Long-Term Soil Fertility Research

Monroeville Experiment Field 1929-1999

Regional Bulletin 27
Alabama Agricultural Experiment Station
William Batchelor, Director
Auburn University

In cooperation with the Alabama Cooperative Extension System
(Alabama A&M University and Auburn University)

AUBURN
ALABAMA AGRICULTURAL EXPERIMENT STATION

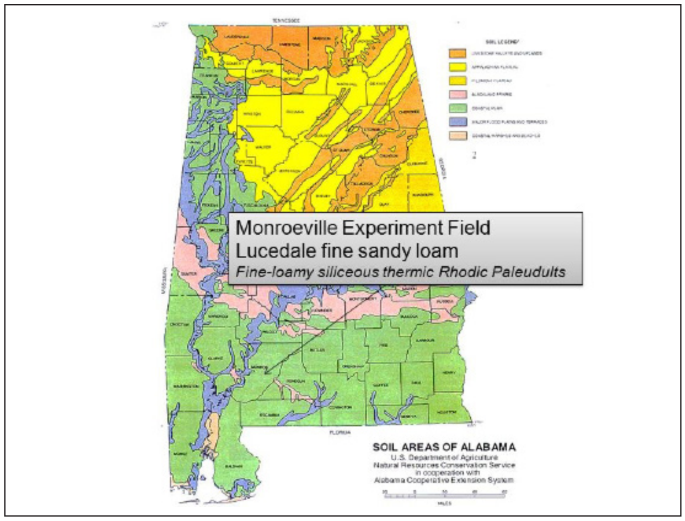
Author

Charles C. Mitchell
Extension Specialist & Professor
Nutrient Management/Soil Science
259 Funchess Hall
334-844-5489
mitchc1@auburn.edu

Table of Contents

Introduction

The Monroeville Experiment Field was established in 1928 along with many of the other outlying units of the Alabama Agricultural Experiment Station. While Substations represented major soil physiographic regions of the state, the Monroeville Experiment Field represented the deep, red, well drained, Coastal Plain soils typical of the cotton-producing region of southwestern Alabama. Cultivated soils on the experiment field were once known as Magnolia fine sandy loams but are today identified as Lucedale loams or Lucedale fine sandy loams (fine-loamy, siliceous, thermic Rhodic Paleudults).



The main purpose of having experiment fields on agronomically significant soils of the state was to conduct research into the efficient and economical use of fertilizers for the major crops being grown, primarily cotton, corn, small grain, and later soybean. There was no public soil testing laboratory in Alabama until 1954 so all soil fertility recommendations were based on actual field experiments throughout the state. Later, these soil fertility experiments provided the scientific basis for soil testing in Alabama and allowed researchers to maintain reliable interpretations of soil test results.

Soils are a Lucedale fine sandy loam, a deep, well drained, moderately permeable soil that formed in loamy sediments of the Southern Coastal Plain.

The Monroeville Experiment Field closed in the early 2000s and most of the long-term, soil fertility experiments were planted to longleaf pine trees.

Objectives

The main objective of this bulletin is to summarize the two oldest, long-term, soil fertility experiments on the Monroeville Experiment Field so this huge volume of data representing 70 years of soil fertility research. will be easily accessible to anyone who can use it.

The Two-Year Rotation (Circa 1929)

The first soil fertility experiment at the Monroeville Experiment Field (and at other locations around Alabama) was called the "Two-Year Rotation." It was established in the fall of 1928 at eight locations. This experiment has been conducted at Monroeville Experiment Field every year until the field closed in 2000. In 2001, the plots were planted in longleaf pines to determine the effect of the established soil treatments on pine establishment and growth. The experiment contained 17 soil fertility variables replicated four times in two, 34-plot tiers. Each plot is 21 feet by 69.2 feet (1/30 acre). Each year, one tier (two of the fertility replications) was planted into one crop (e.g., cotton) which was rotated with a different crop on the other two replications (e.g., corn) thus the name Two-Year Rotation, as shown in Table 1. Soil fertility variables since 1982 are presented in Table 2.

Crop yields prior to the 1980s are presented for the historical record only (Tables 3-5). As rates of fertilizer N, P and K increased gradually over the years, so did yields of cotton, corn, and vetch (Tables 3-6, Figure 1). Generally, treatment 14 (the fertilized control) and treatment 15 (high K treatment) produced the highest yields of cotton throughout the experiment. In the early days of the experiment, 1930 through 1948, added P alone increased yields 60%, from around 460 pounds seed cotton (~175 pound lint) per acre to 750 pounds seed cotton (~280 pound lint) per acre. However, when a modest rate of N (16 lb/a) and 30 pounds K_2O per acre were applied (e.g., treatment 15), seed cotton yields tripled compared to the unfertilized control (Table 3). This type of information was important to advise farmers on the type and amount of fertilizer nutrients to apply to their crops at that time.

Table 1
Crop rotations on the Two-Year Rotation Experiment, 1929-1999

Years	Crop Rotation
1929-1945	Cotton (vetch) - corn (summer legume)
1946-1967	Cotton (vetch) - corn
1968-1977	Corn (wheat) - soybean
1978-1981	Corn - soybean
1982-1988	Grain sorghum - soybean
1989-1991	Soybean (triticale or wheat) -Tropical corn
1992-1999	Cotton - soybean
2001-present	Longleaf pine

Table 2
Soil fertility variables used on the Two-Year Rotation experiment since 1982[1]

Treatment number	Factor studied	Description
1	Untreated	No lime or fertilizer since established in 1929
2	S	No sulfur added
3	P	Intermediate soil P level
4	No lime	No lime since plots established in 1929
5	Mg	No Mg; only calcitic limestone used
6	K	No K
7	K	Low K fertilization
8	Micronutrients	Added micronutrients, Zn, Cu, Mn, Fe, & B
9	No NPK	No NPK added; + limestone
10	N	High N fertilization, 120 or 150 lb. N/acre
11	N	Low N fertilization, 30 or 60 lb. N/acre
12	P	No P added
13	N	Intermediate N fertilization, 60 or 90 lb. N/acre
14	N, P, & K	Standard fertilization; 90 or 120 lb. N/acre
15	K	High K fertilization
16	N	No N
17	Same as 14 in 1978-1982	Rejuvenated plots in 1978-82; no treatment since 1982

[1] Plots were in a residual soil fertility mode from 1982-1999. No additional P and K were applied to any treatments during this time except to treatment no. 14, the standard fertilization treatment.

Table 3
Average seed cotton yields on the Two-Year Rotation, 1930-1954

Treatment Number	$N-P_2O_5-K_2O$[1] (lbs/ac)	Seedcotton Yields (lbs/ac)			$N-P_2O_5-K_2O$[1] (lbs/ac)	Seedcotton (lbs/ac)
	1930-48	1930-36	1937-42	1943-48	1949-54	1949-54
1	0-0-0	560	480	360	0-0-0	430
2	0-40-0	790	710	740	0-80-0	750
3	0-40-15	1000	910	1100	0-80-30	1000
4	16-40-15	1220	1140	1310	32-80-30	1220
5	0-0-0	590	520	520	64-80-30	1470
6	0-40-0	800	770	760	0-80-0	1010
7	0-40-15	1080	1090	1370	0-80-30	1550
8	16-40-15	1300	1300	1550	32-80-30	1810
9	0-0-0	570	550	540	0-0-0	600
10	16-120-45	1150	940	1160	32-160-60	1590
11	16-120-45	1390	1330	1514	32-160-60	1840
12	16-20-15	1210	1020	1440	32-40-30	1710
13	0-0-0	620	540	580	64-120-45	1610
14	16-80-15	1310	1340	1590	32-80-15	1820
15	16-80-30	1410	1360	1680	32-80-30	1850
16	16-0-15	1230	1010	1210	32-160-60	1710
17	0-0-0	560	530	480	0-0-0	535

[1]Nutrients applied to cotton only; additional nutrients may have been applied to other crops in the rotation.

Table 4
Corn grain yields on the Two-Year Rotation, 1930-1954

Treatment Number	$N-P_2O_5-K_2O$[1] (lbs/ac)	Corn Grain Yields (bu/ac)			$N-P_2O_5-K_2O$[1] (lbs/ac)	Corn Grain (bu/ac)
	1930-48	1930-36	1937-42	1943-48	1949-54	1949-54
1	0-0-0	28	24	33	0-0-0	31
2	0-80-0	35	36	43	0-80-0	46
3	0-80-30	37	38	47	0-80-30	51
4	16-80-30 (no lime)	38	41	48	32-80-30	50
5	0-0-0	28	28	37	64-80-30	50
6	0-80-0	36	36	43	0-80-0	51
7	0-80-30	38	41	50	0-80-30	53
8	16-80-30	38	40	50	32-80-30	54
9	0-0-0	30	29	38	0-0-0	42
10	0-0-0	20	17	20	32-0-0	43
11	0-0-0	38	39	51	32-160-60	54
12	0-40-30	38	40	49	32-40-30	52
13	0-0-0	29	29	38	64-120-45	51
14	0-160-30	38	40	52	32-160-30	52
15	0-160-60	38	39	52	32-160-60	57
16	0-0-60	35	33	45	32-80-30	57
17	0-0-0	28	26	35	0-0-0	35

[1] Nutrients applied to vetch or corn only; additional nutrients may have been applied to cotton in the rotation.

