

THE RELATION OF HYDROGEN-ION CONCENTRATION IN SOILS TO THEIR "LIME REQUIREMENT"

HARLAN W. JOHNSON

Iowa Agricultural Experiment Station

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INTRODUCTION

Every state in the humid section of the United States is concerned with the acidity of soils. The nature of the phenomenon has not been understood and considerable controversy exists as to what constitutes this acidity. It has been attributed to the presence of acids, mineral and organic, to colloidal material, to adsorption and absorption, and to the presence of specific compounds. More recently the presence of hydrogen ions has been demonstrated. This is a property accompanying all acid reactions, hence their presence shows that soil acidity is actual acidity and is not a property due to the complicated theoretical phenomena previously advanced.

The presence of hydrogen ions has been demonstrated and their concentration has been measured by several investigators. Gillespie (5), using a hydrogen electrode, showed that of twenty-two samples tested, seventeen were acid and five alkaline, the pH values varying from 4.55 to 8.7. Sharp and Hoagland (18), using somewhat similar apparatus, studied twenty-four soils and found nine acid and fifteen alkaline with a variation in hydrogen-ion concentration of pH 3.7 to pH 9.7. Plummer (15) found a range of pH 4.04 to pH 9.68 in sixty-eight soils tested by the hydrogen electrode. Morse (14), in determining the hydrogen-ion concentration of different fertilizer plots by a colorimetric method, found that different fertilizers affected the acidity, sulfate of ammonia giving a pH value of 4.9 as compared with 5.2 for the check plot and 6.4 for a limed plot. Knight (12), using a hydrogen electrode, demonstrated the presence of hydrogen ions but in measuring his concentrations he used salt solutions, for some reason, so his measurements are not comparable with those of others.

Hydrogen ions may come from any of the organic or inorganic acids, from acid salts or from salts of weak bases and strong acids. Acid soils may contain all of these. The bases of the originally alkaline soils were converted into soluble salts by weathering and used by plants or leached out, leaving the less soluble acid silicates and silicates of iron and aluminum. Under these conditions nitric, sulfuric and many organic acids may accumulate from bacterial action. It is probable that the main sources of hydrogen ions are the acid silicates and the salts of the weak bases, iron and aluminum.

The diversity of opinions as to the nature of soil acidity has led to the formulation and adoption of numerous methods for its measurement. These different methods give such widely varying results that the correctness of any one of them is seriously in doubt. One investigator looks for "apparent acidity," another for "adsorption acidity," another for "real acidity," while all term their results "lime requirement."

Among the most widely adopted methods for the measurement of lime requirement are those of Hopkins (9), Veitch (24), and Tacke (20). These have all been modified by different workers so that there are now numerous methods based upon their principles. Two other methods should be noted also, one by Truog (21) because of its simplicity and practical applicability and another by Bouyoucos (2) because it measures not only the lime needed to neutralize the acidity but also the amount beyond this point which the soil will take up.

There are two general methods for the determination of hydrogen-ion concentrations in soils, one by the use of indicators and the other more accurate, by means of the hydrogen electrode. Gillespie (6), Wherry (25), and Van Altstine (23) have suggested colorimetric methods, including lists of indicators with their pH values, standard solutions and color comparators, especially applicable to soil studies. Such methods, while not so accurate as the hydrogen-electrode methods, are more rapid and probably of sufficient accuracy for many investigations. Almost as many forms of hydrogen electrodes have been devised as there are people working with them. They are compared with a great variety of standard electrodes, including many calomel and standard hydrogen cells and the electromotive force of such chains may be measured by several potentiometer methods and by more simple arrangements such as the one proposed by Hildebrand (7).

The comparative value of the two determinations, the lime requirement and the hydrogen-ion concentration, has not been fully determined. The lime-requirement methods have been in use for some time and a great amount of data is available to show that in general, when soils are found to need lime they are benefited by such applications, especially for certain crops, the legumes. This fact is so generally conceded that it is not necessary to discuss the matter. However, there are numerous cases where clover has been known to grow well on soils showing fairly high lime requirements and others where small applications of lime were as beneficial as larger ones.

