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EFFECT OF SOIL-APPLIED POTASSIUM AND MICRONUTRIENTS ON COTTON YIELD, FIBER QUALITY, PETIOLE NUTRIENTS, AND SOIL PROPERTIES

M. Mozaffari, W.N. Miley, S.J. McConnell, N.A. Slaton, and E. Evans
Department of Crop, Soil, and Environmental Sciences
University of Arkansas
Fayetteville, AR

Abstract

The new fast fruiting cotton (*Gossypium hirsutumn* L.) cultivars may have a higher nutrient requirement than the older cultivars. When planting these cultivars, many growers apply additional K and micronutrients to ensure a good crop, even when the soil test does not indicate the need for supplemental fertilization. A two-year field study was conducted to evaluate the effects of rate and timing of K fertilizer, alone or in combination with Cu, Zn, and Mn, on cotton yield, fiber quality, and petiole nutrients on a Calloway silt loam with high levels of Mehlich-3 (M-3) extractable K, Zn, Mn, and a medium level of extractable Cu. The effects of K and micronutrients on soil properties were also investigated after one cropping season. Treatments consisted of 100-400 lb/A of K_2O alone or in combination with 2, 2, or 5 lb/A of Cu, Mn, or Zn respectively. The experimental treatments were applied in spring 2002 only. Their immediate effect on cotton growth and fiber quality was evaluated in 2002 and their residual effects were evaluated in 2003. Application of K and micronutrients did not have any significant effect on cotton lint yield in either year. Concentrations of K in petiole samples collected during the 5th week of flowering in both years was above the critical K levels regardless of K application. Lint quality was not affected by K or micronutrient application. Application of K fertilizer significantly increased M-3 extractable K in the 0-6" but not in the 6-12" depth. However Cu, Zn, and Mn in the 0-6" and 6-12" depth increments were not affected by application of these micronutrients.

Introduction

Potassium plays a pivotal role in cotton (*Gossypium hirsutumn* L.) growth and lint development. It participates in transportation of sugars and activation of many of the enzymes responsible for various plant metabolic processes (Coker et al., 2003). Plant demand for K is particularly high during fruit development (Oosterhuis et al., 2003). Therefore, K deficiency will negatively impact cotton yield and lint quality. The fast fruiting, high quality cultivars introduced in the past two decades may have different nutritional requirements than the obsolete cultivars that were originally used to develop much of our current fertilizer recommendations. Recent work in neighboring states such as Tennessee (Essington et al., 2002) have suggested that new fast fruiting cultivars grown in loess-derived soils are particularly prone to K deficiency. This has been attributed mostly to the potential K fixation by vermiculite- dominated soil minerals. Substantial acres of loess-derived soils are under cotton production in the Mississippi Delta Region of Arkansas. Additionally the presence of plowpans in many of these soils hampers the utilization of subsoil K by cotton roots. The University of Arkansas Soil Testing and Research Laboratory (UA-STRL) does not recommend supplemental K fertilizer application when (M-3) extractable K in the soil sample exceeds 360 lb/A (using a 1:10 soil:solution ratio) (Sabbe, 1998). In addition to that, UA-STRL currently does not have a specific soil test for micronutrients beyond some general interpretative guidelines, where M-3 extractable (1:10 soil;solution) Mn, Cu, and Zn values greater than 463, 8.8, and 8.5lb/A respectively are considered high. Many growers are concerned about the sufficiency of Cu, Mn, and Zn in loess-derived soils in this region. As a result of these and in the absence of any site-specific data many cotton growers who cultivate short season high-yielding high fiber quality cotton cultivars on loess-derived alluvial soils apply supplemental K and micronutrients even when the soil test levels are very high, to insure a return on their investment.

