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Potassium Fertilization of Conventional- and No-Till Cotton

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INTERPRETIVE SUMMARY

Potassium fertilization of the fast-fruiting cotton (*Gossypium hirsutum* L.) cultivars requires fertilizer information on soils with varying extractable K levels, tillage practices, and K rates. In 1991, research was established to evaluate both foliar- and soil-applied K for conventional- and no-till cotton production on three soils. After 4 yr, the initial objectives were changed, eliminating the foliar evaluations and increasing the number of soil-applied K rates to seven. The effects of soil-applied K rates on extractable leaf and petiole K concentrations and Mehlich-I extractable K levels were evaluated. Field research was conducted between 1995 and 1997 on low extractable K Memphis silt loam (Typic Hapludalfs), high extractable K Lexington silt loam (Ultic Hapludalfs), and high extractable K Loring silt loam (Oxyaquic Fragiudalfs). Both conventional-till and no-till production systems were evaluated on the Memphis silt loam, while no-till production was evaluated on the Lexington and Loring silt loam soils. Evaluations of conventional-till fertilization of the Memphis silt loam and of no-till fertilization of the Loring silt loam were discontinued after 1997. Initially the Mehlich-I extractable K levels were 90 and 80 lb K acre^{-1} in the 0- to 6-inch soil layer of the Memphis silt loam conventional- and no-till systems, respectively. Extractable K was 201 lb K acre^{-1} for the Loring silt loam and was 179 lb K acre^{-1} for the Lexington silt loam. The experimental design was a randomized complete block. Treatments included broadcasting potassium chloride (KCl) at 0, 30, 60, 90, 120, 150, and 180 lb K_2O acre^{-1}, ammonium nitrate (NH_4NO_3) at 80 lb N acre^{-1}, and triple superphosphate [$Ca(H_2PO_4)_2$] at 30 lb P_2O_5 acre^{-1} before planting. The cotton cultivar DPL 50 was planted in 1995 and 1996 and the cultivar DPL 5409 was planted in 1997 through 1999.

Preplant broadcasting of K at rates of 30 to 60 lb K_2O acre^{-1} higher than recommended increased conventional- and no- till yields, regardless of extractable K levels. Average conventional- till lint yields on the low extractable K soil were increased by broadcasting 150 lb K_2O acre^{-1}, while no-till yields were increased by broadcasting 180 lb K_2O acre^{-1}. Average no-till lint yields for the two high extractable K soils responded to broadcasting 90 lb K_2O acre^{-1}. Current K fertilizer recommendations for cotton production on a low extractable K soil is 120 lb K_2O acre^{-1} and 60 lb K_2O acre^{-1} for a high extractable K soil. Annual petiole K concentrations corresponding to the K rate of highest yield response indicated that for certain years, plant K was not sufficient for optimal cotton production. Based on these petiole K concentrations, leaf K concentrations of $\geq$1.11% were considered sufficient for cotton production while concentrations of $\leq$1.04% were considered not sufficient. Critical extractable K levels corresponding to K rates of highest annual yield response varied from 144 to 282 lb acre^{-1}. Petiole K concentrations indicated that plant K was low, suggesting that four of these critical extractable K values were also low. Two of the four extractable K values were for 1995 conventional- and no-till production on the low extractable K Memphis silt loam and K may have been low. The remaining two values occurred in 1999 and dry weather restricted the yield response to K fertilization. The critical extractable K levels of the remaining eight site-years ranged between 200 and 282 lb acre^{-1}. These extractable K levels are higher than the current level used for K fertilization recommendations.

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ABSTRACT

Potassium fertilization meeting the uptake requirements of the fast-fruiting cotton (*Gossypium hirsutum* L.) cultivars requires information on soils of

varying extractable K levels, tillage systems, and K fertilization rates. Field studies were conducted to evaluate K fertilization for cotton produced on soils of different extractable K levels. Preplant K rates of 0, 28, 56, 84, 112, 139, and 167 kg ha^{-1} were evaluated between 1995 and 1997 on Memphis silt loam (fine-silty, mixed, active, thermic, Typic Hapludalfs), Lexington silt loam (fine-silty, mixed, active, thermic Ultic Hapludalfs), and Loring silt loam (fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs). No-till research on the Memphis and Lexington silt loam soils was continued through 1999. Yields were increased by applying 28 to 56 kg ha^{-1} higher K rates than recommended. For the low extractable K soil, conventional-till yields were increased by broadcasting 139 kg K ha^{-1}, while no-till yields were increased by broadcasting 168 kg K ha^{-1}. No-till yields for the two high extractable K soils were increased by broadcasting rates up to 84 kg K ha^{-1}. Based on the sufficiency of petiole K, leaf K concentrations of ≤10.4 g kg^{-1} were insufficient. Extractable K corresponding to the highest yields varied between 72 and 141 mg kg^{-1}. Except for the four lowest values, the remaining values (100 to 141 mg kg^{-1}) are higher than the current values.

