A LIMING STUDY OF SOME SOUTH CENTRAL KANSAS SOILS

by

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INTRODUCTION

The soils of eastern Kansas are acid and are known to need lime, while those of western Kansas are neutral to slightly alkaline with free lime near the surface. In the central area, the surface soil is acid with neutral to alkaline subsoil. A major question in this region is: what is the need for lime? This study was an attempt to determine the pH best suited for the growth of alfalfa and to determine if the optimum pH is related to the availability and uptake of calcium, magnesium, phosphorus, or potassium by alfalfa.

Work along similar lines has been done by numerous workers. It is a well established fact that alfalfa needs a soil well supplied with lime. Long time fertility plots on acid soils have shown liming alone will generally increase crop yields, especially legumes, significantly (Davidson and Smith, 1950; Bauer, et al, 1945). However, Schmehl, et al, (1950) found when an acid soil with a pH of 4.8 was diluted with sand, the growth of alfalfa was increased as much as 500 percent, and that the addition of gypsum to soils with various pH's had no effect or depressed the yields of alfalfa. Schmehl concluded that the deficiency of calcium was not the factor responsible for the poor growth of alfalfa on the acid soil.

Simon (1930) has shown the rate of solubility of phosphorus from a Wooster silt loam was increased by the addition of lime. This was further substantiated by Salter and Barnes (1935) in a long time fertility study on a Wooster silt loam. They found that liming increased both the native and applied phosphorus. Dunn (1943) using western Washington soils found that both yield and phosphorus availability were markedly reduced when the soil was limed to a pH of about 7.5 or greater. However, just below this point (pH 6.5--7.2), the yield and phosphorus availability were at a maximum and as the acidity increased, the yield and available phosphorus decreased.

York and his associates (1954) found the calcium contents of alfalfa, corn, sudan grass, and sericea were generally increased by liming. However, when the yields were not increased by liming, there were no indications of calcium deficiencies. They also found the sum of the cations in alfalfa (expressed in equivalents) tended to be constant despite great variation in the amount of any one cation absorbed. This is consistent with the earlier work in which Bear and Prince (1945) concluded that the sum of the equivalents of Ca, Mg, and K per unit of alfalfa plant material tended to be constant for the production of any one harvest, this constant having a value of approximately 170 M.E. per 100 gm dry matter in the first crop.

York and his associates (1953) also found the concentration of potassium in alfalfa decreased slightly with increasing degree of calcium saturation of the soil; but upon addition of sufficient lime to maintain free calcium carbonate in the soil, the potassium content of the alfalfa increased.

METHODS OF STUDY

Description and Treatment of the Soils

Soils were collected from south central Kansas and brought to Manhattan to be used in the greenhouse. Alfalfa was then grown on these soils which were limed to various pH levels. The forage yields were obtained and then the plant material analyzed chemically for calcium, magnesium, potassium and phosphorus.

Four soils were used in the study; three were obtained near Kingman, Kansas and the fourth from the Agronomy Farm of Kansas State College at

Manhattan. Surface samples of the soils were brought to Manhattan and allowed to air dry. Then these samples were screened and thoroughly mixed and a quart sample taken for laboratory analysis.

Table 1. Textural and chemical characteristics of soils used for the lime study.

Soil	Texture	pH	Lime Requirement	Organic Matter	Available Phosphorus	Available Potassium
A	fine sandy loam	4.9	5,000	1.3	85	550
B	silt loam	5.2	6,000	1.5	25	550
C	loam	5.6	3,000	.7	21	367
D	loam	6.5	———	.9	25	362

An approximate textural classification and the results from the chemical soil tests are given in Table 1. The pH was determined on a 1:1 soil water paste using a Beckman pH meter with a glass electrode. Organic matter was determined colorimetrically by the sulfuric acid-potassium dichromate method as used by the Kansas soil testing laboratories. Available phosphorus was extracted with a solution of 0.03 N NH_4F and 0.025 N HCl and determined colorimetrically using the molybdenum blue method. Neutral normal ammonium acetate was used to extract potassium and then the potassium was determined on a Perkin Elmer flamephotometer using an internal standard of 100 ppm lithium.

The lime requirement of each soil was determined using Woodruff's buffer solution (Woodruff, 1948) as used by the Kansas soil testing laboratories.

To determine the amount of calcium carbonate needed to bring the soils to pH's between 6 and 7, titration curves were obtained by titrating the soil with standard calcium hydroxide or standard hydrochloric acid. Since the reaction was not instantaneous, aliquots of the acid or base were added to the 10 gm soil samples until the pH's at equilibrium ranged between 6 and 7.

To obtain equilibrium the soils were dried on the steam plate after the initial addition of acid or base, then twice moistened with water and dried. The pH was then obtained on a 1:1 soil water paste using a glass electrode and the titration curves plotted. These titration curves are given in Figures 1 to 4 in the appendix. From these curves, the amount of pure calcium carbonate or sulfuric acid which had to be added to each pot in the greenhouse was calculated.

Design of the Experiment

Space was available for 48 six-inch sewer tile, 24 on each side of the center aisle of the greenhouse. Four soils, A, B, C, and D; four treatments, check, pH 6.3, pH 6.6 and pH 6.9; and three replications or blocks were used.

The first block was on the east side of the aisle, the second block split, one-half on the east and one-half on the west, and the third block was on the west side of the aisle. This arrangement was chosen because it made the environmental factors in the three blocks as nearly alike as possible.

The treatments were completely randomized within each block. This made possible a statistical analysis of the results using analysis of variance. The sources of variation used in the analysis were soil, treatment, blocks, interaction soil X treatment, and the remainder as error. LSD's were used to test the significance of individual comparisons.

