$. Means within application methods (lowercase) in 2016 with the same letter are not different at $p < 0.1$

[w] Interaction means (irrigation level and application method) (uppercase) of +b in 2016 with the same letter are not different at $p < 0.1$

[v] Means across the application methods (uppercase) in 2017 with the same letter are not different at $p < 0.1$

[u] Means within application method (lowercase) of uniformity in 2017 with the same letter are not different at p < 0.1

Differences existed for the fiber quality parameters of micronaire, uniformity, elongation, and +b at Lamesa in 2017 (Table 2). Micronaire, elongation, and +b were influenced by the interaction of K rate and application method. Application rates of 0, 45, 90, and 80 kg K ha^{-1} produced micronaire values within the premium range of 3.7 to 4.2, whereas all others were within the base range (4.3-4.9) (Table 3) (Cotton Inc., 2013). Fiber elongation following K fertilizer injected at 0 and 135 kg K ha^{-1} was 9.6%, which was greater than elongation in the control (8.8% elongation).

Potassium fertilizer application rate impacted fiber uniformity at the Lamesa location in 2017, as the broadcast application method at 45 and 90 kg K ha^{-1} resulted in 82.5 and 82.6% uniformity, respectively, which was greater than the 180 kg K ha^{-1} treatment (81.3% uniformity) (Table 3). Pettigrew et al. (1996) reported that the uniformity ratio was decreased when K was deficient and increased when 112 kg K ha^{-1} was applied, which could be due to a lowered amount of assimilates available to the developing fiber (Pettigrew and Meredith, 1994). Similar results are present in the current study, as when K was increased up to 90-kg K ha^{-1}, uniformity increased.

At New Deal in 2016 micronaire, length, uniformity, strength, elongation, +b, and Rd were influenced by the interaction of K rate and irrigation (Table 2). Micronaire values were increased at 30% ET irrigation compared to the 80% ET irrigation treatment (Table 4). All K treatments within the 30% ET treatment produced micronaire values in the discount range, whereas micronaire in all 80% ET irrigation K treatments except the 45 kg K ha^{-1} rate were in the premium range (Cotton Inc. 2013). Within the 80% ET irrigation level, application of 45 kg K ha^{-1} produced greater micronaire than the control. Bennett et al. (1965) observed increased micronaire values with the addition of up to 70 kg K ha^{-1}, which, according to Pettigrew and Meredith (1994), could be due to a possible reduction in the available assimilate supply to the fiber. However, in the current study there was no pattern to the impact on micronaire consistent with increases or decreases in the amount of K applied (Tables 3 and 4). Fiber length when irrigation was supplied at the 80% ET irrigation level was greater than that following the 30% ET irrigation level (Table 4). Uniformity following all K fertilizer application rates at 80% ET irrigation was greater than uniformity values at the 0 and 180 kg K ha^{-1} application rates with 30% ET irrigation. Only the 135 kg K ha^{-1} treatment with the 80% ET irrigation level had a high uniformity value, the rest were in the intermediate range (Cotton Inc., 2013).

At New Deal in 2016, the 90 kg K ha^{-1} treatment with the 30% ET irrigation level resulted in greater fiber strength than that from the 0, 45, and 180 kg K ha^{-1} application rates with the 80% ET irrigation level. However, K fertilizer application rate on fiber strength was greater with the 90 kg K ha^{-1} rate (28.8 g tex^{-1}) within the 30% ET irrigation level than the 45 and 180 kg K ha^{-1} treatments (27.5 g tex^{-1}) within the 80% ET irrigation level. Pettigrew et al. (1996) found no fiber strength response to different K fertilizer application rates when a deficiency in the soil was present. Fiber strength results from this research correspond with Bennett et al. (1965), who reported that fiber strength increased following application of 70 and 140 kg K ha^{-1}, but fiber strength decreased with the K fertilizer application rates of 280, 420, and 560 kg K ha^{-1}. Our results indicate that the observed changes in fiber strength due to K application were in the average range according to Cotton Incorporated (Cotton Inc., 2013), therefore, it would not have affected the market value. Overall, fiber strength was still rated average (26-28 g tex^{-1}) regardless of the K application rate in 2016 at New Deal (Table 4).

