RESPONSE of COTTON to LIME in FIELD EXPERIMENTS

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E. V. Smith, *Director*

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RESPONSE of COTTON to LIME in FIELD EXPERIMENTS

FRED ADAMS, *Professor, Agronomy and Soils*

YIELD EFFECTS from liming cotton in field experiments in Alabama were first reported by the Agricultural Experiment Station at Auburn more than a half-century ago *(4)*. Yet liming continued to be generally neglected by most cotton farmers for decades. Probably the reason was that response to lime was neither predictable nor always profitable. This was because many soils were not acid enough to need liming, and there was considerable difficulty in distinguishing between those that needed lime and those that did not. Methods for measuring soil acidity and lime requirements were not precise, and there was little knowledge of the differences in lime requirements among soils and crops.

A comprehensive summary of all field experiments conducted with lime in Alabama between 1930 and 1955, including those with cotton, was published in 1956 *(1)*. Except for the extremely acid soil conditions (pH 5.0 or less) created by the longtime use of ammonium sulfate at three locations, cotton yields were unaffected by liming in these earlier experiments. It is now known that the lack of yield response to liming in several experiments was because the soil pH was not low enough. In other experiments, however, lime failed to increase cotton yields on soils that were just as acid as others where lime increased yields considerably.

Numerous liming experiments have been conducted in Alabama since 1955, but only preliminary and incomplete results from some of these have been published *(2,3,5)*. Most of these experiments were not designed solely as liming experiments, but they were fertilizer experiments designed so that liming effects could also be measured. This bulletin reports the results of liming soils in field experiments with cotton during the period of 1955-1966 in Alabama.

RATES AND SOURCES OF LIME, 1957-1964

A comprehensive, liming experiment designed expressly for determining the relationship among soil pH, lime rates, and cotton yield was established at three locations (Brewton, Monroeville, and Prattville Experiment Fields) in 1957 and 1958. This experiment was designed to give a broad range in soil pH values with numerous intermediate pH levels. It consisted of six lime rates, two lime sources, two nitrogen fertilizer rates, and three nitrogen sources. Cotton was planted each year for at least 5 years. A single initial application of lime was made at each test site, except for the highest lime rate (8 tons per acre). The 8-ton rate consisted of a 1-ton initial application and a 7-ton application in the winter of 1959-60. All treatments were replicated four times in a randomized complete block.

Yields for the three experiments are given for each year in Tables 1, 2, and 3.

Norfolk (formerly Kalmia) Sandy Loam
Brewton Experiment Field

Liming had little effect on cotton yields during the first 2 years of this experiment, Table 1. Yields of all treatments were low in the third year of the experiment (1959) because of unfavorable weather. During the last 2 years of the experiment (1960 and 1961), however, the effect of different levels of soil acidity on cotton yield was quite striking. By that time the maximum effect of lime applications on soil pH had been obtained, and a wide range in soil pH had been obtained by the different rates of lime and the different rates and sources of N fertilizers.

Soil samples were taken each year; average soil pH values for each treatment are reported in Table 1. One of the striking features of these data is the year-to-year fluctuation in soil pH on the same soil. Although the reason for such behavior is still obscure, it is typical of soil pH measurements. The fluctuation was not random, but the shift in pH was similar in direction and magnitude for all treatments.

The relationship between soil pH and cotton yield can best be seen from the data graphed in Figure 1. The cotton yields decreased sharply as soil pH values decreased below 5.8. The optimum soil pH range was 5.8-6.2. The plotted data suggest

TABLE 1. EFFECT OF RATES AND SOURCES OF LIME AND NITROGEN ON YIELD OF SEED COTTON AND SOIL pH ON NORFOLK (FORMERLY KALMIA) SANDY LOAM, BREWTON EXPERIMENT FIELD, ALABAMA, 1957-1961[1]

Lime/A. rate	N/A. rate[2]	Acre yield of seed cotton by year[3]					Soil pH each February[3]					
		1957	1958	1959	1960	1961	1958	1959	1960	1961	1962	Av.
Ton	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*						
0	60	1,880	2,240	790	1,620	1,140	5.6	5.2	5.2	5.6	5.6	5.4
0	240	1,810	2,300	710	1,500	430	5.4	----	5.0	5.3	5.3	5.2
0.5	60	1,940	2,380	971	1,860	1,560	5.8	5.7	5.5	5.8	5.7	5.7
1.0	0	1,380	1,600	500	1,310	1,250	6.0	----	5.9	6.2	6.0	6.0
1.0	60	1,790	2,420	1,080	1,990	1,770	5.9	5.6	5.6	6.0	5.9	5.8
1.0	240	1,990	2,560	1,220	1,580	1,520	5.8	----	5.3	5.6	5.5	5.5
1.0	240-S[4]	1,890	2,550	1,160	1,530	1,190	5.7	----	5.2	5.4	5.4	5.4
1.0	240-Na[5]	2,170	2,730	1,420	1,940	1,980	6.4	----	5.9	6.3	6.0	6.1
1.0 Cal[6]	60	1,850	2,370	1,060	1,710	1,710	6.0	5.9	5.7	6.0	5.8	5.9
1.0 Cal[6]	240	2,100	2,630	1,320	1,710	1,580	5.9	----	5.3	5.6	5.5	5.6
2.0	60	1,980	2,580	1,290	2,000	2,270	6.1	6.1	6.0	6.2	5.9	6.0
2.0	240	1,840	2,620	1,420	1,800	1,920	5.8	----	5.7	5.8	5.6	5.7
4.0	60	1,910	2,530	1,120	1,840	2,170	6.4	6.5	6.5	6.7	6.3	6.5
4.0	240	1,870	2,600	1,230	1,780	2,070	6.3	----	6.3	6.2	6.1	6.2
4.0 Cal[6]	240	1,730	2,510	1,100	1,510	1,650	6.4	6.6	6.2	6.2	6.0	6.3
8.0[7]	60	----	----	----	1,800	2,020	----	----	----	6.7	6.6	6.6
8.0[7]	240	----	----	----	1,670	1,790	----	----	----	6.6	6.5	6.5

[1] All plots fertilized annually with 52 lb./A. of P (120 lb./A. P_2O_5) and 183 lb./A. of K (220 lb./A. K_2O). Original soil sample from area showed following: pH = 5.4; subsoil pH = 5.3; CEC = 3.9; exchangeable Mg = 52 lb./A; exchangeable K = 70 lb./A.

