2004 BELTWIDE COTTON CONFERENCES, SAN ANTONIO, TX – JANUARY 5-9

CULLARS ROTATION (C. 1911): AMERICA'S OLDEST CONTINUOUS COTTON FERTILITY EXPERIMENT

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Abstract

The Cullars Rotation experiment (circa 1911) on the campus of Auburn University was placed on the National Register of Historical Places in April, 2003. It joins the nearby Old Rotation experiment (circa 1896) as one of only 4 field crop research sites in the U.S. to receive this honor. It is America's oldest cotton fertility experiment, the oldest soil fertility study in the South, and the second oldest, continuous cotton study in the world (The Old Rotation is the oldest). The Cullar's Rotation experiment continues to document long-term trends in non-irrigated crop yields and soil changes due to variable rates of P, K, S, micronutrients and lime. It provides a valuable and accessible teaching tool for monitoring crop nutrient deficiences. It also is a source of uniform soil with variable fertility conditions for allied studies. No other such resource exists in the Coastal Plain of the southern United States.

History of the Cullars Rotation on the Alvis Field

Mr. John P. Alvis and his brother-in-law, Mr. J.A. Cullars, owned and farmed this property in the late 1800s. Mr. Cullars allowed Professor George F. Atkinson of the Agricultural and Mechanical College of Alabama (now Auburn University) and others to conduct numerous early cotton fertility experiments on this property. *Professor Atkinson's research on this site led to the discovery that "cotton rust" was caused by a deficiency of potassium* (Atkinson, 1891, 1892). An appropriation by the Alabama Legislature in 1911 enabled the Alabama Agricultural Experiment Station to conduct on-farm research throughout the state. Alabama Agric. Exp. Sta. Bulletin 219 (1923) summarized 226 experiments on farmers' fields throughout Alabama. An extensive cotton, corn, and legume fertility test begun in 1911 on the Auburn farm of Mr. Cullars and Mr. Alvis is the only one of these experiments that has been continued. Unlike the nearby "Old Rotation" experiment which was begun by Professor J.F. Duggar, records do not credit any single researcher with designing the Cullars Rotation experiment. Names of professors and researchers who have been associated with the Cullars Rotation include J.F.Duggar, E.F. Cauthen, J.T. Williamson, M.J. Funchess, D.G. Sturkie, E.M. Evans, L.E. Ensminger, J.T. Touchton, and C.C. Mitchell.

In 1938, the "Alvis Field" was sold to Alabama Polytechnic Institute (now Auburn University) by Bessie Alvis Emerick and Lillian Alvis Miller, daughters and heirs of John P. Alvis. In the Year 2000, construction of the Jule Collins Smith Museum of Art occupied most of the Alvis Field but the Cullars Rotation experiment with a 40-foot border (approx. 4 acres) is preserved for on-going research and demonstration on sustainable crop production on soils of the southern U.S.

Unlike the nearby "Old Rotation" experiment which was begun by Professor J.F. Duggar in 1896, records do not credit any single researcher with designing the Cullars Rotation experiment. Names of professors and researchers that have been associated with the Cullars Rotation include J.F.Duggar, E.F. Cauthen, J.T. Williamson, M.J. Funchess, D.G. Sturkie, E.M. Evans, L.E. Ensminger, J.T. Touchton, and C.C. Mitchell.

The Cullars Rotation is one of the few sites where controlled nutrient deficiencies can be observed on 5 different crops during the course of a year (cotton, corn, soybean, wheat or rye, and crimson clover. The experiment preserves a site for monitoring nutrient accumulation and loss and soil quality changes and their effects on long-term sustainability of an intensive crop rotation system.

Agronomics and Experimental Design

The Cullars Rotation was designed primarily to study the long-term effect of potassium fertilization on a 3-year rotation which included cotton, corn, small grain and summer legumes (cowpeas or soybean). Yield records since 1911 have been maintained by researchers in the Department of Agronomy and Soils. Today, the experiment is a three-year rotation of (1) cotton followed by winter legumes, (2) corn harvested for grain and followed by winter wheat or another small grain, and (3) soybean double cropped after the small grain is harvested. It is located on a Marvyn loamy sand (fine-loamy, siliceous, thermic Typic Kanhapludults) adjacent to the Auburn University campus (At one time, the soil was called a Norfolk loamy sand). In recent years, the test has been maintained as a (1) field laboratory for students and visitors studying crop nutrient deficiencies, (2) source of soil and plant material for greenhouse and laboratory research, and (3) site for continuous soil test calibration and sustainable crop production research.

