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Cotton Yield Response to Soil- and Foliar-Applied Potassium as Influenced by Irrigation

D.L. Coker*, D.M. Oosterhuis, and R.S. Brown

ABSTRACT

The impact of moisture deficit stress on the yield response of cotton (*Gossypium hirsutum* L.) to foliar-applied K is not well understood. Studies were conducted in Arkansas from1999 through 2002 at three field locations to evaluate the effect of irrigation and soil-applied K on the yield response of cotton to foliar-applied K. Eight treatments consisting of soil-applied K and no soil K with or without foliar-applied K, plus irrigation or no-irrigation were arranged in a split-split plot design with five to six replications. For most site-years, lint yield was not enhanced by foliar K where soil K applications were made according to current University of Arkansas recommendations. Response to soil-applied K varied with initial soil K fertility level. Across site-years, lint yield responded 40% of the time to soil-applied K under irrigated conditions whereas yield did not respond under non-irrigated conditions. Variation in rainfall among the growing seasons moderated the response of lint yield and yield components to irrigation. The data suggest that a yield response to soil-applied K may be observed more frequently in irrigated cotton grown in the mid-south when compared to non-irrigated cotton. Lint yields typically were not enhanced by foliar-applied K applications on soils where preplant, Melich 3 K levels ranged from 270-376 kg K ha^{-1}, irrespective of irrigation. Further research is needed to determine the interactive effects of water-deficit stress and soil- and foliar-applied K on the yield of cotton grown where soil residual K levels range from low to medium.

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INTRODUCTION

Cotton (*Gossypium hirsutum* L.) yield and fiber quality can be adversely affected by potassium (K) nutrient deficiency (Cassman, et al., 1990; Pettigrew, 2003). This is partly because insufficient K negatively affects cotton plant photosynthesis (Bednarz et al., 1998; Zhao et al., 2001), leaf area (Zhao et al., 2001; Pettigrew, 2003), and biomass production (Zhao et al., 2001). More recently, cotton grown in sunlit controlled-environment chambers responded to K deficiency by altering biomass partitioning among plant tissues with the greatest decrease in fruit biomass (Reddy and Zhao, 2005). Potassium deficiencies have occurred inconsistently across the U.S. Cotton Belt. Generally, K deficiency problems occur during boll fill when the developing boll load becomes the dominant sink for available K and there is a concomitant decrease in the rate of root growth (Oosterhuis, 1995).

Cotton requires from 3 to 5 kg K ha^{-1} day^{-1} during boll fill, and an average mature cotton crop is estimated to require a total of 110 to 250 kg K ha^{-1} (Halevy, 1976). According to Mullins and Burmester (1990), approximately 50 to 60% of K taken up by the cotton plant is partitioned to the reproductive organs. Cotton appears to be more sensitive to low soil K availability than most major field crops (Cope, 1981) and often shows signs of K deficiency on soils not considered K deficient for other crops (Cassman et al., 1989). Furthermore, the cotton root system has a low density relative to other major row crops (Gerik et al., 1987), and K, which is relatively immobile in soil, moves slowly by diffusion (Barber, 1984). Therefore, the sensitivity of cotton to the soil K supply, coupled with the large requirement for K and its relative immobility in soil, could lead to a deficiency even on soils that test high in extractable K (Oosterhuis, 1995).

According to Mozaffari et al., (2004), modern, fast-fruiting cotton cultivars introduced in the past two decades may have different nutritional requirements than obsolete cultivars originally used to develop fertilizer recommendations in Arkansas.

In a recent two-year study in Arkansas, a pre-plant application of K fertilizer significantly increased Mehlich 3 extractable K in the 0 to 15-cm soil depth with an initial soil test level of 403 kg K ha^{-1}, but had no effect on cotton yield and fiber quality (Mozaffari et al., 2004). In South Carolina, K deficiency symptoms appeared more frequently in some cotton cultivars compared to other cultivars (Jones and Camberato, 2004). In these studies, cotton growth and development were significantly altered by various rates of pre-plant, soil-applied K fertilizer. However, recently released higher-yielding cultivars such as 'PM 1218BR' and 'DPL 555BR' showed more response to added K fertilizer compared to older, lower-yielding cultivars such as 'Dixie Triumph', 'DES 119' and 'DP 90'. In Tennessee, Essington et al., (2002) found that modern cultivars grown on loess-derived soils were particularly prone to K deficiency. These researchers attributed the K deficiencies to K fixation by vermiculite-dominated soil minerals. Substantial hectares of loess-derived soils also support cotton production in the Mississippi Delta Region of Arkansas (Mozaffari et al., 2004). However, little is known about the effect of K fertility management on lint yield of modern cultivars as influenced by water-deficit stress.