[2] Ammonium nitrate was the source of nitrogen except where otherwise indicated.

[3] Average of four replications.

[4] Ammonium sulfate was the source of nitrogen.

[5] Sodium nitrate was the source of nitrogen.

[6] Calcitic limestone was the source of lime. Dolomitic limestone was used on all others.

[7] One ton was added in 1957 and 7 tons in 1960.

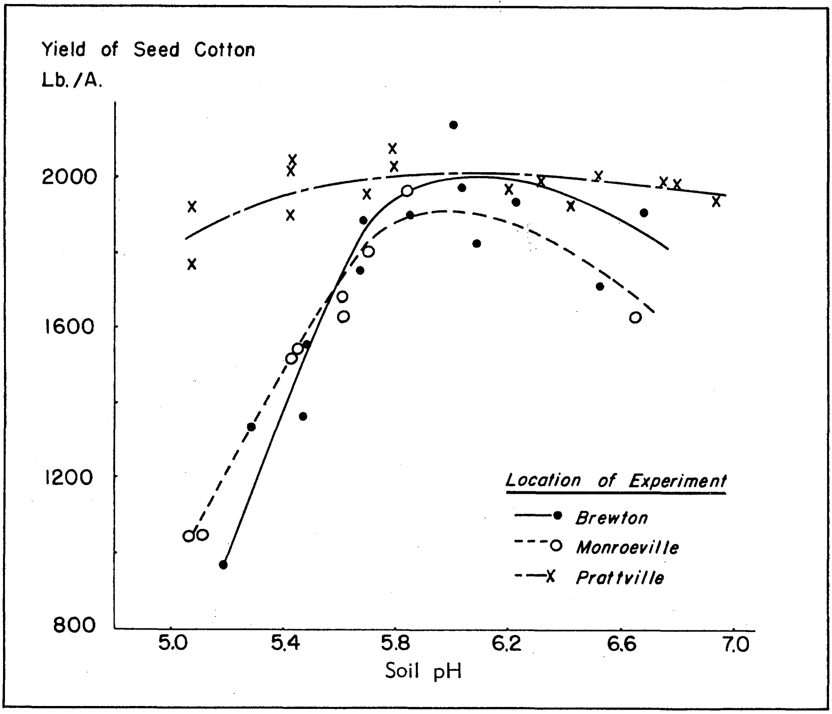

FIGURE 1. Effect of soil pH on yield of seed cotton in a rates and sources of lime experiment on three Coastal Plains soils.

that yields were slightly reduced at the highest lime rate where soil pH was above 6.5.

Cotton yields were increased more by dolomitic limestone than they were by calcitic limestone. For example, 4 tons of magnesium-containing dolomitic limestone increased seed cotton yield over 300 lb. per acre more than did an equal amount of calcitic limestone.

Optimum yields were obtained from the 1-ton rate of lime only during the first 3 years of the experiment. The higher rates of lime definitely produced higher yields in the fifth and final year of the experiment.

Magnolia Fine Sandy Loam
Monroeville Experiment Field

Yields of seed cotton for each year of this experiment are reported in Table 2. A wide range in soil acidity had been created by the third year of this experiment, as shown by the data in

TABLE 2. EFFECT OF RATES AND SOURCES OF LIME AND NITROGEN ON YIELD OF SEED COTTON AND SOIL pH ON MAGNOLIA FINE SANDY LOAM, MONROEVILLE, ALABAMA, 1957-1961[1]

Lime/A. rate	N/A. rate[2]	Acre yield of seed cotton by year[3]					Soil pH each February[3]					
		1957	1958	1959	1960	1961	1958	1959	1960	1961	1962	Av.
Ton	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*						
0	60	1,740	2,080	1,570	1,770	1,260	5.4	5.5	5.3	5.4	5.6	5.4
0	240	1,840	1,740	520	1,400	710	5.2	----	5.0	5.1	5.2	5.1
0.5	60	1,680	2,100	1,410	1,850	1,440	5.7	5.8	5.6	5.6	5.6	5.6
1.0	0	1,270	1,330	1,270	1,500	1,190	5.7	----	5.9	6.1	5.9	5.9
1.0	60	1,870	2,220	1,570	1,980	1,630	5.6	5.7	5.7	5.7	5.7	5.7
1.0	240	1,820	2,170	1,480	1,710	1,370	5.6	----	5.5	5.4	5.5	5.5
1.0	240-S[4]	1,960	1,930	840	1,320	790	5.5	----	5.0	5.3	5.1	5.2
1.0	240-Na[5]	1,930	2,210	1,610	1,690	1,680	5.9	----	6.3	6.4	6.1	6.2
1.0 Cal.[6]	60	1,860	2,090	1,640	1,940	1,370	5.8	5.8	5.8	5.7	5.7	5.8
1.0 Cal.[6]	240	1,920	2,010	1,290	1,550	1,260	5.6	----	5.4	5.4	5.4	5.5
2.0	60	1,820	2,330	1,730	2,230	1,650	5.7	5.9	5.9	5.8	5.8	5.8
2.0	240	1,870	2,200	1,450	1,860	1,490	5.6	----	5.6	5.6	5.6	5.6
4.0	60	1,830	2,130	1,690	2,090	1,600	6.1	6.3	6.4	6.4	6.2	6.3
4.0	240	1,890	2,290	1,870	1,850	1,800	6.0	----	6.2	6.2	5.9	6.1
4.0 Cal[6]	240	1,840	2,010	1,480	1,930	1,530	6.2	6.4	6.4	6.2	6.0	6.2
8.0[7]	60	----	----	----	1,950	1,320	----	----	----	6.6	6.7	6.7
8.0[7]	240	----	----	----	1,980	1,690	----	----	----	6.5	6.4	6.5

[1] All plots fertilized annually with 52 lb./A. of P (120 lb./A. P_2O_5) and 183 lb./A. of K (220 lb./A. K_2O). Original soil sample from area showed following: pH = 5.5; subsoil pH = 5.1; CEC = 5.2; exchangeable Mg = 156 lb./A.; exchangeable K = 125 lb./A.