Experimental Design

Original design was 11 soil treatments replicated 3 times, one replicate for each of the 3 crops in the 3-yr rotation in an ordered block design (Fig. 1). In 1914, an additional 3 treatments (designated A, B, and C) were added to study the effect of winter legumes in the rotation. Plot size is 20 x 99 feet with a 2-foot border between each plot and 20 feet between each tier (block). The cropping area of each tier is marked by concrete pillars in the ground (328.5' x 337'). A 40-foot buffer to nearby parking lots and other development on each side is assured. Therefore, the entire Cullars Rotation occupies 408.5' x 417' (3.9± acres)

Tillage and Other Cultural Practices

Until 1997, all crops were conventionally tilled with moldboard plowing, disking, and regular cultivation. Since 1997 and the introduction of Roundup Ready® cultivars, all crops are grown with minimum tillage. Cotton and corn are planted directly in the previous crop residue in narrow rows (20 to 30 inch rows) after paratilling (subsoiling) using a no-till planter. Soybeans are drilled into wheat residue in June using a no-till drill. In 1999, a Liberty-Link® corn hybrid was used (Pioneer 34A55 LL) which allowed direct planting into crimson clover residue. A stacked gene cotton (Paymaster 1220BG/RR) allowed cotton to be produced with only two applications of Roundup® herbicide. *Since 1996, no insecticides have been applied for insect control.* This has been possible because of the boll weevil eradication program in East Alabama and the advent of Bollgard® technology. All crops are machine harvested although occasional yield estimates are made by hand harvesting portions of each plot.

Fertilization

In the early years of the Cullars Rotation, sources of plant nutrients were blood meal for nitrogen, superphosphate (0-18-0) and rock phosphate for phosphorus, and kainit (0-0-12) for potassium. In recent decades, phosphorus as concentrated superphosphate (0-45-0) or rock phosphate, potassium as muriate of potash (0-0-60), sulfur as gypsum, and a micronutrient mix containing B, Zn, Mn, Cu, and Fe are applied to appropriate plots in split applications in the spring prior to planting cotton and in the fall just prior to planting small grain. Nitrogen as ammonium nitrate (34-0-0) is applied to appropriate plots just prior to planting cotton and corn and as a sidedress application to these crops. The small grain is topdressed with 60 pounds N per acre in late February. Recent soil test results are presented in Table 1.

Crop Yield Summary, 1996-2001

Few research areas exist in the U.S. where one can see such dramatic deficiencies of plant nutrients on one site. Particularly dramatic are the plots were no soil amendment has been applied since 1911 (treatment C), the “no K” plots (treatment 6), the “no lime” plots (treatment 8), and the “no P” plots (treatment 2). Deficiencies sometimes appear on the other treatments but are less dramatic. In general, cotton is most sensitive to low soil K in this experiment while corn, soybean, and small grain are most sensitive to low soil P (Table 2). Cotton yields also seem to be reduced more (12% of limed and fertilized control) in the no lime treatment than yields of the other crops. Without micronutrients (presumably boron), cotton lint yields were only 86 percent of the completely fertilized treatment. Other crops failed to respond at all to micronutrient fertilization. Mean yields of cotton, corn, soybean, and small grain from 1996 through 1999 seem to reflect the long-term trends (Tables 3-6). Long-term trends from selected treatments are presented in Fig. 2.

Record crop yields on the Cullars Rotation were recorded in 1996, 1999, 2000, and 2001:

- 1996: 1580 pounds cotton lint per acre (3+ bales) on plot 7
- 1996: 75.1 bushels soybean per acre on plot 10
- 1999: 161 bushels corn per acre on plot A
- 1999: 63.5 bushels wheat per acre on plot 9
- 2000: 64.7 bushels wheat per acre on plot 5
- 2001: 70.0 bushels wheat per acre on plot 11

These yields are attributed to (1) very favorable growing seasons, (2) adoption of deep tillage to disrupt traffic pans, (3) conservation tillage which allows better moisture infiltration, higher water holding capacity, and cooler soils, (4) higher plant populations, (5) timely planting, (6) better weed control especially through the new genetically modified varieties, and (7) less insect problems as a result of the boll weevil eradication program and the new Bollgard® cotton varieties.