Potassium deficiencies observed in the fast-fruiting cotton (*Gossypium hirsutum* L.) cultivars have stimulated K fertilization research throughout the cotton-producing states. Arkansas researchers (Maples et al., 1988) reported that signs of K deficiency in these fast-fruiting cultivars appeared on leaves in the upper third of the plant. These researchers speculated that the K requirement of fast-fruiting, high-yielding cultivars exceeds plant uptake late in the growing season. Research conducted in Alabama led to the conclusion that cotton is a good indicator of soil K availability (Cope, 1981). Kerby and Adams (1985) reported that K deficiency occurred more frequently and with greater intensity in cotton compared with other agronomic crops. Cassman et al. (1989) reported K deficiency occurred in cotton grown on soils not considered deficient based on soil test K levels. Oosterhuis (1993) concluded that K deficiencies were related to planting cotton on soils having low K availability and inefficient K absorption by earlier-maturing, high-yielding, fast-fruiting cultivars. He suggested that deficiencies may occur in these cultivars because bolls are set over a shorter time during a period of reduced root activity.

Howard et al. (1998) found that a combination of foliar- plus soil-applied K was required to maximize yields on a low Mehlich-I (Mehlich, 1953) extractable K soil. This combination of foliar- and soil-applied K improved yields until the extractable K level was increased to 180 kg ha^{-1} (high level). Research conducted on two high extractable K soils suggests that higher K rates than currently recommended for cotton production are required for no-till production (Howard et al., 1997). They reported that conventional- till yields were increased in only 1 of 8 site-years by applying higher than recommended K rates (>28kg ha^{-1}) . No-till yields, on the other hand, were increased in 4 of the 8 site-years by applying a K rate higher than recommended. These data suggest that K availability may be reduced by surface applications as compared with soil incorporation.

The objectives of this research were to (i) evaluate cotton response to soil-applied K on soils of varying extractable K, (ii) evaluate conventional- and no-till cropping systems on a low extractable K soil, (iii) evaluate the effects of soil-applied K rates on leaf and petiole K concentration and, (iv) evaluate the effect of soil-applied K rates on extractable K. These objectives differ from the initial objectives (Howard et al., 1997; Howard et al., 1998) in that the foliar evaluations were stopped and the number of soil-applied K rates was increased from four to seven to include two higher rates. Also, conventional-till research on the high extractable K Loring and Lexington soils was stopped.

MATERIALS AND METHODS

Field investigations were conducted from 1995 through 1997 on Memphis silt loam (Typic Hapludalfs) at Ames Plantation at Grand Junction, TN; Lexington silt loam (Ultic Hapludalfs) at the West Tennessee Experiment Station, Jackson, TN; and Loring silt loam (Oxyaquic Fragiudalfs) at the Milan Experiment Station, Milan, TN. Both conventional-till and no-till production systems were used in the evaluations on the Memphis silt loam. Initially, within the 0- to 14-cm soil layer, these two sites had Mehlich-I (Mehlich, 1953) extractable K levels of 101 and 90 kg ha^{-1} for the conventional- and no-till systems, respectively. The initial Mehlich-I extractable K level was 225 kg ha^{-1} for the Loring silt loam and 188 kg ha^{-1} for the Lexington silt loam. The extractable K classification was low for the Memphis soil and high for the Lexington and Loring soils (EPSS, 2001). No-till production evaluation was continued on Memphis and Lexington silt loams through 1999.

The experimental design was a randomized complete block with five replications. Treatments included broadcasting 0, 28, 56, 84, 112, 139, and 167 kg K ha^{-1} immediately before planting using potassium chloride (KCl). A total of 90 kg N ha^{-1} was applied as ammonium nitrate (NH_4NO_3) and 15 kg P ha^{-1} as triple superphosphate [$Ca(H_2PO_4)_2$]. In the fall, the conventional-till plots were bedded and reshaped. In the spring, the tops were dragged.All soil-applied fertilizer was broadcast before topping the beds. The no-till cotton was planted by placing the planter gauge wheel on top of the previous year's cotton stubble. Treatments were applied to the same plots each year.

The cultivar DPL 50 was planted in 1995 and 1996, and the cultivar DPL 5409 was planted in the remaining years. The cotton variety tests that were conducted indicated a higher yield potential for DPL 5409, while the DPL 50 yield was decreasing. Also the stability of DPL 5409 was greater than DPL 50 across several locations (Gwathmey et al., 1997). Cotton was planted between 1 and 20 May each year in 97-cm rows on the Lexington silt loam and in 102-cm rows on the Memphis and Loring silt loams. Individual plots were four rows wide and 9.14 m long.