Table 5
Vetch green weight yields on the Two-Year Rotation, 1930-1954[1]

Treatment Number	$N-P_2O_5-K_2O$[2] (lbs/ac)	Vetch Green Weight Yields (lbs/ac)			$N-P_2O_5-K_2O$[2] (lbs/ac)	Vetch Green Weight Yields (lbs/ac)
	1930-48	1930-36	1937-42	1943-48	1949-54	1949-54
1	0-0-0	4740	2280	5430	0-0-0	4570
2	0-80-0	9420	7560	13300	0-80-0	11510
3	0-80-30	10080	7740	16110	0-80-30	13990
4	16-80-30 (no lime)	10410	9200	15570	32-80-30	15100
5	0-0-0	4890	2810	5580	64-80-30	14230
6	0-80-0	3820	3430	13400	0-80-0	14420
7	0-80-30	12420	12930	18700	0-80-30	17970
8	16-80-30	12340	12542	17840	32-80-30	16960
9	0-0-0	5330	3500	5960	0-0-0	5750
10	0-0-0	No legumes planted			32-0-0	No legume
11	0-0-0	10860	10840	16160	32-160-60	18000
12	0-40-30	10700	10860	15330	32-40-30	16210
13	0-0-0	4980	3132	6440	64-120-45	No legume
14	0-160-30	13140	14270	18430	32-160-30	19290
15	0-160-60	14020	14760	19150	32-160-60	20590
16	0-0-60	7680	4810	7880	32-80-30	17240
17	0-0-0	4380	2700	5590	0-0-0	4490

[1]Multiply values by 0.18 to estimate dry matter yields.
[2]Nutrients applied to vetch or corn only; additional nutrients may have been applied to cotton in the rotation.

Data from these experiments from 1959 to 1982 were summarized by Cope (1970, 1984) and repeated in Table 6.

Table 6
Mean crop yields on the Two-Year Rotation, 1959-1982[1]

Treatment Number	Treatment	Cotton	Soybean	Wheat	Soybean	Corn		
		1959-67 6/9 yr[2]	1968-78 7/11 yr	1968-78 7/11 yr	1979-82 2/4 yr	1959-67 6/9 yr	1968-78 7/11 yr	1979-81 3/3 yr
		(% yield relative to treatment 14)						
1	untreated	29	36	--	54	27	36	30
2	No S	--	--	--	95	--	--	84
3		--	--	--	--	--	--	--
4	No lime	83	59	88	79	75	66	39
5	No Mg	94	92	97	90	98	98	105
6	No K	65	90	100	59	92	84	82
7	30 K_2O	101	97	108	95	100	100	104
8	Plus micro-nutrients	115	103	100	103	97	100	104
9		--	--	--	--	--	--	--
10	120 or 150 N	--	--	--	--	--	--	102
11	30, 60 or 90 N	107	95	104	105	87	100	101
12	No P	108	95	96	105	94	92	96
13		--	--	--	--	--	--	--
14	60 K_2O	2020 lb/a	39 bu/a	26 bu/a	39 bu/a	77 bu/a	90 bu/a	113 bu/a
15	120 K_2O	100	103	100	105	101	101	97
16	No N	80	89	62	95	46	66	61
17	Untreated until 1979	34	33	23	87	27	40	75

[1]Data copied from Cope (1984).
[2]Yields represent the mean of 6 out of 9 years; years not included in mean were unusually low yielding years.

Residual Fertility, 1982-1999

In 1982, P and K applications were stopped on all treatments except treatment number 14, the fertilized control treatment. By putting the experiment into a “residual” P and K mode, researchers were able to look at the effect of residual P and K on crop yields and measure changes in soil test P and K with no additional applications. Nitrogen application variables were continued on those crops for which N is recommended, (e.g., sorghum, triticale, cotton, corn.) In an effort to justify maintaining these long-term experiments and to seek outside support for their continuation, some non-traditional crops were grown in the late 1980s on the Two-Year Rotation experiment (Table 7). Grain sorghum averaged 74 bushels per acre on the fertilized control treatment (number 14) from 1982 through 1987 in rotation with soybean (28 bushels per acre). Grain sorghum yields responded to higher N application rates up to 120 pounds N per acre. At these yields, higher soil test P and K levels had little yield effect on grain sorghum in this experiment. Tropical corn following triticale was a disappointment in 1989-1991. Varieties of tropical corn available were better adapted for forage than grain production and drought and insect damage devastated all of the crops. Tropical corn yields presented (Table 7) are for 1991 only.

N rates on Cotton

From 1992 through 1999, the Two-Year Rotation was in a cotton-soybean rotation (Table 8). Soybean yields averaged 33 bushels per acre in the fertilized control treatment (number 14) and cotton yields averaged 2330 pound seedcotton per acre (~890 pound lint per acre). Average cotton yield response to N was maximum at 90 pound N per acre, exactly the same as the current N recommendations for this crop (Mitchell and Huluka, 2012). However, this was confounded by the fact that cotton always followed the soybean crop. Undoubtedly, some residual N from the soybean residue influenced the crop. Cotton response to N rates on the Rates of NPK Experiment which is in cotton every year is found later in this report.

Soil Test P Calibration

Because there are only three fertilizer P variables in this study, no attempt was made to calibrate soil test P with yield. There are more P rate variables in the Rates of NPK Experiment discussed later.

Soil Test K Calibration

The four residual K treatments in this experiment allow calibration of Mehlich-1 extractable K with cotton yields in 1992-1998. Figure 2 also includes similar data from the Two-Year Rotation at the Prattville Experiment Field which is also on a Lucedale sandy clay loam. Figure 2 confirms the existing critical soil test K level at 90 mg K/kg or 180 lbs/ac. Above this value, one would not expect a yield response to added K.

Changes in Residual P

Soil samples were taken from each plot every two years from 1982 through 1996. This allowed us to track changes in soil test P and K values where no additional P and K fertilizer was applied but crops were continued to be produced. The only crop removal in this study was cotton lint and seed and grain. Figure 3 shows almost no change in soil test P where no P was ever applied. Where 30 pound P_2O_5 per acre per two-year rotation was applied prior to 1982, soil test P was rated “high” and no additional P would have been recommended. Soil test P dropped steadily throughout the 15-year period. After 10 years, the value had dropped below the current critical value of 50 pound M1 extractable P (25 mg P/kg). At this point, P fertilization should have been resumed for normal production. The treatment receiving 60 pound P_2O_5 per acre per two-year rotation was the fertilized control (number 14) which continued receiving P fertilization every two years. These plots would have been rated “very high” in P in 1982. Surprisingly, soil test P also dropped on this treatment although it never dropped below the critical value.

Changes in Residual K

Changes in residual K are also presented in Figure 3. The low K treatments stayed low during the 15-year period. The treatment receiving 60 pound K_2O per two-year rotation was the fertilized control. This explains why K continued to increase on this treatment. However, the treatment that had received 90 pound K_2O per two-year rotation prior to 1982 also continued to increase in extractable K during the 15-year period although no additional K was applied. No explanation is attempted for this drop in soil test K because this treand was not seen on the nearby Rates of NPK Experiment to be discussed later.

Soil pH

Two treatments (number 1 and number 4) have never received any agricultural limestone since the experiment began in 1929. Surprisingly, the average soil pH_w (measured in water) was only about 5.1 where nothing has been applied and only slightly lower (4.8) where fertilizer N, P and K have been applied prior to 1982. These values did not change much over the 15 years of this residual study.

Other treatments were limed with dolomitic limestone whenever the pH dropped below ~ 5.8. When the residual mode began in 1982, the limed and fertilized control treatment (number 14) had a mean soil pH_w of 6.1. This dropped to a pH of 5.6 in 15 years. The low Mg treatment (number 5) receives only calcitic limestone. It was only slightly more acidic than the control.

Changes in Residual Mg and Ca

Both Mehlich-1 extractable Mg and Ca dropped dramatically in the fertilized control treatment during the 15 years this treatment did not receive any agricultural limestone (Figure 5). Extractable Mg would have been considered marginally high in the unfertilized treatment and in the low Mg treatment. A critical Mg concentration of 50 pound M1 extractable Mg per acre (25 mg Mg/ kg) was established by Adams (1975) for cotton on finer textured soils and 25 pound Mg per acre (12.5 mg/kg) on sandy, Coastal Plain soils. Adams

(1975) reported that the Two-Year Rotation study at Monroeville did not show a significant cotton yield response to dolomitic limestone with a M1-extractable Mg of 62 pound Mg per acre (31 mg/kg).