Greenhouse Methods

Alfalfa was chosen as the crop to be grown because it is the crop which is most acid sensitive in general farm rotations and it is a heavy feeder on all the plant nutrients. Since it is a deep rooted crop, sewer tile six inches in diameter and 30 inches in length were used instead of the common glazed pots. However it would have been difficult to apply sufficient water, especially on the heavy textured soils, if the tile were filled entirely with soil. Therefore, the tile were set in a metal tray about three inches deep and the tile filled half full of fine quartz sand. In this manner the sand acts as a reservoir for water and water was applied from the bottom as well as from the top of the soil. In addition the small amount of soil used by this technique caused the alfalfa to feed more heavily from the soil and in this manner differences between treatments may have been accentuated.

To be assured of an ample supply of nutrients in the soil, 50 ppm P_2O_5, 25 ppm K_2O, and 12.5 ppm N were added to all the soils. The fertilizers were applied as chemically pure $Ca(H_2PO_4)_2$, KCl, and NH_4NO_3. The alfalfa seed was inoculated to insure the presence of nodule forming bacteria in the soil.

The fertilizers and the finely ground chemically pure calcium carbonate were thoroughly mixed into the entire soil before the soil was put into the tile. After the soil had been placed in the tile, it was completely wetted, and then it was allowed to dry until it could be worked. At this point, the surface was worked to a depth of about two inches. The top one-fourth inch of soil was removed from each pot and approximately 50 alfalfa seeds put in each pot. The soil was replaced in its respective tile. In order to prevent crusting of the soil when the water was added, a thin layer of quartz sand was added to each pot. Distilled water was used throughout the study to water the plants.

When the plants were well established, each pot was thinned to about 15 plants. A total of three cuttings were taken. The alfalfa forage obtained from each tile was put into a paper sack, dried at 60 degrees centigrade in an oven, and then carefully weighed to obtain the yield.

The plant material from each tile was then ground in a micro Wiley mill and the material used for the chemical analysis.

At the last cutting, soil samples were taken using a soil probe to obtain a representative sample from the entire depth of the soil. These soil samples were air dried and the pH and available phosphorus determined.

Chemical Analysis of the Plant Material

The ground plant material was further dried for 12 hours at 80 degrees centigrade and one-gram samples were taken for wet digestion. The method for wet digestion was a slight modification of the procedure described by Smith (1942). The dry residue was taken up in hot 0.1 N HCl and brought to a volume of 50 ml.

Aliquots of this solution were taken to determine calcium, magnesium, potassium and phosphorus. Calcium and magnesium were determined on a Beckman D U spectrophotometer with a flame attachment. The 285.2 mu line was used for magnesium and the 556 mu line for the calcium. The 383 mu line for magnesium was tried but iron was found to interfere. Potassium was determined on the Perkin Elmer flame photometer using an internal standard of 100 ppm lithium. Phosphorus was determined colorimetrically on an Evelyn colorimeter using the molybdenum blue method.

DISCUSSION

Efficiency of Lime Requirement Tests

The lime requirements of the four soils, as measured by Woodruff's buffer or by titration with calcium hydroxide, agreed fairly well as indicated in Table 2. PH 6.9 was used as the reference point in the calculation of the lime requirement from the titration curves. The pH obtained in the greenhouse, using the titration lime requirement, was near the expected value. This is further shown in Table 3, which indicates the desired pH and the actual pH obtained in the greenhouse agreed very well. This was true when pure, finely ground calcium carbonate was used. Commercial lime varies greatly in purity and fineness; therefore the lime requirement test may be only a good approximation when this type of liming material is used.

Table 2. Efficiency of lime requirement tests.

Soil	Lime Requirement Pound per Acre		Av. pH obtained in greenhouse using titration lime requirement
	Woodruff's Buffer Solution	Titration with calcium hydroxide	
A	5,000	4,800	6.9
B	6,000	6,700	7.2
C	3,000	2,600	6.8
D	None	1,000	6.9

Table 3. Relationship of desired and observed pH of the soils used in greenhouse study.

Desired pH	Observed pH			
	Soil A	Soil B	Soil C	Soil D
Check	5.0	5.2	5.6	5.8
6.3	6.2	6.3	6.1	6.3
6.6	6.5	6.8	6.4	6.6
6.9	6.9	7.2	6.8	6.9

Alfalfa Yields

Table 4 gives the average yield of alfalfa for each cutting and the average total yield. The individual yields of each replicate and the total yields are given in Table 14 in the appendix.

Table 4. Average yield of dry alfalfa forage in grams.

Treatment	First Cut	Second Cut	Third Cut	Total Yield
Check	4.57	3.77	2.95	11.29
6.3	4.74	4.87	4.16	13.77
6.6	4.74	5.20	4.22	14.16
6.9	5.26	5.44	4.70	15.40
LSD($p = 0.05$)	2.64	0.97	1.03	0.94

The yields of alfalfa on the pH 6.6 and 6.9 treatments were significantly higher than on the check in the first cutting. In the second and third cuts, all the yields on the limed treatments were larger than check yields, but there were no significant differences between the yields on the different lime treatments. However, the average yields increased consistently with each addition of lime. The only exception was in the first cutting between the 6.3 and 6.6 treatment. These data would seem to indicate that the optimum pH for alfalfa production would have a range of 6.3 to 6.9.

Calcium Content and Uptake

The calcium content of the alfalfa forage is given in Table 5. The calcium contents of individual pots are given in Table 15 in the appendix.

Table 5. Average percent calcium content of the alfalfa forage.

Treatment	First Cut	Second Cut	Third Cut
Check	1.65	1.62	1.28
6.3	1.81	1.81	1.52
6.6	1.71	1.78	1.48
6.9	1.99	1.87	1.53
LSD($p = 0.05$)	.24	.13	.10

As might have been expected, the addition of lime generally increased the percentage of calcium of the forage. In the first cut the only significant difference was between the check and the 6.9 treatment. The second and third cuts showed significant increases in the average percentages of calcium for all treatments over the check; however there were no significant differences between the lime treatments. The differences in average calcium contents very closely paralleled the differences in yields. The only difference was in the first cut; the yield of the 6.6 treatment was significantly greater than that of the check, while there was no significant difference in the calcium content. In the first cut the only significant difference was between the check and 6.9, and in the second and third cuttings the uptakes of calcium on all the lime treatments were significantly greater than the check. No significant differences were obtained within the lime treatments on individual cuttings. The total uptake of calcium for all cuts was significantly greater for all the lime treatments and a significant difference was obtained between the 6.3 and 6.9 treatment. These data are summarized in Table 6. The complete data are given in Table 16 in the appendix.

