Effect of Lime on Availability of Soil Phosphorus[1]

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In regions where the soils are naturally acid, the availability of P in the soil for growings plants is of special interest. Liming of acid soils is a common practice in the humid regions and the studies of some workers indicate that lime seems to help increase the availability of P to plants.

Some of the early workers like Hilgard (9), Liebig (11), and Johnston (10) stressed the highly favorable influence of lime on the availability of P. Cook (6) in his investigation found that an increase in the base saturation through the application of lime resulted in significant increases in the amounts of readily available P over a period of 1 to 20 days. Other workers (13, 16) have also reported that liming of acid soils helps to increase the availability of both the native as well as the applied P. Swenson et al (18) have stated that liming to increase pH of the soils with subsequent release of fixed P is a sound practice, but is of limited value. Ford (7) in his study of six Kentucky soils found that lime did not influence the availability of the native P.

According to Arnon (1) the absorption of phosphate would be depressed by the presence of a high concentration of rapidly adsorbable anions in the nutrient medium and would be increased in a high concentration of rapidly adsorbable cation. Several workers (2, 3, 5) found that liming of the soil increased the amount of P adsorbed by the plants and that the P content increased as the soil pH increased. Naftel (15) studied the influence of lime on the chemical composition of sorghum. He reported that Ca applications decreased the percent P in plants. Other workers (8, 12, 17) reported similar results.

The object of this investigation was: 1) To determine the effect of lime on the availability of soil P as measured by soil and plant analysis, and 2) the comparision of five different chemical methods for the extraction of available soil P.

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Materials and Methods

The Jordan Soil Fertility plots, located on the Pennsylvania State University campus, offered a source material admirably suited for this study, because the history of these soils is known for over 75 years and the treatments applied have produced soils with widely different chemical characteristics. Plot 24, 28, 32 and 34 (table I) of the unlimed tier were selected for the purpose of this study.

A greenhouse experiment was designed to study the effect of lime, with and without P, on the availability of P as measured by the yields and P content of Tall Fescue (Ky. 31). One gallon tin cans were used as containers with a mixture of 50 percent soil and 50 percent sand. Three different lime levels were used. The original soil mixture constituted the zero level. In the second level, enough lime was added to raise the pH of the soil to 7.2. The third level consisted of an excess of 5 tons per acre of lime above the pH 7.2 creating a final pH of 8.0. All treatments included a uniform application of 100 lbs per acre of N and 150 lbs per acre of K_2O. Half the treatments were designed to study the effect of lime on the native and fixed P in the soil and the remaining half were designed to study the effect of lime on P added to the soil at the rate of 50 lbs per acre. The P was added in the form of $Ca(H_2PO_4)_2$.

Table 1.—Fertilizer Treatments to Study the Effect of Lime on the Availability of Phosphorus.

Plot No.	Past Treatments	Lime Level	Lime T/A	pH of the Soil
24	Nothing	0	0	5.2
		1	3.5	7.2
		2	8.5	8.0
28	N P K* (N as $NaNO_3$)	0	0	5.1
		1	4.0	7.2
		2	9.0	8.0
32	N P K* (N as $(NH_4)_2SO_4$)	0	0	4.3
		1	5.0	7.2
		2	10.0	8.0
34	2 Tons Limestone	0	0	8.0

All treatments included a uniform application of N and K_2O. The study included the treatments above with:

1. No additional P. fertilizer applied.
2. 50 lbs./A of P. applied as superphosphate.

*NPK represents 78 lb. N, 48 lb. P_2O_5 as superphosphate and 100 lb. K_2O as KCl applied every other year.

In order to permit the soil to come to equilibrium with the new environment created by the addition of lime and P, the soil in the cans was allowed to set in the greenhouse for two months. Then on January 30, 1958, six cans of each treatment were seeded with fescue at the rate of 5.5 lbs. per 1000 sq. ft. The plants were watered by weight to near field capacity at frequent intervals depending on the weather. The first cutting was obtained on March 1, 1958. At this time four cans with the best stands of fescue were selected for the four replicates and the other two discarded. There were a total of 20 different treatments, with four replicates each, which were arranged in a randomized block design. The last cutting was made on December 24, 1958, making a total of 15 cuttings during the growing season. Final soil samples were taken from all the four replications for soil analysis to be compared with the original soil.

