POTASSIUM NUTRITION OF COTTON ON LONG TERM EXPERIMENTS

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Abstract

Long-term soil fertility experiments (c. 1929) at 5 Alabama locations have been cropped (mostly cotton-soybean rotation) using residual soil K since 1982. Since 1957, K rates applied to crops were 0, 28, 56, and 111 kg K ha $^{-1}$. Plow layer K has been monitored using Mehlich-1 extraction. Profile K was characterized in 1990. Most of the applied K prior to 1982 accumulated in the upper horizons except on sites with the lowest cation exchange capacity (<5 cmol kg^{-1}) where K accumulated in the top of the argillic horizon. Extractable plow-layer K declined very little during the 15-yr residual study. The largest decreases were in the two soils with the lowest CEC (<5 cmol kg^{-1}), the Benndale and Dothan soils. Critical plow-layer soil test K levels for cotton based on soil CEC as currently used by the Auburn University Soil Testing Laboratory were determined to be accurate for the cropping systems used in these studies. Including extractable profile K to a depth of 60 cm did not improve K calibration for cotton.

Introduction

Potassium nutrition of crops on acid, infertile Ultisols of the southeastern U.S. has always been a concern, especially for cotton which is susceptible to K deficiencies. With increasing acreage and yields of cotton on these soils, new varieties, eradication of the boll weevil, and new technologies for insect control, K nutrition is of renewed concern to growers. Alabama's "Two-year Rotation" experiments at 6 locations (c. 1929) have provided information for fertilizer recommendations and data for soil test calibration since their beginning (Cope, 1970, 1981, 1984). In 1982, these experiments were put into a residual P and K mode. Cotton has been a principal crop in these experiments for 46 of the 69 years from 1929 to 1997. Therefore, these experiments offer an excellent opportunity to study soil K changes with time and re-evaluate K nutrition of cotton. The objectives of this summary is to 1) evaluate the effect of 15 years of cropping on extractable, plow-layer soil K; 2) determine the effect of long-term cropping and K fertilization on soil profile K; and 3) re-examine soil test calibration for K on cotton. In order to accomplish these objectives, soil K variable treatments on the "Two-year Rotation Experiment" at five Alabama locations were summarized from 1982 through 1997.

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Materials and Methods

Alabama's "Two-Year Rotation" soil fertility experiments at 5 locations have been in a cotton-soybean rotation since 1992 (Table 1, Fig. 1). All sites represent highly weathered paleudults or kandiudults typical of the southeastern U.S.(Table 2). Each experimental site is a modified randomized block design with 4 replications for each of 17 soil fertility treatments. Rotation crops are planted on two replications each year. Cultivars used are those that have performed well in experiment station variety tests and are available to local growers. Four of the 17 soil fertility treatments are annual K variables which were applied prior to 1982: 1) 0 kg K ha^{-1}; 2) 28 kg K ha^{-1}; 3) 56 kg K ha^{-1} (standard treatment); and 4) 112 kg K ha^{-1}. No fertilizer K has been applied to K-variable plots since 1982 (i.e., residual K since 1982) *except for the standard treatment which continues to receive 56 kg K ha^{-1}*. In addition to the K variables, all plots received annual applications of 25 kg P ha^{-1} (60 lb. P_2O_5 acre^{-1}) prior to 1982 and all test high in P. All plots are maintained at a pH between 5.8 and 6.5 with periodic applications of ground, dolomitic limestone. Plow layer soil samples are tested every other year (after harvest) for Mehlich-1 extractable K. Profile K to a depth of 1 m was examined in 1990 at three of the sites.

Results and Discussion

In 1982 when annual K applications ceased on all treatments except the 56 kg K ha^{-1} treatment, the two highest K treatments were at or above what was considered to be a "high" soil test K level for cotton (Fig. 2-3). A "high" soil test is above an established critical value and is defined as an adequate supply of that nutrient; no additional application of that nutrient is recommended (Adams et al., 1994). On the finer textured soils (Decatur and Lucedale series), soil test K changed very little during the following 15 years when no additional K was applied (Fig. 3). Applications of 56 kg K ha^{-1} to cotton since 1982 resulted in only a slight trend toward increasing levels of extractable K in the plow layer. These data suggest that once these more highly buffered soils reach a "high" level of soil test K, they may be cropped to cotton and soybeans for several years before K becomes a limiting factor.