[2] Ammonium nitrate was source of nitrogen except where indicated otherwise.

[3] Average of four replications.

[4] Ammonium sulfate was source of nitrogen.

[5] Sodium nitrate was source of nitrogen.

[6] Calcitic limestone was source of lime. Dolomitic limestone was source of lime for all others.

[7] One ton was added in 1957 and 7 tons in 1960.

Table 2. The effects of these different soil pH levels on cotton yields were clearly evident at that time. The relationship between soil pH and cotton yields is best shown in Figure 1.

The results of this experiment were very similar to those obtained from the same experiment on Norfolk sandy loam at Brewton. For example, the optimum soil pH range was 5.8-6.2 with sharply reduced yields as soil pH decreased below 5.8. There was also some yield reduction at pH 6.5 and above. In addition, yields were greater from dolomitic limestone than they were from calcitic limestone, which showed the need for adding magnesium to this soil.

Lucedale (formerly Greenville) Sandy Clay Loam
Prattville Experiment Field

The experiment was begun in 1958 and continued through 1964. Even after 7 years cotton yields were much less affected by the different liming and nitrogen treatments than they were on the Norfolk and Magnolia soils, Table 3. The data in the table, however, show that soil pH values were changed as much in the Lucedale soil by the different lime and fertilizer treatments as they were in the Norfolk and Magnolia soils.

The effect of soil pH on cotton yield is illustrated in Figure 1. The data clearly show that the soil pH required for maximum cotton yields was somewhat less for the Lucedale (formerly Greenville) soil than it was for either Norfolk or Magnolia. For example, maximum yields were obtained on both Norfolk and Magnolia soils near pH 6.0, with sharp reductions in yields below pH 5.5, whereas there was practically no yield reduction on Lucedale soil until the pH reached a low of about 5.0.

When this test site was selected, the soil was not considered to be acid enough to provide a suitable experiment for lime rates. Consequently, it was acidified during 1957 by a high rate of ammonium sulfate fertilizer to corn (1,000 pounds per acre). This sharply lowered the soil pH, and the lime experiment was begun the following year. It is not known if creating soil acidity with high N rates during such a short time interval has effects other than soil pH changes.

The Lucedale soil was not magnesium deficient, since dolomitic limestone was not superior to calcitic limestone.

TABLE 3. EFFECT OF RATES AND SOURCES OF LIME AND NITROGEN ON YIELD OF SEED COTTON AND SOIL pH ON LUCEDALE (FORMERLY GREENVILLE) SANDY CLAY LOAM, PRATTVILLE EXPERIMENT FIELD, ALABAMA, 1958-1964[1]

Lime/A. rate[2]	N/A. rate[2]	Acre yield of seed cotton by years[3]								Soil pH in February[3]				
		1958	1959	1960	1961	1962	1963	1964	Av.	1959	1960	1961	1963	Av.
Ton	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*					
0	60	1,900	1,130	2,160	2,100	1,500	1,710	2,490	1,860	5.3	5.4	5.6	5.8	5.5
0	240	2,190	1,340	1,960	2,290	1,580	1,680	2,500	1,930	5.0	5.0	5.1	5.3	5.1
0.5	60	2,120	1,140	2,160	2,180	1,520	1,800	2,490	1,920	5.6	5.6	5.9	5.8	5.7
1.0	0	1,480	470	1,150	800	790	740	1,140	940	5.8	5.9	6.2	6.1	6.0
1.0	60	2,030	1,140	2,310	2,270	1,630	1,800	2,540	1,960	5.7	5.8	6.0	5.9	5.9
1.0	240	2,320	1,440	1,970	2,490	1,590	1,760	2,690	2,030	5.5	5.5	5.4	5.5	5.5
1.0	240-S[4]	1,960	1,440	2,030	2,190	1,460	1,630	2,250	1,850	5.3	5.3	4.7	5.0	5.1
1.0	240-Na[5]	2,290	1,310	2,000	2,360	1,530	1,720	2,510	1,960	6.4	6.3	6.7	6.2	6.4
1.0 Cal[6]	60	2,200	1,250	2,220	2,230	1,590	1,810	2,640	1,990	5.8	5.8	5.9	5.8	5.8
1.0 Cal[6]	240	2,320	1,440	2,080	2,400	1,550	1,830	2,620	2,030	5.5	5.6	5.4	5.6	5.5
2.0	60	2,240	1,260	2,160	2,210	1,540	1,780	2,570	1,970	6.1	6.1	6.3	6.1	6.2
2.0	240	2,210	1,440	1,880	2,620	1,550	1,850	2,800	2,050	5.8	5.8	5.6	5.8	5.8
4.0	60	2,240	1,310	2,150	2,220	1,580	1,790	2,510	1,970	6.6	6.7	6.8	6.6	6.7
4.0	240	2,470	1,510	2,220	2,380	1,520	1,770	2,680	2,090	6.4	6.4	6.3	6.1	6.3
4.0 Cal[6]	240	2,380	1,380	2,040	2,270	1,550	1,810	2,630	2,010	6.8	6.7	6.4	6.2	6.5
8.0[7]	60	----	----	2,240	2,010	1,520	1,700	2,530	2,000	----	----	6.7	7.0	6.9
8.0[7]	240	----	----	2,000	2,190	1,670	1,750	2,470	2,020	----	----	6.4	6.9	6.7

[1] All plots fertilized annually with 52 lb./A. of P (120 lb./A. P_2O_5) and 183 lb./A. of K (220 lb./A. K_2O). Original soil sample from area showed following: pH = 5.4; subsoil pH = 5.5; CEC = 8.9; exchangeable Mg = 96 lb./A.; exchangeable K = 312 lb./A.