Foliar K has shown potential to remediate early symptoms of plant K deficiency in cotton (Oosterhuis, 1995) and may be used to supplement soil applications as a means to maximize lint yields (Howard et al., 1998a). In Tennessee, a total of four foliar applications of 4.1 kg K ha^{-1} of KNO_3 per application plus a surfactant increased the four-year average concentration of K in leaves and petioles relative to a control (Howard and Gwathmey, 1995). These studies showed that the second harvest and total lint yield were increased by foliar K relative to the check (control) treatment. According to Howard et al. (1998b), the level of response to foliar K applications could depend on choice of K source, buffering the spray solution, applying K with B, and the tillage system used. Yield and economic advantages of timely foliar-K applications to supplement soil-applied K have been documented (Oosterhuis, 1999a; Weir, 1999). However, the impact of mid-season water-deficit stress on the efficiency of foliar-K uptake and yield response to foliar-K fertilization has not been documented. Furthermore, mid-season water-deficit stress may account for the sporadic appearances of K deficiency and inconsistent yield responses to foliar K.

Changes in partitioning of dry matter from vegetative to reproductive structures contribute to the greater lint yield of modern versus obsolete cultivars (Brown et al., 2001). From these studies, modern cultivars are reported to have more bolls per square meter and more seeds per boll than obsolete cultivars. However, the response of seed mass, number of seeds per boll, and the amount of lint per seed to varying soil moisture levels has largely been ignored (Pettigrew, 2004a). He pointed out that insight into yield plateaus and variability could be gained by understanding how various environmental stresses impact lint yield and all of the components that go into its development.

Little information has been generated reporting how adverse environmental conditions such as water-deficit stress may influence cotton yield response to K deficiency or to soil-applied K. Furthermore, related management details are lacking about the potential benefits of supplemental, foliar-applied K (foliar K) to cotton yield under water-deficit and soil K-deficient conditions. Since K is integral to maintaining plant water relations (Hearn, 1994; Kramer and Boyer, 1995), a hypothesis was formulated that water-deficit stress could alter the effect of soil-applied K on cotton lint yield and yield components. Earlier studies showed that water-deficit stress adversely affected the rate of foliar N uptake and yield response to foliar N (Oosterhuis, 1995). Plant uptake of foliar K was suspected to behave similarly to the uptake of foliar N. Therefore, a second hypothesis was that water-deficit stress would change the potential for foliar K to remediate any pending K deficiency and increase cotton lint yield. Thus, the objectives of this study were (1) to determine the effect of recommended, soil-applied K under water-deficit stress on cotton yield and components of yield, and (2) to evaluate the response of cotton yield and related components to foliar K under water-deficit stress and different soil K regimes.

MATERIALS AND METHODS

Plant Culture. Cotton cultivar 'SG 125' was planted on 11 May, 1999 and 19 May, 2000 into a moderately well-drained Hebert silt loam (very-fine, mixed, thermic Aeric Ochraqualfs) at Rohwer, AR. Due to the short supply of cultivar 'SG 125 seed, cultivar, 'SG 747' (result of backcrossing to 'SG 125' as recurrent parent) was planted on 16 May, 2000 and 9 May, 2001 into a moderately well-drained

Dundee silt loam (fine-silty, mixed, thermic Aeric Ochraqualfs) at Clarkedale, AR. Cultivar 'SG 215 BR' (bollguard and glyphosate equivalent of 'SG 747') was planted into a well-drained Captina silt loam (fine-silty, mixed, thermic Typic Fragiudults) at Fayetteville, AR on 23 May, 2002. All involved cultivars were selected because they were closely related, had similar maturity ratings, widespread commercial use, as well as proven fiber yield and quality performance in University trials throughout the Mississippi River Delta of Arkansas.

