

This holds good not only for the averages of the limed and unlimed soils but also for each one of the plats so treated.

The limed plats containing alfalfa have in each case produced more nitrates than the limed soil growing no alfalfa, but where no lime was added the presence of alfalfa does not seem to have had any effect on nitrification.

It may be concluded from these experiments that a substantial increase in the basicity of a soil favors nitrification, and that the growth of alfalfa, and possibly other legumes, on soil well supplied with lime, also contributes to the nitrifying process. Whether the alfalfa acts in this way by increasing the quantity of easily decomposing organic matter through the production and decomposition of tubercles or small roots, or in some other way, has not been demonstrated.

#### CONCLUSIONS.

These experiments confirm the opinion heretofore held that the presence of a certain degree of basicity in the soil is favorable to nitrification, and that the addition of lime produces a substantial increase in the nitrates for at least four years after its application.

Soil on which alfalfa grew possessed greater nitrifying power than did similar soil cropped to timothy. The growth of a legume is thus apparently favorable to the process of nitrification.

Alfalfa grown on soil in need of lime contained a higher percentage of nitrogen when lime was added to the soil than when none was added. The average difference on ten limed and ten unlimed plats amounted to 88 pounds of crude protein per ton of alfalfa hay containing 10 per cent. moisture.

Timothy growing with alfalfa contained a higher percentage of nitrogen than did the same grass growing alone. When the crop was produced on land that had been well limed this difference was more marked. A possible improvement in the nitrogen content of certain plants by growing them with legumes is thus indicated.

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### THE EFFECT OF LIME UPON THE SOLUBILITY OF SOIL CONSTITUENTS.

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In the review of literature upon the subject of the effect of lime upon the solubility of soil constituents, the writer finds that most of the work done has been done with water extracts, and it seems that no definite conclusions can be drawn from the little that has been accomplished.

Work done of Whitson and Stoddard<sup>1</sup> shows that

<sup>1</sup> *Research Bull.* No. 2, U. of Wis. Agr. Expt. Sta., p. 60.

acid soils are deficient in phosphorus, soluble in N/5 HNO<sub>3</sub>, or in calcium phosphate, and unpublished work done in this laboratory shows that soils low in lime soluble in N/5 HNO<sub>3</sub> are also low in phosphorus in the same solution.

Morse and Curry<sup>1</sup> have shown that lime treatment of soils, for comparatively short periods, does not increase the solubility of potassium, and decreases that of aluminium and iron in water extracts.

Frapps,<sup>2</sup> and Whitson and Stoddard<sup>3</sup> have shown that the N/5 HNO<sub>3</sub> method is reliable for measuring calcium phosphate in soils, but so far as the writer knows, there has been no attempt to determine the effect of lime upon the solubility of other elements present in the soils soluble in N/5 HNO<sub>3</sub>, or other weak acid solutions.

Crop experiments at the Rhode Island Station<sup>4</sup> have indicated that there is no appreciable effect upon the availability of potash by the lime treatment.

The fact that calcium phosphate, whether added or originally in the soil, becomes available to plants, seems to be fairly well established by data obtained by N/5 HNO<sub>3</sub> digestion of soils, crop production of these soils, and crop production by the use of floats and slag.

These facts, together with the statement that the addition of lime and roasted phosphates of iron and aluminum, or other forms of phosphorus, to the soil increases the available phosphorus in these phosphates,<sup>5</sup> would point to the conclusion that the N/5 HNO<sub>3</sub> digestion of the limed soil would give an increased amount of phosphorus in this solution.

Furthermore, if lime replaces iron and aluminum in combination with phosphorus, and the iron and aluminum are precipitated in the soil, we would expect to find an increased amount of these elements in the acid solution.

Following this line of deduction, we would expect the silicates to be broken up and to follow the same course—not only the silicates of iron and aluminum, but those of Mg and K to a greater or less extent. If this were true, we would naturally expect to find an increase in the amount of potassium and magnesium soluble in N/5 HNO<sub>3</sub>.