[2] Ammonium nitrate was source of nitrogen except where indicated otherwise.

[3] Average of four replications.

[4] Ammoninum sulfate was source of nitrogen.

[5] Sodium nitrate was source of nitrogen.

[6] Calcitic limestone was source of lime. Dolomitic limestone was used on all others.

[7] One ton was added in 1957 and 7 tons in 1960.

MAGNESIUM-POTASSIUM-LIME EXPERIMENT, 1957-1962

An experiment with continuous cotton was established at three experimental sites. The primary objective was to determine the availability of magnesium at two levels each of potassium and soil pH. A secondary objective was to measure the yield response of cotton to lime. These experiments were started at the Brewton, Monroeville, and Alexandria Experiment Fields in 1957 and 1958. The limed plots were maintained near pH 6.0 (considered to be optimum) throughout the test-period at all three locations by appropriate use of agricultural-grade, calcitic limestone. All treatments were replicated three times in a randomized complete block.

The data showing the effect of liming on cotton yields at each site are given in Table 4. Yields were increased about 400 pounds of seed cotton per acre on Norfolk (formerly Kalmia) sandy loam at Brewton having a pH of 5.2, about 200 pounds per acre on Magnolia fine sandy loam at Monroeville with a pH of 5.4. The yield response to lime on Norfolk and Magnolia soils were similar, while there was no yield response to lime on Decatur soil at about the same soil pH.

TABLE 4. EFFECT OF AGRICULTURAL LIMESTONE ON YIELD OF SEED COTTON IN MAGNESIUM-POTASSIUM EXPERIMENTS WITH CONTINUOUS COTTON AT THREE EXPERIMENT FIELDS[1]

Location	Soil type	Years	Acre yield of seed cotton[2]		Initial pH
			Unlimed	Limed	
			Lb.	*Lb.*	
Brewton	Norfolk (formerly Kalmia) sandy loam	1957-58	1,340a	1,740b	5.2[3]
Monroeville	Magnolia fine sandy loam	1957-62	1,530a	1,760b	5.4[4]
Alexandria	Decatur clay loam	1958-62	1,620a	1,670a	5.4[5]

[1] Basic fertilizer rate per acre was 80 lb. N, 26 lb. P (60 lb. P_2O_5), 50 lb. K (60 lb. K_2O) at Brewton and Monroeville and 60 lb. N, 26 lb. P, 50 lb. K at Alexandria.

[2] Average of six treatments with three replications each. Yields followed by the same letter within a soil type are not different at 0.01 probability level.

[3] Other soil properties: CEC = 3.8; exchangeable cations (meq./100 g.): Ca = 0.34; Mg = 0.08; K = 0.06.

[4] Other soil properties: CEC = 4.3; exchangeable cations (meq./100 g.): Ca = 0.74; Mg = 0.16; K = 0.08.

[5] Other soil properties: CEC = 6.6; exchangeable cations (meq./100 g.): Ca = 1.77; Mg = 0.44; K = 0.23.

MAGNESIUM-LIME EXPERIMENT, 1960-1967

An experiment was established at 2 different locations in 1960 primarily to determine the rate of fertilizer magnesium required for cotton in a 2-year cotton-corn rotation at 2 soil pH levels. A secondary objective was to determine the response of cotton to lime. The experiments were located on a Norfolk (formerly Kalmia) sandy loam at the Brewton Experiment Field and on a

TABLE 5. EFFECT OF LIME ON YIELD OF SEED COTTON IN A MAGNESIUM EXPERIMENT ON A TWO-YEAR ROTATION OF COTTON AND CORN AT BREWTON EXPERIMENT FIELD AND SAND MOUNTAIN SUBSTATION, ALABAMA, 1960-1967[1]

Location	Soil type	Acre yield of seed cotton[2]		pH of unlimed soil	
		Unlimed	Limed	1960	1967
		Lb.	*Lb.*		
Brewton	Norfolk (formerly Kalmia) sandy loam	1,850a	1,980b	5.7	5.5
Crossville	Hartsells fine sandy loam	2,600a	2,740b	5.3	5.2

[1] Annual fertilizer rates per acre were 100 lb. N, 26 lb. P (60 lb. P_2O_5), 66 lb. K (80 lb. K_2O) at Brewton and 100 lb. N, 26 lb. P, 50 lb. K at Crossville.
[2] Average of four treatments, each with four replications. Yields followed by same letter within a soil type are not different at 0.01 probability level.

Hartsells fine sandy loam at the Sand Mountain Substation, Crossville. The limed plots were maintained near soil pH 6.0 throughout the test-period by use of an agricultural-grade, calcitic limestone. All treatments were replicated four times in a randomized complete block.

The effects of liming these soils on cotton yields are shown by the data in Table 5. Yields were increased about equally by liming the Norfolk soil at pH 5.7 and the Hartsells soil at pH 5.3. Although the average increase in both cases was less than 150 pounds of seed cotton per acre, it was consistent and significant. It is obvious from these data that maximum cotton yields were obtained at a lower soil pH on the Hartsells soil than on the Norfolk soil.