Treatments. Cotton lint yield and yield components were evaluated in 1999 in field plots located at Rohwer (SE Arkansas), in 2000 at Clarkedale (NE Arkansas) and Rohwer, in 2001 at Clarkedale, and at Fayetteville (NW Arkansas) in 2002. Eight treatment combinations of irrigated or non-irrigated conditions, with or without preplant soil-applied K, and with or without foliar K were arranged in a split-split plot design with five replications at Clarkedale and Fayetteville, and six replications at Rohwer. All treatments were randomly distributed within each factor level at all sites. Water level was the main plot, soil-applied K level the sub plot, and foliar K level the sub-sub plot.

Experimental units were four-row plots with various lengths for all site years. At Rohwer, each plot consisted of 12-m length rows spaced 0.9 m apart. At Clarkedale, each plot consisted of 15-m length rows spaced 0.9 m apart. Each plot at Fayetteville consisted of 9-m length rows spaced 1 m apart. For all site-years, soil samples (0-0.15 m depth as recommended in AR) were randomly collected during the fall of the preceding year from the two center rows of non-foliar sub-sub plots according to procedures described by Tyler and Howard (1991). The soil test results were used to determine pre-plant K fertilizer application rates on a plot-by-plot basis for the next growing season. Pre-plant granular KCl fertilizer was hand broadcast and incorporated into designated plots (elevated soil-K) prior to planting at rates according to the following equation [(-0.38 * kg soil test K/ha) + 168.02 = kg applied K_2O/ha]. University of Arkansas' K fertilizer recommendations were based on this equation with 392 kg Mehlich 3 soil K/ha considered optimum for cotton production in Arkansas (Sabbe, 1998). For the Mississippi River Delta locations (Clarkedale and Rohwer), Mehlich 3 extractable (1:7) soil test values ranged from 279 to 376 kg K ha^{-1} and at Fayetteville the average Mehlich 3 extractable (1:7) soil K was 270 kg K ha^{-1} (Fig. 1). Preplant KCl fertilizer application rates in individual plots ranged from 0 to 90 kg K ha^{-1}. Foliar KNO_3 was applied at 4 kg K ha^{-1} $week^{-1}$ (i.e. 11.2 kg KNO_3 ha^{-1}) for four consecutive weeks starting one week after first flower with a pressurized CO_2 backpack sprayer calibrated to deliver 93.5 L ha^{-1} (nozzle size 0.6 gvm).

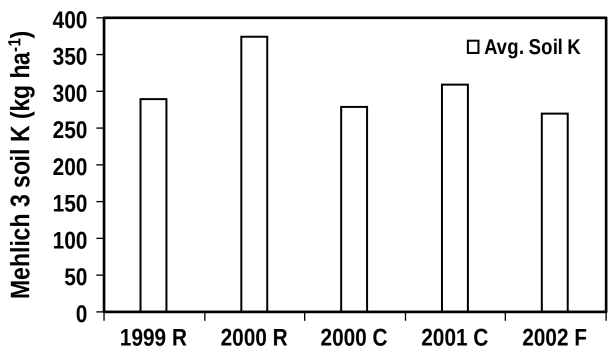

Fig. 1. Average Mehlich 3 (1:7) extractable soil K values from Fall, preplant sampling to a 0.152 m depth conducted each site-year at Rohwer (R), Clarkedale (C), and Fayetteville (F), AR.

Soil-water deficits were estimated and irrigation events scheduled in well-watered plots using the University of Arkansas Irrigation Scheduling Program (Cahoon et al., 1990). This program subtracts daily estimates of crop evapotranspiration from daily inputs of either irrigation or rainfall, and recommends irrigation once the cumulative soil-water deficit reaches a critical value that is determined by soil characteristics and rooting depth. At Rohwer, irrigated treatments were applied by a lateral-move, overhead sprinkler when the estimated soil-water deficit reached 5 cm. Irrigation was withheld on half of the rows in each of six randomized complete blocks at Rohwer to accomplish replication of the water factor. At Clarkedale and Fayetteville, the well-watered treatments were furrow irrigated and excess water diverted away from the end of plots via a series of cross furrows when the estimated soil-water deficit reached 5 cm. After each of four to eight watering events per site-year, we assumed that the soil was fully recharged and that the net quantity of water applied was 5 cm based on program instructions.

