COTTON RESPONSE TO P IN ALABAMA'S LONG-TERM EXPERIMENTS

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Abstract

Thirteen long-term soil fertility experiments (circa 1928 and 1954) at five locations in Alabama have been in a residual P mode since 1982, producing crops on variable soil P levels from P rates applied prior to 1982. Soil test calibration for cotton using Mehlich-1 extract during 1992-1998 indicate that critical values in use by state soil testing laboratories are well within reason for new cultivars and modern cultural practices. There is no need to adjust the critical soil-test values currently in use in Alabama, 25 mg P/kg for soils with CEC < 9 cmol/kg (Coastal Plain soils) and 15 mg P/kg for soils with CEC>9 cmol/kg (Limestone Valley soils). Based on a comparison between 'Deltapine NuCotn35B' (DP35B) and 'Deltapine DP5690' (DP5690) cultivars at one location, there is no difference in responsiveness to residual soil P. However, the new Bollgard® variety, DP35B, averaged 80 pounds lint per acre per year more than the conventional variety. Soil-test P does not appear to change dramatically over a 15-yr period when no fertilizer P is applied. Decreases in Mehlich-1 extractable P at the higher residual P levels is probably associated with shifts in the soil P fractions in the soil rather than with crop removal, runoff, or leaching.

Introduction

Phosphorus fertilization of cotton is one of the oldest fertilizer practices used in the Southeastern U.S. Jones and Bardsley (1968) report that the discovery of rock phosphate in South Carolina in 1867 and in Florida in 1887 culminated in a superphosphate industry in the heart of the old cotton belt. They point out that many of the early experiments with P application to cotton in the Southeastern U.S. showed yield responses up to about 40 pounds P_2O_5 per acre. A 1965 survey found that most agronomists from Alabama to Virginia commonly recommended 60 to 80 pounds P_2O_5 per acre for upland cotton.

Alabama's early P recommendations were based on P-rate experiments maintained by the Alabama Agricultural Experiment Station on research substations in the major land resource areas of the state and on smaller experiment fields in minor soil regions. Six of these experiments which were started in 1928 are still maintained today and are known as the "Two-year Rotation" experiments because they have always involved cotton, corn, sorghum, soybean or peanut rotations (Cope, 1984). Five of these have included cotton since 1992. As a result of standard P recommendations through the early 1950s, many fields in long-term cotton production, had reached high or very high soil P levels and were no longer responsive to additional P applications. The Auburn University soil testing laboratory began service in 1954 to help cotton and corn producers identify those fields that no longer needed additional P application but could benefit from other soil amendments. However, soil test summaries for cotton samples from the Auburn University Soil Testing Laboratory since the early 1960s seem to indicate a gradual trend toward lower soil test P values (Fig. 1). More samples are testing "medium" and "low" in P while fewer samples are testing "high" and "very high". Possible explanations for this trend include (1) use of less P fertilizers for cotton, (2) deeper tillage which dilutes residual soil P, (3) soil erosion, (4) P fixation by soil minerals, and (5) failure of growers/consultants to routinely sample high-testing fields. A cotton soil fertility survey of 312 Alabama cotton fields in 1991 pointed out declining plow layer soil test P levels but identified only 10 percent of the fields which had leaf samples below the established sufficiency range for P; only 9 percent of the plow layers tested "low" or "very low" in P (Mitchell et al., 1992).

In order to maintain a sound research basis for its soil testing services, Auburn University and the Alabama Agricultural Experiment Station established additional soil test calibration experiments in 1954. These new soil fertility experiments were known as the "Rates of N-P-K" experiments and have been continued at seven locations since their establishment. Cotton has been planted on these experiments more than any other crop (Table 1). Five of the seven experiments have been planted in cotton every year since 1992.

In spite of a strong research basis for soil testing in Alabama, producers and their consultants often question the validity of soil test interpretations. No doubt part of this is due to a wide range of interpretations available from different public and private soil testing services, opinions of consultants, and competition for fertilizer sales. Emphasis on precision agriculture may have created expectations from soil testing beyond what it is capable of delivering. Nevertheless, as producers adopt new technologies, genetically improved varieties, and new production practices, they expect and deserve periodic verification of soil testing interpretations from their public laboratories.