NITROGEN-PHOSPHORUS-POTASSIUM EXPERIMENT 1954-1961 AND 1965-1966

An experiment with continuous cotton was established in 1954 at eight locations for the primary purpose of determining optimum fertilizer rates. A secondary objective of the experiment was to determine yield response of cotton to lime on well-fertilized soils. An agricultural-grade, dolomitic limestone was used. Continuous cotton was grown during 1954-1961, followed by continuous corn during 1962-1964. In 1965, the experiment either was reverted to continuous cotton or was discontinued. The soils were sampled periodically and the limed plots were maintained near pH 6.0 throughout the course of the experiment. All treatments were replicated four times.

The average yields on the limed and unlimed plots are reported in Table 6. There was no big yield increase from liming any of the eight soils, and there was no yield increase on half of them.

The soil pH data in Table 6 illustrate the lack of precision in defining the exact soil pH at which a crop is growing and the pH

TABLE 6. EFFECT OF LIME ON YIELD OF COTTON IN AN N-P-K EXPERIMENT WITH CONTINUOUS COTTON AT EIGHT LOCATIONS IN ALABAMA[1]

Locations	Soil type	Years	Acre yield of seed cotton[2]		pH of unlimed soil		
			Unlimed	Limed	1954	1959	1962
			Lb.	*Lb.*			
Brewton Exp. Field	Norfolk[3] sandy loam	1954-61 1965-66	1,890 2,070	1,800 2,130	5.5	5.8	5.5
Monroeville Exp. Field	Magnolia fine sandy loam	1954-61	1,560	1,680	5.4	5.8	5.4
Wiregrass Substation, Headland	Dothan[4] sandy loam	1954-61	1,800	1,980	5.2	5.4	5.5
Prattville Exp. Field	Lucedale[5] sandy clay loam	1954-61 1965-66	1,860 2,170	1,790 2,530	5.6	5.5	5.6
Upper Coastal Plains Sub., Winfield	Savannah very fine sandy loam	1954-61	1,500	1,600	5.1	5.1	5.2
Sand Mt. Substation, Crossville	Hartsells fine sandy loam	1954-61 1965-66	1,810 2,350	2,060 2,780	5.4	5.3	5.2
Alexandria Exp. Field	Decatur clay loam	1954-61	1,410	1,420	5.6	5.7	5.6
Tenn. Valley Substation, Belle Mina	Decatur clay loam	1954-61 1965-66	1,630 2,920	1,640 2,990	5.5	5.3	5.6

[1] Fertilized annually at per-acre rate of 80 lb. N, 44 lb. P (100 lb. P_2O_5), 83 lb. K (100 lb. K_2O).
[2] Average of four replications.
[3] Formerly Kalmia.
[4] Formerly Norfolk.
[5] Formerly Greenville.

at which it will respond to an application of lime. For example, the unlimed Norfolk sandy loam had a pH of 5.5 in 1954. After 5 years and 400 pounds per acre of N from ammonium nitrate, the soil pH was 5.8. Similar variations in soil pH occurred with the Magnolia and Dothan (formerly Norfolk) soils.

One of the reasons for these fluctuations in soil pH on the unlimed soils is the unexplained year-to-year variations previously noted. In addition to this unexplained fluctuation, there is a seasonal fluctuation in soil pH that is greater but better understood. It is caused by differences in amounts and kinds of fertilizer remaining in the soil as a result of uptake of mineral nutrients by plants, action of soil microorganisms on organic matter and nitrogen, and leaching of the soil by excess water. Soils are most acid following the addition of fertilizers and nitrification of ammonia fertilizers. The soil pH increases gradually but erratically following nitrification and reaches its highest value in late winter or early spring. This seasonal change in soil pH is frequently in excess of 0.5 pH unit, especially on coarser textured soils. No effort was made to sample the soils of this experiment at the same time of year. Thus, differences in soil pH of the same unlimed soil in different years, Table 6, resulted from seasonal as well as annual fluctuations. Seasonal fluctuation is probably the main reason that soil samples taken in 1962 were no more acid than those taken in 1954 even though 640 pounds of N per acre from acid-forming ammonium nitrate had been added between the sampling dates.

Following 3 years of corn and the addition of 900 pounds per acre more of acid-forming ammonium nitrate, cotton was again planted at four locations. The second sequence (1965-66) of continuous cotton showed a greater yield increase from liming at three of the locations than was shown during the 1954-1961 period. The yield response to lime on the Hartsells soil was about double. On Norfolk and Lucedale (formerly Greenville) soils there was a significant yield response to lime where there was none during the first sequence. However, liming the Decatur soil at the Tennessee Valley Substation still had no effect on cotton yield.

TWO-YEAR ROTATION OF COTTON-VETCH-CORN, 1960-1966

The experiment with a 2-year rotation of cotton-vetch-corn was established in 1929 and 1930 at several different sites throughout Alabama. Although the experiment had been discontinued by 1960 at a few locations, it was still being conducted at seven locations.

There were 15 different treatments, each replicated 4 times, in the entire experiment. One of the well fertilized treatments had remained unlimed since its establishment, while a comparable treatment had been limed periodically to maintain the soil pH near 6.0. Fertilizer rates were increased from time to time to keep them current with recommended practices. The last fertilizer adjustment was made in 1960. Only the cotton yields obtained since that time are considered here.

The yields of seed cotton on the limed and unlimed soils at the various experimental sites are reported in Table 7. Only four of the seven soils showed a yield response to lime even though soil pH was less than 5.5 at all sites except at Alexandria. There was no yield response to lime on the Lucedale soil even at a pH of about 5.0. Neither was there a yield response to lime on the Decatur soil at Belle Mina with a pH barely greater than 5.0.