At the same time, applications of 56 kg K ha^{-1} will maintain or slightly increase soil test K. This is reasonable considering that 1120 kg lint ha^{-1} (about 2 bales per acre) would remove only around 25 kg K ha^{-1} (27 lb. acre^{-1}) (Mullins and Burmester, 1990). However, on the sandier, weakly buffered soils of the Coastal Plain, the Benndale and the Dothan series, there were gradual declines in soil test K during the 15-yr residual study (Fig. 2). Although 56 kg K ha^{-1} were applied each year to cotton in the standard treatment, after 15 years plow-layer K was at or below the critical value for cotton for all treatments.

Further differences in the K buffering capacity of these soils are evident when extractable profile K is examined as it was in 1990 at three of the five sites included in this study (Fig. 4). In the Lucedale and Decatur soils, K accumulated in the upper soil horizons. Highest K levels were in the Ap horizon. However, in the weakly buffered Benndale ls at Brewton Experiment Field, highest extractable K was found in the upper part of the argillic horizon between 20 and 40 cm. Because of the low CEC of this soil, much less total K accumulated in the soil profile compared to the finer textured soils. There is a trend toward lower yields on the weakly buffered soils (Table 3).

Mean cotton lint yield from each residual K treatment was compared with mean yield for the standard fertilization treatment that received 56 kg K ha^{-1} to calculate a relative yield. Relaltive yield is expressed as a percentage of the standard treatment yield. Relative yield by location and year was then compared to the mean soil test K value for each treatment at that location to develop a soil test calibration for cotton for the period 1992 through 1997 (Fig. 5). There has been much grower concern that with higher yielding, earlier maturing, modern varieties, soil test calibration for K on cotton needs adjusting. However, these data indicate that the sufficiency level approach to *critical K values as used by the Auburn University Soil Testing program in Alabama (Adams et al., 1994) is still very reliable and accurate*. The weakly buffered soils with a CEC £ 4.6 cmol kg^{-1} (the Dothan and Benndale series) are included in one graph and the two Lucedale soils (CEC = 4.6 to 9.0 cmol kg^{-1}) are included in another graph according to current Alabama soil test calibration. The Decatur soil which is representative of cotton producing soils of the Tennessee Valley region has the highest CEC (10.0 cmol kg^{-1}) and the highest critical soil test K level. In a separate but related study, we found that cotton yields on the two Lucedale soils and on the Benndale soil were highly significantly related ($P<.05$) to soil test K in the 0 to 20 cm depth, in the 20 to 40 cm depth, or in the 40 to 60 cm depth. However, using soil test K from different depths did not improve soil test calibration (Mitchell et al., 1995).

Potassium recommendations (in pounds per acre of K_2O) are made according to the following equations when soil test K is reported in "pounds per acre" (2 times mg kg^{-1}):

Soil CEC (cmol kg^{-1})	K_2O recommendation (lb $acre^{-1}$)
0 – 4.6	120 – 0.99 (soil test K)
4.6 – 9.0	120 – 0.67 (soil test K)
9.0+	120 – 0.50 (soil test K)

The fine textured, highly buffered, smectitic and often calcareous soils of the Alabama Black Belt prairie region are tested with another extractant and have a different calibration not included in this study.

Summary

Cotton and soybean cropping of five Alabama soils that had received 54 years of variable K rates did not deplete soil-test (M1) K dramatically over 15 years of no K fertilization. Potassium applied prior to 1982 accumulated in the upper soil horizons. Loss of K by leaching should not be a concern except in those soils with a CEC < 5 cmol kg^{-1}. Current soil test calibration critical extractable K values for Alabama soils are still accurate for modern varieties and yields. Plow-layer, soil test K is still a very reliable tool for predicting the need for K fertilization on Alabama soils when other factors are not limiting.

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This paper is dedicated to the memory of Dr. Tom Cope, Jr. (1921-1998), Professor Emeritus of Agronomy and Soils, who passed away on 11 October 1998. Dr. Cope was a mentor to the senior author and was responsible for the "Two-Year Rotation" experiments from the 1950s until his retirement in 1984. His publications from these experiments provided the basis for Alabama's current soil test calibration and fertilizer recommendations (Cope, 1970, 1981, 1984; Cope et al., 1981), and his interest in long-term research helped to assure their continuation.