Before planting, winter vegetation was killed using glyphosate {*N*-(phosphonomethyl) glycine} at 1.12 kg a.i. ha^{-1}. Immediately after planting, a tank mixture was applied, consisting of paraquat {1,1'-dimethyl-4,4'-bipyridinium ion} at 395 g a.i. ha^{-1}; pendimethalin {*N*-(1-ethylpropyl)-3,4-dimethyl -2,6-dinitrobenzenamine} at 1.03 kg a.i. ha^{-1}; fluometuron {*N*,*N*-dimethyl-*N'*-[3-(trifluoromethyl)phenyl]urea} at 1.88 kg a.i. ha^{-1}; and a 0.5% (v/v) nonionic surfactant. Post-directed weed control was applied as needed. The post-directed materials included clethodim {(*E*,*E*)-2-[1-[[(3-chloro-2-propenyl)oxy]imino]propyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} at 140 g a.i. ha^{-1}; a tank mixture of pyrithiobac-sodium {2-chloro-6-[(4,6-dimethoxy-2-pyrimidinyl)thio]benzoic acid} at 71.5 g a.i. ha^{-1}; or a tank mixture of cyanazine {2-[[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl]amino]-2-methylpropanenitrile} at 1.12 kg a.i. ha^{-1} plus MSMA {monosodium methylarsonate} at 2.24 kg a.i. ha^{-1}. Insecticides, defoliants, etc., were applied as recommended for Tennessee cotton production (Shelby, 1996).

Plant materials, leaves and petioles, were collected each year from the two center plot rows during the first week of bloom. Twenty fully expanded (mature) leaves and petioles were collected from the third or fourth node from the top. Petioles and leaves were separated, oven-dried at 64°C, and ground. The plant materials were extracted with a 2% acetic acid solution (Snyder et al., 1995), and K concentrations were determined on an atomic absorption spectrophotometer (Model 3100, Perkin Elmer, Norwalk, CT).

A recommended defoliant was applied when 60% of the bolls were open. The center rows were mechanically picked to evaluate yields. Cotton was picked 2 wk after leaf drop, followed by a second picking 3 wk later.

Lint percentage was determined by combining seed cotton sub-samples from individual treatments across replications (<4.5 kg) and ginning on a 20-saw gin with dual lint cleaners. Lint yields were calculated by multiplying the lint percentage by seed cotton weights. Total lint yields were calculated by adding the first- and second-harvest yields.

Soil samples (15-cm depth) were collected in the falls of 1994, 1996, 1997, 1998, and 1999 for Mehlich-I extractable K determination. An equal number of soil cores were collected from the row and between-row positions to compensate for normal K segregation associated with no-till production (Howard et al., 1999). Mehlich-I extractable K was determined using a 1:5 soil–extractant ratio, and K concentrations were determined with an atomic absorption spectrophotometer.

Statistical analyses of treatment effect on yields, leaf and petiole K concentrations, and extractable K were conducted using the SAS Mixed Model procedure (SAS Inst., 1997). The Mixed Model procedure provides Type III *F*-values but does not provide mean square values for each element within the analysis or the error terms. Mean separation was accomplished through a series of protected pairwise contrasts among all treatments (Saxton, 1998). Means having Type III *F*-error probabilities >0.05 were categorized as nonsignificant.

RESULTS AND DISCUSSION

Soil-applied K increased yields on the three soils, but the effects and number of research years varied with soil type, and thus each soil will be discussed separately.

Memphis Silt Loam (1995–1999)

Both conventional- and no-till cotton lint yields were increased by preplant broadcast fertilizer K applications on the low extractable K Memphis silt loam (Table 1). The K fertilization effect on conventional-till yields was consistent across the 3 yr (no Y*K interaction), but the effect on no-till yields was not consistent across the 5 yr (Y*K interaction).

Fertilizer K rates of highest annual conventional-till yield response corresponded to broadcasting either 112 or 139 kg K ha^{-1} (Table 2). The 3-yr-average yields are reported since fertilizer recommendations are formulated from multi-year data. The 3-yr-average lint yield corresponded to broadcasting 139 kg K ha^{-1}, which is higher than the 112 kg ha^{-1} recommended for cotton production on a low extractable K soil (EPSS, 2001).

The K rates of highest annual no-till yield response were 84, 139, 112, 139, and 56 kg ha^{-1} for the 5 yr, respectively (Table 2). The fertilization K rate of the highest 5-yr-average lint yield response was 167 kg K ha^{-1}, which is higher than recommended (112 kg ha^{-1}) for a low extractable K soil. The 1999 yield response to broadcast K (56 kg ha^{-1}) may have been restricted by the low rainfall accumulation between 15 July and 31 August. Rainfall accumulation through 15 July was higher in 1998 than in 1999. Accumulation after 15 July, however, was higher in 1998 with a yield response to 139 kg K ha^{-1}, than in 1999 with a yield response to 56 kg ha^{-1}.