Then, too, the wide variations in results by the different methods bring up the question as to what is the correct amount to apply in a definite case. The hydrogen-ion determination does not indicate the lime requirement directly but shows only the strength or intensity of the acidity. The methods for such determinations have been so recently put into use that no data are available as to its practical applications. A large amount of data has accumulated, however, to show that, in culture media, the strength of the acid and not the quantity present is the factor affecting bacterial and mold growth. Enzyme

activity also has been shown to be dependent on hydrogen-ion concentration. So positively is this proven that the adjustment of the reaction of such media is now made on this basis and not on the basis of titratable acid. Clark and Lubs (4) in 1917 collected and summarized sufficient data on this subject to prove the necessity of such adjustments. Many other workers have since shown conclusively their importance. If this is true of the lower organisms it is highly probable that the higher plants also are subject to the same factors. Wherry (25) makes the statement that, "Only the hydrogen ions developed directly by water in the soil can have any influence on the growth of plants." Hoagland (8) has studied the effect of hydrogen ions on the growth of barley seedlings and Joffe (10) their effect on alfalfa. Each found a range of hydrogen-ion concentrations which was favorable to the growth of the plants and concentrations on either side that were injurious.

From all of the foregoing considerations the question arises, "What is the relation between lime requirement as determined by the various methods and hydrogen-ion concentration?" If there is a definite relationship, as Blair and Prince (1) have shown to exist in the plots at the New Jersey station, we can interpret the data secured by lime requirement methods in terms of hydrogen-ion concentration. If there is no such relation, as might be indicated in the work by Joffe (11), then the inconsistencies of the data from lime requirement results may be explained.

In an attempt to answer this question lime requirement and hydrogen-ion concentration determinations have been made on fifty widely different soils. The results secured follow:

EXPERIMENTAL PROCEDURE

Fifty soils were selected from samples collected in connection with the soil surveys of seven different counties. Twenty-two different series including four different textures are represented, giving a wide variety of types for study. The types are listed in table 2.

The lime requirement of each sample was determined by both the Veitch and Truog methods. Hydrogen-ion concentrations were measured by the use of a hydrogen electrode.

The Veitch method was used because it has probably been more widely adopted and has been used as a standard for comparison of other methods more universally than any other of the lime requirement tests. It has been a standard method in this laboratory for several years.

The logical use of lime water in only sufficient amounts to bring about an alkaline reaction and the fact that results somewhat comparable with actual field tests are possible, have been just causes for its popularity. However, it has three serious disadvantages that have drawn to it very severe criticism. First, it is a long and tedious test applicable only in a laboratory; second, it shows only the amount of lime needed to give a reaction alkaline to phenol-

phthalein, an indicator which changes at a point quite toward the alkaline side of neutral; third, and very much the most serious disadvantage, it is so sensitive to very slight variations in its manipulation that it is almost impossible to obtain concordant results except by long and tedious trials so that the results obtained by two different workers can not be accurately compared. This last criticism has been demonstrated by Stephenson (19) and Robinson (16).

Considerable difficulty was encountered in this work in securing results which could be depended upon as correct. An attempt was made to determine the lime requirements to within 200 pounds, but this, except in cases of small requirements, was abandoned and a variation of 400 pounds was allowed with most samples and even 800 pounds with soils showing need for

TABLE 1
Illustrating the difficulty in securing duplicate tests with the Veitch method

SOIL NUMBER	LIME WATER*	REACTION	LIME WATER	REACTION	LIME WATER	REACTION	LIME WATER	REACTION	LIME WATER	REACTION	LIME WATER	REACTION	LIME WATER	REACTION	LIME WATER	REACTION	LIME WATER	REACTION
	cc.		cc.		cc.		cc.		cc.		cc.		cc.		cc.		cc.	
15	10	Acid	8	Acid	8	Acid	9	Acid	10	Acid	10	Acid	11	Alk.	10	Acid		
	15	Alk.	12	Alk.	10	Acid	10	Acid	11	Acid	11	Acid	12	Alk.	11	Alk.		
	20	Alk.	16	Alk.	12	Alk.	11	Acid	12	Alk.	12	Acid	13	Alk.	12	Alk.		
23	10	Acid	20	Acid	16	Acid	18	Acid	18	Acid	18	Acid	18	Acid	19	Alk.	19	Acid
	15	Acid	25	Alk.	20	Alk.	20	Acid	19	Alk.	19	Acid	19	Acid	20	Alk.	20	Alk.
	20	Acid	30	Alk.	24	Alk.	22	Acid	20	Alk.	20	Alk.	20	Acid	21	Alk.	21	Alk.
30	25	Alk.	15	Acid	18	Acid	22	Acid	24	Acid	24	Alk.	23	Acid	23	Acid		
	30	Alk.	20	Acid	22	Acid	24	Acid	26	Acid	26	Alk.	24	Acid	24	Acid		
	35	Alk.	25	Alk.	26	Alk.	26	Acid	28	Acid	28	Alk.	25	Alk.	25	Alk.		