The purpose of this study is to summarize cotton yield response to residual soil P since 1992 in order to validate or update Alabama's current soil test calibration for P using modern varieties with higher yield potentials. The P variables on the "Two-year Rotation" and "Rates of N-P-K" experiments have been in a residual mode since 1982. This also allows us to determine changes in soil test P under continuous cropping.

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Materials and Methods

The "Two-year Rotation" experiments (c. 1928) involve:

- 5 N rates
- 3 P rates prior to 1982 (0, 30, and 60 lb. P_2O_5/acre/rotation)
- 4 K rates
- a fertilized control (annual rate of 90-60-60 lb/acre N-P_2O_5-K_2O)
- a no-lime treatment
- low Mg
- no fertilizer plus lime
- + micronutrients
- untreated since 1928

The "Rates of N-P-K" tests (c. 1954) involve:

- 6 N rates
- 4 P rates prior to 1982 (0, 20, 40, and 60 lb. P_2O_5/acre/year)
- 5 K rates
- Fertilized control (annual rate of 90-100-100 lb/acre N-P_2O_5-K_2O)
- No lime
- Untreated since 1954

This study focuses only on the P variables in these experiments.

Since 1982, the P variable treatments in both experiments have been in a residual mode, i.e. they have not received any additional P applications. However, they continued to be fertilized with other nutrients as in the fertilized control. Having the experiments in a residual P mode allows true soil test P calibration because responses are a result of residual soil P and are not complicated by additional P fertilization. Only the fertilized control treatments continued to receive P fertilization. These treatments served as a standard for yield comparison. Plow-layer soil samples were collected from each plot every other year and analyzed by the Auburn University soil testing laboratory using the Mehlich-1 extraction procedure.

Soils in Alabama's Long-term Soil Fertility Experiments with Cotton

Brewton Experiment Field: Benndale loamy sand (*coarse-loamy, siliceous, thermic Typic Paleudults*)

Wiregrass Research & Extension Center: Dothan sandy loam (*fine-loamy, siliceous, thermic Plinthic Kandiudults*)

Monroeville Experiment Field: Lucedale fine sandy loam (*fine-loamy, siliceous, thermic Rhodic Paleudults*)

Prattville Experiment Field: Lucedale sandy clay loam (*fine-loamy,siliceous, thermic Rhodic Paleudults*)

Tennessee Valley Research & Extension Center: Decatur silt loam (*clayey, kaolinitic, thermic Rhodic Paleudults*)

Cropping sequences used on the two experiments are given in Table 1. Since 1992, the "Two-year Rotation" has been planted to a cotton-soybean or peanut rotation at 5 of the 6 locations. Five of the seven locations of the "Rates of N-P-K" test have been in cotton every year since 1992. All sites have been conventionally tilled (moldboard plow, disked or chisel, plant, and cultivate). Sites are not irrigated. Cultivars are the recommended varieties for that particular area of the state.. 'Deltapine DP5690' (DP5690) is a widely planted, standard cotton variety used in Central and South Alabama. With the introduction of genetically modified cotton that contained the Bt (Bollgard®) gene to combat cotton boll worm problems, many growers substituted 'Deltapine NuCotn 35B' (DP35B) for DP5690 beginning in 1996 when this cultivar was first released.. With the additional technology fee that growers had to pay for these new cultivars, they were concerned about how these new varieties would respond to soil fertility variables. A simple way to address this issue was to split the plots in the "Rates of N-P-K" experiment at one location and compare two similar varieties, one with and one without the Bollgard® technology. This was done on a Lucedale s.c.l. at the Prattville Experiment Field in Central Alabama in 1996, 1997, and 1998, using the two Deltapine cultivars.

To remove the large year-to-year variation in yield, yields are reported as a percent yield relative to the fertilized control treatment in each test for each year. The control treatments received a standard N rate of 90 pounds N per acre in split applications and a K rate of 60 pounds K_2O per acre in the "Two-year Rotation" and 100 pounds K_2O per acre in the "Rates of N-P-K" experiment. Actual mean lint yields are given in Table 2 for each test and year. Missing data were years and sites where the experiment was not planted or not harvested.