Table 6. Average calcium uptake by alfalfa forage expressed in milligrams.

Treatment	First Cut	Second Cut	Third Cut	Total
Check	74.1	59.9	37.7	171.7
6.3	87.3	89.0	63.4	239.7
6.6	79.6	90.4	62.2	232.3
6.9	104.1	98.3	70.8	273.2
LSD($p = 0.05$)	21.0	18.4	14.9	32.8

Magnesium Content and Uptake

The chemical properties of magnesium and calcium are very closely related. Therefore, the increase in the calcium content of the alfalfa on the lime treatments might have been accompanied presumably by decreased magnesium content. This was not the case; the magnesium content of the alfalfa forage was almost constant for each cut. The average percent magnesium content is given in Table 7. The individual magnesium contents of each pot are given in Table 17 in the appendix.

Table 7. Average percent magnesium content of the alfalfa forage.

Treatment	First Cut	Second Cut	Third Cut
Check	.34	.33	.38
6.3	.34	.35	.36
6.6	.31	.29	.38
6.9	.34	.32	.38
LSD	No Significant Differences		

Table 8. Average uptake of magnesium by alfalfa forage expressed in milligrams.

Treatment	First Cut	Second Cut	Third Cut	Total
Check	15.1	12.6	11.4	39.1
6.3	16.1	17.4	14.9	48.4
6.6	14.2	14.9	15.2	44.3
6.9	17.8	17.1	17.9	52.8
LSD($p = 0.05$)	4.0	6.0	3.5	13.9

The magnesium uptake in the first and second cuttings was higher in the lime treated plots but the difference was not significant. The same was true of the total uptake. However, on the third cutting the limed treatments were significantly higher than the check. These data are summarized in Table 8. The individual uptake for each pot is given in Table 18 in the appendix.

Potassium Content and Uptake

No significant differences were obtained for the average percent potassium content in any of the three cuts. When yield and percentage potassium were considered together as uptake, significant differences were obtained. There were no significant differences in uptake in the first cut; but in the second and third cuts, the uptake of potassium on all the limed treatments were significantly larger than on the check. No significant differences in uptake occurred between the lime treatments. The uptake differences paralleled the yield differences. The potassium content and uptake are summarized in Tables 9 and 10. The complete data are listed in Tables 19 and 20 in the appendix.

Table 9. Average percent potassium content alfalfa forage.

Treatment	First Cut	Second Cut	Third Cut
Check	2.92	3.05	3.41
6.3	3.10	3.18	3.49
6.6	3.02	3.21	3.46
6.9	2.84	3.09	3.47
LSD	No Significant Differences------------------------		

Table 10. Average potassium uptake by alfalfa forage in milligrams.

Treatment	First Cut	Second Cut	Third Cut	Total
Check	136	115	99	350
6.3	145	152	141	438
6.6	139	167	143	449
6.9	148	168	163	479
LSD(p = 0.05)	36	30	28	110

Phosphorus Content and Uptake

The phosphorus content was found to be approximately constant for each cutting. No significant differences were found in phosphorus content. The average phosphorus content is given in Table 11 and the complete tabulation is given in Table 21 in the appendix.

Table 11. Average percent phosphorus content of alfalfa forage.

Treatment	First Cut	Second Cut	Third Cut
Check	.139	.160	.175
6.3	.141	.163	.177
6.6	.154	.169	.193
6.9	.139	.172	.185
LSD	No Significant Differences--------------------------		

In the first cut no significant differences were obtained in the average phosphorus uptake; however, the average phosphorus uptake consistently increased with each addition of lime. Significant differences were obtained in the average phosphorus uptake for the second cut, the third cut, and the total. The differences occurred between the same treatments in each case; the 6.6 and 6.9 treatments were significantly above the check and the 6.9 was significantly above the 6.3 treatment. This was the only analysis where these differences occurred in those places. Since these differences did not parallel yield differences or content differences, they seemed to indicate that lime increased the phosphorus availability as measured by the total amount taken up by the alfalfa. The soil test for available phosphorus made after the third cut showed no differences in the availability. This may have been due to the plant using the phosphorus almost as rapidly as it was becoming available.

Table 12. Average phosphorus uptake by alfalfa forage in milligrams.

Treatment	First Cut	Second Cut	Third Cut	Total
Check	6.19	6.02	4.96	17.17
6.3	6.77	7.79	6.36	20.92
6.6	7.05	8.74	8.08	23.87
6.9	7.34	9.55	8.67	25.56
LSD ($p = 0.05$)	1.68	2.04	1.99	4.41

Total Cation Content

Total cation was used to refer to the calcium, magnesium, and potassium cations only. The average total cation content is given in Table 13. The complete table is given in Table 23 in the appendix.

Table 13. Average total cation content of the alfalfa forage expressed as milliequivalents per 100 grams.

Treatment	First Cut	Second Cut	Third Cut
Check	184	188	185
6.3	198	203	198
6.6	189	197	196
6.9	200	200	200
LSD	18	12	8

The data showed that the total cation content was about constant. However, when the data were subjected to statistical analysis, the first cut had no significant differences. The cation contents on the pH 6.9 and 6.3 treatments had a significantly greater total cation content on the third cut.

SUMMARY AND CONCLUSIONS

A greenhouse and laboratory study was made to find if the soils of south central Kansas should be limed. These soils had an acid surface with free carbonate in the subsoil. Alfalfa was grown on four soils from this region and the yield of the dry forage was obtained. The forage was analyzed chemically for calcium, magnesium, phosphorus, and potassium.