The "Two-year Rotation Experiments" have continued because of the work and dedication of the superintendents and staff of the outlying units of the Alabama Agricultural Experiment Station:

- Randy Akridge, Brewton and Monroeville Experiment Fields
- Don Moore, Prattville Experiment Field
- Larry Wells, Wiregrass Research & Extension Center
- Chet Norris, Tennessee Valley Research & Extension Center

Table 1. Cropping and fertilization history of Alabama's "Two-Year Rotation" experiments (c. 1929)

1929	Established at 6 Alabama locations with 17 soil fertility variables (including pH, N, P, K, Mg, S and micronutrients). Original cropping system was a cotton (winter legume)-Corn (winter legume) rotation
1957	K variable treatments changed from 0, 18, and 36 kg K ha^{-1} to 0, 28, 56, and 112 kg K ha^{-1}
1968	Corn (winter wheat) – soybean/peanut rotation established
1982	Grain sorghum – soybean/peanut rotation; residual P and K study initiated.
1989	Tropical corn (winter wheat or triticale) – soybean/peanut rotation; residual P and K continued.
1992	Cotton – soybean/peanut rotation at 5 locations and forages at the Sand Mt. location; residual P and K continued.
1998	Residual P and K discontinued; annual fertilization resumed at all locations.

Table 2. Physical and chemical properties of the soils in this study.

Horizon	Depth	Texture	CEC	Organic C	Mineralogy
	-cm-		-cmol/kg-	---%---	
			Benndale ls		
			(*coarse-loamy, siliceous, thermic Typic Paleudults*)		
Ap	0-30	ls	3.1	0.7	kaolinite,
Bt1	30-75	sl	2.9	0.1	HIV
Bt2	75-105	sl	3.2	0.1	
			Dothan sl		
			(*fine-loamy, siliceous, thermic Plinthic Kandiudults*)		
Ap	0-15	sl	4.5	---	
Bt1	15-33	l	4.5	---	kaolinite,
Bt2	33-70	scl	5.6	---	HIV
Bt3	70-105	scl	3.7	---	
			Lucedale scl (Prattville)		
			(*fine-loamy, siliceous, thermic Rhodic Paleudults*)		
Ap	0-20	scl	7.9	0.6	
Bt1	20-33	scl	6.1	0.2	kaolinite,
Bt2	33-105	scl	6.3	0.2	HIV
			Lucedale fsl (Monroeville)		
			(*fine-loamy, siliceous, thermic Rhodic Paleudults*)		
Ap	0-30	fsl	5.5	0.6	
Bt1	30-45	scl	5.1	0.2	kaolinite,
Bt2	45-75	scl	4.8	0.2	HIV
B3	75-105	scl	4.5	0.1	
			Decatur sicl		
			(*clayey, kaolinitic, thermic Rhodic Paleudults*)		
Ap	0-30	sil.c.l.	10.0	0.7	kaolinite,
Bt1	30-60	sil.c.	11.0	0.4	smectite,
Bt2	60-105	clay	10.4	0.3	HIV, mica

Table 3. Mean Cotton Lint Yields from the Standard Fertilization Treatment in the "Two-Year Rotation" at 5 Locations since 1992

	Soil series and location				
Year	**Benndale ls** (Brewton)	**Dothan sl** (Wiregrass)	**Lucedale fsl** (Monroeville)	**Lucedale scl** (Prattville)	**Decatur sicl** (Tenn.Valley)
	-----------------------cotton lint yield (kg ha^{-1}---------------------------				
1992	1210	860	800	1480	1420
1993	1220	610	900	730	1150
1994	600	----	890	1500	1420
1995	1570	820	820	390	660
1996	1160	890	1140	1040	1040
1997	380	610	700	1520	1190