Measurements. At major phenological stages (pinhead square, first flower, first flower plus three and five weeks), the water potential (Ψ_w) of uppermost, fully-expanded leaves was measured. Three 0.64 cm^2 discs were collected per leaf and sealed in sample chambers with end-window thermocouple psychrometers between 1100 and 1300 h (J.R.D. Merrill Specialty

Equipment Company, Logan, UT). The procedures used to measure the components of leaf water potential and discussions of the theory behind thermocouple psychrometry are those of Oosterhuis (2003a; 2003b).

Final lint yield was determined by machine (spindle picker) harvest of the middle two rows in each plot at Rohwer and Clarkedale. At Fayetteville, lint yield was determined by hand harvest of open bolls in a 1-m length of each of the middle two rows. These two methods of harvesting are equitable and widely used (Willcutt et al., 2002; Pettigrew, 2004a). In all site years, yield components were determined from each plot by first hand picking a 1-m length from each of the two center rows and counting and weighing the bolls. In these studies, conventional yield components were identified as the number of bolls per unit land area, average weight per boll, and gin turnout. Basic yield components were identified as the number of seeds per unit land area and average weight of fiber per seed or lint index (Groves and Bourland, 2007). From the hand-picked seed cotton sample in each plot, a 150-g subsample was randomly collected, ginned, and weighed for determination of fiber quality, gin turnout, and basic yield components. Preliminary tests were conducted to determine differences in the amount of error associated with the size of a subsample used for predicting seed cotton counts in the original sample. Thus, seven hundred seed from a ginned seed cotton subsample were randomly collected, weighed, and the information used, along with the total plot seed cotton yield, to calculate the number of seed ha^{-1} and the lint index (Meredith and Bridge, 1973; Lee, 1984).

Data Analysis. Data from individual site-years were pooled into one dataset and subjected to analysis of variance using the PROC MIXED procedure of SAS (version 8.1; SAS Institute Inc.; Cary, NC). Site-year, water, soil K, and foliar K were fixed effects in the model. When one or more of the treatments interacted significantly with site-year, lint yield and yield component differences were compared within site-years using the PDIFF option within the LSMEANS statements. When significant treatment interactions with site-year were not detected, lint yield and yield component comparisons were made across site-years using the PDIFF option within the LSMEANS statements.

RESULTS AND DISCUSSION

Lint Yield Response to Foliar K, Soil-Applied K, and Irrigation. Cotton yield response to foliar K applications was variable across seasons as indicated by the significant year × foliar K interaction (Table 1). Yields responded to foliar K only in 2002 at Fayetteville where initial Mehlich 3 soil-K levels averaged 270 kg ha^{-1} (Table 2 and Fig. 1). At all other test sites, initial Mehlich 3 soil-K levels were between 279 and 376 kg

Table 1. Analysis of variance of cotton yield and components of yield across five site-years: Rohwer (1999 and 2000), Clarkedale (2000 and 2001) and Fayetteville (2002).

Effect	Lint Yield	Open Boll	Boll Weight	Gin Turnout	Seed	Lint Index
	kg ha^{-1}	# m^{-2}	g $boll^{-1}$	%	# ha^{-1}	mg $seed^{-1}$
Site-year (Y)	***[z]	***	NS[y]	***	***	NS
Water (W)	***	***	***	NS	*	***
Y × W	***	*	***	*	NS	***
Soil K (SK)	*	NS	NS	NS	NS	NS
Y × SK	NS	NS	NS	NS	NS	NS
W × SK	*	NS	NS	NS	NS	NS
Y × W × SK	NS	NS	NS	NS	NS	NS
Foliar K (FK)	**	NS	**	NS	***	NS
Y × FK	*	*	***	NS	NS	NS
W × FK	NS	NS	**	*	NS	NS
Y × W × FK	NS	NS	***	NS	NS	NS
SK × FK	NS	NS	NS	NS	NS	NS
Y × SK × FK	NS	NS	NS	NS	NS	NS
W × SK × FK	NS	NS	NS	NS	NS	NS
Y × W × SK × FK	NS	NS	NS	NS	NS	NS

[z] Sources of variation denoted with *, **, and *** are significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

[y] Source of variation is not significant at $P > 0.05$.