This scenario highlights the need for addressing these potential fertility problems in high testing loess- derived soils. In order to start addressing these potential fertility problems, a two-year field experiment was initiated on a Calloway silt loam (Fine-silty, mixed thermic, Glassoaquic Fragiudalf) with a very high soil test K value. The production field was fertilized with 130 lb/A of K_2O annually including the previous five years. This soil is a representative loessial soil of the Mississippi Delta Region of Arkansas, where cotton is the predominant crop. The objectives of the study were to evaluate the following effects for a high yielding, high quality, short season cotton cultivar grown on a representative loess-derived silt loam soil:

1. The effects of rate and timing of supplemental K fertilizer on cotton lint yield, petiole K, and lint quality.
2. The effects of Zn, Cu, and Mn alone or in combination with K on cotton yield and lint quality.
3. The effects of K, Cu, Zn, and Mn on soil properties.

Material and Methods

A two-year field experiment was conducted on a Calloway silt loam with high levels of M-3 extractable K, Zn, Mn, and a medium level of extractable Cu (Table1). Experimental treatments consisting of 100 to 400 lb/As of K_2O alone or in combination with various rates of Cu, Zn, and Mn (Table 2) were applied only in 2002. Potassium and Cu were supplied by granular muriate of potash and granular cupper sulfate respectively. Manganese and Zn were supplied by reagent grade manganous sulfate monohydrate and zinc sulfate respectively. The residual effects of these treatments were also evaluated in 2003. The experimental design was a completely randomized block with four replications of each treatment. Individual plots were 30' long and four rows wide with a 38"row spacing. The cotton cultivar was FiberMax 966 in 2002 and FiberMax 966 BGRR in 2003. The field was irrigated with a center pivot system that applied at least ¾ inch of irrigation every 5 days as needed. The primary weather limitations were a period of excessive rainfall both years and abnormally cool and cloudy conditions during the boll maturation period in 2003. Nitrogen, P fertility and pests were managed by the grower and his consultants according to the recommendations issued by the University of Arkansas Cooperative Extension Service in both years. Plant growth was favorably regulated by multiple applications of Mepiquat chloride totaling 30 oz/A each year. Composite soil samples were collected from 0-4" and 5-8" in the check plots prior to treatment application in Spring of 2002 and after crop harvest from all plots at 0-6" (topsoil) and 6-12" (subsoil) depths in the fall of 2002 and analyzed for nutrients using Mehlich-3 solution (1:10 soil/solution ratio) by UA-STRL. Soil pH was determined in distilled water (1:1 w/v) Organic matter was measured by loss on ignition. In each year petiole samples were collected in the 5^{th} week of flowering and analyzed for N, P, and K by UA-STRL. At maturity two central rows of each plot were harvested in 2002 and one row in each plot in 2003 by hand and lint yield was calculated assuming a 36% lint component.

Results and Discussion

Effect on Cotton

Lint yield in 2002 was 1400-1490 lb/A and was not affected by time or rate of K application or K and any of the micronutrients (Fig. 1). These yields are within the historical yields obtained by the grower at this site. In 2003 the lint yield was 1132-1270 lb/A and was not significantly affected by the residual levels of K and micronutrients applied in 2002 (Fig. 2). In 2003, the yields were in general lower than 2002 perhaps due to cooler temperature during the boll-filling period or slow initial cotton growth due to an unusually high amount of rain in the month of May, where about 10 inches of rain fell in two days when cotton was at the seedling stage. In general the yield data suggest that K deficiency was not a yield-limiting factor at this site in either year. Neither was the yield limited by deficiencies of Cu, Zn, and Mn.

Potassium levels in petiole samples collected during the 5^{th} week of flowering were not affected by K or micronutrient application (Table 3). Petiole K was 5.4-6.1% in 2002, and 4.1-4.7% in 2003 respectively. Current critical K level for cotton petioles during the 5^{th} week of flowering in Arkansas is 2.5% (Snyder et al., 1995). Similar to the yield data petiole data suggest that K deficiency was not limiting the yield at this site. Potassium application had no effect on fiber length, strength or micronaire in 2002 (Table 4).