The 135 kg K ha^{-1} application rate with the 30% ET irrigation level resulted in greater elongation than that observed following the 180 kg K ha^{-1} application rate with the 30% ET irrigation level and all the K application rates with the 80% ET irrigation level at New Deal in 2016 (Table 4).When K was deficient, elongation was reduced by 3 and 6%; however, our results determined that elongation increased 6 to 10% when greater amounts of K were applied (Pettigrew, 2003; Pettigrew et al.,1996).

Differences existed for micronaire and +b at New Deal in 2017 due to an interaction of K rate and irrigation level (Table 4). Micronaire with the 135 kg K ha^{-1} with the 80% ET irrigation was greater than that following the 0, 45, 90, and 180 kg K ha^{-1} application rates with the 30% ET irrigation level. Micronaire following the 135 kg K ha^{-1} application rate within the 80% ET irrigation level was in the premium range (3.7), whereas lower values (3.4) were observed following the 135 and 180 kg K ha^{-1} application rates within the 30% ET irrigation level. Cassman et al. (1990), Pettigrew et al. (1996), and Bennett et al. (1965) all reported that low K levels reduced micronaire.

Fiber quality is an important factor in gross income because one or several fiber quality parameters can result in a discounted fiber value. These results illustrate that K fertilizer application can improve some of these parameters, although when no K was applied, fiber quality discounts were not noted. Prior research indicated inconsistent results in K fertility impacting various fiber quality characteristics, and our results support these inconsistencies. These inconsistencies might indicate only indirect effects of fiber traits to K applications (Pettigrew, 2008). Fiber quality parameters are determined by varietal genetics, climatic conditions, and season-long crop management; whereas color is 21% genetics and 79% environmental and micronaire is 41% genetics and 59% environmental (NCC, 1996).

Table 4. Simple mean fiber quality values in 2016 and 2017 at the New Deal location with 80% ET and 30% ET irrigation levels

Year	Irr.	K Rate (kg ha^{-1})	Length (in)	Strength (g tex^{-1})	Micronaire	Uniformity (%)	Elong. (%)	Rd[z]	+b[y]
2016	High (80% ET)	0	1.15 A[x]	27.9 BC	3.9 C	82.5 A	10.5 BC	76.8 A	8.6 AB
		45	1.15 A	27.5 C	4.2 B	82.4 A	10.2 C	77.0 A	8.5 AB
		90	1.16 A	28.6 AB	4.0 BC	82.5 A	10.1 C	76.8 A	8.5 AB
		135	1.15 A	28.4 AB	4.0 BC	82.6 A	10.2 C	76.9 A	8.4 BC
		180	1.14 A	27.5 C	3.9 BC	82.4 A	10.2 C	77.2 A	8.6 A
	Low (30% ET)	0	1.09 B	28.7 AB	5.4 A	81.2 B	11.0 AB	75.5 B	8.5 AB
		45	1.10 B	28.6 AB	5.2 A	81.5 AB	11.0 AB	75.9 B	8.6 A
		90	1.11 B	28.8 A	5.4 A	81.5 AB	10.6 A-C	75.8 B	8.6 AB
		135	1.10 B	28.6 AB	5.4 A	81.9 AB	11.1 A	76.0 B	8.3 BC
		180	1.09 B	28.4 AB	5.3 A	81.1 B	10.3 BC	75.8 B	8.2 C
2017	High (80% ET)	0	1.12	28.8	3.6 AB	80.6	9.1 A	75.5	9.2 A-C
		45	1.16	27.7	3.5 A-C	79.0	9.0 AB	74.6	9.8 A
		90	1.11	28.2	3.6 A-C	80.4	8.6 C-E	74.9	9.0 BC
		135	1.11	28.6	3.7 A	80.6	9.0 A-C	76.1	9.4 AB
		180	1.12	28.6	3.5 A-C	80.1	8.9 A-D	75.5	9.2 A-C
	Low (30% ET)	0	1.14	28.9	3.3 C	79.5	8.5 DE	76.0	8.8 BC
		45	1.12	28.5	3.3 C	79.7	8.4 DE	76.5	8.7 C
		90	1.13	29.1	3.3 C	80.4	8.6 C-E	76.5	8.6 C
		135	1.12	29.1	3.4 A-C	79.3	8.6 B-E	75.0	8.6 C
		180	1.13	28.4	3.4 BC	80.4	8.4 E	76.0	8.6 C