TABLE 7. EFFECT OF LIME ON YIELD OF SEED COTTON IN A TWO-YEAR ROTATION OF COTTON-VETCH-CORN AT EIGHT LOCATIONS IN ALABAMA, 1960-1966[1]

Locations	Soil type	Acre yield of seed cotton[2]		pH of unlimed soil	
		Unlimed	Limed	1958	1963
		Lb.	*Lb.*		
Main Station, Auburn[3]	Alaga (formerly Lakeland) loamy sand	2,080	2,670	----	5.1
Brewton Experiment Field	Norfolk (formerly Kalmia) sandy loam	1,800	2,120	5.1	5.3
Monroeville Experiment Field	Magnolia fine sandy loam	1,730	2,140	4.8	5.0
Wiregrass Substation, Headland	Dothan (formerly Norfolk) sandy loam	2,310	2,750	5.4	4.9
Prattville Experiment Field	Lucedale (formerly Greenville) sandy clay loam	2,210	2,290	5.2	4.9
Sand Mountain Substation, Crossville	Hartsells fine sandy loam	2,170	2,500	5.2	5.2
Alexandria Experiment Field	Decatur clay loam	1,980	1,970	5.8	5.6
Tennessee Valley Substaton, Belle Mina	Decatur clay loam	2,320	2,090	5.4	5.1

[1] Fertilized annually at per-acre rate of 60 lb. N, 26 lb. P (60 lb. P_2O_5), 50 lb. K (60 lb. K_2O).

[2] Average of 4 replications.

[3] Three-year rotation of cotton-winter legume-corn-oats-soybean.

The lack of yield response to lime on Lucedale (formerly Greenville) and Decatur soils is in sharp contrast to the 300- or 400-pound increase in seed cotton per acre obtained by liming Norfolk (formerly Kalmia), Magnolia, and Dothan (formerly Norfolk) soils at about the same pH.

When the response to lime in this experiment is compared with that of other experiments at the same locations, it becomes apparent that cotton yields were less affected by low soil pH in the 2-year rotation of corn-cotton-vetch than in the experiments of continuous cotton and 2-year rotations of cotton and corn. The reason for this is not known, but the data strongly suggest that long-term cropping systems influence in some unexplained manner the critical soil pH at which liming increases crop yield on a particular soil.

SOURCE OF NITROGEN EXPERIMENT, 1960-1966

An experiment was established in 1929 and 1930 at several locations in the State to determine if lime affected relative merits of different nitrogen fertilizers. It was a 2-year rotation of cotton and corn and consisted of 15 different treatments, each replicated four times. The experiment had been discontinued at all but four locations by 1960 and has since been discontinued at two of these.

The treatments included in this report have been altered since establishment of this experiment only by increasing annual rates of fertilizer to keep them with current recommendations. The last fertilizer-rate change was made in 1960, and only yield data since that time are reported here.

The continuous use of equal N rates from ammonium sulfate, ammonium sulfate plus lime, or sodium nitrate resulted in widely different soil pH levels after several years. These soil pH values in 1960 and average cotton yields since 1960 for each treatment are given in Table 8.

The detrimental effect of very low soil pH on cotton yield was quite striking on the Magnolia, Dothan (formerly Norfolk) and Hartsells soils. Practically no cotton was produced on the most acid Hartsells soil (pH 4.5), primarily because seedlings failed to survive in the spring. Yields were less than one-half maximum on the most acid Magnolia (pH 4.8) and Dothan (pH 5.2) soils. On the other hand, maximum yield was made on the Decatur soil at pH 5.1.

TABLE 8. EFFECT OF SOIL pH ON YIELD OF SEED COTTON IN A NITROGEN-SOURCE EXPERIMENT IN A TWO-YEAR ROTATION OF COTTON AND CORN AT FOUR LOCATIONS IN ALABAMA, 1960-1966[1]

Location	Soil type	Years	Ammonium sulfate[2]		Ammonium sulfate+lime[2]		Sodium nitrate[2]	
			Yield	Soil pH in 1960	Yield	Soil pH in 1960	Yield	Soil pH in 1960
			Lb./A.		*Lb./A.*		*Lb./A.*	
Monroeville Exp. Field	Magnolia fine sandy loam	1960-63	840	4.8	2,020	5.6	2,130	5.7
Wiregrass Substation, Headland	Dothan[3] sandy loam	1960-61	790	5.2	1,680	6.0	1,770	5.9
Sand Mt. Substation, Crossville	Hartsells fine sandy loam	1960-66	110	4.5	2,380	5.5	2,030	6.1
Tenn. Valley Substation, Belle Mina	Decatur clay loam	1960-66	2,250	5.1	2,310	5.7	2,160	5.9

[1] Fertilized annually at per-acre rate of 72 lb. N, 26 lb. P (60 lb. P_2O_5), 50 lb. K (60 lb. K_2O).

[2] Average of four replications.

[3] Formerly Norfolk.

SUBSOIL ACIDITY

The effect of subsoil acidity on crop yields has not been adequately determined primarily because the subsoil is so inaccessible. It is both tedious and laborious to adjust and control subsoil pH without altering many other soil properties. The investigations reported here are probably the first field experiments with cotton in which subsoil pH has been altered with reasonable control of other variables.

To determine the effect of low subsoil pH on cotton yields, three field experiments were conducted on Coastal Plains soils in central and southern Alabama during 1962-1966. The different subsoil acidity levels had been clearly established by prior additions of nitrogen fertilizers and lime without disturbing the subsoil. Subsoil pH differences had been created at each site by surface applications of nitrogen fertilizers of different residual acidity values.

The soil profile of each plot was carefully sampled prior to the experiment and the surface soil was differentially limed with a very fine lime (finer than 100-mesh) to adjust the surface soil to the pH range of 6.0 to 6.5. Each treatment was replicated four times.

The results in Table 9 show that cotton yields were significantly reduced where limed and fertilized surface soils were underlain by strongly acid subsoils (pH 5.0 or less). Moderately acid subsoils (pH 5.2 to 5.5), however, had no adverse effect on yields. The unusually low subsoil pH values of Lucedale (formerly Greenville) soil were caused by the rapid manner in which this soil was acidified. These plots had received up to 1,000 pounds of nitrogen per acre as ammonium sulfate in each of the two preceding years; insufficient time had elapsed for leaching to have removed the excess acid and salts retained by the subsoil.

