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Response of Peanuts and Other Crops to Fertilizers and Lime in Two Long Term Experiments[1]

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ABSTRACT

Two long term fertility experiments on a Dothan fine sandy loam (Plinthic Paleudult) included peanuts for short periods. Peanuts were in a rate of N-P-K experiment during 1973-75 and 1981-83. They did not respond to N. Mehlich-1 extractable soil test P dropped from 30 mg/kg in 1954 to 11 mg/kg by 1983. No yield response to P was found for any crop. The soil test K level of 44 mg/kg remained about the same over the 30 years. Cotton yield was doubled by the addition of 37 kg/ha of K, which also increased the soil test level to 56 mg/kg. Peanut and corn yields were increased by 19 kg/ha K, with no further response to higher rates. The addition of lime produced large yield increases from all three crops.

A 2-year rotation experiment from 1929 through 1983 included cotton, corn, soybeans, and wheat at different periods until 1982 and 1983, when the crops were peanuts and grain sorghum. Soil test P in 1929 was 33 mg/kg. No response to P was found on summer crops in over 50 years, and soil test P decreased to only 21 mg/kg during this period. Plots that received no K maintained a constant soil test K level of about 36 mg/kg for 54 years. Annual applications of 28 kg/ha increased the level to around 60 mg/kg. Cotton and grain sorghum produced maximum responses to this rate of K. When peanuts were planted in this experiment for the first time in 1982 and 1983, they produced no response to K. All crops except wheat responded to lime.

Key Words: Response to fertilizers, soil tests, fertility build-up or depletion, response to lime.

Peanuts (*Arachis hypogaea* L.) are generally recognized to be less responsive to direct fertilization than most crops with which they may be rotated. The level of production is related to soil fertility, and they are known to reduce nutrients in soils to levels that will be deficient for other crops. In a recent review on liming and fertilization of peanuts, Cox et al. (7) found few recent reports of response to N, P, or K. Since *Rhizobium* that cause nodulation in peanuts belong to the cowpea cross-inoculation group and are widespread in peanut growing areas, nodulation commonly occurs which eliminates the need for N fertilization. Occasional responses reported have usually been on small seeded varieties, on soils very low in organic matter, or where no effective rhizobia were present.

Soil test P levels that are adequate for peanuts are lower than those required for most other crops. Responses reported have in most cases been on unfertilized soils that were very low in P. Fertilization usually results in a buildup of P in peanut soils because of the low amount removed in the nuts and the low fixing capacity of sandy soils on which they are grown. Scarsbrook and Cope (9) and Hartzog and Adams (8) found no response to P in cooperative experiments with farmers on previously fertilized fields. No reports were found of recent research which showed a response to P by peanuts in the Southeastern United States.

Volk (11) found that digging peanuts for several years reduced soil K to extremely low levels and that cotton (*Gossypium hirsutum* L.) following peanuts was subject to leaf rust. Skinner et al. (10) obtained no yield increase on peanuts from 53 kg/ha of K but found that cotton rotated with peanuts should receive enough K to supply both crops. Walker et al. (12) found a response to K only on soils "quite low in K". Scarsbrook and Cope (9) reported an average yield increase of 170 kg/ha of peanuts in 13 cooperative experiments where soil K was low but no response in 5 tests where soil K was high. Hartzog and Adams (8) reported no response to P and K in 34 experiments and concluded that adding fertilizer directly to peanuts was not a good practice but that fertilizer should be added to crops rotated with peanuts. Negative responses to K fertilizer have been reported, especially where soil Ca supply is short.

A critical nutrient element in peanut production is Ca. Research in North Carolina in the 1940's showed that nut development was dependent on an adequate supply of Ca in the surface soil when nuts were developing (1,2). Numerous reports have shown a response to gypsum or lime when soil Ca was low. The need for Ca varies among cultivars, with large seeded cultivars generally having higher requirements than smaller seeded ones.

Soil test interpretation is based on yield response, and some of the most dependable information used for this purpose comes from long-term fertility experiments. This report presents data from two long-term fertility experiments on a Dothan fine sandy loam (fine loamy, siliceous, thermic Plinthic Paleudult) on the Wiregrass Substation at Headland, Alabama. The purpose of this report is to evaluate peanut response and soil-test values to long-term applications of N, P. K, Mg, and lime. Response of other crops in the rotation are also evaluated.