Table 1. Mixed model *F* (Fisher's *F* value) and *P* (probability) values for evaluating K fertilization effect on yield of conventional-till and no-till cotton produced on Memphis silt loam and no-till cotton produced on Lexington and Loring silt loams.

		Memphis silt loam, conv.-till		Loring silt loam, no-till			Memphis silt loam, no-till		Lexington silt loam, no-till	
Source	**df**	***F***	***P* > *F***	***F***	***P* > *F***	**df**	***F***	***P* > *F***	***F***	***P* > *F***
Year (Y)	**2**	**38.7**	**0.0001**	**13.8**	**0.0026**	**4**	**97.1**	**0.0001**	**89.1**	**0.0001**
Error a	**8**					**16**				
K rate (K)	**6**	**77.9**	**0.001**	**12.5**	**0.0001**	**6**	**255.8**	**0.0001**	**36.0**	**0.0001**
Y*K	**12**	**0.6**	**0.834**	**1.8**	**0.059**	**24**	**2.2**	**0.0028**	**4.3**	**0.0001**
Error b	**71**					**118**				

Table 2. Effect of K fertilization rates on conventional-till and no-till cotton yields.

K rate	**1995**	**1996**	**1997**	**1998**	**1999**	**5-yr avg.**	**1995**	**1996**	**1997**	**3-yr avg.**
	kg ha^{-1}									
	Memphis silt loam, no-till						**Memphis silt loam, conventional-till**			
0	**541d†**	**180f**	**316d**	**261f**	**168d**	**293f**	**444d**	**207e**	**310e**	**321e**
28	**879c**	**541e**	**774c**	**612e**	**553c**	**671e**	**740c**	**432d**	**606d**	**594d**
56	**929bc**	**699d**	**838c**	**673d**	**643a**	**750d**	**856b**	**603c**	**746cd**	**735c**
84	**988ab**	**783c**	**948b**	**759bc**	**690a**	**826c**	**893b**	**667bc**	**862bc**	**807c**
112	**978ab**	**798bc**	**980ab**	**730c**	**630a**	**829bc**	**1059a**	**761b**	**961b**	**927b**
139	**1046a**	**853ab**	**962ab**	**795ab**	**632a**	**865b**	**1088a**	**820a**	**1113a**	**1007a**
167	**1030a**	**875a**	**1076a**	**820a**	**648a**	**904a**	**1072a**	**811a**	**1039a**	**974ab**
	Lexington silt loam, no-till						**Loring silt loam, no-till**			
0	**1090b**	**893c**	**1110c**	**675c**	**674b**	**888d**	**1213c**	**1122b**	**1092c**	**1142d**
28	**1193a**	**1091b**	**1266b**	**1116b**	**809a**	**1095c**	**1259bc**	**1211b**	**1290b**	**1253bc**
56	**1197a**	**1107b**	**1280b**	**1207ab**	**839a**	**1126bc**	**1270bc**	**1170b**	**1302b**	**1248c**
84	**1189a**	**1080b**	**1385a**	**1239ab**	**899a**	**1160ab**	**1339ab**	**1200b**	**1373ab**	**1304abc**
112	**1215a**	**1154ab**	**1366ab**	**1294ab**	**848a**	**1175a**	**1332b**	**1212b**	**1390ab**	**1311ab**
139	**1187a**	**1158ab**	**1389a**	**1351a**	**829a**	**1183a**	**1450a**	**1205b**	**1386ab**	**1347a**
167	**1161ab**	**1221a**	**1345ab**	**1274ab**	**827a**	**1166a**	**1364ab**	**1316a**	**1409a**	**1363a**

† Yield means within a year column by soil, followed by the same letter, are not significantly different at α = 0.05.

Table 3. The effect of K fertilization on leaf and petiole K concentrations of conventional-till and no-till cotton produced on Memphis silt loam.