Table 7
Mean crop yields on the Two-Year Rotation, 1982-1991

	(lbs/ac)	(bu/ac)			
Treatment Number	**$N\text{-}P_2O_5\text{-}K_2O$[1] 1982-1998**	**Grain sorghum 1982-87**	**Soybean 1982-91**	**Triticale[2] grain 1989-91**	**Tropical corn[3] after triticale 1991**
1	0-0-0	23	14	11	14
2	90-0-0	66	27	31	41
3	90-0-0	70	26	33	39
4	90-0-0 (no lime)	31	21	21	37
5	90-0-0	76	26	33	41
6	90-0-0	65	23	28	36
7	90-0-0	82	25	31	39
8	90-0-0	80	27	31	45
9	0-0-0	48	22	18	22
10	120-0-0	83	27	35	46
11	30-0-0	79	28	24	36
12	90-0-0	69	26	16	43
13	60-0-0	74	27	31	37
14	90-60-60	74	28	38	34
15	90-0-0	70	28	33	38
16	0-0-0	53	28	19	16
17	90-60-60	60	25	31	40
	C.V.	28	45	57	17
	LSD (P<0.05)	18	7	18	12

[1] P and K applied to treatment 14 only during period; no additional P and K applied to soybean in rotation. N rates are for grain sorghum only.
[2] N rate variables for triticale are 0, 20, 40, 80 and 120 pounds N per acre with 20 applied at planting and the remainder in February.
[3] N rate variables for corn are 0, 40, 80, 120 and 160 pounds N per acre with 120 as the standard rate. Tropical corn was planted following triticale in 1989-1991 but weather, insects, and diseases resulted in no yield in 1989 and 1990.

Table 8
Mean crop yields on the Two-Year Rotation, 1992-1999

	(lbs/ac)		(bu/ac)
Treatment Number	Residual P&K $N-P_2O_5-K_2O$[1] 1982-1999	Seedcotton 1992-1999	Soybean[2] 1992-1999
	N rate Variables		
16	0-0-0 no N	2000	29
11	30-0-0	2060	29
13	60-0-0	2190	28
14	90-60-60 control	2330	33
10	120-0-0	2050	25
	Residual P Variables		
12	90-0-0 no P	2000	25
3	90-0-0 med. P	2270	24
14	90-60-60 control	2330	33
	Residual K Variables		
6	90-0-0 no K	640	28
7	90-0-0 med. K	1120	18
14	90-60-60 control	2330	33
15	90-0-0 high K	2370	31
	Other Residual Variables		
1	0-0-0 nothing	410	9
2	90-0-0 no S	2020	24
4	90-0-0 no lime	700	14
5	90-0-0 low Mg	2020	26
8	90-0-0 + micros	1530	27
9	0-0-0 no NPK	660	29
17	90-60-60	1990	22
	C.V.	25.9	17.1
	LSD (P<0.05)	320	3

[1] P and K applied to treatment 14 only during period. N rate variables for cotton are 0, 30, 60, 90 and 120 pounds N per acre with 30 applied at planting and the remainder as a sidedress at squaring.
[2] No additional fertilizer was applied to the soybean crop.

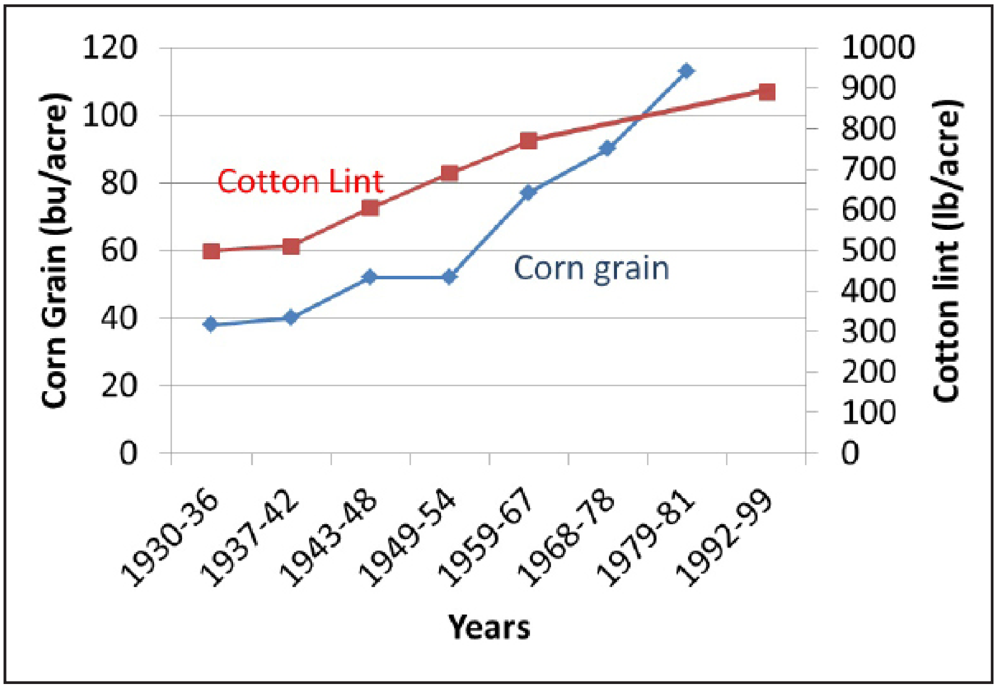


Figure 1. Change in mean cotton and corn yields on the fertilized control treatment (no. 14) on the Two-Year Rotation Experiment at Monroeville, AL, 1930-1999.

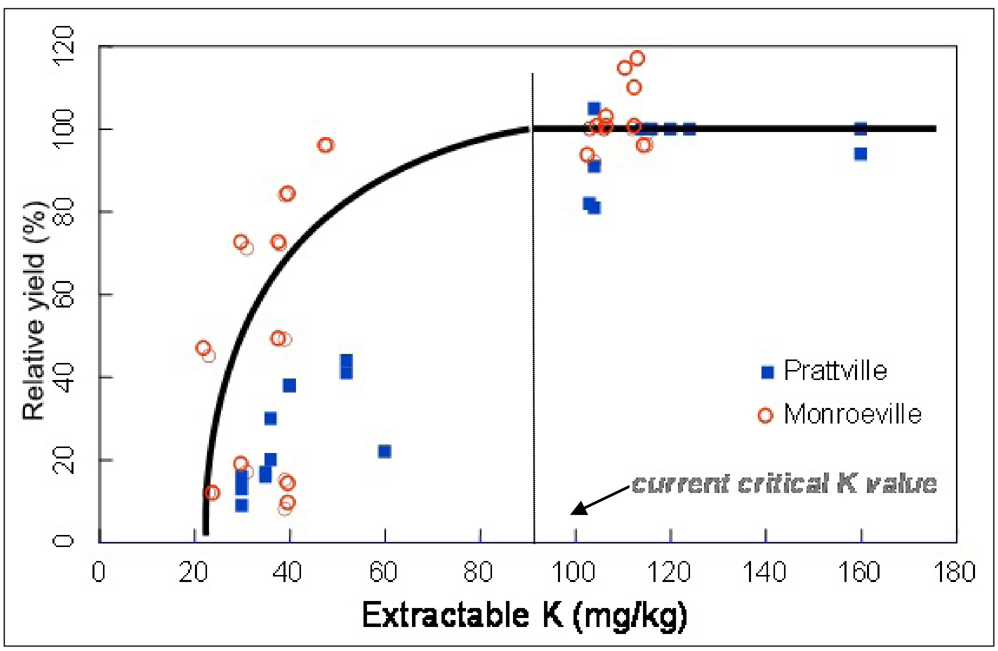


Figure 2. Soil test K calibration for cotton on a Lucedale f.s.l. at Prattville and at Monroeville from the Two-Year Rotation Experiment. The current critical M-1 extractable K concentration is 90 mg K/kg which is confirmed by these data.