ha^{-1} and yield did not respond to foliar K. Across the five site years, foliar K numerically increased lint yield by only 4% (1285 vs. 1337), with a majority (171 kg) of this increase occurring at one site year, suggesting that foliar K applications typically do not increase yields when soil test K levels are adequate, or when recommended rates of K are soil applied. These observations were consistent with an earlier report from Arkansas that indicated a low probability of response to foliar-applied K in irrigated studies where Mehlich 3 soil test K levels were >280 kg K ha^{-1} (Oosterhuis, 1995), which is considered to be in the high range for cotton production in Arkansas. Likewise, in a four-year study, Howard et al. (1997) found no significant cotton yield response to foliar applications of KNO_3 on two silt loam soils in Tennessee that had Mehlich 1 extractable K of 193 to 221 kg ha^{-1}, which are levels considered high for cotton production in Tennessee. The extractable soil K levels reported in Tennessee were similar to the Arkansas studies since the Mehlich 3 solution extracts approximately 1.5 times more K than the Mehlich 1 solution. Under rainfed conditions, Howard et al. (1997) found that the critical soil extractable K level for predicting a yield response to foliar-applied K in cotton ranged from 176 to 180 kg Mehlich 1 K ha^{-1} which corresponds to the 180 kg K ha^{-1} value used to distinguish between medium- and high-testing soils in Tennessee. Converting these critical Mehlich 1 values to Mehlich 3 equivalent resulted in values similar to the lowest soil K levels in this study, a factor that could explain the lack of yield response to foliar-applied K. Contrastingly, on Tennessee soils that tested low in Mehlich 1 extractable soil K (<100 kg K ha^{-1}), foliar-applied K was profitable, even after four years of high soil-applied K_2O rates (Roberts et al., 1997). Irrigated tests in California demonstrated that foliar-applied K would not likely contribute to the yield of cotton unless it was needed to supplement soil K levels (Weir, 1999).

Water-deficit stress was evident three weeks after first flower when leaf Ψ_w averaged -1.53 MPa in irrigated plots and was greater than -2.49 MPa in non-irrigated plots over four site-years (Rohwer and Clarkedale) (data not shown). This trend continued through five weeks after first flower when leaf Ψ_w was higher in irrigated plots (-1.39 MPa) than in non-irrigated plots (-2.14 MPa) for the same site-years. Across site-years, there was no lint yield response to foliar K application regardless of irrigation (Table 1). Thus, an interactive effect of water stress and foliar-applied K on the yield of cotton was likely masked by residual soil-test K ranging from 279 to 376 kg Mehlich 3 ha^{-1} (Fig. 1).

Table 2. Effect of foliar- and soil-applied K on lint yield response of field-grown cotton over five-site years: Rohwer (R), Clarkedale (C) and Fayetteville (F).

Treatment	Lint Yield					
	1999 R	2000 R	2000 C	2001 C	2002 F	Mean
	kg ha^{-1}					
Avg. over Water and Soil K						
No foliar K	1261	1238	1027	1482	1413	1285
With foliar K	1280	1225	1086	1512	1584z	1337
Site-year × foliar K						*y
Avg. over Foliar K						
Irrigated, high soil K	1593	1696	1480	1650	1618	1607
Irrigated, low soil K	1500	1552z	1465	1576	1475x	1513z
Nonirrigated, high soil K	949	811	737	1375	1493	1073
Nonirrigated, low soil K	1041	869	668	1388	1394	1072
Water × Soil K						*
Avg. over Soil and Foliar K						
Irrigated	1546	1624	1472	1612	1546	1560
Nonirrigated	995z	840z	703z	1382z	1443	1073z
Site-year × Water						*

[z] Significant at $P \leq 0.05$ for the paired treatments.

[y] * denotes treatment interaction significant at $P \leq 0.05$.

[x] Significant at $P \leq 0.10$ for the paired treatments.

Yields varied in response to soil-applied K and irrigation as indicated by the water × soil K and year × water interactions (Table 1). The only response to soil-applied K occurred at Rohwer in 2000 and at Fayetteville in 2002 when irrigation was applied (Table 2). Under well-watered conditions, soil-applied K increased lint yield by 6.2% (1607 vs. 1513 kg) across five site-years, again with most of this increase occurring at two of the five site-years, suggesting that under a high soil test K level (>270 kg Mehlich 3 K ha^{-1}), yield responses are unlikely. No lint yield response to soil-applied K occurred under rainfed conditions for individual site-years or across site-years. This lack of yield response to soil-applied K on soils having high extractable K levels was also reported by Howard et al., (1997).