Two methods of obtaining the lime requirements, Woodruff's buffer solution and titration with calcium hydroxide, were checked and found to agree closely. The titration curves, obtained with calcium hydroxide, were used to calculate the amount of calcium carbonate necessary to obtain a pH of 6.3, 6.6, and 6.9 on the various soils. Using the pure, finely powdered calcium carbonate, the pH obtained with the soils in the greenhouse was very close to the desired value.

Alfalfa yields were increased by liming. There were no significant differences in the first cut, but all the lime treatments were significantly above the check in the second and third cuts. Although there were no significant differences between the lime treatments, the greatest yield was consistently obtained on the highest lime treatment.

The calcium content of the alfalfa forage was increased by liming. The calcium contents of the limed treatments were significantly higher than those on the check, but there were no significant differences between the lime treatments.

Liming had no effect on the magnesium, potassium, or phosphorus content of the alfalfa. The uptake of magnesium by alfalfa tended to be constant on the different treatments, while differences were obtained in the uptake of potassium and phosphorus. The increased uptake of potassium paralleled the increased yield. Phosphorus uptake was increased significantly by liming and the uptake indicated that liming increased phosphorus availability. However, this was not substantiated by the soil test for available phosphorus which was run after the third cut.

The total cation content (calcium, magnesium, and potassium) ranged from 184 to 200 M.E. per 100 grams dry material. This might have been called constant, but upon statistical analysis, significant differences were obtained. The cation contents on the lime treatments were generally significantly higher than those on the check treatments. This was probably due to the increased calcium content of the forage obtained from the lime treatments.

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APPENDIX

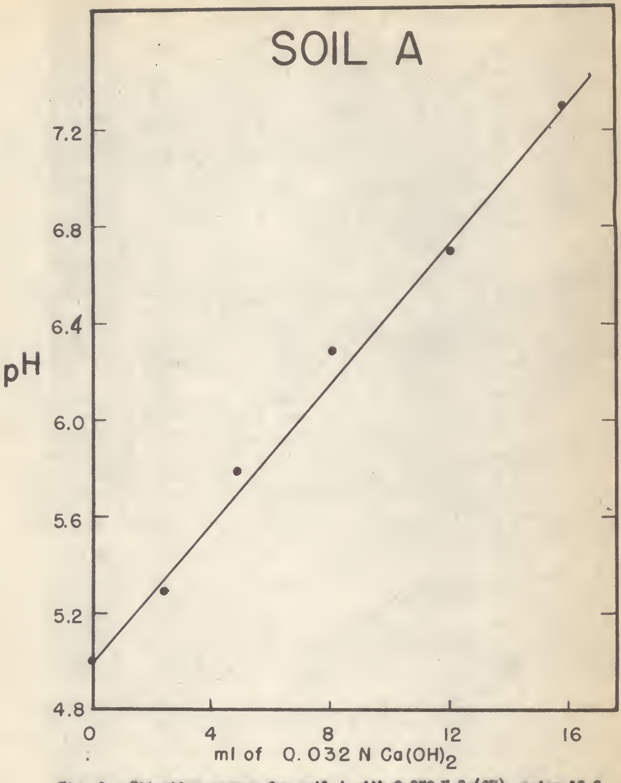

Fig. 1. Titration curve for soil A with 0.032 N $Ca(OH)_2$ using 10.0 gram soil samples.

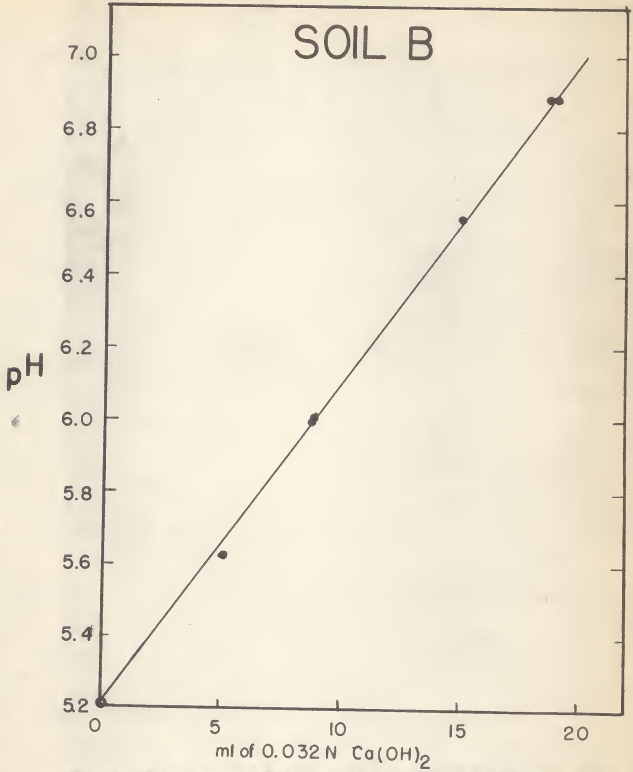

Fig. 2. Titration curve for soil B with 0.032 N $Ca(OH)_2$ using 10.0 gram soil samples.

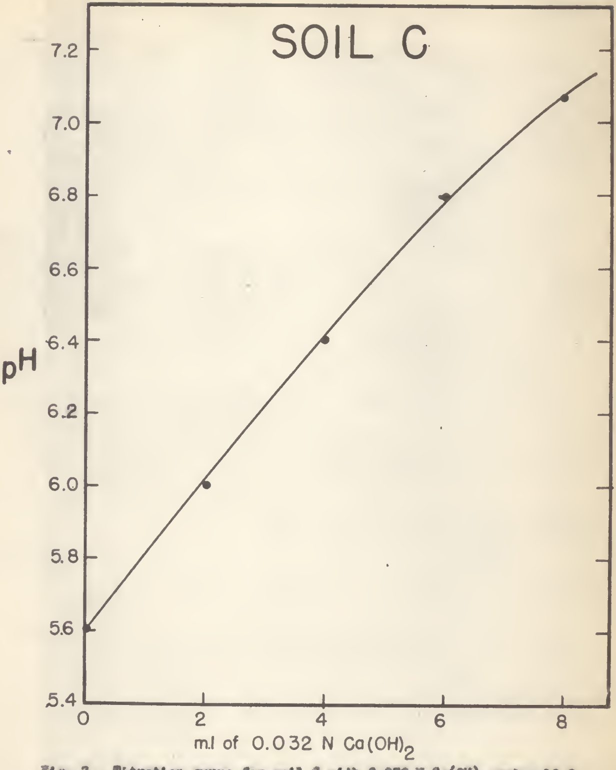

Fig. 3. Titration curve for soil C with 0.032 N $Ca(OH)_2$ using 10.0 gram soil samples.