Potassium Movement and Accumulation in Soil Profile (Fig. 3)

Soil samples taken in incremental depths to 48 inches from the K-variable treatments reveal that large quantities of K accumulate in the upper soil profile in this loamy sand with a CEC near 3.0 cmol/kg. Potassium leaching below 48 inches does occur with the higher K rates as indicated by Mehlich-1 extractable K. Therefore, routine, plow-layer soil sampling appears to be adequate to predict responses to K fertilization. Note that the application of an anion in the form of sulfate-S (as gypsum), increases K leaching.

Summary

The Cullar's Rotation experiment continues to document long-term trends in non-irrigated crop yields and soil changes due to variable rates of P, K, S, micronutrients and lime. It provides a valuable and accessible teaching tool for monitoring crop nutrient deficiences. It also is a source of uniform soil with variable fertility conditions for allied studies. No other such resource exists in the Coastal Plain of the southern United States. For these reasons, The Cullars Rotation was placed on the National Register of Historical Places in 2003.

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Web site for Cullars Rotation: http://www.ag.auburn.edu/dept/ay/cullars.htm

Acknowledgement

In addition to support through the Alabama Agricultural Experiment Station, the Cullars Rotation has received support in 1998 and 1999 through the commodity checkoff program of the Alabama Wheat and Grain Crops Committee and the Alabama Cotton Commission. The USDA National Soil Dynamics laboratory has provided equipment and labor to plant and harvest the test. Mr. Charlie France and the staff of E.V. Smith Research Center have also helped plant, maintain, and harvest.

Table 1. Mean soil pH and Mehlich-1 extractable plant nutrients and rating from 0-6 inch soil samples taken March, 1999 on the Cullars Rotation.

			Mehlich-1 extractable nutrients*			
		pH	**P**	**K**	**Mg**	**Ca**
Plot	**Treatment**	**lb/acre (pp2m)**				
A	No N/+legume	6.2	VH 121	H 139	H 68	900
B	No N/no legume	6.1	VH 108	M 106	H 46	597
C	No soil amendments	**5.3**	**L 19**	**L 34**	**L 20**	**146**
1	No winter legumes/ + N	5.7	H 51	L 49	H 36	373
2	No P	5.8	**VL 7**	M 93	H 33	330
3	No micronutrients	5.9	H 78	M 80	H 49	693
4	4/3 K	6.0	VH 133	M 78	H 52	916
5	Rock phosphate	6.2	**EH 400**	M 95	H 64	2496
6	No K	6.0	VH 188	**VL 29**	H 73	953
7	2/3 K	6.0	VH 114	M 62	H 58	730
8	No lime	4.9	VH 121	M 77	L 19	226
9	No S	5.7	VH 162	M 107	H 50	660
10	Complete fertilization + micros	5.9	149	81	55	856
11	1/3 K	5.9	99	48	55	543
	$LSD_{.05}$	*0.3*	*22*	*32*	*17*	*376*

*Rating based upon cotton on sandy soils (C.E.C. < 4.6 cmol/kg)
Standard lime and fertilizer treatments:

- Limed to pH 5.8 to 6.5
- 100 lb. P_2O_5 per acre per 3-yr rotation
- 270 lb. K_2O per acre per 3-yr rotation
- 90 lb. N/acre on cotton
- 120 lb. N/acre on corn
- 60 lb. N/acre topdress on small grain

Table 2. Mean yield relative to fertilized control in selected treatments in Cullars Rotation

	Crop			
	Cotton	**Corn**	**Small grain**	**Soybean**
Factor	**% relative yield**			
No lime, pH=4.9	12	42	39	19
No K	8	44	73	58
No P	45	42	43	48
No S	87	93	100	86
No micronutrients	86	99	96	94
Fertilized control	100	100	100	100
$LSD_{.05}$	*27*	*32*	*25*	*35*

Table 3. Cotton lint yields on the Cullars Rotation, 1996-1999.