[z] **Rd, Reflectance**

[y] **+b, Yellowness**

[x] **Means separation was performed using Fisher's LSD at $\alpha = 0.1$. Means in 2016 and 2017 across irrigation levels with the same letter are not different at $p < 0.1$**

Regression Analysis. Stepwise regression analysis was used to determine predicted yield based on leaf mineral nutrients retained by the model. It was determined that leaf mineral K had an interactive effect with other minerals on lint yield at Lamesa and New Deal in 2016. Yield was predicted for Lamesa in 2016 with 30% ET irrigation using K and Na ($R^2 = 0.48$, $p = < .0001$) by the equation: yield = (0.023[K]) + (0.55[Na]) + 933.21 (Fig. 10a). There was a positive relationship between leaf mineral K and Na at Lamesa in 2016 with the 30% ET irrigation level, which agrees with previous literature stating K and Na are similar in that they have similar uptake mechanisms (Malvi, 2011). However, high Na levels (> 7.7 dS m^{-1}) in the soil could result in reductions in yield (Ashraf, 2002). Yield was predicted for the Lamesa location in 2016 with the 90% ET irrigation using the leaf minerals K and Cu ($R^2 = 0.23$, $p = 0.007$) by the equation: yield = (0.04[K]) + (62.25[Cu]) + 797.87 (Fig. 10b). There is an indirect relationship between K and Cu; K has been reported to increase the use of Cu by plants (Armstrong and Griffin, 1998; Malvi, 2011). Churchman et al. (1937) determined that Cu increased the size and number of bolls produced by the plant, which can increase yield.

Yield was predicted for New Deal in 2016 with 80% ET irrigation using the minerals P and K ($R^2 = 0.39$, $p = 0.015$) by the equation: yield = (0.44[P]) + (-0.04[K]) + 1791.58 (Fig. 10c). There was a negative relationship between K and yield. Potassium and P are essential for photosynthesis, enzyme reactions, crop maturity, and many other physiological processes (Armstrong and Griffin, 1999). Hons et al. (1990) determined that there was no interaction between P and K on cotton yield. These results demonstrate that yield is difficult to predict and is highly variable due to many factors impacting cotton yield. Although we observed some relationships between nutrient content and yields, the strength of these was weak.