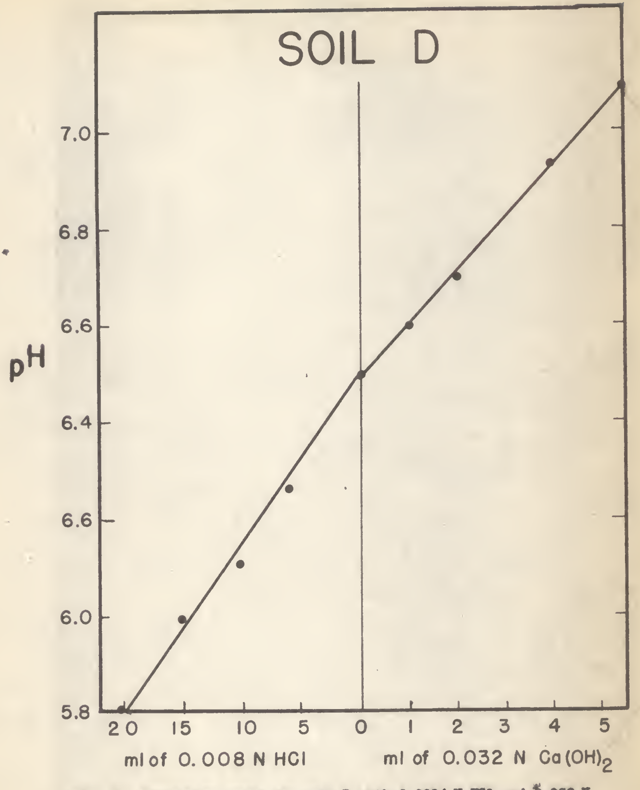

Fig. 4. Titration curve for soil D with 0.0084 N HCl and 0.032 N $Ca(OH)_2$ using 10.0 gram soil samples.

Table 14. Alfalfa yield of individual replicates expressed in grams of dry forage.

Soil	Treatment: pH	First Cut Block I	II	III	Second Cut Block I	II	III	Third Cut Block I	II	III	Total Yield
A	Check	3.80	5.12	7.10	4.80	6.07	4.76	4.00	4.75	4.35	44.75
	6.3	6.43	6.20	6.12	6.86	6.50	5.46	6.74	6.32	5.41	56.04
	6.6	6.42	5.52	7.20	6.24	7.63	6.71	5.72	6.48	5.74	57.66
	6.9	6.15	6.43	6.05	5.06	9.72	7.81	5.40	7.59	6.19	60.40
B	Check	6.55	3.27	4.15	4.12	1.69	2.71	3.32	1.00	1.95	28.76
	6.3	3.22	2.55	3.08	5.20	1.92	2.63	3.94	1.33	1.90	25.77
	6.6	2.73	4.55	3.92	3.84	5.15	3.39	1.82	3.98	2.73	32.21
	6.9	3.85	4.06	6.20	3.70	4.39	6.30	2.95	3.78	4.20	39.43
C	Check	4.05	4.30	4.16	3.53	3.63	3.17	3.22	3.07	——	29.13
	6.3	5.77	4.87	2.62	5.59	4.27	3.83	4.75	3.83	2.34	37.87
	6.6	3.97	3.17	6.95	4.90	4.82	6.25	3.93	2.81	6.79	43.59
	6.9	4.42	3.95	6.55	4.28	3.91	5.37	3.70	4.11	4.88	41.17
D	Check	3.70	5.00	3.60	3.75	4.46	2.51	3.58	3.81	2.37	32.78
	6.3	7.54	3.57	4.95	8.20	4.27	3.68	5.93	3.21	4.25	45.60
	6.6	3.93	4.50	3.98	4.53	4.62	4.29	4.05	3.51	3.02	36.43
	6.9	5.16	5.05	5.30	4.50	4.71	5.51	4.52	3.75	5.35	43.85

Table 15. Calcium content of the alfalfa forage expressed as percent of dry weight.

Soil	Treatment: pH	First Cut Block I	First Cut Block II	First Cut Block III	Second Cut Block I	Second Cut Block II	Second Cut Block III	Third Cut Block I	Third Cut Block II	Third Cut Block III
A	Check	1.32	1.58	1.18	1.25	1.30	1.25	1.02	0.98	1.10
	6.3	1.60	1.62	1.65	1.65	1.42	1.58	1.22	1.38	1.35
	6.6	1.48	1.80	1.15	1.58	1.42	1.45	1.32	1.42	1.35
	6.9	1.52	1.58	1.48	1.52	1.45	1.38	1.25	1.20	1.28
B	Check	1.48	1.50	1.72	1.52	1.48	1.65	1.18	1.10	1.18
	6.3	1.45	1.62	1.22	1.58	1.58	1.58	1.52	1.32	1.35
	6.6	1.35	2.38	1.75	1.62	1.45	1.45	1.42	1.40	1.25
	6.9	1.65	1.65	2.12	1.65	1.58	1.53	1.60	1.38	1.35
C	Check	1.85	2.20	1.22	1.65	1.68	1.32	1.45	1.28	——
	6.3	1.70	2.35	1.62	1.82	1.88	1.55	1.75	1.48	1.45
	6.6	1.98	1.75	1.68	1.88	1.65	1.65	1.58	1.40	1.52
	6.9	2.02	2.50	2.02	1.90	2.18	1.82	1.52	1.78	1.56
D	Check	1.42	2.08	2.25	2.40	1.90	2.08	1.80	1.65	1.48
	6.3	2.05	2.28	2.58	2.32	2.68	2.12	1.82	1.95	1.68
	6.6	2.25	1.58	1.38	2.50	2.72	2.00	1.92	1.78	1.38
	6.9	2.15	2.68	2.52	2.30	2.65	2.40	1.90	1.68	1.90

Table 16. Calcium uptake by the alfalfa forage expressed in milligrams of calcium.