		Cotton lint yields				
		1996	1997	1998	1999	4-yr ave.
Plot	Treatment	pounds/acre				
A	No N/+legume	1310	970	1064	400	940ab
B	No N/no legume	1340	770	990	480	900ab
C	No soil amendments	0	0	0	0	0 d
1	No winter legumes/+ N	870	1310	900	610	920ab
2	No P	520	480	720	280	500 c
3	No micronutrients	1090	1120	980	590	950ab
4	4/3 K	1290	1000	850	590	930ab
5	Rock phosphate	1150	1120	810	500	900ab
6	No K	0	0	360	0	90 d
7	2/3 K	1580	1310	870	640	1100a
8	No lime, pH=4.9	380	0	0	140	130 d
9	No S	1470	880	980	500	960ab
10	Complete fertilization+ micros	1620	1080	980	700	1100a
11	1/3 K	680	1060	770	440	740 bc
						$LSD_{.05}$=300

Standard lime and fertilizer treatments:

- Limed to pH 5.8 to 6.5
- 100 lb. P_2O_5 per acre per 3-yr rotation
- 270 lb. K_2O per acre per 3-yr rotation
- 90 lb. N/acre on cotton
- 120 lb. N/acre on corn
- 60 lb. N/acre topdress on small grain

Table 4. Corn grain yields on the Cullars Rotation, 1996-1999.

		Corn grain yields				
		1996	1997	1998	1999	4-yr ave.
Plot	Treatment	bushels/acre				
A	No N/+legume	106	54	51	161	93ab
B	No N/no legume	82	30	38	130	70 bc
C	No soil amendments	0	0	0	0	0 d
1	No winter legumes/+ N	143	101	89	108	110a
2	No P	63	55	21	39	44 c
3	No micronutrients	137	73	75	135	105a
4	4/3 K	132	75	69	128	101ab
5	Rock phosphate	141	72	76	126	104ab
6	No K	23	36	8	122	47 c
7	2/3 K	140	89	72	135	109a
8	No lime, pH=4.9	59	23	24	72	44 c
9	No S	142	71	86	98	99ab
10	Complete fertilization+ micros	155	87	84	100	106a
11	1/3 K	137	94	93	64	97ab
						$LSD_{0.05}$ = 34 bu/a

Standard lime and fertilizer treatments:

- Limed to pH 5.8 to 6.5
- 100 lb. P_2O_5 per acre per 3-yr rotation
- 270 lb. K_2O per acre per 3-yr rotation
- 90 lb. N/acre on cotton
- 120 lb. N/acre on corn
- 60 lb. N/acre topdress on small grain

Table 5. Soybean yields on the Cullars Rotation, 1996-1999.

		Soybean grain yields				
		1996	1997	1998	1999	4-yr ave.
Plot	Treatment	bushels/acre				
A	No N/+legume	63.8	23.2	14.1	18.2	29.8ab
B	No N/no legume	68.0	22.4	6.3	15.4	28.0abc
C	No soil amendments	9.2	0	0	3.5	3.2 e
1	No winter legumes/+ N	68.7	20.8	15.2	14.1	29.7ab
2	No P	30.2	15.4	7.6	10.1	15.8 cd
3	No micronutrients	70.0	23.5	16.0	13.6	30.8ab
4	4/3 K	67.2	24.0	12.6	14.7	29.6ab
5	Rock phosphate	68.5	21.6	16.0	14.7	30.2ab
6	No K	37.6	23.3	5.3	8.5	18.8 bc
7	2/3 K	66.8	22.0	12.8	15.6	29.3ab
8	No lime, pH=4.9	24.9	0	0	0	6.2 de
9	No S	61.7	21.9	13.6	14.8	28.0abc
10	Complete fertilization + micros	75.1	23.3	15.8	16.1	32.6a
11	1/3 K	62.5	20.7	10.0	15.4	27.2abc
						$LSD_{.05}$=11.5

Standard lime and fertilizer treatments:

- Limed to pH 5.8 to 6.5
- 100 lb. P_2O_5 per acre per 3-yr rotation
- 270 lb. K_2O per acre per 3-yr rotation
- 90 lb. N/acre on cotton
- 120 lb. N/acre on corn
- 60 lb. N/acre topdress on small grain

Table 6. Small grain yields on the Cullars Rotation, 1996-1999.