Effect on Soil Properties

Chemical analysis of soil samples collected from 0-6" and 6-12" depth increments in the Fall of 2002 (after first crop harvest) indicated that K application significantly increased the M-3 extractable K in the topsoil (Table 5). The significant effect was primarily due to application of 400 lb/A of K_2O. Mehlich-3 extractable K in the topsoil of the check plot and the plot that received the highest amount of K was 580 and 788 lb/A respectively. The topsoil M-3 extractable values in all plots were well above the 360 lb/A high soil test K threshold for cotton production in Arkansas (Sabbe, 1998) and explains why we did not observe a yield response to K application. These data suggest that the current high K threshold of 360 lb/A of M-3 extrctable K (1:10 soil:solution) is potentially appropriate for identifying similar soils that will not respond to K fertilization. More research is needed on similar soils with soil K levels above 360 lb/A but lower than 564 lb/A to make a definitive statement about the merit of applying K fertilizer on high K loess-derived soils. Subsoil K was 218-279 lb/A and was not significantly affected by K application, suggesting that no significant leaching of applied K occurred (Table 5). The K saturation ratio in the topsoil was significantly increased by K application and was 4.7% for the check and 7.1% for the highest K rate (data not shown). However, Mg saturation ratio was 13.3-14.4% and was not impacted by K application. In Arkansas the normal range for K saturation ratio is 1-5% and that for Mg is 3-25% (Chapman et al, 1998).

Topsoil pH was 6.2-6.8, thus it was favorable for cotton production. The subsoil pH was slightly higher 6.5-7.0, but still favorable for cotton production. Soluble salts in the topsoil and subsoil were not significantly impacted by the application of K and micronutrients (Table 5). There was no significant increase in Zn, Cu, and Mn in the topsoil or subsoil and the level of each nutrient was higher in the topsoil.The data indicate that in the short-term, micronutrient applications at these rates did not result in significant accumulation of Zn, Cu, and Mn in the topsoil or leaching into the subsoil (Table 5).

Conclusions

For cotton planted in 2002 and 2003 on a Calloway silt loam with very high levels of M-3 extractable K, Zn, Mn and a medium level of Cu, applications of 0-400 lb/A of K_20 alone or in combination with 2 lb/A of Cu or Mn and /or 5 lb/A of Zn in 2002 showed the following effects:

1. Cotton lint yield and quality were not affected by application of up to 400 lb/A of K2O.
2. Cotton lint yield and quality were not affected by application of Cu, Zn, or Mn alone or in combination with varying rates of K2O fertilizer.
3. Petiole K in samples collected during the 5th week of flowering were well above the critical levels in both years.
4. Application of K fertilizer significantly increased the extractable K in the 0-6" but not in the 6-12" depths.Cu, Zn, and Mn in the 0-6" and 6-12" depth increments were not significantly increased by application of these micronutrients.

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Table 1. Rate and time of application of K, Cu, Zn, and Mn in 2002.

Treatment	Amendment	Rate (lb/A)	Application time
1	Check	0	
2	K_2O	100	1st square
3	K_2O	100	1st flower
4	K_2O	100	1st square
	K_2O	100	1st flower
5	Cu	2	1st square
6	K_2O	100	1st square
	Cu	2	
7	K_2O	100	1st square
	Cu	2	
	Zn	5	
8	K_2O	100	1st square
	Cu	2	
	Zn	5	
	Mn	2	
9	K_2O	100	1st square
	Cu	2	1st square
	Zn	5	1st square
	Mn	2	1st square
	K_2O	100	1st flower
10	K_2O	200	1st square
	K_2O	200	3rd week of flowering

Table 2. Soil properties in the check plots prior to application of K, Cu, Zn and Mn in Spring 2002.

