CIRCULAR 161
FEBRUARY 1968

Relative Responses of GRAIN and ANNUAL FORAGE CROPS to LIME, PHOSPHORUS, and POTASSIUM *on Norfolk Sandy Loam*

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SUMMARY

Lime and fertilizer requirements of 13 crops were compared in a field experiment on Norfolk (formerly Kalmia) sandy loam soil at Brewton, Alabama. Yields were affected by lime and fertilizer as follows:

Yield Response to Lime (soil pH = 5.1)

(1) Yields increased greatly: sorghum-sudan, sorghum almum, and ball clover.

(2) Yields increased considerably: grain sorghum and crimson clover.

(3) Yields increased moderately: corn and browntop millet.

(4) Yields increased slightly: pearl millet, ryegrass, soybean forage, and oat forage.

(5) Yields not increased: oats for grain.

Yield Response to P (soil test P = 34 lb./acre)

(1) Yields increased moderately: grain sorghum, sorghum-sudan, sorghum almum, ball clover, crimson clover, vetch, and oat forage.

(2) Yields increased slightly: pearl millet and browntop millet.

(3) Yields not increased: corn, oat grain, soybean forage, and ryegrass.

Yield Response to K (soil test K = 32 lb./acre)

(1) Yields increased greatly: grain sorghum and ball clover.

(2) Yields increased considerably: corn, oats (grain and forage), sorghum-sudan, sorghum almum, crimson clover, vetch, browntop millet, and pearl millet.

(3) Yields increased moderately: soybean forage and ryegrass.

First Printing 3M, February 1968

Relative Responses of Grain and Annual Forage Crops to Lime, Phosphorus, and Potassium on Norfolk Sandy Loam

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ALL CROPS do not require the same level of soil fertility for optimum production. Genetic differences among plant species, and even varieties, cause them to have different lime and fertilizer requirements. Some plant characteristics affected by these genetic differences are: (1) chemical composition of the plant, (2) extent and rate of growth of the plant, (3) efficiency with which the plant can extract nutrients from soil, (4) type of root system and its distribution in the soil, and (5) sensitivity of the plant to soil acidity.

Although differences in soil fertility requirements of crops have been observed, reasons for such differences are not completely understood. Thus, field experiments are necessary to establish lime and fertilizer requirements of individual crops. Purpose of the experiments reported here was to compare the relative requirements for lime, phosphorus, and potassium of several grain and annual forage crops commonly grown in Alabama.

EXPERIMENTAL PROCEDURE

The crops were grown on Norfolk (formerly Kalmia) sandy loam at the Brewton Experiment Field, Brewton, Alabama. The test area was divided into halves, each of which was subdivided into individual plots of 1/60 acre. Fertilizer or lime treatments were randomly repeated four times within each half of the test area.

A 2-year rotation was followed throughout the 10-year test, with each crop in the rotation being planted each year on alternate halves of the test area. The first 6 years of the experiment was a 2-year rotation of corn-oats-grain sorghum. The last 4 years was a 2-year rotation of summer annuals-winter annuals-fallow.

Differences in treatment included rates of phosphorus, potassium, and lime. All plots received the same rate of nitrogen.

Rates of fertilizer and lime were those recommended by this Station.

Soil pH of the limed plots was maintained near pH 6.0 during the entire experiment by liming in 1954, 1958, and 1961. Lime was applied each time at the rate of 1 ton per acre. The pH of unlimed soil was between 5.0 and 5.3 during the experiment. Phosphorus and potassium fertilizers were applied to each crop in the rotation at rates shown in the tables.

RESULTS WITH CORN-OATS-GRAIN SORGHUM (1954-1960)

The first experiment was a 2-year rotation of 'Dixie 18' corn, 'Suregrain' oats, and 'Combine Sagrain' grain sorghum. Annual yields for each crop are reported in Table 1. Corn produced a satisfactory yield each year. Oat yields were satisfactory only in the last 3 years of the experiment, the failures being caused by either freeze or drought. Grain sorghum yields were generally

TABLE 1. EFFECT OF LIME AND FERTILIZER ON GRAIN YIELD OF CORN, OATS, AND GRAIN SORGHUM IN 2-YEAR ROTATION ON NORFOLK SANDY LOAM, BREWTON EXPERIMENT FIELD, BREWTON, ALABAMA, 1955-1960