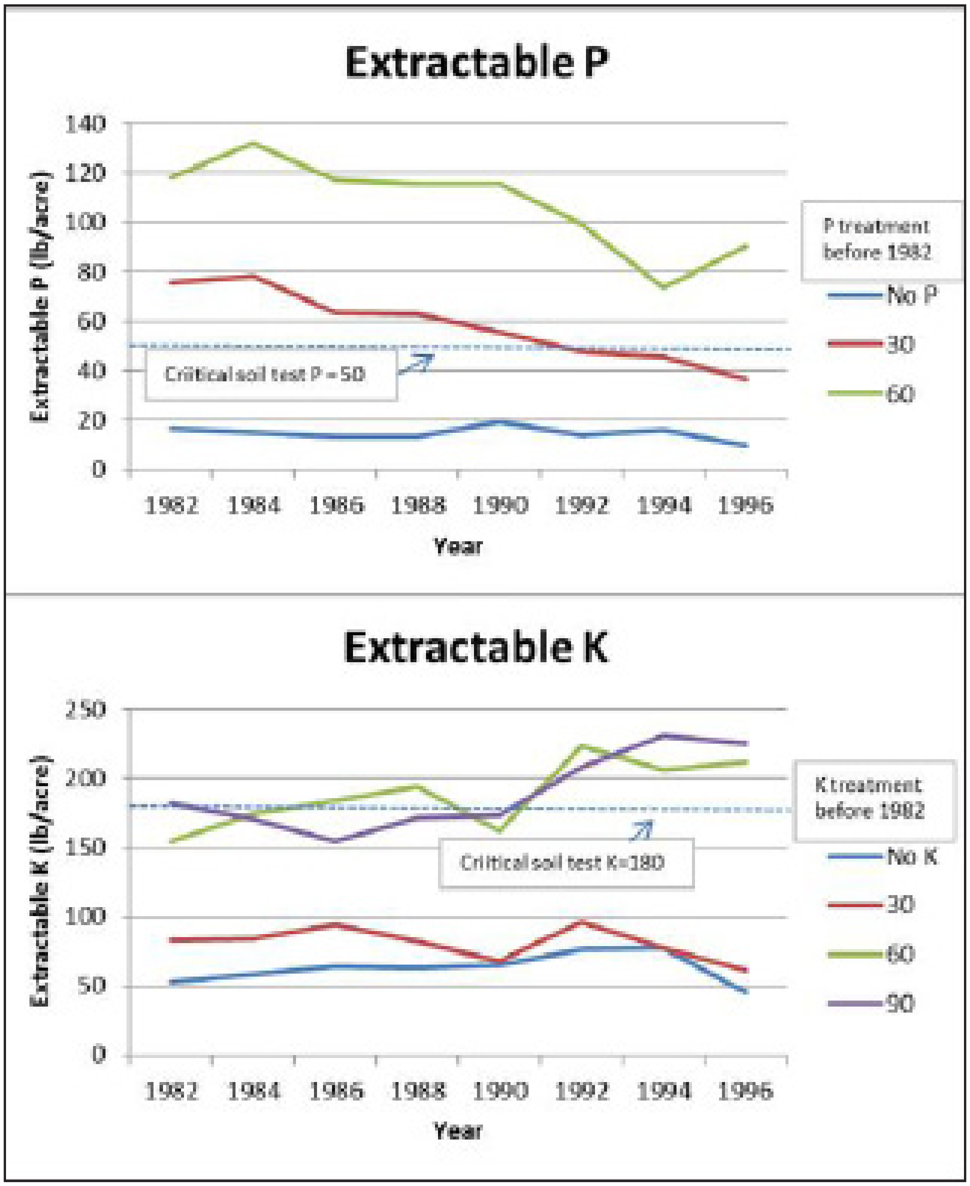


Figure 3. Changes in Mehlich-1 extractable P and K in the Two-Year Rotation from 1982 through 1996 when all plots were in a residual P and K mode, i.e., no additional P or K was applied except to treatment no. 14, the control.

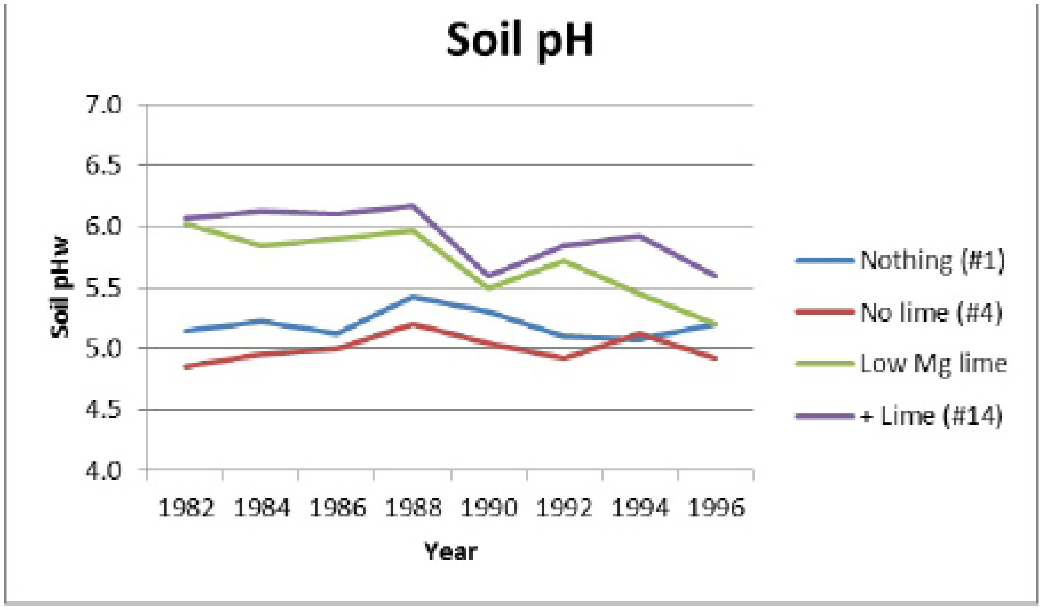


Figure 4. Changes in soil pH_w in the Two-Year Rotation from 1982 through 1996 when all plots were in a residual P and K mode, i.e., no additional P or K or lime was applied.

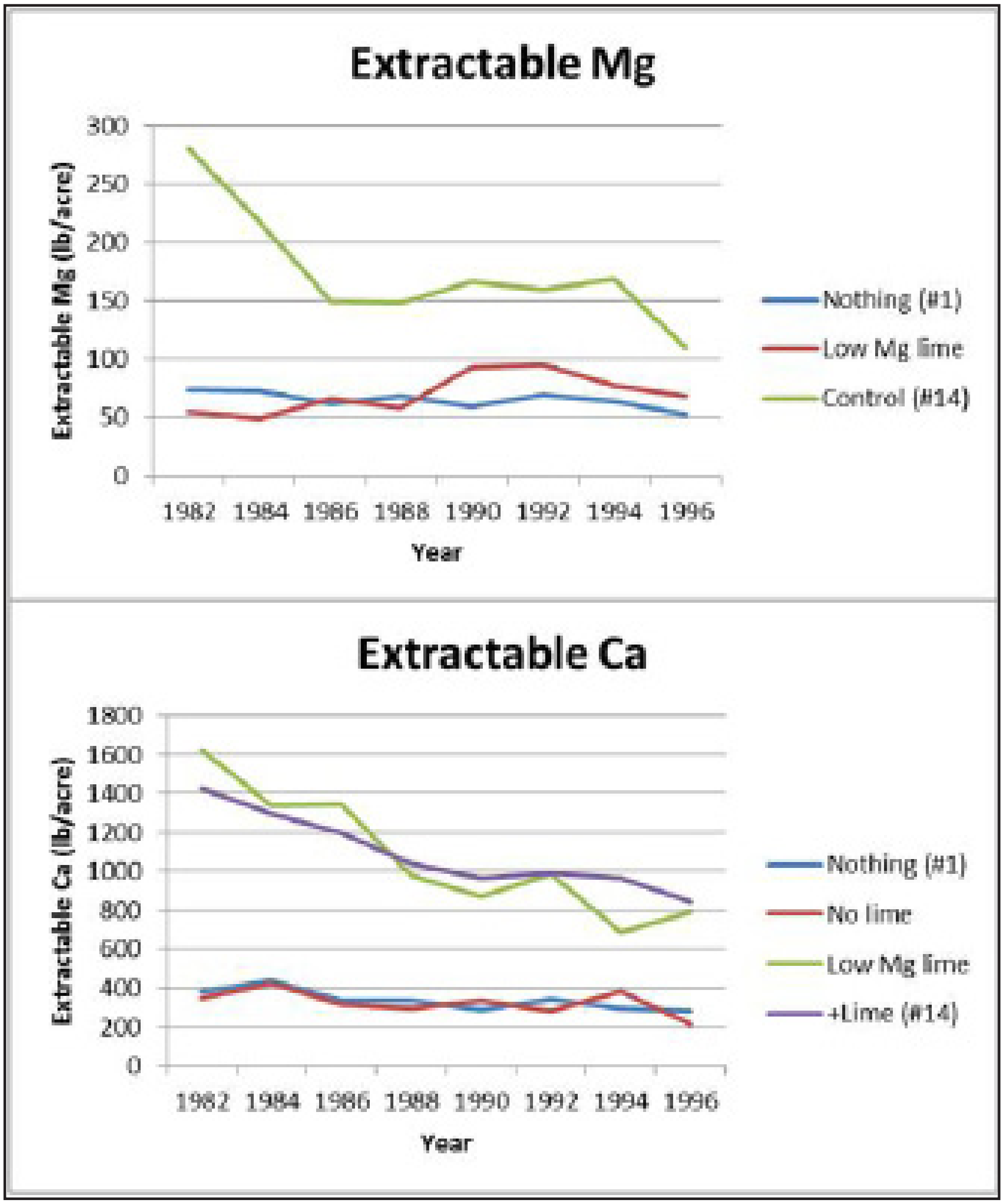


Figure 5. Changes in M1 extractable soil Mg and Ca in the Two-Year Rotation from 1982 through 1996 when all plots were in a residual P and K mode, i.e., no additional P or K or lime was applied.

The Rates of NPK Experiment (Circa 1954)

In 1953, researchers with the Alabama Agricultural Experiment Station realized the need for farmers to monitor changes in soil fertility variables in each field. No longer were fertilizer recommendations based upon field experiments around the state adequate for maximum yields. A public-supported, soil testing laboratory began operation in 1953 to serve farmers and researchers in Alabama. Information from older experiments such as the Two-Year Rotation experiments provided the research basis for soil test interpretations for Alabama crops and soils. However, new and better research information was needed to support Alabama's soil testing program. A new experiment known as the "Rates of NPK Experiment" was initiated at the Monroeville Experiment Field in 1954 and at other research stations around the state. Unlike the Two-Year Rotation, this new experiment was designed using a randomized, block design with 16 soil fertility variables replicated four times. This design allowed data analysis using more appropriate and modern statistical techniques such as analysis of variables (ANOVA). The Rates of NPK Experiment did not allow for crop rotations but the six N rate variables, the five P rate variables and the six K rate variables, along with soil liming and sulfur variables, allowed soil test calibration, correlation, interpretation and recommendations that few other public or private soil testing laboratories could support. Plots on the Rates of NPK Experiment were 21 feet wide and 35 feet long and accommodated seven 36-inch rows of crops. Crops produced on Rates of NPK Experiment are given in Table 9.