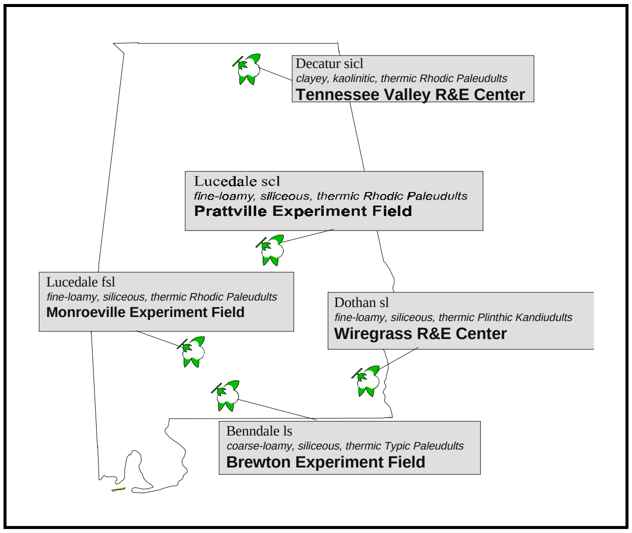

Figure 1. Locations of "Two-Year Rotation" experiments (c. 1929) that have been planted to a cotton-soybean rotation since 1992.

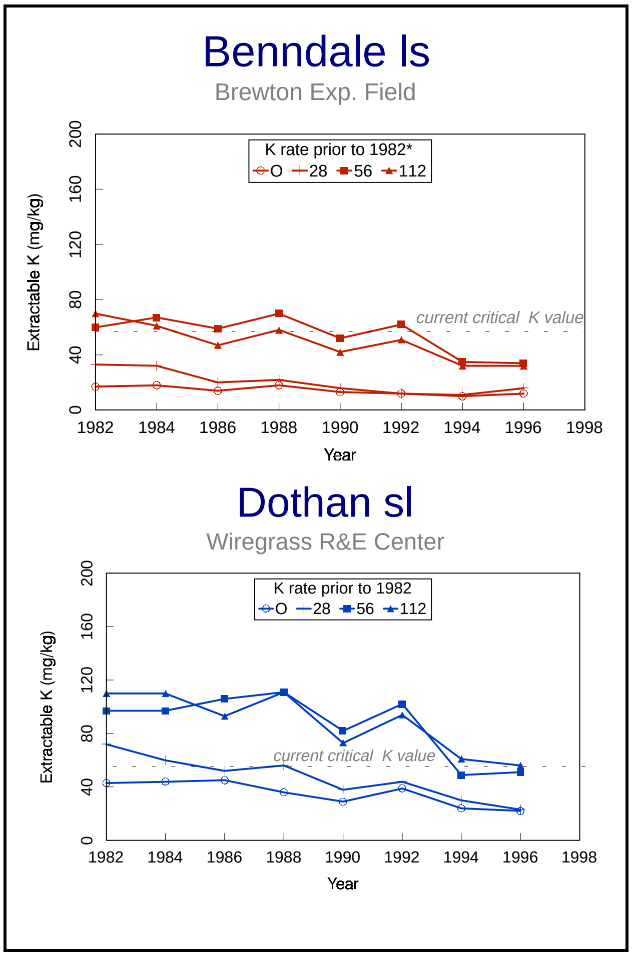

Figure 2. Changes in Mehlich-1 extractable soil K in the plow layer during 15 years of a residual K study on two Coastal Plain soils with a CEC < 4.6 cmol/kg. The 56 kg K ha^{-1} was an annual application to cotton. Other rates received no K during the period.