Unpublished results obtained at this station, in connection with soil fertility experiments, by the analysis of wheat grown on plots with various forms of fertilization and one end limed in 1900, the other in 1905, with 1 ton CaO per acre, seem to give good grounds for the conclusion that the addition of lime to these soils decreases the potassium that may be assimilated by the crop, while, as indicated by the

<sup>1</sup> 19th and 20 Report N. H. Agr. Expt. Sta., pp. 310-292.

<sup>2</sup> *Jour. Amer. Chem. Soc.*, 28, 824.

<sup>3</sup> *Research Bull.* No. 2, U. of Wis. Agr. Expt. Sta., p. 60.

<sup>4</sup> R. I. Expt. Sta., *Bull.* 139, p. 75 and appended references.

<sup>5</sup> R. I. Expt. Sta., *Bull.* 139, p. 72, and appended references. *THIS JOURNAL*, 2, 133-135.

analysis of the same crop, we find an increased per cent. of phosphorus in the crop where lime was used in 1905 over the crop where lime was used in 1900, as is shown by Table I:

TABLE I.—EXTRACTS FROM RESULTS OF ANALYSES OF WHEAT GROWN ON LIMED AND UNLIMED PLOTS.

		Per cent. K <sub>2</sub> O.	Per cent. P <sub>2</sub> O <sub>5</sub> .
No fertilizer, limed 1900	1 ton CaO per acre	0.770	0.305
No fertilizer, limed 1905	1 ton CaO per acre	0.729	0.368
Phosphorus, limed 1900	1 ton CaO per acre	0.724	0.340
Phosphorus, limed 1905	1 ton CaO per acre	0.612	0.413
Phosphorus and potash, limed, 1900	1 ton CaO per acre	0.835	0.351
Phosphorus and potash, limed 1905	1 ton CaO per acre	0.816	0.402
Potash, limed 1900	1 ton CaO per acre	0.885	0.327
Potash, limed 1905	1 ton CaO per acre	0.801	0.352

These facts led to an effort to show, in a chemical way, the effect of lime upon the soil constituents, and after making some determinations of water-soluble constituents, before and after various treatments with lime, without much light being thrown upon the subject, the writer concluded to try the N/5

phosphate, after separating with bromine and the Fe<sub>2</sub>O<sub>3</sub> and Al<sub>2</sub>O<sub>3</sub>, which were dissolved from the filter after the double acetate precipitation, and separated by a 50 per cent. solution of KOH. The Al<sub>2</sub>O<sub>3</sub> was then precipitated as AlPO<sub>4</sub>. A separated portion was pipetted off for Fe<sub>2</sub>O<sub>3</sub> and precipitated with NH<sub>4</sub>OH. After washing, the precipitate was dissolved with HCl and reduced with stannous chloride and titrated with N/200 K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>, using HgCl<sub>2</sub> to precipitate the excess of stannous chloride. The filtrates were tested for iron and found free. The results are shown in Table II.

It is interesting to note the uniform increase in the solubility of all the substances determined, with the single exception of K<sub>2</sub>O, which does not vary materially for any application of lime, except where 2 tons per acre were used, which does not indicate that the amount of lime added causes this increase.

It seems that these results show that the phosphates and silicates are in a measure broken up by lime with the exception of the silicates carrying

TABLE II.