Soil	Treatment pH	First Cut Block I	II	III	Second Cut Block I	II	III	Third Cut Block I	II	III	Total
A	Check	50.2	80.9	83.8	60.0	78.9	59.5	40.8	46.6	47.9	548.6
	6.3	102.9	100.4	101.0	113.2	92.3	86.3	82.2	87.2	73.0	838.5
	6.6	95.0	99.4	82.8	98.6	108.3	97.3	75.5	92.0	77.5	826.4
	6.9	93.5	101.6	89.5	76.9	140.9	107.8	67.5	91.1	80.0	848.8
B	Check	96.9	49.0	71.4	62.6	25.0	44.7	39.2	11.0	23.0	422.8
	6.3	46.7	41.3	37.6	82.2	30.3	41.6	60.0	17.6	25.6	382.9
	6.6	36.8	108.3	68.6	62.2	74.7	49.2	25.8	55.7	34.1	515.4
	6.9	63.5	70.0	131.4	61.0	69.4	99.5	47.2	52.2	56.7	650.9
C	Check	74.9	94.6	50.8	58.2	61.0	41.8	46.7	39.3	——	467.3
	6.3	98.1	114.4	42.4	101.7	80.3	59.4	83.1	56.7	33.9	670.0
	6.6	78.6	55.5	116.8	92.1	79.5	103.1	62.1	39.3	103.2	730.2
	6.9	89.3	98.8	132.3	81.3	85.2	97.7	56.2	73.2	75.6	789.6
D	Check	52.5	104.0	81.0	90.0	84.7	52.2	64.4	59.1	35.1	623.0
	6.3	154.6	81.4	127.7	188.6	114.4	78.0	107.9	62.6	71.4	986.6
	6.6	88.4	71.1	54.9	113.2	125.7	81.8	77.8	62.5	41.7	717.1
	6.9	110.9	135.3	133.6	103.5	124.8	132.4	85.9	63.0	101.6	991.0

Table 17. Magnesium content of the alfalfa expressed as percent of dry weight.

Soil	Treatment pH	First Cut Block I	First Cut Block II	First Cut Block III	Second Cut Block I	Second Cut Block II	Second Cut Block III	Third Cut Block I	Third Cut Block II	Third Cut Block III
A	Check	.27	.25	.25	.22	.34	.34	.31	.37	.37
	6.3	.22	.22	.25	.28	.34	.34	.34	.20	.31
	6.6	.25	.20	.22	.22	.22	.22	.34	.31	.31
	6.9	.22	.20	.20	.22	.34	.18	.34	.31	.40
B	Check	.25	.28	.40	.28	.34	.22	.40	.40	.34
	6.3	.34	.25	.25	.34	.22	.31	.40	.34	.37
	6.6	.28	.34	.22	.28	.17	.22	.40	.31	.37
	6.9	.25	.25	.40	.34	.20	.31	.40	.40	.34
C	Check	.34	.50	.20	.44	.44	.22	.44	.40	—
	6.3	.34	.47	.34	.40	.47	.37	.40	.44	.28
	6.6	.40	.34	.28	.40	.34	.31	.40	.44	.31
	6.9	.40	.40	.40	.44	.40	.31	.40	.40	.28
D	Check	.44	.44	.44	.44	.44	.22	.40	.44	.40
	6.3	.44	.40	.50	.44	.44	.20	.44	.44	.40
	6.6	.44	.25	.53	.44	.50	.20	.47	.44	.40
	6.9	.40	.47	.50	.44	.53	.22	.44	.44	.47

Table 18. Magnesium uptake by the alfalfa forage expressed as milligrams of magnesium.

Soil	Treatment pH	First Cut Block I	First Cut Block II	First Cut Block III	Second Cut Block I	Second Cut Block II	Second Cut Block III	Third Cut Block I	Third Cut Block II	Third Cut Block III	Total
A	Check	10.3	12.8	17.8	10.6	20.6	16.2	12.4	17.6	16.1	154.3
	6.3	14.2	13.6	15.3	19.2	22.1	18.6	22.9	12.6	16.8	155.3
	6.6	16.1	10.4	15.8	13.7	16.8	14.8	19.4	20.1	17.8	144.9
	6.9	13.5	12.9	12.1	11.1	33.1	14.1	18.4	23.5	24.8	163.4
B	Check	16.8	9.2	16.6	11.5	5.8	6.0	13.3	4.0	6.6	89.8
	6.3	11.0	6.4	7.7	17.7	4.2	8.2	15.8	4.5	7.0	82.4
	6.6	7.6	15.5	8.6	10.8	8.8	7.5	7.3	12.3	10.1	88.4
	6.9	9.6	10.2	24.8	12.6	8.8	19.5	11.8	15.1	14.3	126.7
C	Check	13.8	21.5	8.3	15.5	16.0	7.0	14.2	12.3	——	108.5
	6.3	19.6	22.9	8.9	22.4	20.1	14.2	19.0	16.8	6.6	150.4
	6.6	15.9	10.8	19.5	19.6	16.4	19.4	15.7	12.4	21.1	150.6
	6.9	17.7	15.8	26.2	18.8	15.6	16.7	14.8	16.4	13.7	155.7
D	Check	16.3	22.0	15.8	16.5	19.6	5.5	14.3	16.8	9.5	136.3
	6.3	33.2	15.7	24.8	36.1	18.8	7.4	26.1	14.1	17.0	193.1
	6.6	17.3	11.2	21.1	19.9	23.1	8.6	19.0	15.4	12.1	147.8
	6.9	20.6	23.7	26.5	18.0	25.0	12.1	19.9	16.5	25.1	187.5