	Sampling Depth	
Soil property	**0-5”**	**5-10”**
pH	6.3	6.5
Organic matter	2.3	1.6
P (lb/A)	91	131
K (lb/A)	564	224
Ca (lb/A)	2896	577
Mg (lb/A)	591	446
Mn (lb/A)	617	560
Zn (lb/A)	13.6	9.3
Cu (lb/A)	6.8	6.5
B (lb/A)	2.2	1.7
CEC (meq/100 g)	13.3	14.0
EC (mmohs/cm)	100	28
Base saturation (%)	77	83
K saturation (%)	5.4	2.0
Mg saturation (%)	13.9	13.9
K-saturation/Mg-saturation	2.6	6.9

Table 3. Analysis of cotton petiole samples collected in the 5th week of flowering in 2002 and 2003.

	2002			2003		
	K	N	P	K	N	P
Treatment	%	ppm		%	ppm	
1	5.7	370	2461	4.4	456	4351
2	5.6	708	2224	4.4	456	4339
3	5.9	441	2351	4.6	491	5000
4	6.1	292	2530	4.4	387	4886
5	6.1	520	2416	4.7	491	4279
6	5.6	439	2079	4.3	387	4235
7	6.1	553	2443	4.1	491	4176
8	5.5	404	2232	4.5	564	4196
9	5.4	328	2013	4.5	456	4358
10	5.8	329	2368	4.5	529	4063
Statistical significance	NS	NS	NS	NS	NS	NS

Current critical level of K in petiole for cotton at 5th week of the flowering is 2.5% (Snyder et Al., 1995).

Table 4. Effect of K, Cu, Zn, and Mn on fiber quality in 2002.

Treatment	Miconaire	Elongation (%)	Strength (g/tex)	Staple Length (50%)	Staple Length (2.5%)
1	3.6	5.9	24.7	0.58	1.2
2	3.4	6.4	24.7	0.56	1.2
3	3.6	6.1	24.9	0.58	1.2
4	3.6	6.2	24.3	0.57	1.2
5	3.4	6.2	25.2	0.56	1.2
6	3.5	6.4	24.6	0.57	1.2
7	3.6	6.2	24.2	0.57	1.2
8	3.6	6.1	24.9	0.58	1.2
9	3.5	6.1	24.6	0.57	1.2
10	3.5	6.2	24.6	0.56	1.2
Significance	NS	NS	NS	NS	NS

Table 5. Chemical properties of soil samples collected from the 0-6" and 6-12" depth after cotton harvest in Fall of 2002.

	pH		K (lb/A)		Mn (lb/A)		Cu (lb/A)		Zn (lb/A)		EC (mmhos/cm)	
Treatment	0-6"	6-12"	0-6"	6-12"	0-6"	6-12"	0-6"	6-12"	0-6"	6-12"	0-6"	6-12"
1	6.7	6.7	580	272	624	525	6.9	3.7	19	16	55	45
2	6.7	6.6	565	252	614	488	6.0	3.6	15	12	62	47
3	6.6	6.9	590	279	596	508	5.9	3.4	24	10	66	36
4	6.8	7.0	615	259	627	564	5.8	3.7	16	12	61	40
5	6.2	6.8	506	218	595	516	8.2	3.8	19	8	56	43
6	6.5	6.7	579	240	625	495	9.0	3.3	14	6	58	36
7	6.7	7.0	609	298	592	524	8.5	3.9	24	11	69	38
8	6.4	6.6	551	238	609	505	7.3	3.5	18	14	56	34
9	6.4	6.5	533	247	625	564	6.3	3.0	21	8	47	50
10	6.7	6.8	788	275	580	431	6.0	3.5	17	9	63	39
Significance	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
MSD at 0.05	_	_	185	_	_	_	_	_	_	_	_	_