Lime treatment[1]	N-P-K per acre[2]	Grain yield per acre by year						
		1955	1956	1957	1958	1959	1960	Av.[3]
	Lb.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Corn								
None	116-21-40	93	87		76	80	87	85
Dolomitic	116-21-40	97	85		76	80	95	87
Dolomitic	116-0-40	95	88		80	76	95	87
Dolomitic	116-11-40	91	88	Failure	76	69	95	84
Dolomitic	116-21-20	82	78		74	66	83	77
Dolomitic	116-21-0	66	56		37	38	49	49
Oats								
None	50-21-40				70	82	92	81
Dolomitic	50-21-40				81	86	91	86
Dolomitic	50-0-40				81	82	90	84
Dolomitic	50-11-40	Failure	Failure	Failure	80	85	94	86
Dolomitic	50-21-20				68	78	95	80
Dolomitic	50-21-0				49	42	63	51
Grain sorghum								
None	60-13-25	35	18	30		7	4	19
Dolomitic	60-13-25	37	24	39		19	28	29
Dolomitic	60-0-25	37	17	34		20	19	25
Dolomitic	60-7-25	36	27	37	Failure	21	24	29
Dolomitic	60-13-13	35	18	32		16	20	24
Dolomitic	60-13-0	29	10	12		2	8	12

[1] Lime added at rate of 1 ton per acre in 1954 and relimed at same rate in 1958.
[2] Multiply rate of P by 2.24 to obtain rate of P_2O_5; multiply rate of K by 1.2 to obtain rate of K_2O.
[3] Crop failures not included in averages.

low and sometimes quite variable because of extensive damage from birds.

Response to Lime (soil pH = 5.1). Grain sorghum was the most responsive grain crop to lime, whereas oats responded least. The yield of oat grain was unaffected by lime, even though the soil pH of unlimed plots was only 5.1 at conclusion of the experiment in 1961, Table 4. Corn yields were increased by lime only the sixth year (1960), and this increase was 8 bushels per acre. Yield of grain sorghum was increased by liming each year except the first. Yields on the unlimed soil became progressively poorer, being almost a complete failure the sixth year.

Response to P (soil test P = 34 lb./acre). Phosphorus fertilizer failed to increase yields of oats or corn. Although yields were somewhat erratic, there was an average increase of 4 bushels of grain sorghum for the first increment of phosphorus.

Response to K (soil test K = 32 lb./acre). Severe potassium deficiency symptoms were evident on all three crops each year on the soil receiving no potassium fertilizer. Potassium deficiency was most severe on grain sorghum and about equally severe on corn and oats. Average yield increases from the lowest rate of potassium were 26, 29, and 12 bushels per acre for corn, oats, and grain sorghum, respectively. Maximum yields were not obtained most years from the first increment of potassium fertilizer. Average yield increases from the second increment were 11, 6, and 4 bushels per acre for corn, oats, and grain sorghum, respectively.

RESULTS WITH SUMMER AND WINTER FORAGE ANNUALS (1961-1964)

At the conclusion of the 2-year rotation experiment with corn-oats-grain sorghum in 1960, a new study was begun on the same plots. Each of the 1/60-acre plots was divided into five 1/300-acre plots for the new rotation. Fertilizer and lime treatments were continued on the same plots as in the previous experiments. A 2-year rotation with annual forage crops was grown in the sequence of summer annuals-winter annuals-fallow.

Response of Summer Annuals

Yields of the different summer annual crops as affected by lime, phosphorus, and potassium are given in Table 2. Twice each year forage was harvested of 'Starr' pearl millet, sorghum almum, and

TABLE 2. EFFECT OF LIME AND FERTILIZER ON DRY FORAGE YIELD OF SEVERAL SUMMER ANNUALS IN A 2-YEAR ROTATION WITH WINTER ANNUALS ON NORFOLK SANDY LOAM, BREWTON EXPERIMENT FIELD, BREWTON, ALABAMA, 1961-1963