Table 9
Crops planted on the Rates of NPK Experiment, 1954-2001

Years	Crop(s)
1954-61	Cotton
1962-64	Corn grain
1965-1972	Cotton
1973-75	Soybean
1976-80	Corn grain
1981-84	Soybean double-cropped after rapeseed/canola†
1985-88	Grain sorghum (incomplete records)
1989-91	Triticale followed by tropical corn for grain‡
1992-1999	Cotton
2001- present	Longleaf pine

† Winter-kill resulted in very poor rapeseed yields; yields recorded only in 1983 and the highest yield was only 800 lbs/ac.
‡ Tropical corn yields were very low (<40 bushels/acre) and were not recorded every year.

Cope (1970) used data from the Rates of NPK Experiment to refine optimum N recommendations for non-irrigated cotton and corn. This same publication improved soil test calibration for Mehlich-1 (dilute, double acid) extractable P and K values. Shortly before he retired, Cope (1984) summarized yields from this experiment since the 1970 bulletin. Fertilizer treatments and crops prior to 1982 are presented in Tables 10-12.

Efforts were made in the 1980s to gather soil test calibration data for some potentially new and expanding crops in Alabama. Rapeseed or canola production as a winter crop following soybean was not successful with the cultivars available in the early 1980s. Yields were disappointingly low; only one canola crop in 3 was harvested at Monroeville. Soybean as a summer crop after canola did yield useful soil test calibration data (Table 13). In the late 1980s, grain sorghum was promoted as a better alternative to growing corn in Alabama. There were major problems with insect and bird damage in small plots such as the Rates of NPK Experiment. Yield data are recorded for one year (1988) out of four at Monroeville (Table 13). In 1989 through 1991, support from the Alabama Wheat and Feed Grain Committee allowed planting triticale followed by a tropical corn cultivar as an intensive grain production system. Triticale did well but late planted tropical corn was a three-year disappointment. No corn grain yields are reported because they were so low due primarily to insect damage and lack of moisture; the cultivars available at that time were primarily silage-types and did not produce high grain yield.

Soil Test Verification For Cotton

Similarly to the Two-Year Rotation experiment, non-irrigated cotton yields were produced on this experiment at Monroeville from 1992 through 1999 when the experiment was in a residual P and K mode, i.e. no additional P and K were applied to the P and K variables except for the control treatment (treatment number 5). This allowed verification of recommended N rates and soil test calibration for P and K on this soil.

N Rates For Cotton

Figure 6 illustrates that current, total annual N rates for cotton (90 pounds N per acre) is adequate for maximum yield produced over an eight-year period (near 3 bales per acre). Within this range of yields produced at Monroeville on non-irrigated cotton, there is no clear evidence of a relationship between yield potential and N rate recommended. Higher N rates up to 150 pounds N per acre apparently do not reduce yields.

P Rates and Soil Test P Levels

Figure 7 illustrates soil test calibration for P on cotton at Monroeville.

Seedcotton yield relative to the mean yield on treatment number 5 each year (the fertilized control) was compared with soil test P from each of the P treatments. The P rates are the P rates prior to 1982 when this experiment was put into a residual P and K mode. There was a very weak correlation between soil test P on the P variable treatments and relative cotton yield from 1992 through 1999. However, from the data presented in Figure 7, the current critical P value of 50 pound M1-extractable P per acre (25 mg P/kg) seems reasonable.

K Rates and Soil Test K Levels

Figure 8 illustrates soil test calibration for K on cotton at Monroeville using only the K rate variable treatments with relative yield compared to the mean yield of treatment number 5 (the fertilized control). Correlation between M1-extractable K and relative cotton yields is only slightly better than that for P. However, the current critical K value for cotton, 180 pound K per acre (90 mg K/kg), appears to be satisfactory.

Changes in Soil Test P and K Over 15 years

Unlike the Two-Year Rotation experiment, Mehlich-1 extractable P concentrations did not change over the 15 years that the experiment was in a residual P mode (Figure 9). This suggests that once soil test P reaches a High or Very High rating (above the critical 50 pound extractable P per acre or 25 mg P/kg), it will stay at this level for a long time without additional P applications. Where 100 pounds P_2O_5 were applied per acre every year, there was a small increase in extractable P. Only seedcotton and grains were harvested during this 15-year period. Soil test K dropped only slightly in those plots that did not receive any K fertilization but there was a lot of variation in extractable K from year to year, probably due to the time of the year the samples were taken. The highest K rate that was applied to the fertilized control treatment (number 5) resulted in a gradual increase in soil test K as a result of the 100 pounds K_2O per acre per year that was applied. Extractable K increased from a low of 220 pound K/acre in 1985 to 314 pound/acre in 1997 (Table 15).

Some of the year-to-year variability in soil test K was believed to be associated with a gradual increase in soil test K following crop harvest each year (Figure 11). Although every effort was made to sample soon after harvest each fall, sometimes the sampling could be delayed until the following spring. In 1987, samples were collected every month following grain sorghum harvest in the fall from two of the residual K treatments in the Rates of NPK Experiment at each location, the “no K” treatment and the treatment that had received 80 pound K_2O per acre prior to 1982. At every location there was a gradual increase in soil test K following harvest. This change was particularly dramatic on the Lucedale soil at Monroeville (Figure 11).

Foliar K on Cotton

In the early 1990s, there was considerable interest in supplemental K applications on cotton through foliar fertilization with a diluted potassium nitrate fertilizer. Plots for the Rates of NPK Experiment were split with half of each plot receiving 4 applications of a dilute, foliar applied KNO_3 solution (4.5 pounds K/acre/application) and the other half receiving the same total N application as a foliar-applied urea solution. Applications began at early bloom. As expected, there was an increase in seedcotton yield as residual soil K increased but there was no significant response to foliar K versus the same rate of N as foliar urea (Figure 10). Similar results were observed at other locations around Alabama on the Rates of NPK Experiment (Mitchell and Mullins, 1993; Mitchell et al., 1994).

Table 10
Rates of N-P_2O_5-K_2O and mean crop yields on the Rates of NPK Experiment, 1954-1964.

Treatment Number	1954-61 Rate of N-P_2O_5-K_2O (lbs/ac/yr)	1954-61 Mean seed cotton (lbs/ac)	1962-64 Rate of N-P_2O_5-K_2O (lbs/ac/yr)	1962-64 Mean corn grain (bu/ac)	1965-69 Mean seed cotton (lbs/ac)
			N Variables		
1	0-100-100	900	0-100-100	13	1070
2	20-100-100	1160	30-100-100	28	1720
3	40-100-100	1380	60-100-100	38	1990
4	60-100-100	1620	90-100-100	42	1990
5	80-100-100	1680	120-100-100	47	1950
6	100-100-100	1640	150-100-100	44	2010
			P_2O_5 variables		
7	80-0-100	1400	120-0-100	50	1740
8	80-20-100	1620	120-20-100	49	1870
9	80-40-100	1580	120-40-100	46	1890
10	80-60-100	1660	120-60-100	52	1950
5	80-100-100	1680	120-100-100	47	1950
			K_2O variables		
11	80-100-0	410	120-100-0	35	1150
12	80-100-20	940	120-100-20	41	1770
13	80-100-40	1250	120-100-40	40	1930
14	80-100-60	1570	120-100-60	47	1970
15	80-100-80	1570	120-100-80	45	1970
5	80-100-100	1680	120-100-100	47	1950
			Other variables		
16	80-100-100 no lime	1560	120-100-100 no lime	47	1930
	Coef. Variability L.S.D. (P<0.05)				11% 140

Table 11
Rates of N-P_2O_5-K_2O and average crop yields on the Rates of NPK Experiment, 1965-75

Treatment Number	1965-69 Rate of N-P_2O_5-K_2O (lbs/ac/yr)	1965-69 Seed Cotton Yield (lbs/ac)	1970-77 Rate of N-P_2O_5-K_2O Residual P&K (lbs/ac/yr)	1970-72 Seed Cotton Yield (lbs/ac)	1973-75 Soybean[†] (bu/ac)
			N variables		
1	0-100-100	1070	0-0-0	1340	27
2	30-100-100	1720	30-0-0	1550	29
3	60-100-100	1990	60-0-0	1830	27
4	90-100-100	1990	90-0-0	2040	--
5	120-100-100	1950	120-100-100	1910	--
6	150-100-100 no sulfur since 1969	2010	150-0-0	2000	--
			P_2O_5 variables		
7	120-0-100	1740	120-0-0	1740	21
8	120-20-100	1870	120-0-0	2020	27
9	120-40-100	1890	120-0-0	1990	26
10	120-6-100	1950	120-0-0	1930	28
5	120-100-100	1950	120-0-0	1910	29
			K_2O variables		
11	120-100-0	1150	120-0-0	1300	23
12	120-100-20	1780	120-0-0	1680	26
13	120-100-40	1930	120-0-0	1790	26
14	120-100-60	1970	120-0-0	1950	27
15	120-100-80	1970	120-0-0	2220	28
5	120-100-100	1950	120-0-0	1910	29
			No Lime		
16	120-100-100 no lime	1930	120-0-0	1760	22
	Coef. Variation	11		12	12
	LSD ($P<0.05$)	140		210	3

[†]Only the 30- and 60- pound N per acre rates applied as N variables on soybean. No N applied to P and K variables. Phosphorus and K variable rates resumed in 1973-75.