NS not significant at p=0.0

** significant at p=0.05 probability level

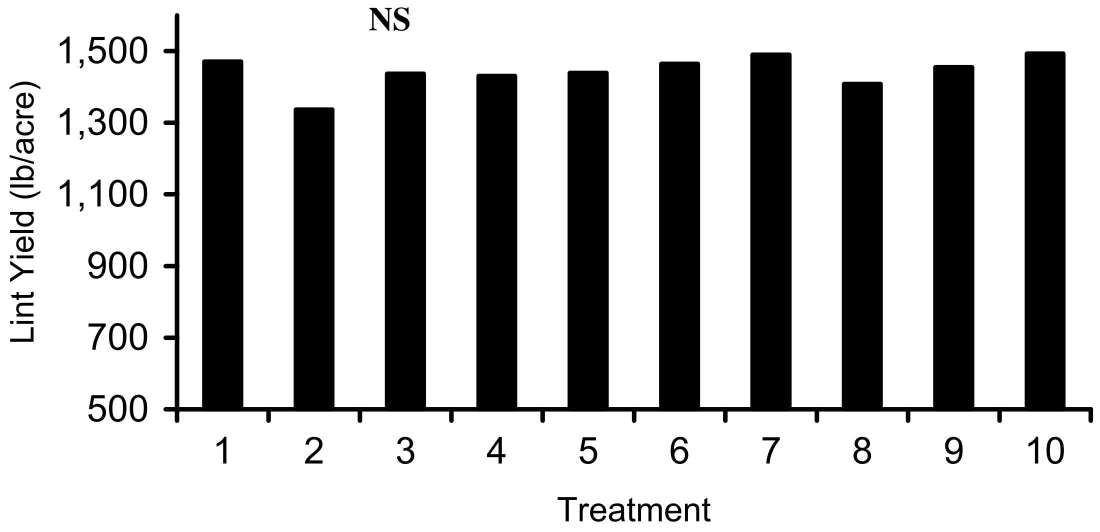

Figure 1. Effect of K, Cu, Zn, and Mn on lint yield in 2002.

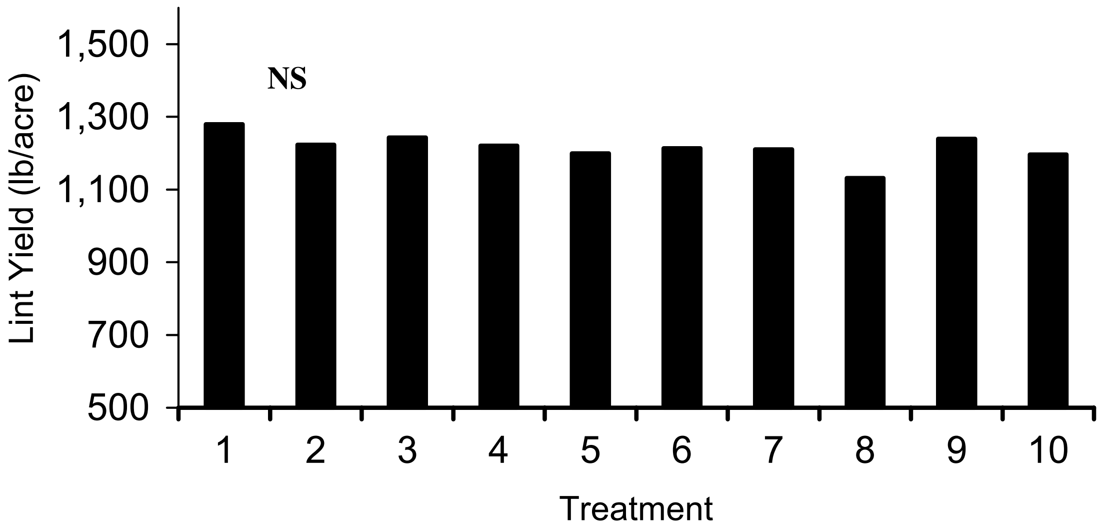

Figure 2. Effect of K, Cu, Zn, and Mn on lint yield in 2003.