	K concentrations									
	Conventional-tillage				No-tillage					
K rate	1995	1996	1997	3-yr avg.	1995	1996	1997	1998	1999	5-yr avg.
$kg\ ha^{-1}$	$g\ kg^{-1}$									
	Leaf K concentrations									
0	6.5e†	6.7e	7.9d	7.0f	7.0e	5.9d	7.1e	5.6e	5.0e	6.1f
28	7.1de	6.8de	8.3d	7.4f	8.3d	7.3cd	8.6d	7.4d	6.3e	7.6e
56	7.7c	8.0cd	9.2d	8.3e	9.0d	7.8c	10.0c	8.2d	8.4d	8.7d
84	8.6c	8.0cd	10.8c	9.1d	10.4c	9.2b	12.62b	9.6c	10.6c	10.5c
112	9.5b	8.7c	11.6bc	9.9c	12.5b	10.1b	13.3b	10.7bc	12.9b	11.9b
139	10.1ab	10.0b	12.3ab	10.8b	13.0ab	11.5a	14.4a	13.0a	15.7a	13.5a
167	10.9a	11.3a	13.5a	11.9a	14.0a	12.2a	14.5a	11.7ab	15.9a	13.7a
	Petiole K concentrations									
0	9.8e	13.0c	23.3d	15.3d	12.4e	10.4g	23.4f	8.3e	12.7f	13.4f
28	14.1d	13.9c	26.9cd	18.2d	20.2d	16.7f	33.1e	13.2d	20.2e	20.7e
56	15.8d	19.1b	33.1c	22.7c	24.0c	22.6e	42.1d	19.0c	29.1d	27.4d
84	19.8c	19.6b	43.5b	27.6b	30.9b	29.3d	52.4c	29.7b	39.4c	36.3c
112	25.0b	21.8b	44.0b	30.3b	37.5a	39.7c	59.3b	32.2b	40.3bc	41.8b
139	31.2a	28.4a	52.9a	37.5a	41.3a	44.9b	64.7ab	45.2a	45.3ab	48.3a
167	30.9a	30.9a	56.4a	39.4a	40.6a	49.2a	68.0a	42.5a	49.4a	50.0a

† Yield means within the same year by plant part, followed by the same letter, are not significantly different at $\alpha = 0.05$.

Lexington Silt Loam (1995–1999)

Potassium fertilization increased no-till cotton yields produced on the high extractable K Lexington silt loam (Table 1). The K fertilization rate of highest annual lint yield response varied over the 5 yr (Y*K interaction).

The K rates of the highest yield response were 28, 112, 84, 56, and 28 kg ha^{-1} for the 5 yr, respectively (Table 2). The 5-yr-average lint yield responded to broadcasting 84 kg K ha^{-1}. This K fertilization rate is higher than recommended (56 kg K ha^{-1}) for cotton production on a high extractable K soil (EPSS, 2001). The 1999 yield response to broadcasting 28 kg K ha^{-1} was restricted by low rainfall accumulation between 15 July and 31 August.

Loring Silt Loam (1995–1997)

No-till yields on the high extractable K Loring silt loam were increased by K fertilization (Table 1). The K fertilization effect on lint yields was consistent over the 3 yr, as indicated by the nonsignificant Y*K interaction.

The K rates of highest yield response were 84, 167, and 84 kg K ha^{-1} for the 3 yr, respectively (Table 2). The highest 3-yr-average yield response corresponded to broadcasting 84 kg K ha^{-1}, which is higher than recommended (56 kg K ha^{-1}) for a high extractable K soil (EPSS, 2001).

Leaf and Petiole K Concentrations

Annual leaf and petiole K concentrations of conventional-till cotton produced on the Memphis silt loam were increased by broadcasting either 139 or 167 kg K ha^{-1} (Table 3). Highest 3-yr-average leaf K concentration corresponded to broadcasting 167 kg K ha^{-1}, while highest average petiole K concentrations corresponded to broadcasting 139 kg K ha^{-1}.

The K fertilization rate producing the highest K concentration of both leaves and petioles collected between bloom and 7 d after bloom may differ from the fertilization rate producing the highest yield response. Reduced rainfall between bloom and harvest restricted yields, especially in 1999, reducing the K rate of highest response. Differences may also have been affected by luxury plant consumption.

The K rates of highest conventional-till yield response in 1995 and 1996 were 112 and 139 kg K ha^{-1}, respectively. Petiole K concentrations corresponding to these K fertilization rates were 25.0 and 28.4 g kg^{-1}. Extractable K concentrations of 35 g kg^{-1} for petioles collected at bloom or 30 g kg^{-1} for petioles collected 7 d after bloom have been reported to be sufficient for Arkansas cotton production

Table 4. The effect of K fertilization on leaf and petiole K concentrations of no-till cotton produced on Lexington silt loam and Loring silt loam.