The influence of irrigation on lint yield varied depending on the season as indicated by the significant site-year × water interaction (Table 1). Irrigation increased lint yields in each of four site-years in the Mississippi River Delta of Arkansas (Table 2). However, irrigation did not increase lint yield at Fayetteville in 2002, due in part to a two-day, 18-mm rainfall received during peak boll development. Across seasons and locations, lint yields were reduced by water-deficit stress by an average of 487 kg ha^{-1} (45%). Pettigrew (2004a) reported similar findings from research conducted in the Mississippi River Delta.

Conventional Yield Component Response to Foliar K, Soil-Applied K, and Irrigation. Foliar-applied K showed variable effects on the number of open bolls, average boll weight, and gin turnout of cotton across site-years. The effect of foliar K on the number of open bolls was inconsistent across years as indicated by the year × foliar K interaction (Table 1). The number of open bolls was increased by foliar K in 1999 at Rohwer (Fig. 2). Besides high residual soil K (>270 kg Mehlich 3 K ha^{-1}), it was speculated that the observed variability in how the number of open bolls responded to foliar K could also be related to greater rainfall received during July, August, and September of 1999 at Rohwer compared to the other site-years (Table 3).

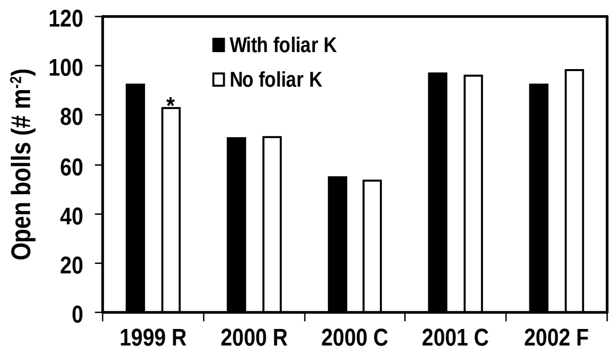

Fig. 2. Effect of foliar-applied K on the number of open bolls from field-grown cotton for each site-year at Rohwer (R), Clarkedale (C), and Fayetteville (F), AR. The * indicates that a significant difference ($P \leq 0.05$) exists between paired treatments.

Table 3. Current precipitation, maximum day temperatures, and minimum night temperatures compared to a long-term averages during the flowering and boll development period at Rohwer (R), Clarkedale (C), and Fayetteville (F) for each of five site-years.[z]

Month	1999 R	2000 R	2000 C	2001 C	2002 F
			precipitation, mm		
June	102	122	15	16	14
July	39	14	1	20	2
Aug.	28	0	0	1	20
Sept.	91	40	4	9	1
			mean maximum temperature, °C		
June	31.8	31.1	30.3	30.0	28.7
July	33.8	33.7	33.0	32.5	31.1
Aug.	33.6	35.6	35.7	32.2	31.5
Sept.	27.0	29.2	29.9	28.2	28.8
			mean minimum temperature, °C		
June	20.1	21.0	20.5	19.7	18.9
July	23.1	21.8	22.1	23.5	21.6
Aug.	19.6	21.9	21.3	22.7	20.7
Sept.	14.2	15.7	17.1	16.7	15.7

[z] **All observations made by local NOAA weather stations present at each test location.**

The response of some conventional yield components to foliar K was influenced by water treatment. The effect of foliar K on gin turnout and boll weight data varied with irrigation and year as indicated by the water × foliar K interaction and year × water × foliar K interaction for gin turnout and boll weight, respectively (Table 1). The year × water × foliar K interaction resulted when boll weight was increased in the non-irrigated plots in 2002 at Fayetteville (Table 4). This interaction could have been related to the generally cooler temperatures occurring between first square (June) and boll development (August) at Fayetteville relative to temperatures at Rohwer and Clarkedale (Table 3). Higher than optimum temperatures occur frequently throughout the U.S. Cotton Belt during flowering and boll development, thereby compromising the reproductive efficiency of the crop (Ashraf et al., 1994; Reddy et el., 2004). Furthermore, elevated night temperatures during the peak flowering and boll development stage can decrease boll weight (Oosterhuis, 1999b; Reddy et al., 1996), and in the case of the current study, would likely minimize the response of boll weight to foliar-applied K.