Cotton plants on the most acid subsoil plots appeared normal but shorter than those on less acid subsoil plots. Excavation along the ends of rows showed that roots failed to proliferate extensively in the subsoils and resulted in smaller plants and lower yields. Lack of root growth in the subsoil zones was also evident during the growing season by the early onset of wilting. Plants on the most acid subsoils showed signs of wilting in midseason within 3 or 4 days following a rain, whereas those on moderately acid subsoils were able to withstand droughts of 10 to 14 days without wilting.

Data in Table 9 show that, even though strongly acid subsoils reduce cotton yields, acid subsoils are not as detrimental to cotton as are equally acid surface soils. The range in subsoil

TABLE 9. EFFECT OF SUBSOIL ACIDITY ON YIELD OF SEED COTTON AT THREE LOCATIONS IN ALABAMA

Location	Soil type	Years	Subsoil (6-12 in.)	Average acre yield[1]
			pH	*Lb.*
Headland	Dothan (formerly Norfolk) sandy loam	1962-64	5.0	1,620 b
			5.5	2,680 a
			6.4	2,620 a
Monroeville	Magnolia fine sandy loam	1964-66	4.9	1,710 b
			5.4	2,040 a
			6.0	1,810 ab
Thorsby	Lucedale (formerly Greenville) fine sandy loam	1965-66	4.2	1,380 c
			4.4	1,770 b
			5.2	2,170 a
			5.9	2,140 a

[1] Average of four replications. Yields followed by the same letter within a soil type are not different at the 0.01 probability level.

acidity established by surface applications of nitrogen fertilizers and lime, Table 9, also show that subsoil pH will be maintained within a favorable pH range if the surface soil pH is maintained within the pH range that is favorable for plants.

RESPONSE BY PHYSIOGRAPHIC REGION

Coastal Plains Soils

There are 18 different liming experiments on Coastal Plains soils reported here. The most complete data on liming a particular soil for cotton have been obtained on the Brewton, Monroeville, and Prattville Experiment Fields. The results of five experiments each at the Brewton and Monroeville Experiment Fields and three experiments at Prattville Experiment Field are reported. From the results of these experiments, a distinct pattern between soil pH and response of cotton to lime is evident.

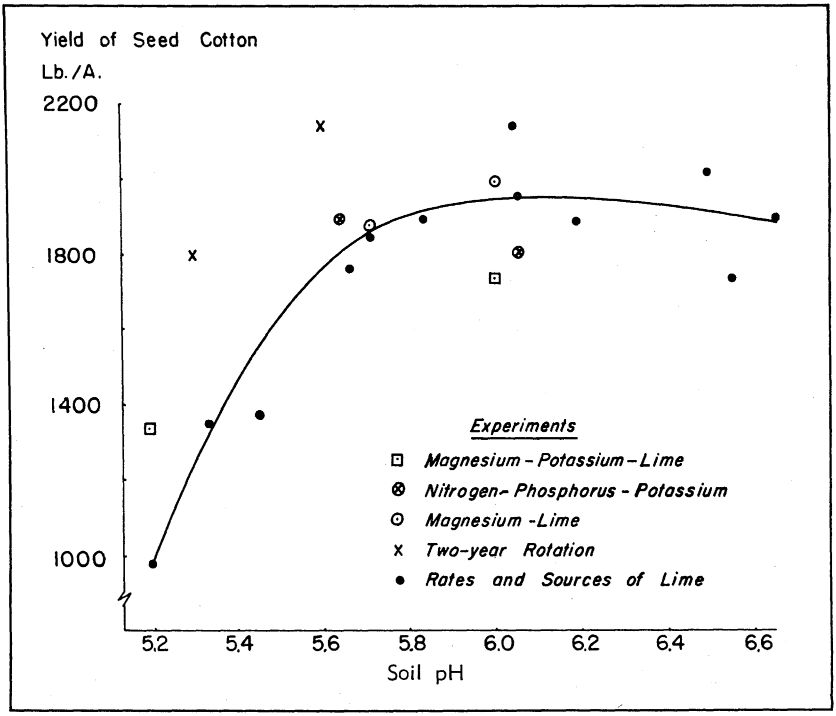

FIGURE 2. Effect of soil pH on yield of seed cotton in five experiments on Norfolk (formerly Kalmia) sandy loam near Brewton, Alabama.

The average cotton yields at Brewton for all limed and unlimed treatments reported in the tables are plotted in Figure 2 against the average soil pH for each. It is clearly evident from these data that cotton yields were progressively lower as the soil pH decreased below about 5.8. The data plotted in Figure 3 show remarkably similar results from cotton on the Magnolia soil at Monroeville. The results from experiments on Dothan (formerly Norfolk) soil at Headland and on Alaga (formerly Lakeland) soil at Auburn were also similar to those on Norfolk (formerly Kalmia) and Magnolia soils.

In sharp contrast to these results are those from experiments on Lucedale (formerly Greenville) soil at the Prattville Experiment Field. The data reported in Tables 3, 6, and 7 show soil pH values ranging from 5 to 7, yet there was only a slight yield reduction on the most acid soil. Similar results were obtained from the one experiment on Savannah very fine sandy loam at Winfield, Table 6.