		Small grain yields				
		1996 Rye	1997 Wheat	1998 Rye	1999 Wheat	3-yr ave.
Plot	Treatment	bushels/acre				
A	No N/+legume	Not harvested due to freeze	13.9	11.2	17.5	14.2 c
B	No N/no legume		5.8	7.7	15.8	9.8 cd
C	No soil amendments		0	4.2	0	1.4 d
1	No winter legumes/+ N		44.2	32.7	50.5	42.5ab
2	No P		26.1	14.1	20.9	20.4 c
3	No micronutrients		51.4	27.8	56.9	45.4ab
4	4/3 K		48.0	34.2	54.6	45.6ab
5	Rock phosphate		55.8	29.8	55.0	46.9ab
6	No K		26.3	33.3	43.8	34.5 b
7	2/3 K		41.6	32.2	61.7	45.2ab
8	No lime, pH=4.9		8.8	16.5	29.9	18.4 c
9	No S		50.8	32.7	63.5	49.0a
10	Complete fertilization + micros		47.5	33.8	60.9	47.4a
11	1/3 K		41.3	52.2	57.6	50.4a
						$LSD_{.05}$=12

Standard lime and fertilizer treatments:

- Limed to pH 5.8 to 6.5
- 100 lb. P_2O_5 per acre per 3-yr rotation
- 270 lb. K_2O per acre per 3-yr rotation
- 90 lb. N/acre on cotton
- 120 lb. N/acre on corn
- 60 lb. N/acre topdress on small grain