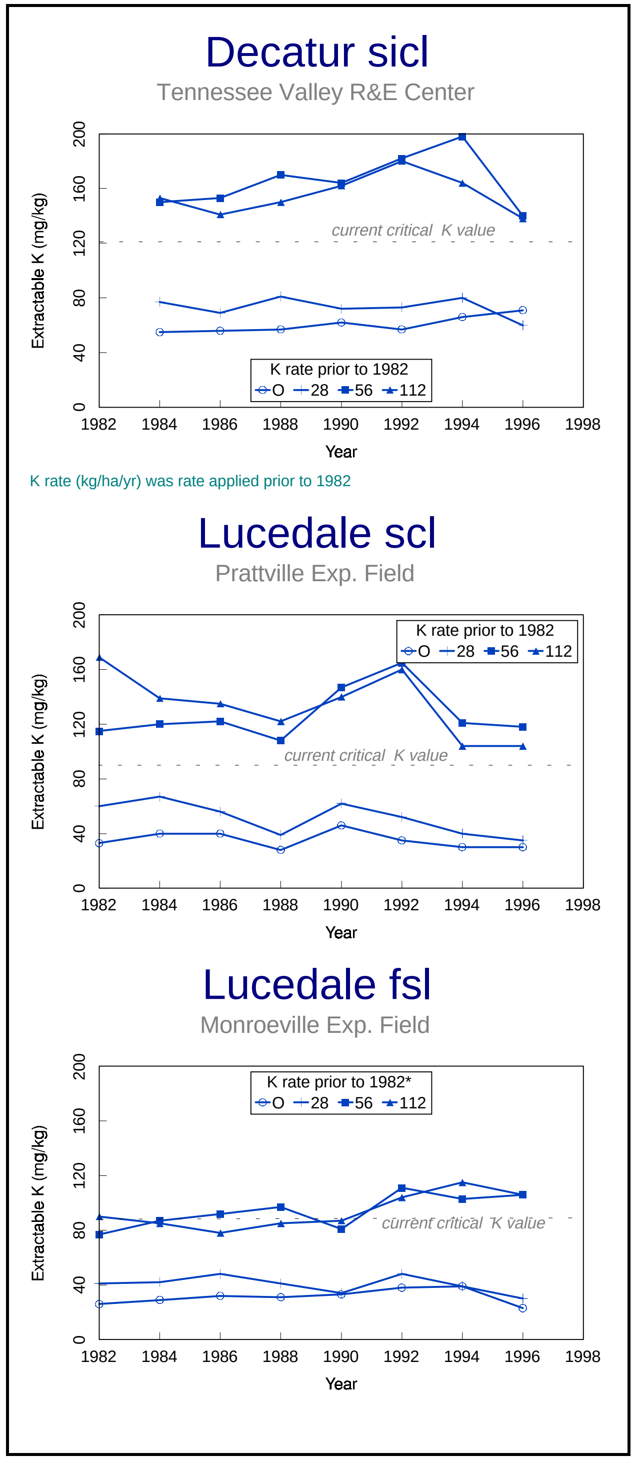

Figure 3. Changes in Mehlich-1 extractable soil K in the plow layer during 15 years of a residual K study on sites with finer textured soils (CEC> 4.6 cmol/kg). The 56 kg K ha^{-1} was an annual application to cotton. Other rates received no K during the period.