Four different methods, Morgan (14), Truog (19), Bray 0.1 N HCl (4), Bray .025 N HCl (4), were used on the soils prior to seeding and after harvest. In addition, continuous leaching with 0.002 N H_2SO_4 (six leachings of four hours each, for six consecutive days) was used for the determination of available P in the soil after harvest.

All dried plant material was ground to pass a 30 mesh sieve. One gram of the oven dried tissue was ashed at 490°C in a muffle furnace for 12 hours. The silica was dehydrated by treating the ash with 2 ml concentrated HCl and evaporated to dryness on a steam plate. The molybdate blue procedure (19) was used to estimate the P extracted by the use of a Coleman colorimeter in all cases. The Ca in the solution was determined by the Beckman DU Spectrophotometer.

Results and Discussion

Highly significant increases in the yields were obtained from both the first and the second lime level as compared to the zero level (table 2). Although there was an increase in yield at the second lime level over the first level, this increase was not statistically significant. The effect of lime on crop production is best shown by plot 32, which produced a 900 percent yield increase at lime level one over the zero level.

The general effect of liming the acid soils was a rise in the P content of fescue when the soil was limed to pH 7.2 followed by a slight decrease when overlimed to pH 8.0. Highly significant increases in the Ca content of fescue were also obtained by the liming of acid soils. The total uptake of P by fescue was increased by the presence of a high concentration of Ca.

The results from the five different chemical methods used for the extraction of available P from the soil samples collected prior to the seeding and also after the harvest of fescue are shown in tables 3 and 4. The previous history of the soil and the P level had a considerable effect on the amount of available P removed by the extractant in all five methods. When Morgan, Truog, and the continuous leaching methods were used, the data clearly showed that the liming of acid soils increased the availability of the soil P and the efficiency

of the applied P. However, when Bray's (O. 1 N HCl and 0.025 N HCl) methods were used, the data indicated that liming of acid soils considerably decreased the availability of both the native and applied P. A possible explanation of this is that the presence of the flouride ion in the extractant may have caused a precipitation of P as fluorapatite or complex phosphocarbonates.

TABLE 2. The P and Ca content of Tall Fescue Clippings from Four Jordan Plot Soils With and Without P.

Plot No.	P Level lb./A.	Lime Level	Clippings Gm Dry Wt/Pot	P Content %	P Content Total Gm/Pot	Ca Content %	Ca Content Total Gm/Pot
24	0	0	9.87	.105	.010	.143	.014
24	0	1	10.40	.140	.015	.210	.022
24	0	2	12.28	.165	.020	.235	.029
24	50	0	10.84	.225	.024	.133	.014
24	50	1	12.56	.280	.037	.165	.021
24	50	2	13.57	.266	.038	.203	.028
28	0	0	11.16	.173	.020	.130	.015
28	0	1	14.43	.283	.041	.150	.022
28	0	2	15.31	.223	.034	.173	.026
28	50	0	12.66	.195	.025	.133	.017
28	50	1	15.59	.300	.047	.158	.025
28	50	2	16.91	.218	.037	.190	.032
32	0	0	1.60	.070	.001	.065	.001
32	0	1	14.34	.220	.032	.140	.020
32	0	2	15.29	.173	.026	.233	.036
32	50	0	8.24	.143	.012	.105	.009
32	50	1	14.29	.278	.040	.158	.023
32	50	2	16.43	.175	.029	.225	.037
34	0	0	8.05	.108	.009	.225	.018
34	50	0	10.39	.148	.015	.223	.023

Correlation between Ca (%) and P (%) = .045
Correlation between total uptake of Ca and P = .571**

TABLE 3.—The Availability of Phosphorus Prior to Seeding of Tall Fescue (Ky. 31) as Measured by Four Methods on Four Jordan Plot Soils With and Without Additional Phosphorus.