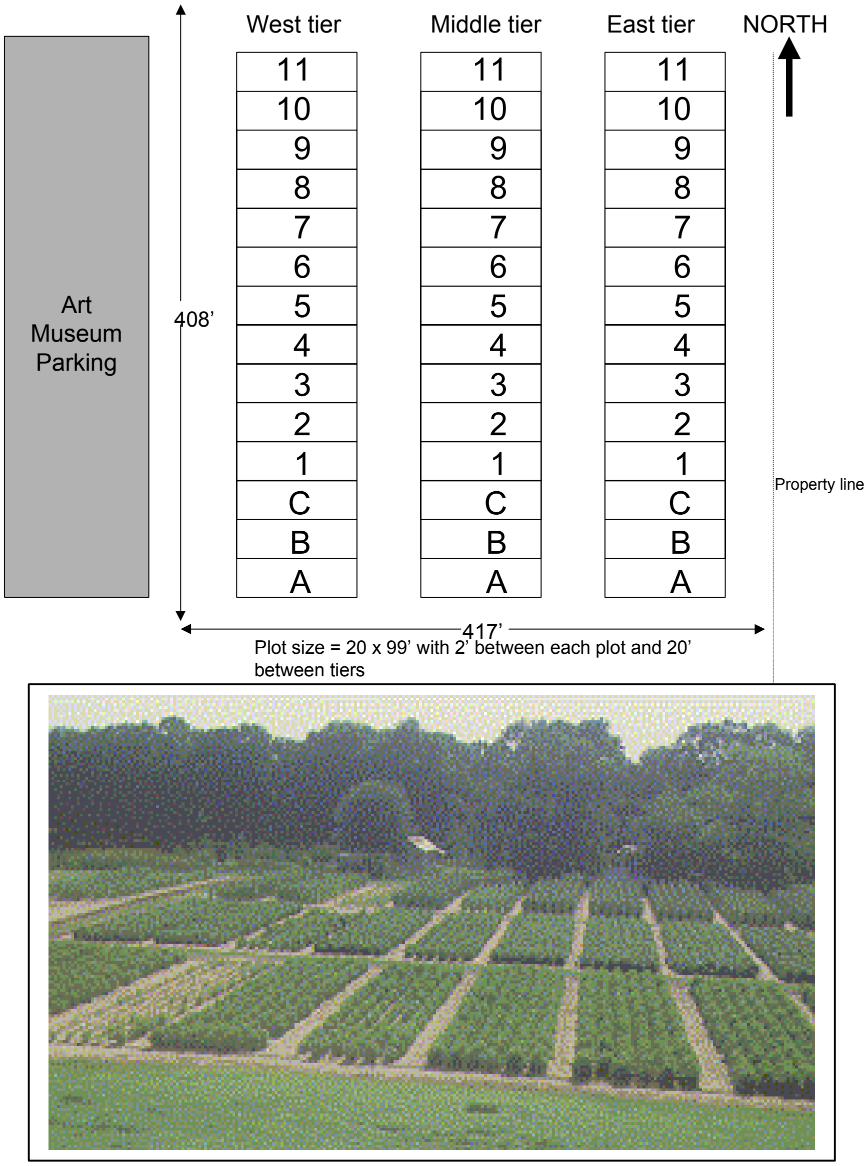

Figure 1. Schematic of Cullars Rotation (not drawn to scale) and view of experiment looking toward the east.

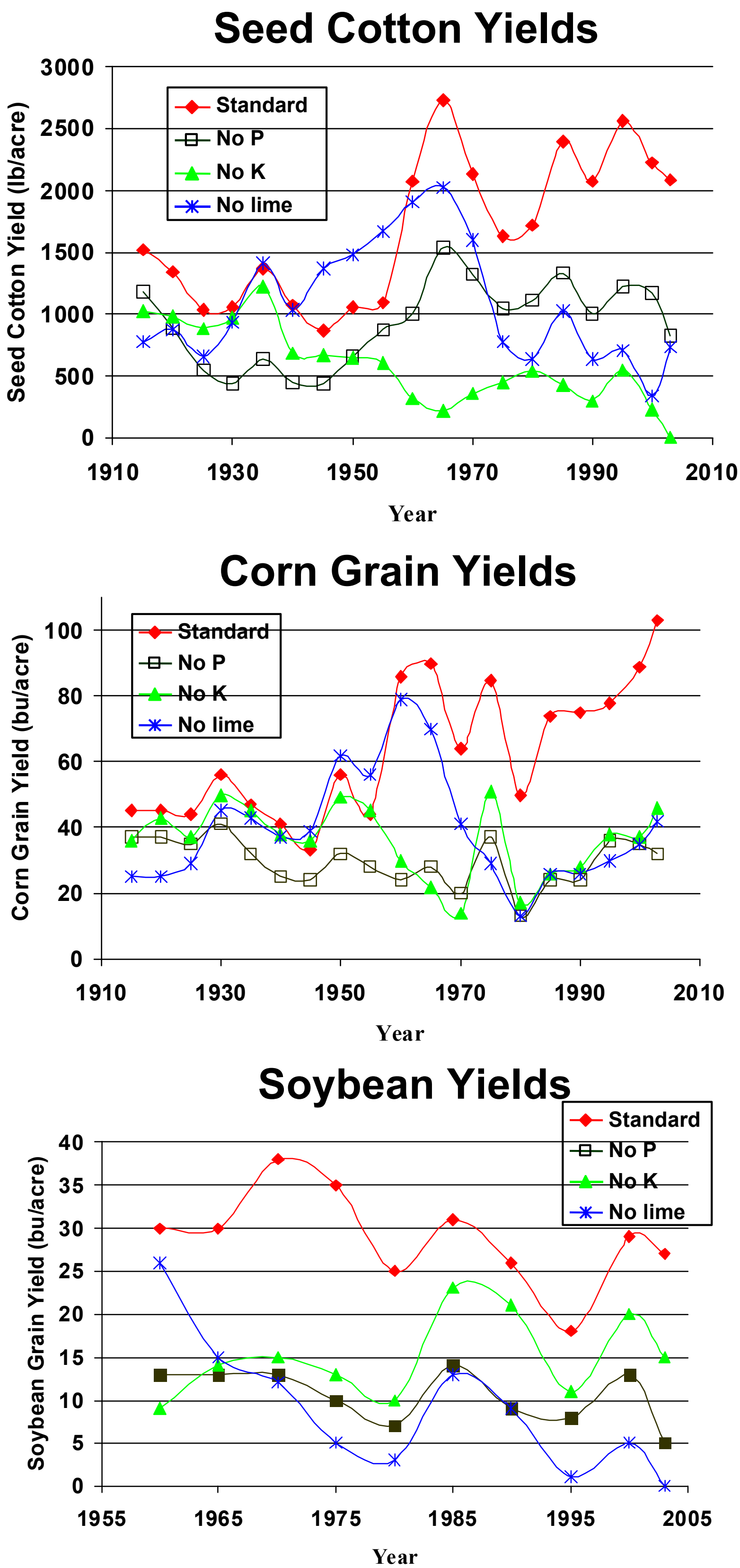

Figure 2. Long-term yield trends for cotton, corn grain, and soybean on the Cullars Rotation, 1911-2003. Each point is a 5-yr average.