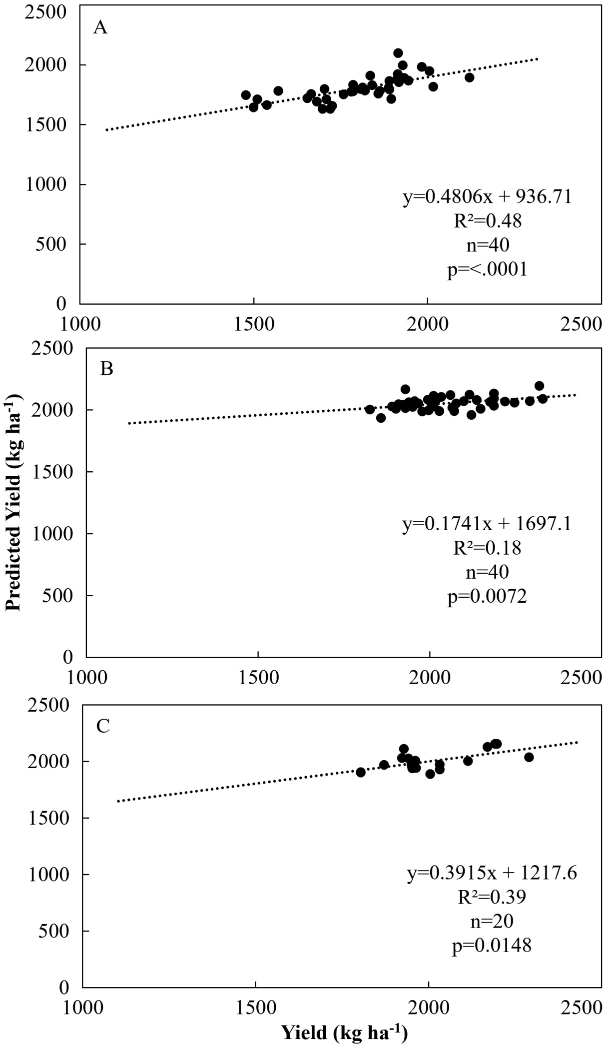

Figure 10. Predicted yield vs yield in (A) 2016 at the Lamesa location with the 30% ET irrigation level. Yield = (0.023[K]) + (0.552[Na]) + 933.213, (B) 2016 at the Lamesa location with the 90% ET irrigation level. Yield = (0.040[K]) + (62.247[Cu]) + 797.868, and (C) 2016 at the New Deal location with the 80% ET irrigation level. Yield = (0.440[P]) + (-0.037[K]) + 1791.575.

Fiber quality parameters were analyzed with stepwise regression to determine the predicted parameter based on the leaf mineral nutrient contents retained by the model (Table 5). Potassium and the interaction between other nutrients influenced micronaire, uniformity, +b, and Rd at Lamesa in 2016. Potassium was the only nutrient involved in the model equation ($R^2 = 0.25$, $p = 0.024$) to determine Rd with the 30% ET irrigation level when applied by injection. When K was injected and irrigation supplied at the 30% ET level, +b was only impacted by K ($R^2 = 0.16$, $p = 0.085$). Yellowness was impacted by K and Cu ($R^2 = 0.18$, $p = 0.028$) in the 90% ET irrigation level when application method was combined, whereas K and S ($R^2 = 0.17$, $p = 0.033$) influences +b in the 30% ET irrigation level when the application methods were combined.

Fiber uniformity when irrigation was applied at the 90% ET irrigation level was influenced by K, Na, and Zn ($R^2 = 0.30$, $p = 0.005$) within the model equation when the application methods were combined (Table 5). Fiber uniformity when the 90% ET irrigation level was used and K fertilizer was broadcast applied was affected by the minerals K, Mg, and Zn ($R^2 = 0.62$, $p = 0.001$). Uptake of Zn can increase with high solar radiation and temperature and lower rainfall conditions (Havlin et al., 2016). Pabuayon et al. (2021) observed an increase in Zn being partitioned to the bolls in newer cotton cultivars.

When the 30% ET irrigation level was used and K fertilizer was injected, micronaire was impacted by K, Na, and Mn ($R^2 = 0.72$, $p = < .0001$), whereas Rd ($R^2 = 0.25$, $p = 0.024$) and +b ($R^2 = 0.16$, $p = 0.085$) were impacted by K (Table 5). Ashraf et al. (2017) observed that micronaire was decreased by sodium chloride (NaCl) due to the antagonistic effects between Na and K and that when K was added to the NaCl treatments, it diminished the harmful effects of Na and improved the fiber quality parameters.

In 2017, when K fertilizer was injected at Lamesa, Rd was affected by the minerals K, Ca, and S ($R^2 = 0.75$, $p = < .0001$). Uniformity was impacted in 2016 at New Deal with 80% ET irrigation by the minerals K and B ($R^2 = 0.46$, $p = 0.006$), whereas +b was affected by K and S ($R^2 = 0.32$, $p = 0.039$). Boron is known for promoting proper fruiting development in cotton and is taken up in the reproductive tissues (Camacho-Cristobal et al., 2008; Pabuayon et al., 2021). However, the relationship was quadratic instead of linear. Micronaire was impacted by the minerals K and Na ($R^2 = 0.49$, $p = 0.003$) at New Deal with 80% ET irrigation in 2017, whereas at 30% ET irrigation, fiber length was affected by K ($R^2 = 0.31$, $p = 0.011$) (Table 5). Bennett et al. (1965) observed that the addition of K fertilizer increased fiber length and that yield is difficult to predict and is highly variable due to many factors impacting cotton yield. Although we observed some relationships between nutrient content and fiber quality parameters, the strength of these was weak. Correlations between lint yield and fiber quality differences with leaf tissue minerals were not consistently observed in this study, which is similar to other research conducted.