Lime treatment[1]	N-P-K per acre[2]	Yield per acre of dry forage			
		1961	1962	1963	Av.[3]
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Browntop millet					
None	40-27-50	1,100	3,600	3,100	2,600
Dolomitic	40-27-50	2,900	5,100	3,800	3,900
Dolomitic	40-0-50	2,300	5,000	3,200	3,500
Dolomitic	40-13-50	2,700	5,200	3,600	3,800
Dolomitic	40-27-25	2,700	3,700	3,900	3,400
Dolomitic	40-27-0	1,800	2,700	2,900	2,500
Pearl millet					
None	80-27-50	6,600	8,900	6,300	7,300
Dolomitic	80-27-50	8,300	10,000	8,000	8,800
Dolomitic	80-0-50	7,000	8,900	7,200	7,700
Dolomitic	80-13-50	6,700	10,000	7,200	8,000
Dolomitic	80-27-25	6,500	9,200	6,200	7,300
Dolomitic	80-27-0	5,600	6,800	4,800	5,700
Sorghum almum					
None	80-27-50	600	5,200	3,000	2,900
Dolomitic	80-27-50	6,000	10,500	7,300	7,900
Dolomitic	80-0-50	4,100	7,200	5,100	5,500
Dolomitic	80-13-50	5,200	8,600	6,100	6,600
Dolomitic	80-27-25	4,400	7,900	7,500	6,600
Dolomitic	80-27-0	3,000	4,900	4,800	4,200
Sorghum sudan					
None	80-27-50	900	5,000	3,700	3,200
Dolomitic	80-27-50	6,600	10,500	8,400	8,500
Dolomitic	80-0-50	3,600	9,000	6,500	6,400
Dolomitic	80-13-50	6,300	9,900	7,600	7,900
Dolomitic	80-27-25	5,100	8,000	6,700	6,600
Dolomitic	80-27-0	3,700	6,700	4,600	5,000
Soybeans					
None	0-27-50	Failure	2,400	4,500	3,400
Dolomitic	0-27-50		4,000	5,000	4,500
Dolomitic	0-0-50		3,800	5,400	4,600
Dolomitic	0-13-50		3,500	5,900	4,700
Dolomitic	0-27-25		4,400	5,200	4,800
Dolomitic	0-27-0		2,800	4,600	3,700

[1] Limed plots relimed in 1961 at rate of 1 ton per acre.

[2] Phosphorus, potassium, and 40 pounds per acre of nitrogen applied broadcast prior to seeding. An additional 40 pounds per acre of N applied after each cutting except final cutting. Multiply rate of P by 2.24 to obtain rate of P_2O_5; multiply rate of K by 1.2 to obtain rate of K_2O.

[3] Crop failures not included in averages.

'DeKalb SX-11' (a sorghum-sudan hybrid). Browntop millet and 'Otootan' soybean forage were each harvested once annually.

RESPONSE TO LIME (soil pH = 5.1). Forage yield increases from liming were greatly different. Pearl millet production was increased only about 20 per cent by lime, whereas yields of

sorghum-sudan and sorghum almum were almost tripled (about 5,000 pounds per acre of dry forage) by lime. Soybeans made a slightly greater percentage yield increase from lime than did pearl millet, but somewhat less than the increase by browntop millet.

RESPONSE TO P (soil test P = 34 lb./acre). Sorghum-sudan and sorghum almum were the only crops to respond very much to phosphorus fertilizer. Yields of both were increased about one-third by addition of 27 pounds per acre of P (60 pounds P_2O_5). Only slight yield increases from the first increment of phosphorus were obtained with browntop and pearl millets, and no yield increase occurred with soybeans.

RESPONSE TO K (soil test K = 32 lb./acre). The greatest yield increases from potassium fertilizer were with sorghum-sudan and sorghum almum. Yields of both crops were almost doubled by 50 pounds per acre of K (60 pounds K_2O). Yields of both browntop and pearl millets were also increased by each increment of potassium fertilizer. Although actual yield increases from potassium fertilizer were much greater for pearl millet than browntop millet, the percentage increases were about equal. Soybean yields were least affected by potassium, showing no response to the second increment.

Response of Winter Annuals

Forage yields of 'Suregrain' oats, Italian ryegrass, ball clover, 'Autauga' crimson clover, and 'Warrior' vetch as affected by lime and rates of phosphorus and potassium fertilizers are given in Table 3. Two or three clippings were made annually, depending on weather conditions and amount of plant growth. Since there was a stand failure with vetch in 3 of the 4 years, yield data for this crop must be interpreted with caution.

RESPONSE TO LIME (soil pH = 5.1). Forage yields of oats and ryegrass were unaffected by liming. The results with oats agree with the earlier experiment in which grain yields were unaffected by liming this acid soil. However, forage yield of ball clover was more than doubled by liming. It was the most responsive winter annual forage to lime, with crimson clover being somewhat less responsive.

RESPONSE TO P (soil test P = 34 lb./acre). Phosphorus fertilizer failed to affect the forage yield of ryegrass, and only slightly

affected oats. Yields of the three legumes were somewhat erratic, but the data suggest a modest yield increase from the first increment of phosphorus.