	K concentrations									
	Lexington silt loam						Loring silt loam			
K rate	1995	1996	1997	1998	1999	5-yr avg.	1995	1996	1997	3-yr avg.
kg ha^{-1}	g kg^{-1}									
	Leaf K concentrations									
0	11.5bc†	10.2d	9.5c	9.7c	5.9f	9.2e	10.3c	9.7c	9.1e	9.7e
28	11.2c	11.1cd	10.6c	11.2bc	8.4ef	10.4d	11.2bc	10.2c	10.7d	10.7d
56	12.7abc	12.3cd	12.6b	12.5b	10.0de	11.9c	11.3bc	10.6c	11.5cd	11.1cd
84	11.7bc	12.9bc	13.8b	13.1b	11.5cd	12.5c	11.6b	10.3c	12.4c	11.4c
112	13.4ab	14.9ab	14.3b	15.7a	14.1ab	14.3b	12.0ab	11.6b	13.8b	12.4b
139	14.4a	15.8a	16.4a	16.8a	17.9a	16.1a	13.0a	12.3ab	14.9ab	13.4a
167	14.1ab	16.8a	16.8a	16.8a	16.7ab	16.1a	12.2ab	12.6a	15.3a	13.4a
	Petiole K concentrations									
0	35.0e	27.8e	33.7e	28.1d	12.9f	27.5f	24.5e	23.7e	27.7e	25.3e
28	41.5de	32.4de	42.8d	40.7c	26.6e	36.8e	31.6cd	26.8de	31.9de	30.1d
56	47.3cd	38.4cd	48.7cd	45.5bc	29.3de	41.8d	28.5de	29.1cd	36.5cd	31.4cd
84	51.6bc	43.5bc	54.9bc	51.0b	37.3cd	47.7c	33.0bc	29.8cd	38.8bc	33.9c
112	57.1ab	50.7ab	61.6ab	61.6a	45.4bc	55.3b	36.9ab	33.5bc	43.8ab	38.1b
139	63.3a	54.7a	64.5a	66.9a	52.0ab	61.5a	38.3a	36.5ab	44.0ab	39.6ab
167	59.9ab	56.5a	64.6a	65.2a	58.2b	59.7ab	40.7a	38.1a	45.2a	41.3a

† Yield means within the same column by plant part, followed by the same letter, are not significantly different at $\alpha = 0.05$.

(Snyder et al., 1991). Based on sufficient petiole K concentrations, extractable petiole K concentrations corresponding to the K rate of highest yield response in 1995 and 1996 would be low. The 1997 extractable petiole K concentration of cotton fertilized with 139 kg K ha^{-1} was higher (52.9 g kg^{-1}) than the sufficient level. The 3-yr-average petiole K concentration (37.7 g kg^{-1}) corresponding to broadcasting 139 kg K ha^{-1} would be sufficient for cotton production.

Extractable leaf K concentrations of 9.5 and 10.0 g kg^{-1} corresponding to the 1995 and 1999 extractable petiole K concentrations of 25.0 and 28.4 g kg^{-1} would be low. The 12.3 g kg^{-1} extractable leaf K concentration in 1997 would be sufficient for cotton production. The 3-yr-average leaf K concentration of 10.8 g kg^{-1} would be sufficient for cotton production.

Annual and 5-yr-average leaf K concentrations of no-till cotton produced on the Memphis silt loam were increased by broadcasting 139 kg K ha^{-1} (Table 3). Annual petiole K concentrations were increased by broadcasting 112, 167, 139, 139, and 139 kg K ha^{-1} for 5 yr, respectively. The 5-yr-average petiole K concentration corresponded to broadcasting 139 kg K ha^{-1}. Based on the K rate of highest yield response, extractable petiole K concentrations were 30.9, 44.9, 59.3, 45.2, and 29.1 g kg^{-1} for the 5 yr, respectively. The 30.9 and 29.1 g kg^{-1} concentrations determined in 1995 and 1999 may indicate low plant K. Yield responses to broadcasting 84 and 56 kg K ha^{-1} are low compared with the fertilization rate of highest response for the other 3 yr. These lower responses also suggest that extractable petiole K may be low for the 2 yr. Low rainfall accumulation between 15 July and 31 August of 1999 restricted the yield responses to K fertilization to a lower K rate and a lower petiole K concentration. This petiole K concentration was lower than the sufficiency level, even though petiole K concentrations were higher for the higher fertilization rates. Late-season dry weather conditions would affect yields with little or no effect on petiole concentrations. Extractable leaf K concentrations that correspond to the K rates producing these annual petiole K concentrations were 10.4, 11.5, 13.3, 13.0, and 8.4 g kg^{-1}, respectively. Based on the 1995 and 1999 petiole data, the 10.4 and 8.4 g kg^{-1} leaf K concentrations would be low. These leaf K concentrations (10.4 and 8.4 g kg^{-1}) are similar with the conventional-till leaf K concentrations (9.5 and 10.0 g kg^{-1}).

Annual leaf and petiole K concentrations of no-till cotton produced on the Lexington silt loam were increased by broadcasting K rates ranging from 56 to 139 kg ha^{-1} (Table 4). Petiole K concentrations corresponding to the fertilizer K rates of highest yield response were 41.5, 50.7, 54.9, 45.5, and 26.6 g kg^{-1} for the 5 yr, respectively. Except for the 1999 petiole concentration (26.6 g kg^{-1}), these K concentrations were higher than the sufficiency level for Arkansas. The 1999 petiole K concentrations reflected the low rainfall accumulation after 15 July, restricting the yield response to K fertilization. Leaf K concentrations for the 4 yr of high petiole K concentrations were 11.2, 14.9, 13.8, and 12.5 g kg^{-1}, respectively. The 1999 extractable leaf K concentration of 8.4 g kg^{-1} was low, similar to the low Memphis silt loam leaf K concentrations.