No. CaO per acre.	P <sub>2</sub> O <sub>5</sub> .	MgO.	Al <sub>2</sub> O <sub>3</sub> .	Fe <sub>2</sub> O <sub>3</sub> .	SiO <sub>2</sub> .	Mn <sub>2</sub> O <sub>4</sub> .	CaO.	K <sub>2</sub> O.
Check.....	0.00216	0.0321	0.0982	0.0375	0.0245	0.0295	0.0899	0.0089
Check.....	0.00252	0.0376	0.0989	0.0364	0.0290	0.0281	0.1031	0.0104
No. 4000.....	0.00225	0.0342	0.1006	0.0440	0.0545	0.0335	0.2953	0.0133
No. 8000.....	0.00284	0.0321	0.1206	0.0552	0.0800	0.0405	0.5239	0.0089
No. 12000.....	0.00428	0.0326	0.1316	0.0656	0.1000	0.0443	0.7771	0.0093
No. 16000.....	0.00486	0.0360	0.1480	0.0704	0.1215	0.0456	0.8926	0.0087
No. 20000.....	0.00720	0.0488	0.2000	0.0880	0.1730	0.0706	1.2738	0.0084
No. 24000.....	0.00796	0.0512	0.1956	0.0952	0.1970	0.0741	1.4260	0.0087
No. 30000.....	0.00860	0.0560	0.2327	0.1104	0.2230	0.0867	1.5774	0.0096
No. 36000.....	0.00999	0.0618	0.2399	0.1424	0.2740	0.1071	2.0724	0.0100
No. 40000.....	0.01094	0.0664	0.2431	0.1568	0.2925	0.1108	2.3034	0.0090
No. 50000.....	0.01300	0.1064	0.2853	0.1824	0.3150	0.1296	2.6664	0.0080

NOTE—Samples 1 and 2 explanation: Sample 1 was taken when the soil was put into the pots, air-dried and prepared, sealed in tight jar. Sample 2 was taken from the check pot receiving no lime but crop grown on this the same as on the other pots. All other samples received lime as indicated in column 1, the lime being mixed with the soil in proportion to weight, assuming 2,000,000 lbs. to be weight of an 8" acre.

HNO<sub>3</sub> method on some soil that was being used to test the effect of caustic lime upon the growth of alfalfa, five-gallon earthenware pots being used.

The soil was taken from a portion of the Station farm not under systematic cultivation, and classed by the U. S. Bureau of Soils as Volusia Silt Loam, lime being added as shown in the following table.

The samples were taken a few weeks before the second crop of alfalfa, grown in the pots, was harvested. The samples were air-dried and passed through a 1/2 mm. sieve, 10-gram portions being used for preliminary digestion to determine the amount of HNO<sub>3</sub> required to make the solution N/5 at the end of the digestion. Two hundred and twenty grams were then weighed into 2500 cc. Winchester bottles and 2200 cc. of HNO<sub>3</sub> solution added, which would give a solution N/5 at the end of the digestion. This was shaken at intervals of 30 minutes for 5 hours and filtered. The portions for analysis were pipetted off in duplicate as follows: For P<sub>2</sub>O<sub>5</sub>, 400 cc.; for SiO<sub>2</sub>, Mn<sub>2</sub>O<sub>4</sub>, CaO, MgO and K<sub>2</sub>O, and Al<sub>2</sub>O<sub>3</sub>, 400 cc. Determinations were made by the official methods, except Mn<sub>2</sub>O<sub>4</sub>, which was determined as the

potassium, which, if attacked at all, are not disturbed sufficiently to liberate the potash to an appreciable extent.

#### CONCLUSIONS.

Lime renders insoluble phosphates in the soil soluble, by replacing iron and aluminum, which is in combination with the phosphorus and renders all three more soluble in N/5 HNO<sub>3</sub>.

Lime breaks up certain silicates in soils and renders them more soluble in N/5 HNO<sub>3</sub>, but does not act upon insoluble potassium compounds in the soil to such an extent that N/5 HNO<sub>3</sub> can be used as a measure of such potassium.

The addition of caustic lime to soils has the effect of diminishing the amount of K<sub>2</sub>O assimilated by wheat grown on such soils.

The theory held, "that lime added to the soil increases the amount of available potash in the soil," is either erroneous, or requires more positive proof than has heretofore been obtained before it can be accepted.