Table 1. Cropping systems used on the "Two-year Rotation" and "Rates of N-P-K" experiments at five Alabama locations.

Two-year Rotation (c. 1928)		Rates of N-P-K Experiment (c. 1954)	
Year	**Cropping system**	**Year**	**Crop**
1929	Cotton-winter legume-corn-winter legume	1954	Cotton
1967	Corn-wheat-soybean	1962	Corn
1978	Corn-soybean	1965	Cotton
1982	Grain sorghum-soybean or peanut	1973	Corn or sorghum
1989	Tropical corn/small grain-soybean	1989	Sweet potato (3 locations)
1992	Cotton-soybean or peanut	1992	Cotton

Table 2. Mean cotton lint yields on the fertilized control plots on the "Two-year Rotation" and "Rates of N-P-K" experiments, 1992-1998.

	Location				
	Brewton	**Wiregrass**	**Monroe-ville**	**Prattville**	**Tennessee Valley**
Year	Pounds lint/acre				
	"Two-year Rotation"				
1992	1080	770	--	1320	1270
1993	1080	550	800	650	1030
1994	540	--	800	1340	1270
1995	1400	730	740	340	590
1996	1040	800	1020	930	930
1997	340	550	620	1360	1070
1998	620	--	890	1080	810
	"Rates of N-P-K"				
1992	760	950	420	1480	1490
1993	--	670	1250	660	920
1994	500	--	970	1290	1180
1995	--	790	900	140	740
1996	1030	830	1020	1280	1420
1997	930	620	820	1180	1170
1998	780	--	1030	1100	1090

Results and Discussion

Soil Test Calibration using Relative Yields

When Mehlic-1 extractable soil P is calibrated with relative cotton yields for each of the experiments at each of the five location, several locations and tests fail to demonstrate a response to increasing levels of residual soil P. Treatments on all soils except the Lucedale s.c.l. at Prattville Experiment Field would be rated "low" by the southern public soil testing laboratories (Table 3). Failure to get dramatic responses all the time demonstrate the inherent difficulties of trying to make soil testing a definitive and infalible tool. However, when yield and soil data from both tests at all Coastal Plain locations over the entire 7-yr period are pooled (Fig. 2), a reasonable critical value for Mehlich-1 extractable P can be estimated. The current critical value used by the Auburn University Soil Testing Laboratory for these soils is 25 mg P/kg. The Soil Science Society of America (1997) defines *critical soil test concentration* as ". . . that concentration at which 95% of maximum *relative yield* is achieved. . . usually coincides with the inflection point of a curvilinear yield response curve." Above this value, no fertilizer P is recommended because the probability of a yield response is extremely low. Below this value, P is recommended in increasing increments. Alabama's critical value is within the range used by other public soil testing laboratories in the region for Mehlich-1 P and cotton on Coastal Plain soil (18 to 30 mg P/kg). No attempt was made to fit a regression to these data because the purpose was to determine if the current critical values are still valid for modern yields, cultivars, and production practices. Evans (1987) summarized calibration results in on-farm tests for 7 Alabama crops on Coastal Plain soils and found a critical Mehlich-1 extractable P level of 18 mg/kg, somewhat lower than the 25 mg/kg value that has been used. He used the following regression for the responsive region of the curve in Fig. 2.

$$\textit{Relative yield} = 54.6 + 4.86\,(M\text{-}1\ P) - 0.132\,(M\text{-}1\ P)^2$$

The fine-textured soils of the Tennessee Valley have a high P fixation capacity and a lower critical P value as currently used by the Auburn University Soil Testing Laboratory (Adams et al., 1994). These data verify the current value of 15 mg P/kg for these soils (Fig. 2). Other state laboratories also recognize lower critical values for finer textured soils (Table 3).

The current soil test calibration for P on cotton as used by the Auburn University Soil Testing Laboratory was established by Rouse (1968) and verified and updated in numerous Alabama Agricultural Experiment Station reports since then. (Cope, 1970, 1983, 1984; Burmester et al., 1981; Adams et al.; Cope et al., 1981). While the 25 mg P/kg value used for Coastal Plain soils (soils with CEC < 9.0 cmol/kg) is higher than that proposed by Evans (1987) and will result in more P fertilizer recommended for cotton than Evans's suggestion, it is still a reasonable critical value considering values used throughout the region and the fact that we are seeing declining soil test P levels in Alabama cotton soils. The values in use still appear as accurate as possible.