Table 12
Rates of N-P_2O_5-K_2O and average crop yields on the Rates of NPK Experiment, 1976-1982

	(lbs/ac/yr)		(bu/ac)	
Treatment Number	**1976-77 Rate of N-P_2O_5-K_2O Residual P & K**	**1978-82 Rate of N-P_2O_5-K_2O**	**1976-80 Corn Grain Yield**	**1981-82 Soybean†**
		N variables		
1	0-0-0	0-100-100	45	32
2	30-0-0	30-100-100	--	31
3	60-0-0	60-100-100	74	33
4	90-0-0	90-100-100	81	--
5	120-100-100	120-100-100	88	--
6	150-0-0	150-100-100 no sulfur since 1969	85	33
		P_2O_5 variables		
7	120-0-0	120-0-100	65	29
8	120-0-0	120-40-100	84	34
9	120-0-0	120-60-100	82	33
10	120-0-0	120-80-100	91	34
5	120-0-0	120-100-100	88	33
		K_2O variables		
11	120-0-0	120-100-0	80	28
12	120-0-0	120-100-20	90	31
13	120-0-0	120-100-40	86	34
14	120-0-0	120-100-60	83	32
15	120-0-0	120-100-80	83	33
5	120-0-0	120-100-100	88	33
		Other variables		
6	150-0-0	150-100-100 no sulfur since 1969	85	33
16	120-0-0	120-100-100 no lime	49	27
	Coef. Variation LSD (P<0.05)		23 18	10 3

†Only the 30- and 60- pound N per acre rates applied as N variables on soybean. No N applied to P and K variables.

Table 13
Rates of N-P_2O_5-K_2O and average crop yields on the Rates of NPK Experiment, 1982-1991

Treatment Number	(lbs/ac/year) 1982-91 Residual P & K Previous rate of N-P_2O_5-K_2O	(bu/ac) 1982-84 Soybean	1982-84 Canola	(bu/ac) 1985-1988 Grain Sorghum from 1988†	(bu/ac) 1989-91 Triticale‡
		N variables			
1	0-100-100	22	No	39	16
2	30-100-100	21	yield	56	31
3	60-100-100	22	recorded	55	37
4	120-100-100	25	due to	61	38
5	90-100-100	24	winter	57	43
6	150-100-100	23	injury	56	47
			to crop		
		P_2O_5 variables			
7	90-0-100	21		56	40
8	90-0-100	22		50	34
9	90-0-100	23		59	46
10	90-0-100	24		58	41
5	90-100-100	24		57	43
		K_2O variables			
11	90-100-0	20		57	40
12	90-100-0	22		49	39
13	90-100-0	22		57	40
14	90-100-0	24		57	39
15	90-100-0	23		59	42
5	90-100-100	24		57	43
		Other variables			
16	90-100-100 (no lime)	17		9	22
6	150-100-100 (no S)	23		56	47
	Coef. Variation	55%		11%	33%
	LSD (P<0.05)	NS		8	4

†Grain sorghum was produced in 1985-88 but only 1988 yields were recorded.
‡ In 1989-91, triticale was grown double-cropped with a tropical corn hybrid; corn grain yields were so low that they were not recorded. The highest yielding year was 1991 when corn grain averaged 33 bu/acre.

Table 14
Rates of N-P_2O_5-K_2O and average seed cotton yields on the Rates of NPK Experiment, 1992-1999

Treatment Number	Rate of N-P_2O_5-K_2O Residual P & K (lbs/ac/year)	Seedcotton Yield (lbs/ac)
	N variables	
1	0-100-100	1220
2	30-100-100	2060
3	60-100-100	2190
4	120-100-100	2360
5	90-100-100	2390
6	150-100-100	2240
	P_2O_5 variables	
7	90-0-100	2190
8	90-0-100	2140
9	90-0-100	2350
10	90-0-100	2240
5	90-100-100	2390
	K_2O variable	
11	90-100-0	1920
12	90-100-0	2010
13	90-100-0	2370
14	90-100-0	2460
15	90-100-0	2360
5	90-100-100	2390
	Other variables	
16	90-100-100 (no lime)	530
6	150-100-100 (no S)	2240
	Coef. Variation	23%
	LSD (P<0.05)	324

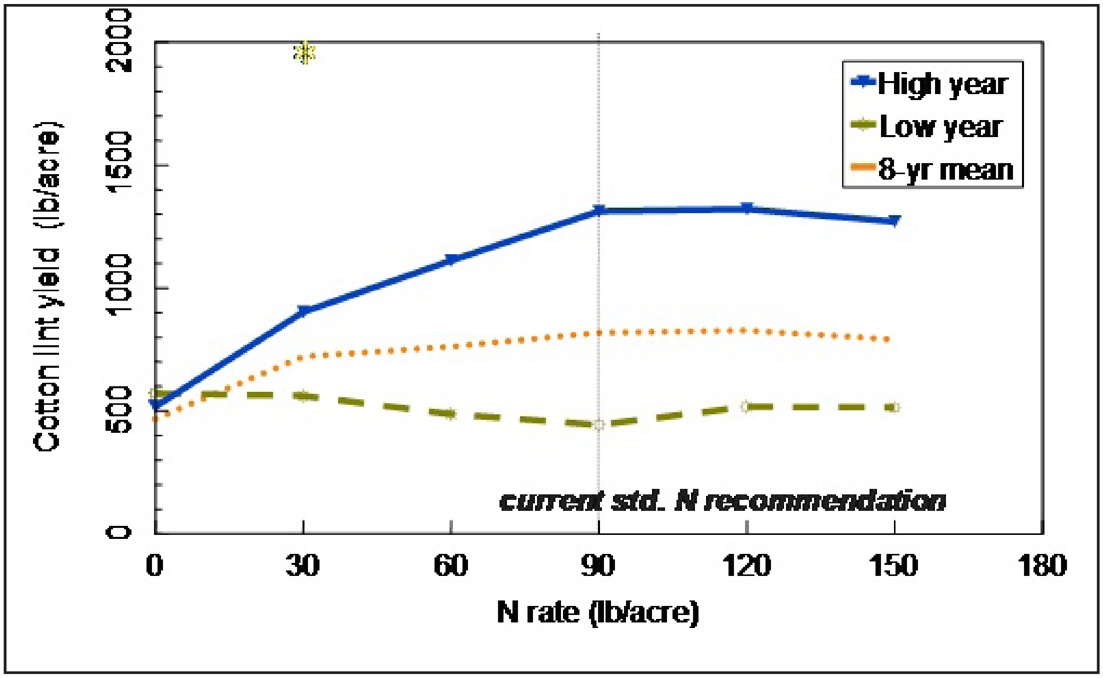


Figure 6. The current, standard total N rate recommended for cotton is 90±30 pounds N per acre. Data from 1992 through 1999 at Monroeville Experiment Field suggest that this rate is appropriate for non-irrigated cotton regardless of yield potential.

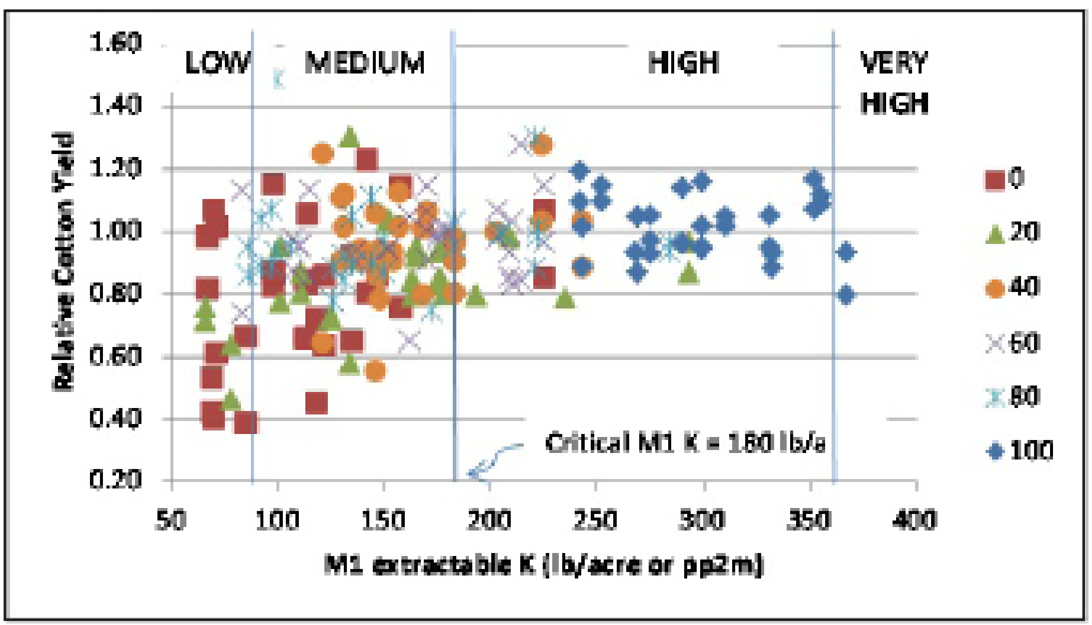


Figure 7. Relationship between Mehlich-1 extractable P and relative cotton lint yields from 1992-1999. Relative yield was calculated by comparing the yield from each plot with the mean yield from the treatment receiving 100 lb P_2O_5/acre/year for each year in the study. Symbols represent P_2O_5 applied prior to 1982 except for the 100 lbs/ac rate which was applied annually during this study. Ratings are those currently used by the Auburn University Soil Testing Laboratory.