All site-year × water treatment interactions were significant for the conventional yield components (Table 1). Irrigation increased open boll number at all five site-years and boll weights at two of the five site-years (Table 5). The lack of a statistical response in boll weight to irrigation may have been influenced by differences in weather patterns between each site-year (Table 3). This research showed that lint yield of dryland plants was reduced 45% (1560 vs. 1072) across site-years (Table 2), primarily due to a 25% reduction in the number of bolls produced per unit ground area (461 vs. 347.6), which agrees with findings of Pettigrew (2004a) in Mississippi. Boll weight reductions in the non-irrigated plots are consistent with the findings of Grimes et al. (1969) and

Table 4. Effect of foliar-applied K on boll weight of field-grown cotton cv. 'SG 125' under irrigated and non-irrigated conditions at Rohwer (R), Clarkedale (C), and Fayetteville (F) for each of five site-years.

Treatment	Boll Weight				
	1999 R	2000 R	2000 C	2001 C	2002 F
	----------g $boll^{-1}$----------				
Averaged over Soil K					
Irrigated, no Foliar K	4.12	4.12	4.37	4.20	3.84
Irrigated, with Foliar K	4.06	4.37	4.19	4.25	3.90
Nonirrigated, no Foliar K	3.80	3.29	3.52	4.04	3.45
Nonirrigated, with Foliar K	3.86	3.45	3.63	4.06	4.97[z]

[z] Significant at $P \leq 0.05$ for the paired treatments.

Table 5. Irrigation effects on the conventional yield components of field-grown cotton averaged across the K treatments at Rohwer, Clarkedale, and Fayetteville for each of five site-years.

Site-year	Treatment	Open Boll	Boll Weight	Gin Turnout
		# m^{-2}	g $boll^{-1}$	(%)
1999 Rohwer	Irrigated	103.0	4.09	39.0
	Nonirrigated	72.2[z]	3.83	39.6
2000 Rohwer	Irrigated	83.2	4.25	42.5
	Nonirrigated	58.3[z]	3.37[z]	41.4
2000 Clarkedale	Irrigated	69.5	4.28	41.6
	Nonirrigated	39.0[z]	3.58[z]	39.8[y]
2001 Clarkedale	Irrigated	104.6	4.23	41.1
	Nonirrigated	88.2[y]	4.05	41.5
2002 Fayetteville	Irrigated	100.7	3.87	40.0
	Nonirrigated	89.9[y]	4.21	40.2

[z] Significant at $P \leq 0.001$for the paired treatments.

[y] Significant at $P \leq 0.05$ for the paired treatments.

Gerik et al. (1996), yet contrast findings by Pettigrew (2004a). The year by water interaction effect on gin turnout resulted when irrigation increased turnout at Clarkedale in 2000 (Table 5). Thus, plant water stress appeared to have less influence on gin turnout percentage as compared to the number and weight of bolls. Other reports have indicated little to no response in lint percentage to varying soil moisture levels (Kimball and Mauney, 1993).

Basic Yield Component Response to Foliar K, Soil-Applied K, and Irrigation. The effect of foliar K on seed number and lint index was consistent for both water levels as indicated by the non-significant interaction (Table 1). This observation suggested that the water status of plants in these studies had little influence on the response of the basic yield components to foliar-applied K.

The foliar K main effect was significant for the number of seeds ha^{-1} (Table 1). Averaged across the water- and soil-K treatments, foliar K increased the number of seeds ha^{-1} by 13% (Fig. 3). Keino et al. (1999) reported that foliar K stimulated the additional uptake of K by roots of young cotton plants grown in a greenhouse. This effect would explain the increase in the number of seeds ha^{-1} through increased carbohydrate flow to the developing boll load and reduced shedding of young bolls (Oosterhuis, 1995). However, an increase in the numbers of seed ha^{-1} due to foliar K did not translate to a yield response of cotton grown on soils of high extractable K levels.