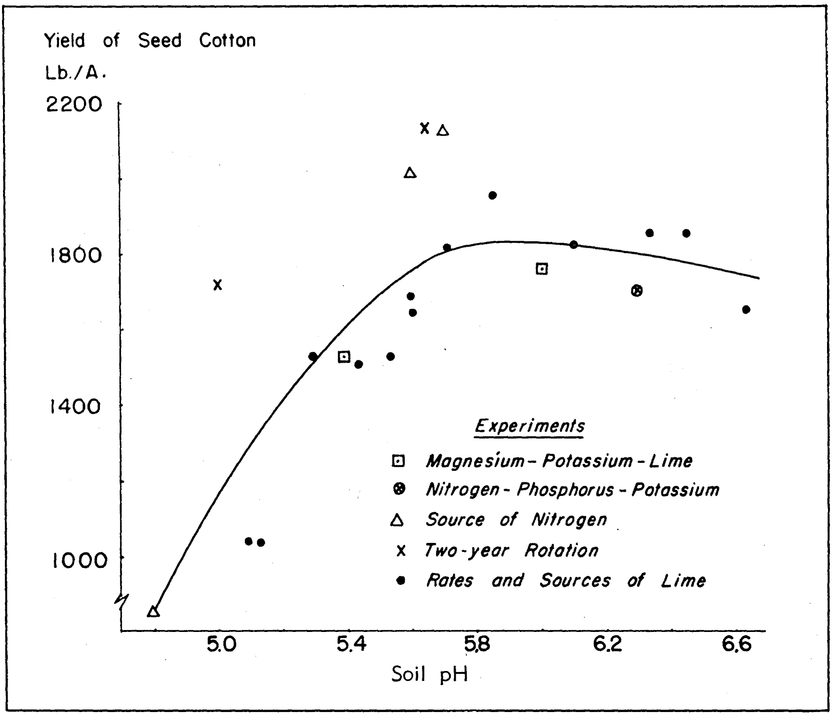

FIGURE 3. Effect of soil pH on yield of seed cotton in five experiments on Magnolia fine sandy loam near Monroeville, Alabama.

Appalachian Plateau (Sand Mountain)

The results of four experiments on Hartsells soil at the Sand Mountain Substation are graphed in Figure 4. There appears to have been no yield reduction in cotton until the soil pH was somewhat below 5.5. However, at pH 4.5 cotton yields were almost nil.

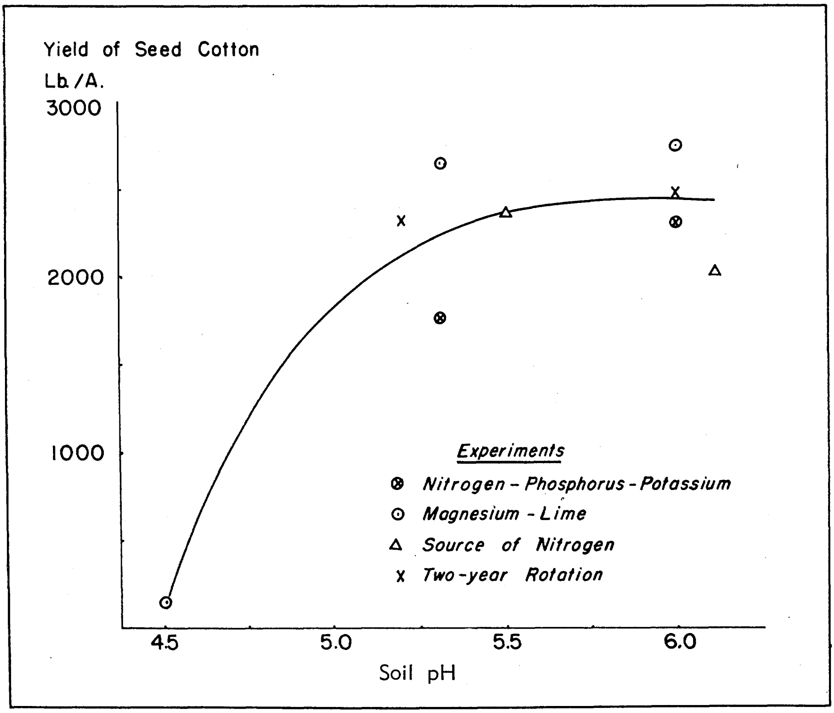

FIGURE. 4. Effect of soil pH on yield of seed cotton in four experiments on Hartsells fine sandy loam near Crossville, Alabama.

Limestone Valleys

Cotton yields were not affected by liming in any of the six experiments on the red soils of the limestone valleys. Since soil pH of the unlimed soils ranged between pH 5.1 and pH 5.7, it is obvious that soil pH must be less than about 5.0 before cotton yields are adversely affected by excess soil acidity on those soils.

SUMMARY AND CONCLUSIONS

Results of 31 different field experiments are reported. The experimental sites were located throughout Alabama and represent some of the major soil types in the State. Since all experiments were conducted without supplemental irrigation, there were considerable differences in yields from year to year as a result of rainfall differences. However, the average yield on the limed soil was near 2,000 pounds of seed cotton per acre in most experiments. The lowest average yield on limed soil was 1,420 pounds of seed cotton per acre at Alexandria and the highest yield was 2,990 pounds per acre on a similar soil at Belle Mina. These are considered to be good yields for solid-planted, nonirrigated cotton in Alabama.

The following conclusions are drawn from these experiments:

(1) There is a relatively wide soil pH range within which cotton yield is not greatly affected by soil pH. However, yields are greatly reduced by increasing acidity after the soil has become acid enough to slightly reduce yields.

(2) The maximum soil pH at which cotton responds to lime varies with different soils. Soils with the highest pH (above 5.5) at which cotton responded to liming were Alaga (formerly Lakeland), Dothan (formerly Norfolk), Magnolia, and Norfolk (formerly Kalmia); soils with lowest pH (less than 5.0) for response to liming were Decatur and Lucedale (formerly Greenville); soils with intermediate pH for response to liming were Hartsells and Savannah.

(3) Magnesium deficiency occurred on some soils where the source of limestone was calcitic instead of dolomitic.

(4) There is considerable fluctuation in soil pH from year to year and from season to season on the same soil area.

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