RESPONSE TO K (soil test K = 32 lb./acre). Of the winter annuals, ball clover suffered most from potassium deficiency.

TABLE 3. EFFECT OF LIME AND FERTILIZER ON DRY FORAGE YIELD OF SEVERAL WINTER ANNUALS IN A 2-YEAR ROTATION WITH SUMMER ANNUALS ON NORFOLK SANDY LOAM, BREWTON EXPERIMENT FIELD, BREWTON, ALABAMA, 1962-1964

Lime treatment[1]	N-P-K per acre[2]	Yield per acre of dry forage			
		1962	1963	1964	Av.[3]
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Oats					
None	120-27-50	3,300	1,800	2,700	2,600
Dolomitic	120-27-50	3,400	1,700	3,200	2,800
Dolomitic	120-0-50	3,200	1,500	2,500	2,400
Dolomitic	120-13-50	3,300	1,800	3,100	2,700
Dolomitic	120-27-25	2,900	1,500	3,000	2,500
Dolomitic	120-27-0	2,400	1,000	2,100	1,800
Ryegrass					
None	120-27-50	2,000	2,300	3,100	2,500
Dolomitic	120-27-50	2,200	2,300	3,500	2,700
Dolomitic	120-0-50	2,000	2,500	3,800	2,800
Dolomitic	120-13-50	2,100	2,600	3,600	2,800
Dolomitic	120-27-25	2,000	2,100	3,000	2,400
Dolomitic	120-27-0	1,900	1,800	2,800	2,200
Ball clover					
None	0-27-50	1,300		400	800
Dolomitic	0-27-50	2,300		1,400	1,800
Dolomitic	0-0-50	1,500	Failure	1,500	1,500
Dolomitic	0-13-50	2,000		2,100	2,000
Dolomitic	0-27-25	1,800		1,300	1,500
Dolomitic	0-27-0	1,000		<100	500
Crimson clover					
None	0-27-50	1,100	1,400	700	1,100
Dolomitic	0-27-50	1,900	1,800	1,400	1,700
Dolomitic	0-0-50	1,200	2,300	1,000	1,500
Dolomitic	0-13-50	1,400	1,800	1,900	1,700
Dolomitic	0-27-25	1,600	1,900	1,600	1,700
Dolomitic	0-27-0	1,300	1,200	800	1,100
Vetch					
None	0-27-50	1,900			1,900
Dolomitic	0-27-50	2,000			2,000
Dolomitic	0-0-50	1,500	Failure	Failure	1,500
Dolomitic	0-13-50	1,900			1,900
Dolomitic	0-27-25	2,100			2,100
Dolomitic	0-27-0	1,200			1,200

[1] Limed plots relimed in 1961 at rate of 1 ton per acre.

[2] Phosphorus, potassium, and 40 pounds per acre of nitrogen applied broadcast prior to seeding. An additional 40 pounds per acre of N was applied after each cutting except final cutting. Multiply rate of P by 2.24 to obtain rate of P_2O_5; multiply rate of K by 1.2 to obtain rate of K_2O.

[3] Crop failures not included in averages.

Yields were extremely low on the "no potassium" plots, and yield increases resulted from both increments of potassium fertilizer. Oats, crimson clover, and vetch responded about equally to potassium fertilizer. The yield of each was increased about 50 per cent by the first 30 pounds of potassium. Ryegrass was the least responsive crop to potassium.

SOIL FERTILITY RATINGS

The average soil test values for soil acidity (pH), available phosphorus (P), and available potassium (K) are given for each treatment in Table 4. Soil samples were obtained at conclusion of the first experiment in 1961 and are representative of the soil fertility status during the entire experimental period. Since the soil was sampled just before reliming in 1961, the pH values listed in Table 4 were minimum pH levels for the limed soil during the experiment.

With lime added at the rate of 1 ton per acre in each of 1954, 1958, and 1961, soil pH of about 6.0 was maintained throughout the experimental period. The data in Table 4 show that available soil P and K were altered considerably by 6 years of fertilizer treatment. Each rate of P fertilizer resulted in about a 50 per cent higher level of available soil P (19 and 27 pounds of P per acre). The lower rate of fertilizer K also increased level of available K about 50 per cent (14 pounds of K per acre), while the higher application rate caused an additional 25 per cent increase (12 pounds of K per acre).