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Materials and Methods

N-P-K Experiment

This experiment was established in 1954 with six rates of N, five rates of P, six rates of K, and two pH levels. Plots were 6.4 by 15.8 m with 4 replications in completely randomized blocks. Treatments continued on the same plots for 30 years. Fertilizers were broadcast and soils turned in opposite directions in alternate years to minimize soil movement from plowing. Crops grown were cotton, 1954-61; corn, (*Zea mays* L.), 1962-64; cotton, 1965-72; peanuts, 1973-75; corn, 1976-79; and peanuts, 1981-83. The original soil pH was 5.6, soil test P was 30 mg/kg and K was 44 mg/kg. Soil samples were taken every 2 years and soil pH was maintained near 6.0 on all except the unlimed plots. Annual yields for all treatments were reported by Cope (3) for 1954 through 1969. Yields from 1970-82 are reported (6) along with soil test values for each treatment throughout the 30 years. Gypsum was applied to all plots annually at the rate of 187 kg/ha through 1969, when one of the N rate treatments was converted to a "no sulfur" treatment.

Two-Year Rotation

This experiment started in 1929, but was not in peanuts until 1982 and 1983. It was a 2-year rotation with two summer crops grown on adjacent tiers each year. Rotations were cotton-vetch (*Vicia villosa* L.) - corn 1929-67, soybeans (*Glycine max* L. Merr.)-corn-wheat, 1968-78; soybeans-corn, 1979-81; and peanuts-grain sorghum, (*Sorghum bicolor* Moench) 1982-83. Plots were 6.4 by 31.6 m with two replications on both crops. Treatments included rates of N, P, K, lime, Mg, S and micronutrients (Table 2). The standard treatment, which is assigned a relative yield of 100, received 30 kg/ha of P, 56 kg/ha of K and recommended rates of N for each crop. The "O-P" treatment received 15 kg/ha of P from 1929 through 1957 but no P during the periods reported. The "O-K" treatment received no K since 1928. Other K rates were continuous from 1957 through 1981.

Only the standard treatment received P and K in 1982-83. The "O-lime" treatment has been unlimed since 1928 and the "O-Mg" treatment has been limed as needed, with calcitic limestone and all other treatments have been limed with dolomitic limestone as needed. The micronutrient treatment received a mixture of Zn, B, Mn, Cu, and Mo broadcast before planting corn every other year beginning in 1959. Soil test values of original samples (stored since 1929) are presented along with those from samples taken in 1967, 1976, and 1983.

Soil test data are from Mehlich 1 extractions, which consist of 5 g of soil in 20 mL of .05 *N* HCl and .025 *N* H_2SO_4, and shaken for 5 min. Yield data were subjected to analysis of variance to determine significance at the 5% level. Soil test ratings are those defined by Cope et al. (5). For peanuts on low CEC soil, the *Medium* ranges for P and K are 13 to 25 and 20 to 40 mg/kg, respecitvely.

Early leafspot (*Cercospora arachidicola* Hori.) and late leafspot (*Cercosporidium personatum* (Berk. & Curt.) Deight.) diseases of peanuts were controlled with chlorothalonil applications on a 10 to 14 day schedule beginning approximately forty days after planting. Seven or eight applications were made annually. Insects were controlled as needed, and other best management practices used for each crop. Both experiments were unirrigated, and seasonal drought or excessive rainfall limited yields of all crops at some time during the experiments. Years of crop failures or low yields due to drought or other natural disasters are not included in the average yields presented in Tables 1 and 2.

Results and Discussion

N-P-K Experiment

Yields of the standard treatment for all crops are presented in Table 1 in kg/ha. Yields from other treatments are shown as percentages of the standard, to facilitate comparisons. Although the experiment included N rates for cotton, corn, and peanuts, yield data for these are not shown. Cotton and corn showed significant yield responses to 67 kg/ha of N with no response to higher rates. Peanuts showed no yield response to N during either period in which the crop was grown.

Table 1. Relative Yields of Cotton, Corn and Peanuts and Soil Test Values from Rates of P and K on Dothan fsl, 1956-83.

Annual Rate P	K	Seed Cotton 4 years 65-72	Peanuts 3 years 73-75	Corn 3 years 76-79	Peanuts 3 years 81-83	Soil test values by year 1965	1975	1983
		Crop and year[1]						
-kg/ha-		%				mg/kg		
						Soil Test P		
0	93	99	98	95	102	19	16	11
20	93	97	96	105	102	43	30	20
50	93	100	100	100	100	55	55	46
						Soil Test K		
50	0	45*	82*	85*	94	40	38	39
50	19	87*	96	103	103	55	41	44
50	37	99	99	105	100	56	65	61
50	56	98	98	102	99	63	80	63
50	74	98	96	103	108	65	88	68
50	93	2840 kg/ha	4390 kg/ha	5710 kg/ha	4360 kg/ha	67	84	77
						Soil pH		
No Lime		51*	57*	33*	34*	5.5	5.2	4.9
No Sulfur (after 1969)		--	100	99	104	---	---	---
CV		15	9	15	7	---	---	---
LSD(05)		13	7	15	9	---	---	---

[1]Crop was grown during the period indicated. Years of poor yields due to drought or other natural disasters were not included in the average.