Five-year-average leaf and petiole K concentrations were increased by broadcasting 139 kg K ha^{-1}. This K fertilization rate is higher than the fertilizer K rate of highest yield response (84 kg K ha^{-1}) and corresponded to an average 47.7 g kg^{-1} petiole K concentration. The 5-yr-average leaf K concentration of 12.5 g kg^{-1} corresponded to broadcasting 84 kg K ha^{-1}.

Leaf and petiole K concentrations of no-till cotton produced on the Loring silt loam were increased by broadcasting 112 to 139 kg K ha^{-1} (Table 4). Three-year-average leaf and petiole K concentrations were increased by broadcasting 139 kg K ha^{-1}. Petiole K concentrations corresponding to the K rates of highest yield response were 33.0, 38.1, and 38.8 g kg^{-1} for the 3 yr, respectively. These petiole K concentrations exceed the sufficiency level of Arkansas petiole K concentrations. Leaf K concentrations corresponding to these K fertilization rates were 11.6, 12.6, and 12.4 g kg^{-1}.

Extractable petiole K concentrations corresponding to the K rate of highest yield response were low for 5 of the 15 site-years. The concentrations 25.0, 28.4, 30.9, 29.1, and 26.6 g kg^{-1} were low for cotton production based on Arkansas data. Two of these low values (25.0 and 30.9 g kg^{-1}) were determined for conventional- and no-till cotton produced in 1995 on the low extractable K Memphis silt loam. Two values (29.1 and 26.6 g kg^{-1}) corresponded to the low fertilizer K yield responses of 1999 limited by rainfall. The higher petiole K concentrations resulting from higher fertilizer K applications in 1999 indicated that extractable plant K concentration was sufficient but late-season rainfall limited yields. Extractable leaf K concentrations for 5 of the 15 site-years were 9.5, 10.4, 10.4, 8.4, and 8.4 g kg^{-1}. Based on the corresponding petiole K concentrations, these values were deficient for cotton production.

Soil Extractable K

Mehlich-I extractable K of the conventional- and no-till systems differed with year and K rates (analyses not presented). Increases in extractable K with applied fertilizer K were expected with treatments being maintained on the same plots.

Highest annual Mehlich-I extractable K within the conventional-till Memphis silt loam system resulted from broadcasting 112, 139, and 139 kg ha^{-1} for the 3 yr, respectively (Table 5). Fertilizer K rates resulting in the highest extractable K levels may or may not correspond to the K fertilization rates of highest yield response. The 1995 K rate of highest yield response was to broadcasting 112 kg K ha^{-1}, while extractable K was increased from broadcasting 139 kg K ha^{-1}. A critical extractable K level corresponding to the K rate of highest yield response is needed for soil test calibration. Critical extractable K levels corresponding to K fertilization rates for conventional-till cotton produced on the Memphis silt loam in 1995 and 1997 were 79 and 128 mg kg^{-1} corresponding to broadcasting 112 and 139 kg K ha^{-1}, respectively. The 1995 extractable petiole K concentration of 25.0 g kg^{-1} indicated low plant K, suggesting that the 79 mg kg^{-1} extractable K level was also low. This critical level is similar to the critical extractable K level (80 mg kg^{-1}) used for fertilizer K recommendations.

For the no-till Memphis silt loam, extractable K levels were increased by broadcasting 139, 167, 167, 112, and 167 kg K ha^{-1} for the 5 yr, respectively. These K rates are higher than the K rates corresponding to the highest yield response, which were 84, 112, 139, and 56 kg ha^{-1} for the 1995, 1997, 1998, and 1999 yields, respectively. Extractable K levels corresponding to these fertilization rates were 72, 100, 127, and 82 mg kg^{-1}. The 1995 and 1999 extractable petiole K concentrations of 30.9 and 29.1 g kg^{-1}, along with possible restricted yield response, indicated possible low plant K, suggesting that the 72 and 82 mg kg^{-1} extractable K levels were also low. The low critical extractable K values of 1999 were limited by dry weather.

Annual extractable K levels resulting from broadcasting increased fertilizer K rates to the Lexington silt loam were maximized by broadcasting

Table 5. Effect of soil-applied K rates on Mehlich-I extractable K.