Plot No.	P Level lb./A.	Lime Level	Available P (lb./A.) Morgan	Truog	Bray.025N	Bray .1N
24	0	0	3.3	9.0	17.9	20.2
24	0	1	5.8	8.0	6.2	13.4
24	0	2	6.3	10.0	7.8	14.6
24	50	0	6.3	22.0	33.3	57.1
24	50	1	11.3	36.0	30.2	48.7
24	50	2	15.5	42.0	18.5	45.4
28	0	0	3.8	12.0	25.2	31.9
28	0	1	6.5	15.0	7.3	28.6
28	0	2	10.0	22.0	10.1	28.6
28	50	0	7.8	38.0	61.6	52.6
28	50	1	11.3	46.0	33.0	44.8
28	50	2	14.0	53.0	27.4	42.6
32	0	0	10.5	40.0	89.6	129.4
32	0	1	13.3	52.0	47.0	73.9
32	0	2	18.3	68.0	37.0	71.1
32	50	0	15.3	64.0	135.5	152.9
32	50	1	16.0	79.0	89.6	131.0
32	50	2	23.0	111.0	61.6	126.0
34	0	0	3.3	4.0	6.2	8.4
34	50	0	11.3	17.0	14.0	34.2

TABLE 4.—The Availability of Phosphorus After the Harvest of Tall Fescue (Ky. 31) as Measured by Five Methods on Four Jordan Plot Soils With and Without Additional Phosphorus.

Plot No.	P Level lb./A.	Lime Level	Available P (lb/A.) Morgan	Truog	Bray .025N	Bray .1N	.002N H_2SO_4
24	0	0	3.5	7.0	14.3	25.5	16.8
24	0	1	7.4	8.0	7.8	16.0	16.8
24	0	2	8.8	10.5	6.2	13.7	14.5
24	50	0	3.8	19.0	18.8	37.0	29.3
24	50	1	7.8	28.0	12.9	38.9	39.5
24	50	2	11.5	30.0	12.3	27.2	31.0
28	0	0	4.3	11.0	17.9	25.2	17.8
28	0	1	9.6	18.0	12.0	25.2	25.3
28	0	2	9.1	23.0	10.4	23.0	22.3
28	50	0	6.6	28.5	44.0	50.1	26.5
28	50	1	10.9	35.5	28.6	42.6	33.8
28	50	2	15.4	40.5	12.3	35.6	30.8
32	0	0	6.5	35.0	88.8	122.6	33.0
32	0	1	10.9	35.5	39.8	84.3	42.5
32	0	2	21.4	53.5	28.3	77.6	43.8
32	50	0	9.0	48.5	131.0	148.7	38.8
32	50	1	14.9	57.5	62.9	144.5	45.5
32	50	2	26.6	61.5	49.0	125.2	46.3
34	0	0	3.8	3.0	6.4	10.6	8.0
34	50	0	8.9	12.0	11.2	25.8	11.5

Simple correlations between the available P as measured by five methods and the yield, percent P and total P uptake by fescue were calculated and were as follows:

Method of Determination	TALL FESCUE (KY. 31) CLIPPINGS Yield/pot	% P	Total P
Morgan	.609**	.225	.566**
Bray (0.025 N HCl)	—.384	.234	—.265
Bray (0.1 N HCl)	—.138	.128	—.056
Truog	.371	.281	.391
Continuous Leaching	.321	.384	.423

The Morgan method gave a highly significant correlation with yield and total P absorbed by fescue. The Truog and continuous leaching method, also showed some correlation, but was not statistically significant. Both Bray methods gave a negative correlation which shows that they were not suitable for testing the effect of lime on the availability of P.

Summary

A greenhouse experiment was designed to study the effect of lime, with and without additional P, on the availability of P as measured by the yield and P content of Tall Fescue (Ky. 31). Jordan Soil Fertility Plots 24 (check), 28 (NPK, N as $NaNO_3$), 32 (NPK, N as $(NH_4)_2SO_4$), and 34 (excess limestone), of the unlimed tier were selected for the purpose of this study. Three different lime levels were used and all treatments included a uniform application of N and K. Five methods, Morgan, Truog, Bray .025 N HCl, Bray .1 N HCl, and continuous leaching, were used for the extraction of available P from the soil samples collected prior to the seeding and after the harvest of fescue.

The previous history of the soil and the P level had a considerable effect on the amount of P removed. The results obtained with the Morgan, Truog, and continuous leaching methods indicated that liming increased the availability of the native soil P and the efficiency of the applied P. However, Bray's (.1 N HCl and .025 N HCl) methods showed a decrease in the availability of both the native and applied P.

Simple correlations between the available P as measured by the five methods and the yield, percent P and total P uptake by fescue were calculated. The sodium acetate method gave a highly significant correlation with yield and the total P absorbed by fescue. Truog and continuous leaching methods also showed some correlation but were not statistically significant. Both Bray methods gave negative correlations.

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