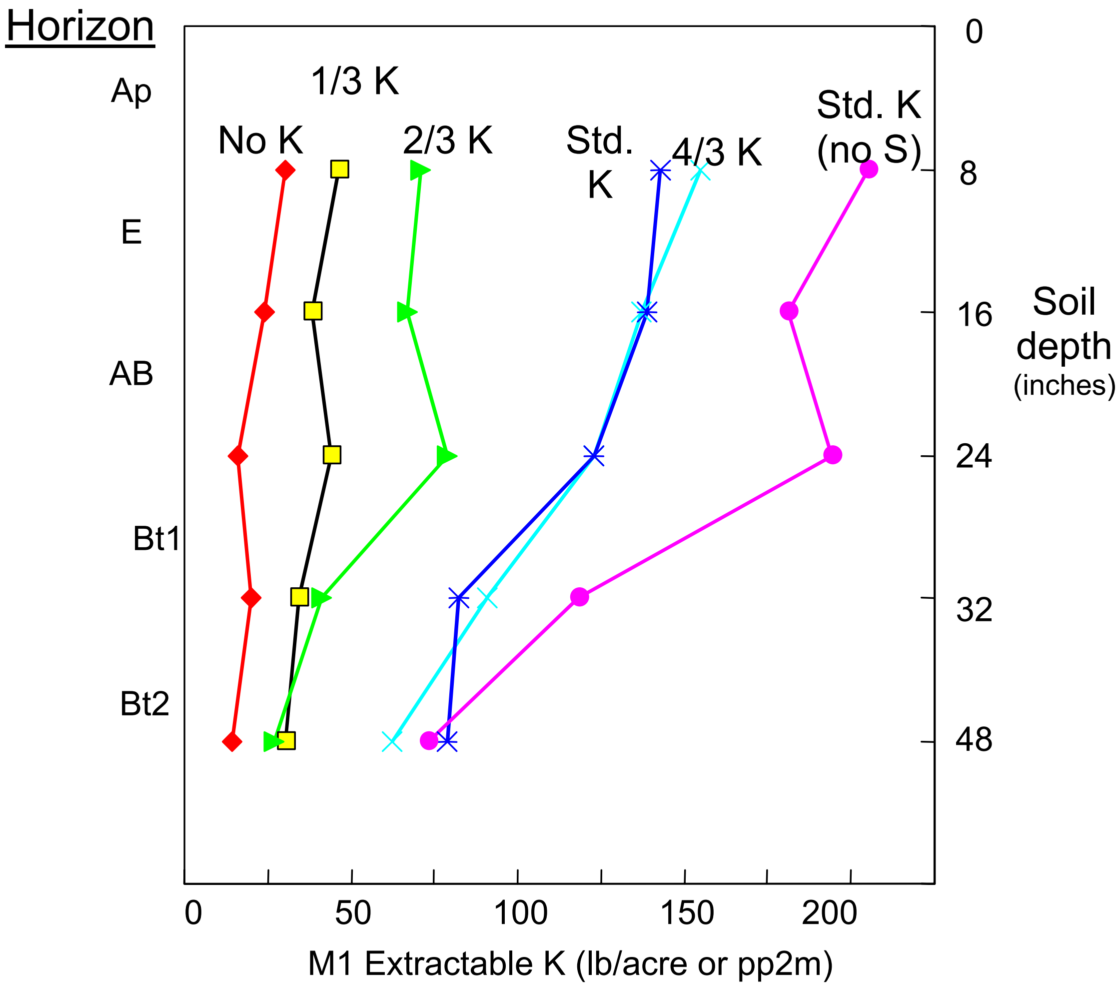

Figure 3. Soil Profile K after 90 years of K fertilization.