[2]Original soil test values in 1954 were pH 5.6, P-30 mg/kg (High), and K-44 mg/kg (High for corn and peanuts, Medium for cotton).

*Indicates a significant difference from yield of the standard treatment at the 5% level.

Phosphorus. The original soil test P level in 1954 was 30 mg/kg, which is *High* (above 25 mg/kg). Where no P was applied, the level declined to 11 mg/kg, which is just below the *Medium* range of 13 mg/kg, by 1983. No crop showed a yield response to P during the 30 years of this experiment. Therefore, the data are presented only for P rates of 20 and 50 kg/ha, although rates of 10 and 30 kg/ha of P were included. The 20 kg/ha rate did not maintain the original *High* P level in the surface soil. This is attributed to an increase in plowing depth from 15 cm to 25 cm during the course of the experiment, which diluted the P accumulated in the surface soil. The 30 and 50 kg/ha rates increased the P level substantially over the 30-year period.

Potassium. The original soil test K level was 44 mg/kg (*High* for corn and peanuts and *Medium* for cotton). The soil K level of plots which received no K remained about the same over the 30-year period, showing that K released by mineral weathering maintained this level under continuous cropping.

Cotton showed large yield responses to K during 1954-61 and 1965-72. The optimum rate was 37 kg/ha of K, which doubled the yield in both periods (see Cope (3) for first period). This rate also increased the soil-test level to *High* for cotton. Peanuts showed yield increases from the application of 19 kg/ha of K from 1973-75 but not during 1981-83. Corn yields were also increased by adding 19 kg/ha of K. Higher K rates increased soil test K but not peanut or corn yield.

Soil test K fluctuated more from year to year than did soil test P. This was attributed to the extent of leaching of K caused by variable rainfall levels. In years of extreme summer drought, soil K was found to be higher in samples taken in the fall.

Lime and other nutrients. The most consistent yield response among all crops was to liming. Cotton yield was cut in half where no lime was applied at pH 5.5. Peanut yields were reduced by 1890 (1973-75) and 2880 (1981-83) kg/ha where no lime was applied. Corn yield was reduced by 2/3 at pH 5.2. Lack of Ca on the unlimed plots reduced SMK from72 to 58% and nuts were of poor quality. Percent SMK was not affected by rates of P or K. No response to sulfur was found on peanuts or corn after the "O-S" treatment was started in 1970.

Two-Year Rotation Experiment

Yields of cotton, soybeans, corn, wheat and grain sorghum are presented along with peanut yields in Table 2 so that responses can be compared on the same plots. Cotton, corn, wheat, and grain sorghum yields were increased by N fertilizer. Soybeans and peanuts did not respond to N. Yields from N rates are not included in Table 2 but have been published (3, 6).

Table 2. Relative Yields of Cotton, Soybeans, Corn, Wheat, Grain Sorghum and Peanuts and Soil Test Values from Rates of P and K on a Two-Year Rotation on Dothan fsl, 1959-83.

Annual Rate P	K	Crop and years[1]: Seed Cotton 6 years 59-67	Soybeans 10 years 68-81	Corn 10 years 68-81	Wheat 7 years 68-78	Grain Sorghum 2 years 82-83	Peanuts 2 years 82-83	SMK	Soil test values by year: 29	57	71	83
kg/ha		%							mg/kg			
									Soil Test P			
0	56	97	100	105	98	93	113	71	33	60	30	21
30	56	100	100	100	100	100	100	70	33	73	60	65
									Soil Test K			
30	0	58*	94*	91*	100	70*	104	71	45	37	32	38
30	28	106	100	98	97	95	105	73	45	52	56	72
30	56	3270 kg/ha	2280 kg/ha	5830 kg/ha	2760 kg/ha	6400 kg/ha	3120 kg/ha	71	45	62	65	96
30	112	102	98	98	94	101	86*	70	45	72	81	111
									Soil pH			
No Lime		90*	88*	87*	95	24*	79*	68*	5.8	5.5	5.3	5.1
									Soil Test Mg			
No Mg		98	100	94	93	96	111	71	18	21	20	16
									Soil Test Ca			
Plus Micro nutrients		107	100	101	93	99	104	71	170	140	170	140

[1]Crop was grown during the period indicated. Years of poor yields due to drought or othern natural disasters were not included in the average.

*Indicates a significant difference from the standard treatment at the 5% level.

Phosphorus. Soil test P had been built up to *High* levels (33 mg/ka) by fertilization prior to acquisition of the station in 1928. No response to P has been found on summer crops at this station in over 50 years. Response to P was found on winter legumes grown for green manure in the early years of this experiment. When the "O-P" treatment was begun in 1957, the soil test P level was 60 mg/kg (*Very High*). No yield response to P was found on any crop from 1957 through 1983. The soil test P level dropped to 21 mg/kg (*Medium*) during this 26-year period. When the experiment was planted to peanuts in 1982-83, the "O-P" plots produced the highest numerical yield of any treatment (nonsignificant), even though no P had been applied for 25 years.