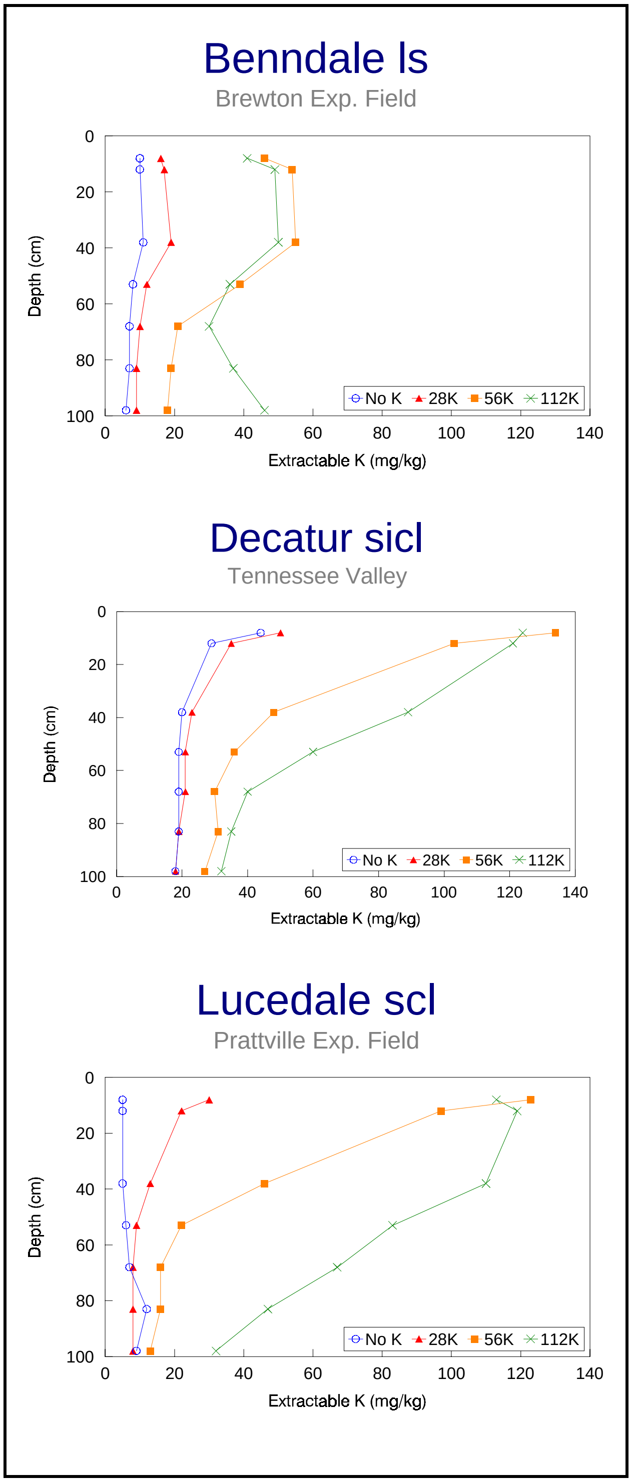

Figure 4. Soil profile K (Mehlich-1 extractable) at 3 locations after 8 years in the residual K study.

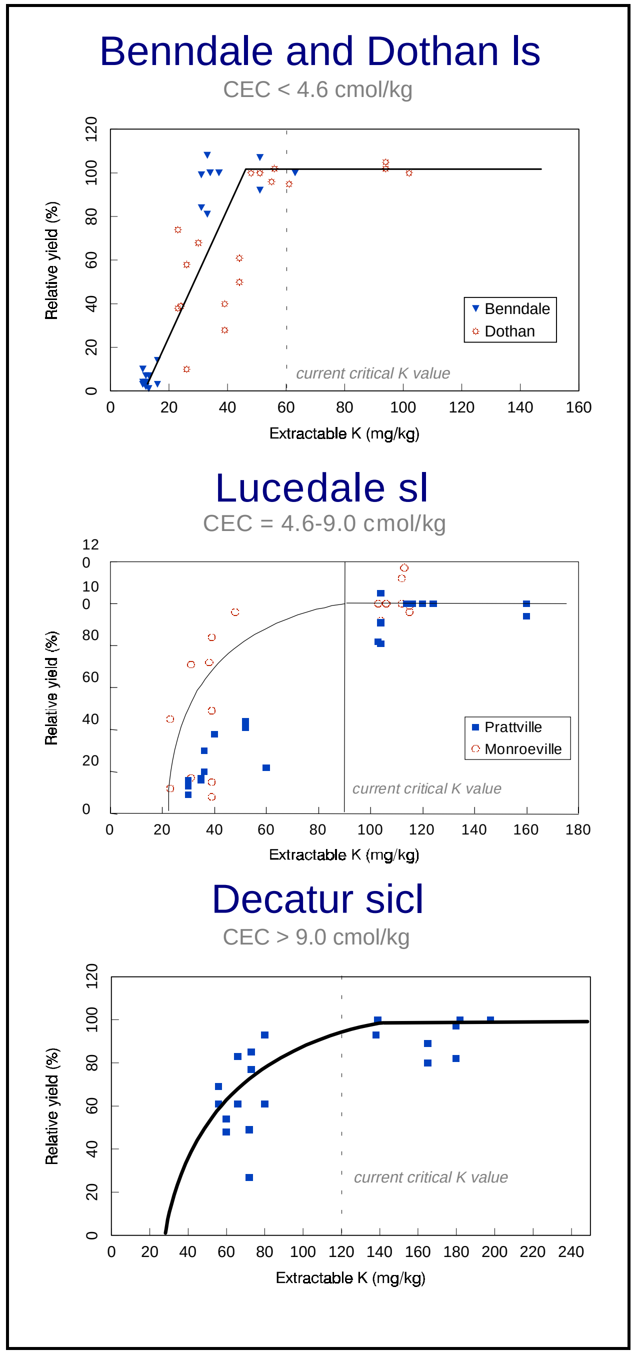

Figure 5. Relative cotton lint yields as affected by residual soil test K levels since 1992 compared to existing critical soil test K values.