TABLE 4. AVERAGE SOIL TEST VALUES[1] OF PLOTS TREATED WITH DIFFERENT RATES OF LIME, PHOSPHORUS, AND POTASSIUM FROM SOIL SAMPLES TAKEN IN FEBRUARY 1961, PRIOR TO RELIMING THE LIMED PLOTS, BREWTON EXPERIMENT FIELD, BREWTON, ALABAMA

P-K fertilizer per acre[2]	Lime treatment	Soil pH	Lime requirement per acre	P per acre	K per acre
Lb.			*Lb.*	*Lb.*	*Lb.*
27-50	No lime	5.1	3,100	60	52
27-50	Lime	5.8	1,500	80	58
0-50	Lime	5.8	1,500	34	61
13-50	Lime	5.8	1,600	53	56
27-25	Lime	5.7	1,500	75	46
27-0	Lime	5.8	1,600	66	32

[1] All determinations made by the Auburn University Soil Testing Laboratory using its standard procedures.

[2] Average annual rate of P-K; rate of N was same for all treatments. Multiply rate of P by 2.24 to obtain rate of P_2O_5; multiply rate of K by 1.2 to obtain rate of K_2O.

The soil fertility rating of any soil for P, K, or lime is dependent on the fertility requirement of the crop as well as on the soil. Yield of the crop on the unfertilized or unlimed soil as compared with that on the fertilized and limed soil is the "relative yield." The best treatment is assigned a relative yield of 100, and all other yields are then calculated as a percentage of that produced by the best treatment. The relative yield in turn is used as a measure of soil fertility level.

The P, K, and pH levels of a soil are rated according to the relative yield of crops on the unfertilized or unlimed soil. Relative yield levels and soil fertility levels in use by the Auburn University Soil Testing Laboratory are as follows:

Relative yield	*Fertility rating*
100 per cent and above	high
75 to 99 per cent	medium
50 to 74 per cent	low
Below 50 per cent	very low

The relative yields and soil fertility ratings for each crop are listed in Table 5.

TABLE 5. RELATIVE YIELDS AND SOIL FERTILITY RATING[1] FOR DIFFERENT CROPS ON NORFOLK SANDY LOAM, BREWTON EXPERIMENT FIELD, BREWTON, ALABAMA

Crop	Soil pH = 5.1		Soil test P = 34 lb./acre		Soil test K = 32 lb./acre	
	Rel. yield	Fert. rating	Rel. yield	Fert. rating	Rel. yield	Fert. rating
Corn-oats-grain sorghum						
Grain sorghum	66	low	86	medium	41	very low
Corn	97	medium	95	medium	57	low
Oats	94	medium	98	medium	59	low
Summer annual forages						
Sorghum almum	37	very low	70	low	53	low
Sorghum-sudan	38	very low	75	low	59	low
Browntop millet	67	low	90	medium	64	low
Pearl millet	83	medium	88	medium	65	low
Soybeans	76	medium	102	high	82	medium
Winter annual forages						
Ball clover	44	very low	83	medium	28	very low
Vetch[2]	95	medium	75	medium	60	low
Crimson clover	65	low	88	medium	65	low
Oats	93	medium	86	medium	64	low
Ryegrass	93	medium	104	high	81	medium

[1] For additional explanation of soil fertility ratings, see Bulletin 375, "Soil Test Theory and Calibration for Cotton, Corn, Soybeans, and Coastal Bermudagrass," Auburn University Agricultural Experiment Station.

[2] Satisfactory yields were obtained in only 1 year of the experiment. Soil fertility ratings: high = 100 per cent or above relative yield, medium = 75-99 per cent relative yield, low = 50-74 per cent relative yield, very low = less than 50 per cent relative yield.

Soil Rating for pH

Soil pH of the unlimed soil was about 5.1. This level was "medium" for corn, oats, pearl millet, soybeans, vetch, and ryegrass; "low" for grain sorghum and crimson clover; and "very low" for sorghum almum, sorghum-sudan, and ball clover.

Soil Rating for P

Soil test P of the unfertilized soil was 34 pounds per acre. This level of P was "high" for soybeans and ryegrass; "medium" for grain sorghum, corn, oats, millet, ball clover, vetch, and crimson clover; and "low" for sorghum almum and sorghum-sudan.

Soil Rating for K

Soil test K of the unfertilized soil was 32 pounds per acre. This was "medium" for soybeans and ryegrass; "low" for corn, oats, sorghum almum, sorghum-sudan, millet, vetch, and crimson clover; and "very low" for grain sorghum and ball clover.