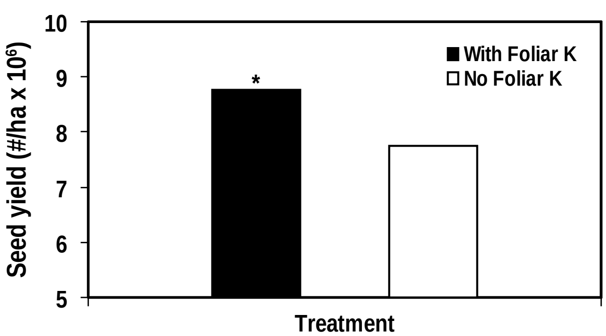

Fig. 3. Effect of foliar-applied K on the number of seed ha^{-1} at final harvest. The * indicates that a significant difference ($P \leq 0.05$) exists between treatments at Rohwer, Clarkedale and Fayetteville, AR.

Generally, the basic yield components paralleled those of the conventional yield components with respect to differences between the irrigated and non-irrigated treatments. Applying water increased the number of seed ha^{-1} relative to the non-irrigated plots (data not shown). The effect of applied water on lint index varied significantly with site-year (Table 1). Irrigation increased lint index in 2000 at Rohwer and at Clarkedale (Fig. 4). Contrastingly, lint index did not change significantly due to irrigation in 2001 at Clarkedale and decreased in 2002 at Fayetteville. The effect of irrigation on lint index may have been due to the numerically higher day temperatures during August and September of 2000 (Table 3), thus leading to an additional accumulation of heat units at Rohwer and Clarkedale not available in other site years. Pettigrew (2004a) found that water deficit stress on dryland plants reduced the seed mass and lint index one of four years as compared to irrigated plants which was similar to observations reported by McMichael and Hesketh (1982) and to those in the current study. Year-to-year variability among climatic factors can affect the timing, duration, severity, and rate of moisture deficit development and plant response (Pettigrew, 2004b). Thus, to some degree, climatic variation between seasons also affected how the components of lint yield responded to the main effect of water, in the current studies.

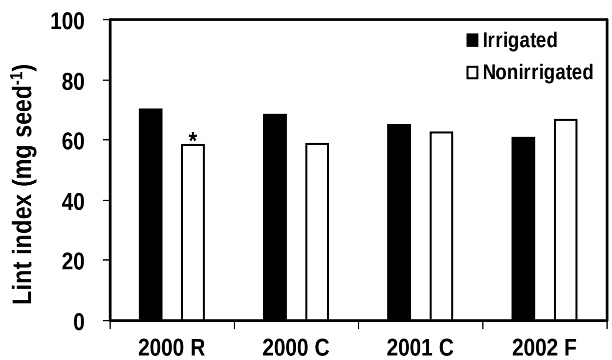

Fig. 4. Irrigation effects on the lint index of field-grown cotton averaged across the K treatments for each site year at Rohwer (R), Clarkedale (C), and Fayetteville (F), AR. The * indicates that a significant difference ($P \leq 0.05$) exists between paired treatments.

CONCLUSIONS

According to these studies, cotton lint yield response to foliar K was unlikely when soil- applied K was provided according to current University of Arkansas recommendations. Furthermore, this research suggests that the likelihood of a lint yield response to foliar K on cotton grown under conventional tillage in the Mississippi Delta of Arkansas is low when pre-plant Mehlich 3 soil test levels are in the high range of 270 to 376 kg K ha^{-1}. Under these conditions, interactive effects of water-deficit stress with foliar K or soil- with foliar-K application on the yield response of cotton are unlikely. In some seasons, water-deficit stress encountered in non-irrigated systems can minimize the benefit of soil-applied K. Further research is needed on soils testing low to medium in K to better understand potential interactive effects of soil moisture on lint yield response to soil-applied K. The interactive effects of water level on conventional yield components such as gin turnout and boll weight response to foliar K may not necessarily be mirrored by the yield response. In contrast, the basic yield components showed no interactive effects of water stress with foliar K or soil K level and foliar K which mirrored the absence of a yield response to the same factors. As shown in previous studies, seasonal rainfall governs the degree to which both categories of yield components respond to irrigation. More research is needed on the response of cotton yield and yield components to soil- and foliar-applied K under irrigated versus non-irrigated systems with soil K levels that range from low to medium. This information would assist researchers in establishing optimal strategies for K inputs across a broader spectrum of soil test K values.

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