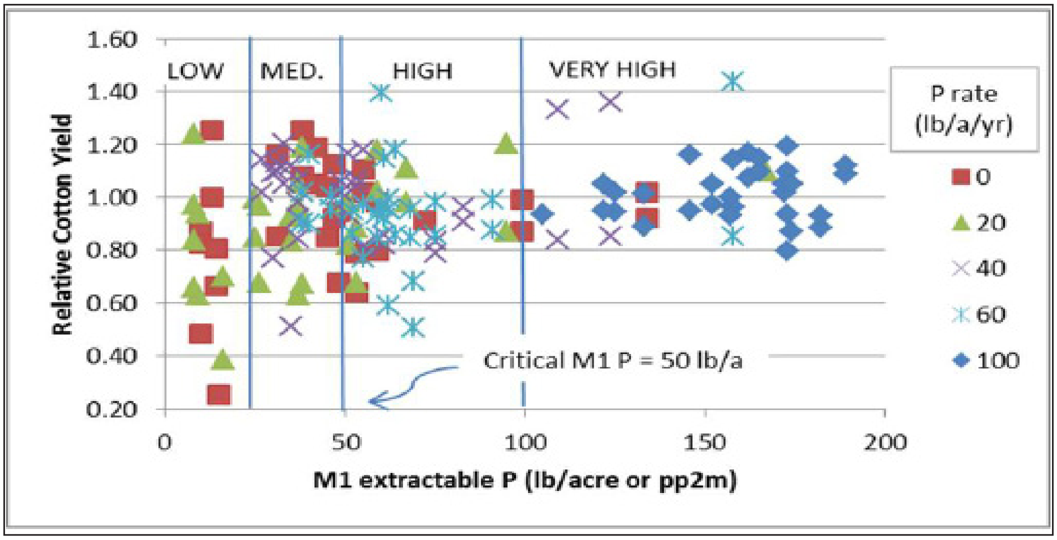


Figure 8. Relationship between Mehlich-1 extractable K and relative cotton lint yields from 1992-1999. Relative yield was calculated by comparing the yield from each plot with the mean yield from the treatment receiving 100 lb K_2O/acre/year for each year in the study. Symbols represent K_2O applied prior to 1992 except for the 100 lbs/ac rate which was applied annually during this study. Ratings are those currently used by the Auburn University Soil Testing Laboratory.

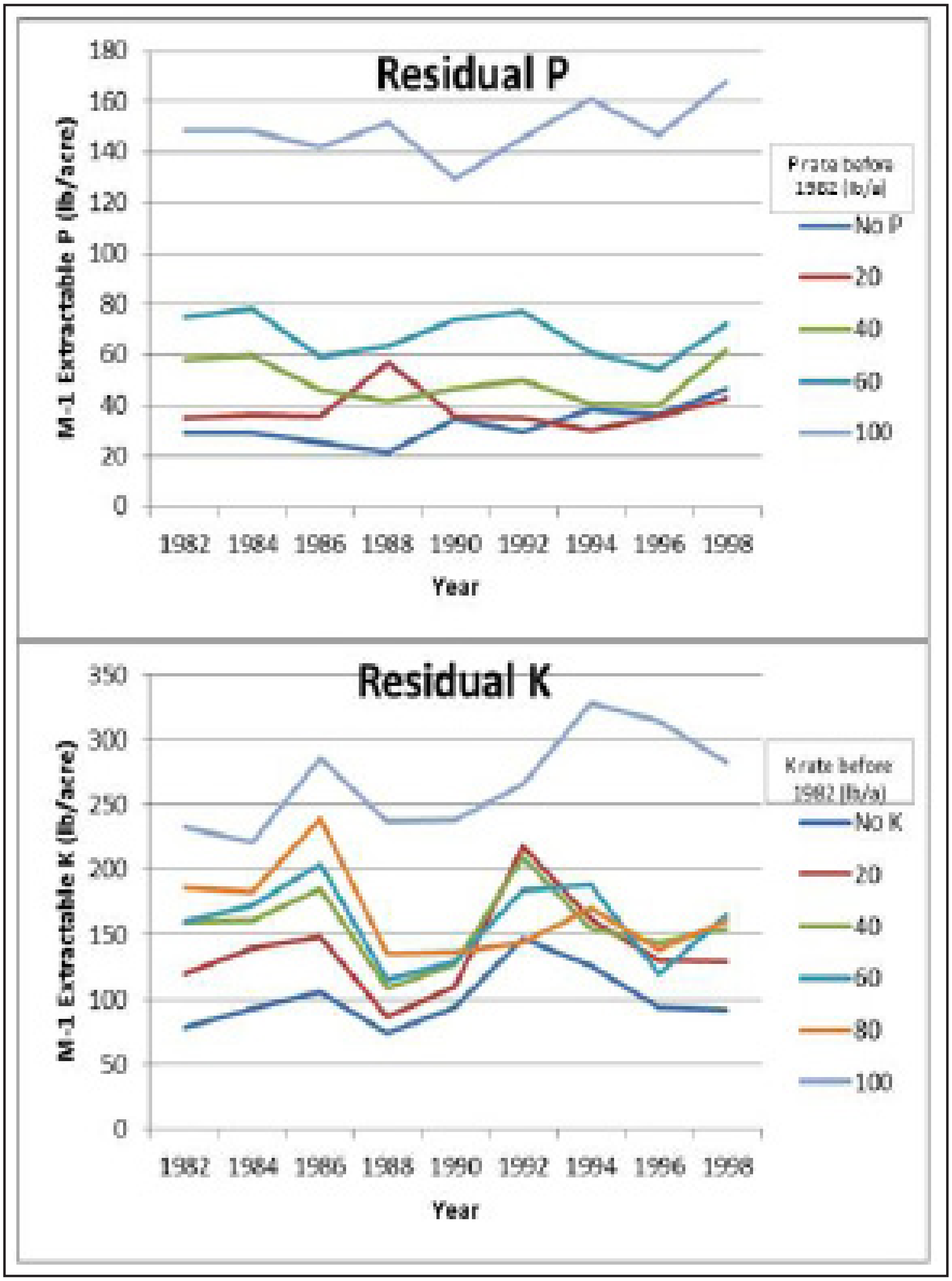


Figure 9. Changes in M-1 extractable soil P and K in residual P and K treatments from 1982 through 1998.

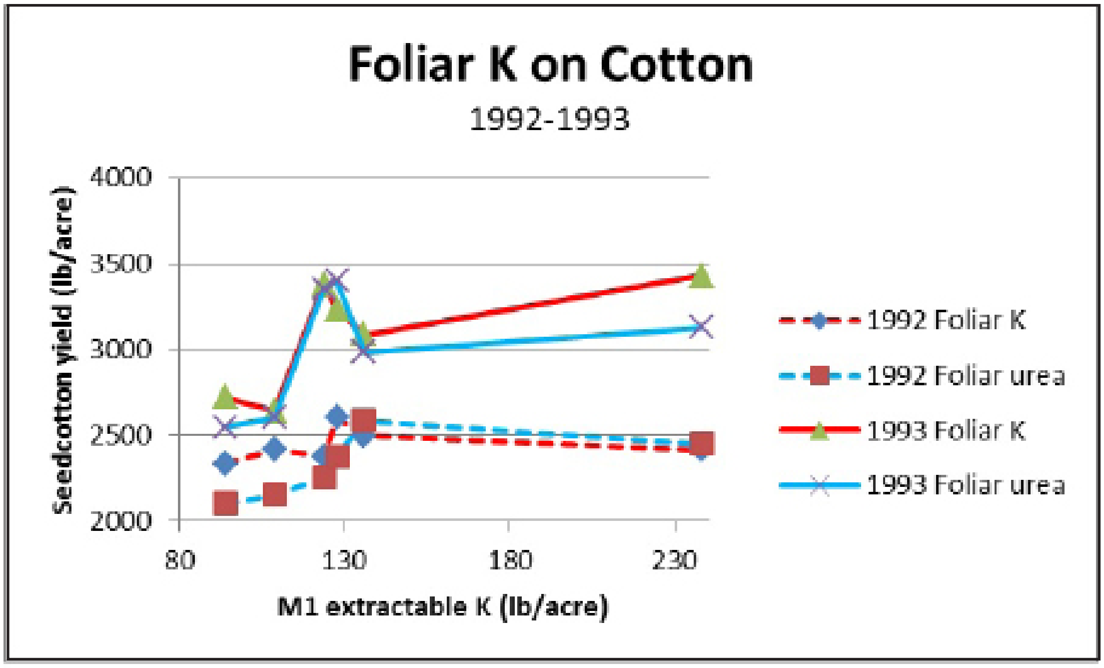


Figure 10. Effect of 4 applications of foliar applied KNO_3 and urea on seedcotton yields. At Monroeville in 1992 and 1993. Values are shown only for the K variables in the Rates of NPK experiment.