Table 19. Potassium content of the alfalfa forage expressed as percent of dry weight

Soil	Treatment: pH	First Cut Block I	First Cut Block II	First Cut Block III	Second Cut Block I	Second Cut Block II	Second Cut Block III	Third Cut Block I	Third Cut Block II	Third Cut Block III
A	Check	2.92	3.00	4.64	3.24	3.30	3.08	3.19	3.24	2.91
	6.3	2.59	2.92	4.91	2.86	3.14	3.52	3.19	3.63	3.74
	6.6	2.86	3.03	2.53	3.13	3.47	3.41	3.26	3.19	3.68
	5.9	2.92	2.86	2.80	3.46	2.92	3.24	3.52	3.58	3.90
B	Check	2.53	3.36	2.53	3.08	3.13	3.30	3.63	3.90	3.57
	6.3	3.30	3.58	3.30	3.46	3.30	3.41	3.80	4.29	3.90
	6.6	4.24	3.03	2.75	3.57	3.41	3.30	3.74	3.74	3.68
	6.9	2.97	3.52	2.31	3.08	3.57	3.30	3.80	3.90	3.90
C	Check	2.42	2.97	2.48	2.97	3.08	2.79	3.36	3.41	——
	6.3	3.24	2.81	3.08	2.75	3.86	3.52	2.91	3.14	3.68
	6.6	3.41	3.08	2.31	3.08	3.14	3.02	3.53	3.30	2.80
	6.9	3.30	2.31	2.48	3.42	2.79	2.79	3.30	3.14	3.02
D	Check	2.48	2.70	2.97	2.75	2.86	2.97	2.97	3.68	3.63
	6.2	2.20	2.53	2.70	2.64	2.92	2.81	2.92	3.63	3.08
	6.6	2.53	3.24	3.24	2.92	3.02	3.02	3.24	3.96	3.30
	6.9	2.31	3.30	2.97	2.86	2.86	2.75	2.86	3.68	3.08

Table 20. Potassium uptake by the alfalfa forage expressed as milligrams of potassium.

Soil	Treatment: pH	First Cut Block I	First Cut Block II	First Cut Block III	Second Cut Block I	Second Cut Block II	Second Cut Block III	Third Cut Block I	Third Cut Block II	Third Cut Block III	Total
A	Check	111.0	153.6	329.4	155.5	200.3	146.6	127.6	153.9	126.6	1,504.5
	6.3	166.5	181.0	300.5	196.2	204.1	192.2	215.0	229.4	202.3	1,687.2
	6.6	183.6	167.3	182.2	195.3	264.8	228.8	192.2	206.7	211.2	1,632.1
	6.9	179.6	183.9	169.4	175.1	283.8	253.0	190.1	271.7	241.4	1,948.0
B	Check	165.7	109.9	105.0	126.9	52.9	89.4	120.5	39.0	69.6	878.9
	6.3	106.3	91.3	101.6	179.9	63.4	89.7	149.7	57.0	74.1	913.0
	6.6	115.8	137.9	107.8	137.1	175.6	111.9	68.1	148.9	100.5	1,103.6
	6.9	114.3	142.9	143.2	114.0	156.7	207.9	112.1	147.4	163.8	1,302.3
C	Check	98.0	127.7	103.2	104.8	111.8	88.4	108.2	104.7	-----	846.8
	6.3	186.9	136.8	80.7	153.7	164.8	134.8	138.2	120.3	86.1	1,202.3
	6.6	135.4	97.6	160.5	150.9	151.3	188.8	138.3	92.7	190.1	1,305.6
	6.9	145.9	91.2	162.4	146.4	109.1	149.8	122.1	129.0	147.4	1,203.3
D	Check	91.8	135.0	106.9	103.1	127.6	74.5	106.3	140.2	86.0	971.4
	6.3	165.9	90.3	133.6	216.5	124.7	103.4	173.2	116.5	130.3	1,255.0
	6.6	99.4	145.8	129.0	132.3	139.5	129.6	131.2	139.0	99.7	1,145.5
	6.9	119.2	166.7	157.4	128.7	134.7	151.5	129.3	138.0	164.8	1,290.3

Table 21. Phosphorus content of the alfalfa forage expressed as percent of dry weight.

Soil	Treatment pH	First Cut Block I	II	III	Second Cut Block I	II	III	Third Cut Block I	II	III
A	Check	.129	.129	.128	.165	.180	.150	.191	.125	.150
	6.3	.114	.212	.146	.180	.175	.196	.208	.196	.160
	6.6	.125	.138	.155	.196	.134	.201	.245	.185	.212
	6.9	.125	.146	.155	.196	.222	.155	.23 8	.160	.165
B	Check	.138	.155	.134	.146	.222	.146	.190	.225	.170
	6.3	.146	.121	.141	.155	.180	.165	.165	.201	.180
	6.6	.231	.165	.114	.180	.155	.121	.190	.175	.190
	6.9	.138	.109	.134	.150	.155	.201	.208	.201	.201
C	Check	.138	.141	.121	.160	.190	.192	.175	.185	——
	6.3	.141	.114	.180	.146	.180	.114	.190	.175	.171
	6.6	.165	.170	.121	.190	.165	.117	.165	.180	.141
	6.9	.138	.106	.146	.190	.134	.134	.212	.165	.141
D	Check	.165	.138	.150	.134	.180	.160	.160	.138	.219
	6.3	.155	.118	.109	.109	.170	.185	.165	.180	.141
	6.6	.175	.155	.134	.165	.180	.225	.190	.201	.245
	6.9	.155	.180	.134	.180	.155	.190	.165	.150	.225

Table 22. Phosphorus uptake by the alfalfa forage expressed in milligrams of phosphorus.