Table 3. Calibration of Mehlich-1 extractable P for cotton by state soil testing laboratories in the southeastern U.S..

State	Soil test rating for P		
	Low	Medium	High (critical value)
	---------------Extractable P (mg/kg)--------------		
Alabama			
CEC<9	<12.5	12.5-25	25+
CEC=9+	<7.5	7.6-15	15+
Florida			
All soils	<7.5	7.6-30	30+
Georgia			
Coastal Plain	<15	15-30	30+
Piedmont	<10	10-20	20+
South Carolina			
Coastal Plain	<15	5-30	30+
Piedmont	<10	10-20	20+
Tennessee			
All soils	<18	19-30	30+
Virginia			
All soils	<6	6-18	18+

Bollgard® Versus Standard Variety

There was no interaction between residual soil P and yield, but there were significant differences ($P<0.05$) in yields between the two cultivars for each year (Table 4). The genetically improved Bollgard® variety, DP35B, yielded an average of 80 pounds lint per acre per year more than the standard variety, DP5690. The test was routinely scouted for insects and sprayed as needed for insect control. Nevertheless, the differences may be attributed to more effective boll worm control in the Bollgard® variety.

Table 4. Comparison of mean yields of DP35B and DP5690 across all P variables in the “Rates of N-P-K” experiment at Prattville Experiment Field, 1996-1998. There was no interaction between soil P levels and yield during this time.

Year	Cultivar	
	DP35B	DP5690
	---------Pounds lint/acre---------	
1996	1160	1120
1997	1220	1150
1998	1080	950
3-yr mean	*1150*	*1070*

Changes in Soil Test P over 15 Years

Under the conditions of these experiments, Mehlich-1 extractable, plow-layer P did not change dramatically over a 15-year period when no fertilizer P was applied (Fig. 3). The only exception was the Dothan s.l. at the Wiregrass Research & Education Center. Because of missing data in the “Rates of N-P-K” experiment, the “Two-year Rotation” experiment was used at this site to track changes. There is a decline in extractable P during the 15-yr period at the higher soil test P levels. Even the highest P rate which was applied annually resulted in a gradual decline in soil test P. This site may be an anomaly since the other sites did not show this trend. These research sites are protected from soil erosion and losses from crop removal by the crops produced during the 15-year period were minimal since only grain or seed cotton was removed. Of course, higher yields at the higher P levels at some locations would have resulted in somewhat higher P removal by crops. Conventional tillage practices have changed very little on these experiments over the 15-yr period. Therefore, we conclude that continuous cropping under the conditions of these experiments will have little effect on soil test P over a 15-yr period. Once soil test values reach a “high” rating, growers can expect them to stay near this value for many years even with no additional P fertilization. In fact, at all sites, “high” soil test P levels in 1982 remained “high” in 1997 although the actual values may have dropped.

Summary

Soil test calibration for cotton using Mehlich-1 extract on five Alabama soils during 1992-1998 indicate that critical values in use by state soil testing laboratories in the southeastern U.S. are well within reason for new cultivars and modern cultural practices. There is no need to adjust the critical values currently in use in Alabama, 25 mg P/kg for soils with a CEC < 9 cmol/kg (Coastal Plain soils) and 15 mg extractable P/kg for soils with a CEC>9 cmol/kg (limestone valley soils). Based on a comparison between DP NuCotn 35B and DP5690 cultivars, there is no difference in responsiveness to residual soil P. However, the new Bollgard® variety, DP35B, averaged 80 pounds lint per acre per year more than the conventional variety. Soil test P does not appear to change dramatically over a 15-yr period when no fertilizer P is applied.