Potassium. Maximum yield of all crops was produced with an annual K rate of 28 kg/ha or less. Cotton showed an average yield increase of 1370 kg/ha of seed cotton to 28 kg/ha of K during 1959-67. Soybeans and corn yields showed small but significant yield increases to 28 kg/ha of K from 1968-81, while wheat yield was not affected by K fertilizer. When the experiment was planted in peanuts and grain sorghum in 1982 and 1983 for the first time, no P or K was applied except to the standard treatment. The residue from an annual rate of 28 kg/ha K increased grain sorghum yield 1600 kg/ha. Peanut yields were unaffected by K fertilizer, even though none had been applied for 54 years. the "O-K" plots maintained around 36 mg/kg of soil test K during this period. This level is rated *Medium* for all crops by the Alabama soil testing laboratory. Annual applications of 28 kg/ha increased soil-test K to around 60 mg/kg (*High*). These data show tremendous differences in yield response to K among these crops. The ranking from greatest to least response to K was cotton > grain sorghum > corn > soybeans > wheat and peanuts. The latter two crops showed no response to K. The K rate of 112 kg/ha raised the soil test K level to 111 mg/kg (*Very High*), resulting in a significant decrease in peanut yield in 1982 and 1983.

Lime. All crops except wheat showed significant yield increases from liming. The most sensitive crop to soil acidity was grain sorghum, with many plants failing to survive during the seedling stage at pH 5.1 and soil test Ca level of 140 mg/kg, which is *Medium*. Peanut yields were reduced 660 kg/ha (21%) where no lime was applied at pH 5.1, and the percent SMK was reduced from 71 to 62%. Yields of cotton, soybeans and corn were reduced 10, 12, and 13 percent, respectively, where no lime was applied and as pH dropped from 5.5 to 5.1 during this cropping sequence.

Other Nutrients. No crop yield was significantly affected by using dolomitic instead of calcitic limestone. Soil test Mg remained near the original level of about 20 mg/kg from 1929 through 1983 where calcitic lime was used. These data support the present Mg rating of *High* for this soil. There was also no effect from adding a micronutrient mixture (B, Cu, Fe, Mo, Zn) to these crops.

Sub-soil Nutrient Levels. Achievement of maximum yield with 28 kg/ha of K or less annually on all of these crops was surprising. In order to determine if this lack of response was due to K reserves in the sub-soil, as found by Woodruff and Parks (13), individual plots were sampled by horizon to a depth of 90 cm. Samples from the Ap, Be, Btl, and Bt2 horizons, were analyzed for pH, P, K, and Mg to determine effects of these long term applications on depletion or accumulation in these sub-soil layers. Data are presented in Table 3.

Table 3. Soil test levels in surface and sub-soil horizons of Dothan fsl after 53 years of fertilization with different rates of P, K, and Mg.

Horizon	Depth	Nutrient and rate (kg/ha): Phosphorus 0	Phosphorus 56	Potassium 0	Potassium 28	Potassium 56	Potassium 112	Magnesium[1] 0	Magnesium[1] Cal.	Magnesium[1] Dol.
	-cm-	mg/kg								
Ap	0-25	21	65	38	72	96	111	16	20	54
Be	26-40	1	5	20	35	63	85	20	26	43
Btl	41-66	0	0	13	20	42	82	31	40	60
Bt2	67-90	0	0	7	16	27	59	30	36	47

[1]Calcitic or dolomitic limestone applied to maintain soil pH near 6.0.

The soil test data show that very little P leached below the plowed layer although annual applications were made from 1929 through 1981. The total amount of P applied to the standard treatment over this period was 1584 kg/ha. The increase in available P found by soil test extraction in 1983 was less than 5% of the amount applied over this period. Therefore, over 95% of that applied was removed in crops, fixed into the soil reserve supply or lost by surface erosion. The amount found in the surface soil was almost double the original level of 33 mg/kg which was adequate to supply crops for over 50 years without response to P. Rates of buildup and depletion from different rates of P and K at this and four other locations were compared in 1981 (4).

The soil test K level in the untreated surface soil in 1983 was about the same as in the original samples stored in 1928. The K level below the plowed layer decreased with depth at all K rates, but the amount of K at each level increased with each rate. Although the amounts below the plowed layer were less than in the surface soil, they represent substantial reserves above that of the untreated plots. This helps explain why such soils can produce maximum yields of peanuts or other low K requiring crops for several years without K application after *High* soil test levels are attained by fertilization.

Levels of Mg on unlimed plots increased with depth. Application of dolomitic lime increased Mg in all samples to the 90-cm depth. Levels of Mg in the sub-soil were probably responsible for the lack of a yield response to Mg by any crop during this period.

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