Soil	Treatment: pH	First Cut Block I	II	III	Second Cut Block I	II	III	Third Cut Block I	II	III	Total
A	Check	4.9	6.6	9.1	7.9	10.9	7.1	7.6	5.9	6.5	66.5
	6.3	7.3	13.1	8.9	12.4	11.4	10.7	1.4	12.4	8.7	86.3
	6.6	8.0	7.6	11.2	12.2	10.2	13.6	14.0	12.0	12.2	100.9
	6.9	7.7	9.4	9.4	9.9	21.6	12.1	12.8	12.1	10.2	105.3
B	Check	9.0	5.1	5.6	6.0	3.8	4.0	6.3	2.2	3.3	45.3
	6.3	4.7	3.1	4.3	8.1	3.5	4.3	6.5	2.7	3.4	40.6
	6.6	6.3	7.5	4.5	6.9	8.0	4.1	3.4	7.0	5.2	52.9
	6.9	5.3	4.4	8.3	5.6	6.8	12.7	6.1	7.6	8.4	65.2
C	Check	5.6	6.1	5.0	5.6	6.9	2.9	5.6	5.7	—	43.5
	6.3	8.1	5.6	4.7	8.2	7.7	4.4	9.0	6.7	4.0	58.3
	6.6	6.6	5.4	8.4	9.3	8.0	7.3	6.5	5.1	9.6	66.0
	6.9	6.1	4.2	9.6	8.1	5.2	6.8	7.8	6.8	6.9	61.5
D	Check	6.1	6.9	5.4	5.0	8.0	4.0	5.7	5.3	5.2	51.6
	6.3	11.7	4.2	5.4	8.9	7.3	6.8	9.8	5.8	6.0	65.8
	6.6	6.9	7.0	5.3	7.5	8.3	9.6	7.7	7.1	7.4	66.8
	6.9	8.0	8.6	7.1	8.1	7.3	10.5	7.5	5.6	12.0	74.7

Table 23. Total cation content of alfalfa expressed as milliequivalents per 100 grams.

Soil	Treatment: pH	First Cut Block I	First Cut Block II	First Cut Block III	Second Cut Block I	Second Cut Block II	Second Cut Block III	Third Cut Block I	Third Cut Block II	Third Cut Block III
A	Check	163	176	198	165	180	171	160	165	162
	6.3	164	174	229	180	181	199	173	180	190
	6.6	168	184	140	178	179	179	182	190	189
	6.9	169	170	164	184	177	168	183	179	199
B	Check	159	184	184	180	184	186	187	190	180
	6.3	185	193	166	199	183	194	209	206	200
	6.6	199	224	176	197	175	176	202	193	189
	6.9	179	193	198	191	188	191	213	204	197
C	Check	182	227	141	197	202	157	197	187	180
	6.3	196	228	189	197	234	201	197	193	191
	6.6	219	194	166	208	193	187	204	193	175
	6.9	218	217	197	221	216	190	196	205	180
D	Check	171	209	215	229	207	199	201	210	202
	6.3	195	215	239	222	248	196	205	229	198
	6.6	214	182	196	239	258	195	220	229	189
	6.9	200	257	243	214	252	210	207	217	215

Table 24. Available phosphorus in the soil after the third cut of alfalfa.

Soil	pH Treatment	Available Phosphorus Pounds per Acre		
		Block I	Block II	Block III
A	Check	54	57	66
	6.3	57	60	63
	6.6	54	63	63
	6.9	54	70	54
B	Check	23	27	27
	6.3	25	25	29
	6.6	25	27	29
	6.9	23	27	29
C	Check	18	16	29
	6.3	21	18	27
	6.6	18	16	27
	6.9	18	16	27
D	Check	27	21	32
	6.3	27	25	29
	6.6	25	25	29
	6.9	32	29	29

A LIMING STUDY OF SOME SOUTH CENTRAL KANSAS SOILS

by

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AN ABSTRACT OF A THESIS

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The soils of eastern Kansas are acid and are known to need lime; while the soils of western Kansas are neutral to slightly alkaline with free lime near the surface. In the central area of the state, the surface soil is acid with a neutral to alkaline subsoil. This study was an attempt to determine the need for lime in this central area.

Soils were collected from south central Kansas and brought to Manhattan to be used for a greenhouse and laboratory study. The soil varied in texture from a fine sandy loam to a silt loam and the original pH's varied from 4.9 to 6.5.

Titration curves, using calcium hydroxide, were obtained to calculate the amount of calcium carbonate required to bring the soil to the various pH's.

The greenhouse study was set up using a check and three limed treatments, pH 6.3, pH 6.6, and pH 6.9, on four soils with three replications. The treatments were completely randomized within each block. This made possible a statistical analysis of the results.

The plant material was ground. One-gram samples of this material were wet digested using perchloric acid and brought to volume. Calcium, magnesium and potassium were determined on the extract using flamephotometer techniques and phosphorus was determined colorimetrically.

Two methods of obtaining the lime requirement, Woodruff's buffer solution and titration with calcium hydroxide, were checked and found to agree closely.

Alfalfa yields were increased by liming. There were no significant differences in the first cut, but all the lime treatments were significantly above the check in the second and third cuts. Although there were no significant differences between the lime treatments, the greatest yield was consistently obtained on the highest lime treatment.

The calcium content of the forage from the lime treatments was significantly higher than that from the check but there were no differences in calcium content of the forage on the different lime treatments.

The uptake of magnesium tended to be constant, while differences were obtained in the uptake of potassium and phosphorus. The increased uptake of potassium paralleled the increased yield. Phosphorus uptake was significantly incrsased by liming and the uptake indicated that liming increased phosphorus availability.

No significant differences were obtained in the magnesium, potassium, or phosphorus content of the alfalfa.

The total cation content (calcium, magnesium, and potassium) ranged from 184 to 200 M.E. per 100 grams dry material.