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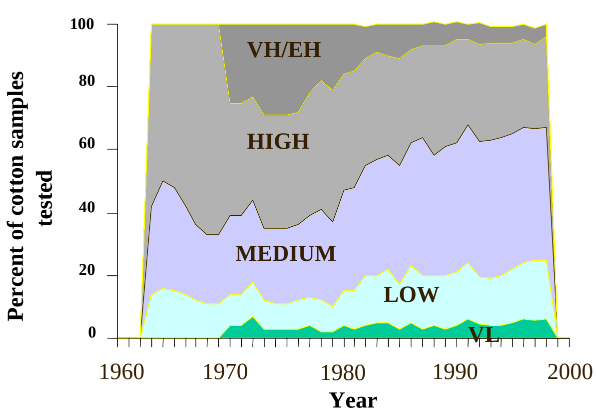


Figure1. Soil test P ratings for Alabama soils, 1963-1998.

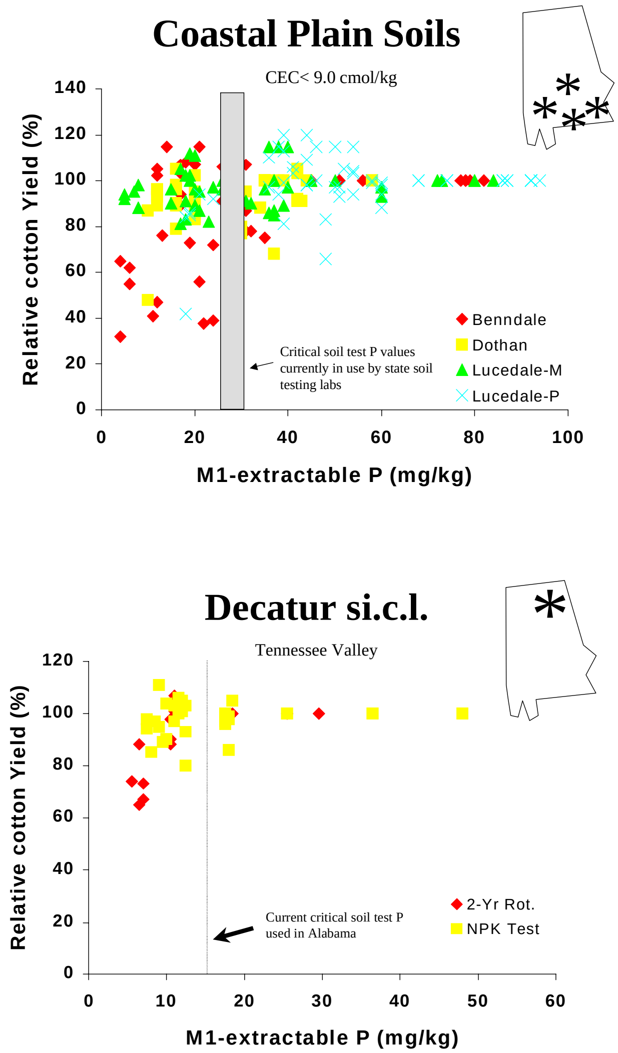
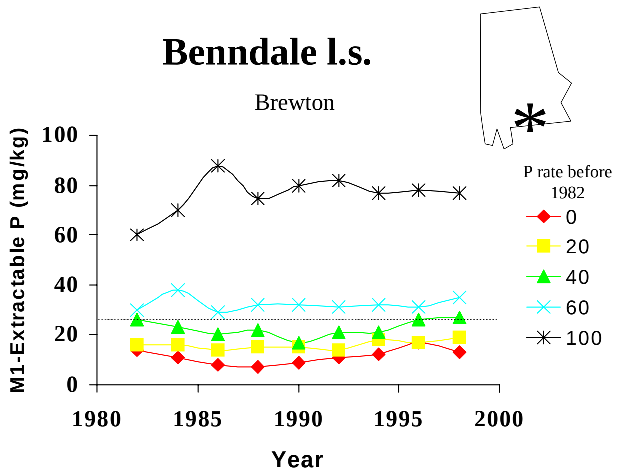
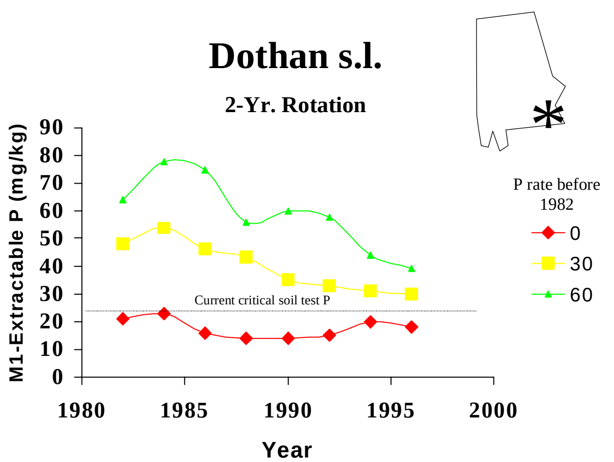