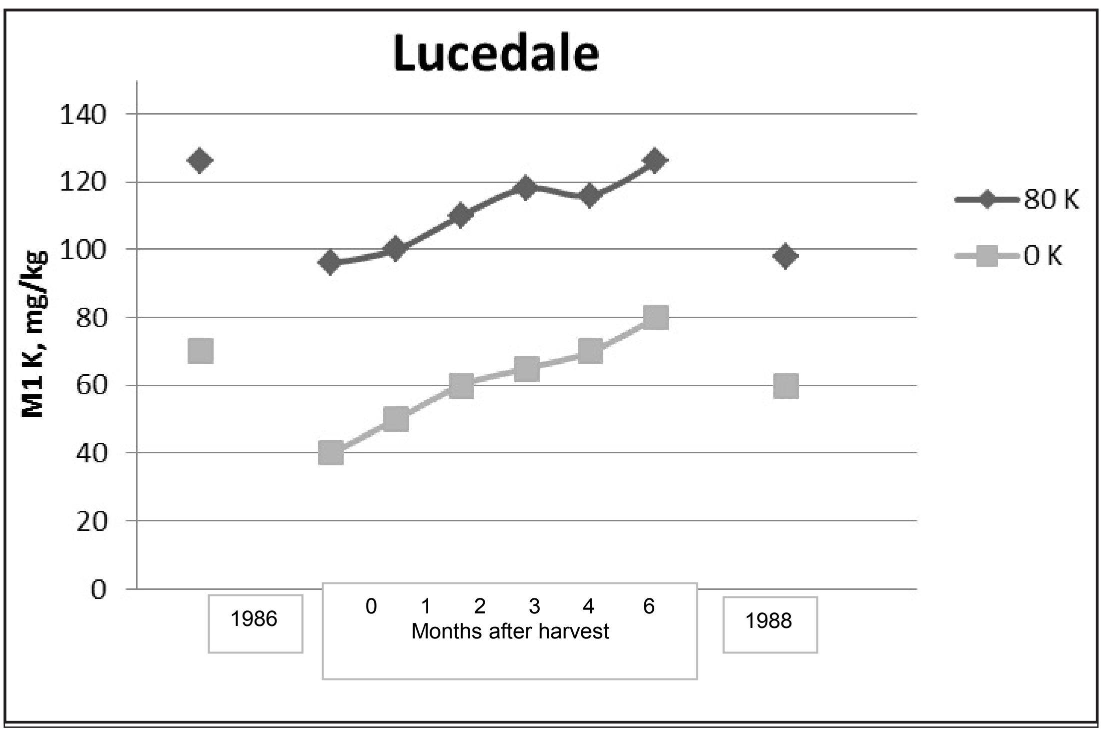


Figure 11. Change in residual soil test K after grain sorghum harvest in the fall of 1987 on the Rates of NPK Experiment at Monroeville.

Table 15
Change in mean extractable P and K values on selected treatments.

Rates of P_2O_5 or K_2O (lbs/ac)	1954	1965	1969	1972 (residual†)	1975	1981	1983 (Residual P and K†)	1985	1987	1989	1991	1993	1995	1997	1999	Soil test rating
Mehlich-1 Extractable P (lbs/ac or pp2m)																Low
0	29	21	24	16	22	24	25	29	25	21	34	71	38	36	46	Medium
20		33	46	60	36	33	35	36	36	56	36	74	30	35	42	
40		51	60	40	50	43	51	60	46	42	46	80	41	40	62	High
60		68	80	52	67	54	75	78	59	63	74	77	61	54	72	
100		94	110	100	123	130	148	148	141	152	129	146	161	146	168	Very High
Mehlich-1 Extractable K (lbs/ac or pp2m)																
0	75	68	80	70	79	83	78	93	105	74	94	147	125	94	92	Low
20		88	91	77	98	115	120	139	147	86	109	217	161	130	129	
40		109	109	91	142	124	149	160	184	108	126	163	154	143	154	Medium
60		121	122	111	173	153	159	171	204	114	128	183	188	118	164	
80		125	131	121	207	174	186	182	238	135	136	144	170	138	160	
100		141	148	170	220	235	233	220	276	236	238	266	327	314	282	High
Soil pH without limestone	5.4	5.3	5.3	5.3	5.2	5.3	4.8	4.8	5.0	4.8	4.8	5.2	4.8	4.8	4.4	

†Only the 100 lbs/ac rate was applied every year; all other treatments were in residual P and K mode.

Summary

Long-term soil fertility experiments at the Monroeville Experiment Field, like those on other outlying units of the Alabama Agricultural Experiment Station, have served the needs of Alabama crop producers by providing a reliable and unbiased evaluation of crop response to plant nutrients since the early days of crop fertilization in Alabama.

Data from these experiments were the basis of fertilizer recommendations for farmers on the red soils of Southwest Alabama, and later served to calibrate soil tests for the Auburn University Soil Testing Laboratory when it opened in 1954. These experiments continued to be used to evaluate nutrients on new crops and cropping systems and to refine and verify soil test calibration. Some of the most valuable information came in the last years of these experiments when both the Two-Year Rotation and the Rates of NPK Experiments were in residual P and K modes. Soil test data demonstrated that soil P and K levels change very slowly when only seedcotton and grain are harvested and producers do not need to quickly replace P and K just because a grain crop was harvested. Other factors such as the mineralization of crop residues can significantly affect extractable soil K. These experiments demonstrated that foliar-applied KNO_3 will not substitute for soil K in producing cotton yields.

Although the Monroeville Experiment Field was closed in the early 2000s for formal research and the Two-Year Rotation and Rates of NPK Experiments were planted in longleaf pine trees, the long-term plots are still there with their established levels of soil acidity, P, K, Mg and micronutrients.

Works Cited

Adams, F. (1975). Field experiments with magnesium in alabama – cotton, corn, soybean, peanuts. *Alabama agricultural experiment station, 472*. Retrieved from http://www.aaes.auburn.edu/comm/pubs/pubs-by-type.php.

Cope, J.T. (1984) Long-term fertility experiments on cotton, corn, soybeans, sorghum and peanuts, 1929-1982. *Alabama agricultural experiment station, 561.* Retrieved from http://www.aaes.auburn.edu/comm/pubs/pubs-by-type.php

Cope, J.T. (1970). Response of cotton, corn, bermudagrass to rates of N, P and K. *Alabama agricultural experiment station, 181.* Retrieved from http://www.aaes.auburn.edu/comm/pubs/pubs-by-type.php.

Cope, J.T. (1968). Changing patterns in fertilizer use. *Social science society of america*, 250.

Summary of some agronomic experiments on the substations, experiment fields and main station, 1930-1955 (1956). *Dep. Agronomy & Soils*, special publication.

Evans, C.E. & Mitchell, C.C. (1989). Rates of n, p and k at seven alabama locations for 35 years. *Agronomy,* abstract, 238.

Mitchell, C.C. (1989). Soil test potassium following sorghum production. *Southern branch of the american association of agronomy, 16*(9).

Mitchell, C.C. & Huluka, G. (2012). Nutrient recommendation tables for alabama crops. *Alabama agricultural experiment station.* Retrieved from http://repo.lib.auburn.edu/repo/handle/123456789/44102.

Mitchell, C.C. & Mullins, G.L. (1993). Effect of residual soil k on cotton yield responses to foliar-applied k at five locations. *Beltwide cotton conference,* 1313-1316. Retrieved from www.cotton.org.

Mitchell, C.C., Mullins, G.L. & Burmester, C.H. (1994). Foliar applied k and residual soil k interactions in five long-term studies. Proc. *Beltwide cotton conference,* 1313-1316. Retrieved from www.cotton.org.

Rouse, R.D. (1968). Soil test theory and calibration for cotton, corn, soybeans and coastal bermudagrass. *Alabama agricultural experiment station, 375*. Retrieved from http://www.aaes.auburn.edu/comm/pubs/pubs-by-type.php.

Acknowledgements

These long-term, soil fertility experiments on the Monroeville Experiment Field and at other locations throughout the state would not have existed without the long-term support of the project leaders at Auburn University and the superintendents and staff of the outlying units where the experiments are actually located. Project leaders at Auburn who have contributed to this research include the following professors, many of whom were also outstanding leaders of the College of Agriculture and the Alabama Agricultural Experiment Station:

M.J. Funchess
J.T. Williams
George D. Scarseth
J.W. Tidmore
N.J. Volk
G.W. Volk
L.E. Ensminger
R.D. Rouse
J.T. Cope

Superintendents at the Brewton and Monroeville Experiment Fields since they were established in 1928 include:

J.W. Richardson
E.L. Carden
F. Brown
J.A. Pitts
Randy Akridge