	Mehlich-I extractable K							
K rate	**1994†**	**1996**	**1997**	**1998**	**1999**	**1994†**	**1996**	**1997**
	mg kg^{-1}							
	Memphis silt loam, no-till					**Memphis silt loam, conv.-till**		
0	**41d‡**	**39f**	**38e**	**45e**	**47e**	**45d**	**58e**	**54f**
28	**48cd**	**50f**	**52e**	**61d**	**65de**	**55cd**	**72d**	**65ef**
56	**57c**	**62e**	**68d**	**82c**	**83d**	**60c**	**79d**	**84de**
84	**72b**	**78d**	**96c**	**106b**	**119c**	**66c**	**93c**	**101cd**
112	**76b**	**100c**	**121b**	**135a**	**159b**	**79b**	**105b**	**122c**
139	**101a**	**119b**	**127b**	**144a**	**172b**	**103a**	**128a**	**153b**
167	**81b**	**135a**	**143a**	**150a**	**193a**	**95a**	**132a**	**190a**
	Lexington silt loam, no-till					**Loring silt loam, no-till**		
0	**90d**	**79e**	**75e**	**80c**	**83e**	**101d**	**84d**	**87c**
28	**109cd**	**93de**	**99de**	**107bc**	**109d**	**122cd**	**102d**	**104c**
56	**122c**	**106cd**	**125cd**	**131b**	**133cd**	**130bc**	**128c**	**140b**
84	**122c**	**119c**	**146bc**	**135b**	**154c**	**121cd**	**141c**	**140b**
112	**153b**	**151b**	**172b**	**181a**	**200b**	**161a**	**183b**	**180a**
139	**178a**	**188a**	**205a**	**188a**	**204b**	**157a**	**215a**	**201a**
167	**183a**	**190a**	**202a**	**207a**	**232a**	**165a**	**219a**	**207a**

† Soil samples collected in the fall. Samples were not collected in the fall of 1995.

‡ Extractable K means for each year within the same column, followed by the same letter, are not significantly different at $\alpha = 0.05$.

112 to 167 kg K ha^{-1}. The extractable K levels corresponding to the K rate of highest yield response were 109, 119, 125, and 107 mg kg^{-1}, resulting from broadcasting 28, 84, 56, and 28 kg ha^{-1} of fertilizer K, respectively. The 1999 low extractable petiole K concentration (26.6 g kg^{-1}) indicated a low corresponding extractable K level of 107 mg kg^{-1}. Dry weather or low soil moisture conditions restricted the 1999 yield response, lowering the corresponding extractable K level. These critical extractable K levels, including 1999, are higher than the current level used for recommendations.

Extractable K levels were maximized by broadcasting 112, 139, and 112 kg ha^{-1} of fertilizer K to the Loring silt loam. No-till cotton yields responded to broadcasting 84 kg K ha^{-1} in 1995 and 1997, corresponding to 121 to 141 mg kg^{-1} extractable K, which are higher than the critical K level used for cotton fertilizer recommendations.

Critical extractable K levels, corresponding to the K rates of highest yield response, for the four sites ranged between 72 and 141 mg kg^{-1}. The petiole K concentrations of 4 of these 12 site-years were at or below the sufficiency level, indicating that extractable K levels may be low. These four extractable K levels were 79, 72, 82, and 107 mg kg^{-1}. Two of the low extractable K levels were associated with the 1995 yields produced on the low extractable K soil, while the other two were associated with the 1999 yields that were restricted by dry weather. Critical extractable K for the other 8 site-years ranged from 100 to 127 mg kg^{-1} and are higher than the 80 mg kg^{-1} critical level being used for fertilizer recommendations. These data suggest the need to re-calibrate soil test K for cotton production on the loess-derived soils.

CONCLUSIONS

No-till and conventional-till yields were increased by preplant broadcasting K rates higher than recommended. Broadcasting 28 to 56 kg K ha^{-1} higher than recommended rates increased yields regardless of extractable K levels (low or high) or tillage system. Average conventional-till yields from the low extractable K Memphis silt loam were increased by broadcasting 139 kg K ha^{-1}, while average no-till yields were increased by broadcasting 167 kg K ha^{-1}. Average no-till cotton yields produced on two high extractable K soils corresponded to broadcasting 84 kg ha^{-1}. Petiole K concentrations corresponding to the K rate of highest yield response were low during certain years of the research. On the basis of petiole K concentration sufficiency, leaf K concentrations of $\geq$11.1 g kg^{-1} were sufficient while leaf K concentrations of $\leq$10.4

$g\ kg^{-1}$ were low. Extractable soil K concentrations were increased by surface broadcasting increased K rates. Annual critical extractable K values corresponding to K rates of highest yield response varied between 72 and 141 $mg\ kg^{-1}$. Four of the lowest critical K levels were classified as low on the basis of low petiole K concentrations. Two of these four low critical K levels were from yield responses (conventional- and no-till) on the low extractable K Memphis silt loam. Dry weather conditions in 1999 reduced the yield response to K fertilization, lowering the critical extractable K level on two soils. The eight remaining critical extractable K levels ranged from 100 to 141 $mg\ kg^{-1}$ and were higher than the value used for K recommendations. These data suggest the need to re-calibrate K fertilizer recommendations for cotton production on loess-derived soils.

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