Table 5. Regression and *p*-values for fiber quality parameters vs predicted fiber quality parameters in 2016 and 2017 at the New Deal and Lamesa locations. Values were determined after the model equation was determined when K was involved

Loc.	Year	Irr[z]	App[y]	Fiber Quality	Model	p-value	R^2
Lamesa	2016	90% ET	Inj[x]+ Brd[w]	Uni.	$Y= (9.93x10^{-5}[K]) + (-1.75x10^{-3}[Na]) + (0.19[Zn]) + 77.05$	$p = 0.0048$	0.30
		90% ET		+b[v]	$Y= (-7.39x10^{-5}[K]) + (-0.11[Cu]) + 11.42$	$p = 0.0281$	0.18
		30% ET		+b	$Y= (4.56x10^{-5}[K]) + (4.65x10^{-5}[S]) + 6.60$	$p = 0.0328$	0.17
		90% ET	Brd	Uni.	$Y= (1.91x10^{-4}[K]) + (-5.15x10^{-4}[Mg]) + (0.27[Zn]) + 72.51$	$p = 0.0012$	0.62
		30% ET	Inj	Mic.	$Y= (-4.23x10^{-5}[K]) + (-5.75x10^{-4}[Na]) + (-1.14x10-2[Mn]) + 5.72$	$p = <.0001$	0.72
		30% ET		Rd[u]	$Y= (2.52x10^{-4}[K]) + 68.02$	$p = 0.0239$	0.25
		30% ET		+b	$Y= (4.89x10^{-5}[K]) + 7.21$	$p = 0.0846$	0.16
	2017	60% ET	Inj	Rd	$Y= (-2.49x10-4[K]) + (1.93x10-4[Ca]) + (-4.96x10-4[S]) + 87.37$	$p = <.0001$	0.75
New Deal	2016	80% ET	Inj	Uni.	$Y= (-1.90x10^{-4}[K]) + (4.55x10^{-2}[B]) + 80.82$	$p = 0.0056$	0.46
		80% ET		+b	$Y= (-3.15x10^{-3}[S]) + (1.85x10^{-7}[S^2]) + (6.03x10^{-4}[K]) + (-1.56x10^{-8}[K^2]) + 16.08$	$p = 0.0388$	0.32
	2017	80% ET	Inj	Mic.	$Y= (-1.20x10^{-4}[K]) + (1.04x10^{-3}[Na]) + 4.86$	$p = 0.0033$	0.49
		30% ET		Length	$Y= (-8.73x10^{-6}[K]) + 1.24$	$p = 0.0113$	0.31

[z] **Irr, Irrigation**

[y] **App, Application**

[x] **Inj, Injection**

[w] **Brd, Broadcast**

[v] **+b, Yellowness**

[u] **Rd, Reflectance**

CONCLUSIONS

This research evaluated the effect of K fertilizer application rate and application method with different irrigation levels on cotton growth, yield, and fiber quality in the Texas High Plains. Potassium did not offset the negative effects of moisture stress on cotton lint yield in the semiarid environment of the Texas High Plains. Although a positive lint yield response to added fertilizer K given that soil test levels were greater than the Mehlich III K critical level were not expected, a positive response due to K fertilizer application on lint yield following broadcast and injection applications across irrigation level was observed at Lamesa in 2016. However, response of fiber quality parameters was not consistent between years, irrigation levels, application methods, or locations. There are inconsistencies in the current literature regarding fiber quality parameters as affected by potassium fertilizer application. Potassium rate and application method are important production management decisions due to yield responses when the fertilizer was broadcasted compared to injected. Predicting lint yield and fiber quality with leaf tissue mineral concentrations had a relatively poor relationship.

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