Figure 2. Mehlich-1 soil test calibration for cotton based on data from Alabama's "Two-year Rotation" and "Rates of N-P-K" experiments at five Alabama locations. Shaded area includes the current critical Mehlich-1 extractable P values used by public soil testing laboratories in Alabama, Georgia, Florida, South Carolina, and Tennessee. All Coastal Plain soils in these experiments had CEC < 9.0 cmol/kg.





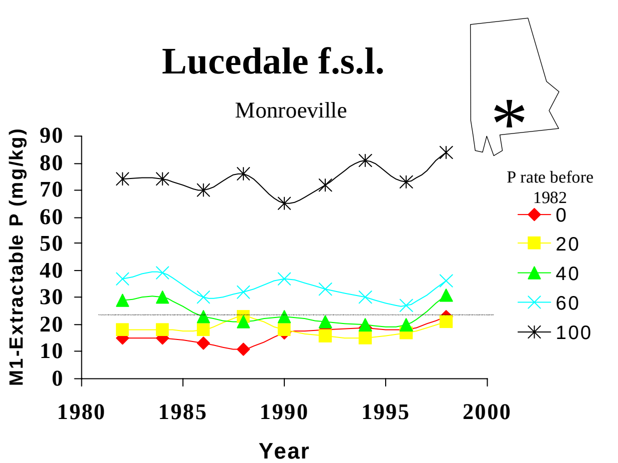
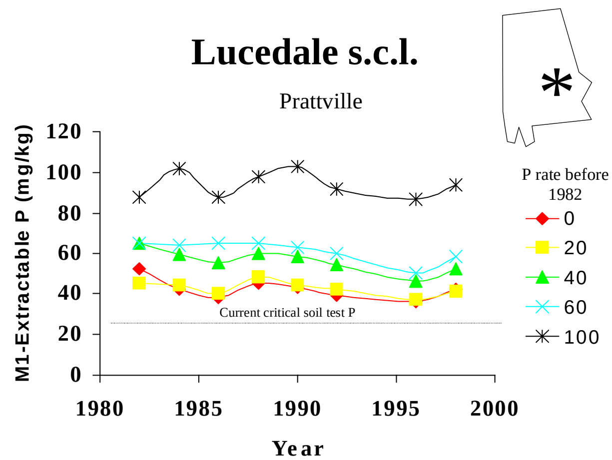


Figure 3. Changes in Mehlich-1 extractable, plow-layer P during a 15-yr period of no P fertilization at five locations. Annual P rates are those used prior to 1982; the highest P rate was applied during the residual study (continued).



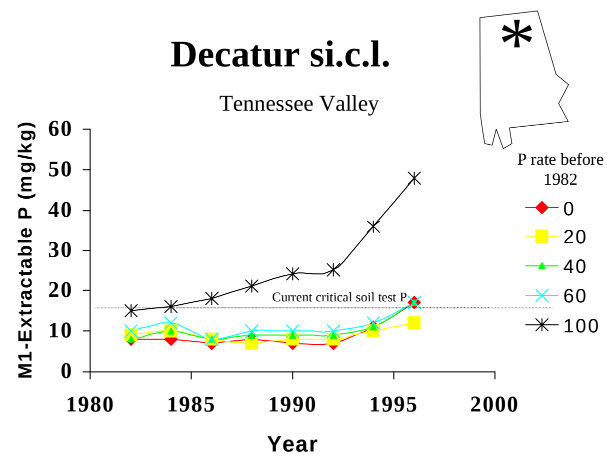


Figure 3. (continued). Changes in Mehlich-1 extractable, plow-layer P during a 15-yr period of no P fertilization at five locations. Annual P rates are those used prior to 1982; the highest P rate was applied during the residual study (continued).