*Each cubic centimeter of lime water is equivalent to 200 pounds of limestone, CaCO_3 , per acre of 2,000,000 pounds of soil.

the largest amounts of lime. Apparently good results could be secured easily but attempts to duplicate the test frequently failed. Results in table 1 illustrate the difficulties encountered in checking tests with three representative samples.

In all the work double-distilled water was used and extreme care was taken to see that all manipulations were as nearly the same as possible at all times.

The results reported in table 2 and used throughout this article were accepted only after repeated trials, as shown in the above table, had proved their accuracy.

The Truog test was compared with the hydrogen-ion determinations because it has largely supplanted the Veitch method at this station for routine analyses and tests for field applications. It is also widely used for practical tests out-

side of the experiment stations. The lime requirements reported in table 2 are results of two agreeing tests.

The hydrogen-ion determinations were made with a hydrogen electrode, patterned after the one used by Sharp and Hoagland (18), modified slightly as shown in figure 1, A. The platinum electrode consists of a $\frac{3}{8}$ -inch square of heavy platinum foil coated with platinum black deposited from a 3 per cent solution of platinic chloride containing a trace of lead acetate. Two hydrogen electrodes were held in a shaking device, as illustrated in figure 1 B, which was operated by an electric motor regulated so as to give between 160 and 180 complete strokes, $\frac{3}{4}$ -inch long, a minute. Hydrogen was generated electrolytically and purified by passing over heated, platinized asbestos. Connection was made to a normal calomel electrode through a saturated potassium chloride solution by means of a tube filled with agar made up with a saturated potassium chloride solution.

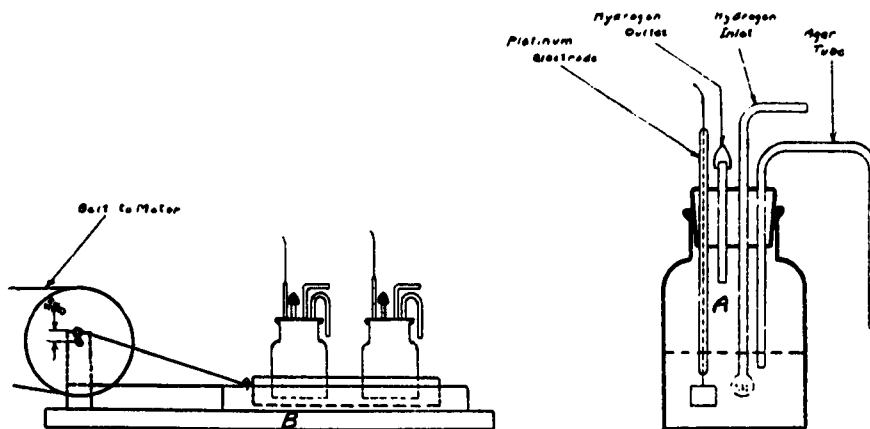


FIG. 1. HYDROGEN ELECTRODE AND SHAKER

The electromotive force of the chain was measured by an apparatus as suggested by Hildebrand (7), using an accurate voltmeter calibrated from 0 to 1.5 volts by intervals of .01 volt and readable to 2 millivolts. Ten grams of soil with 25 cc. of neutral water were used for the determinations. Readings on duplicate samples checked to within 5 millivolts in every case and frequently checked exactly. The accuracy of the determinations is within .05 of a pH value.

The hydrogen-ion concentrations of the fifty samples are reported in table 2 in pH values, a term which has been used so much of late that there is no necessity for its explanation here. However, Schmidt and Hoagland (17), Clark and Lubs (4) and Leeds and Northrup (13) explain in detail the method by which it is obtained. It should be remembered that 7.0 pH is neutral and that a lower pH value shows acidity, corresponding to a higher hydrogen-ion concentration, while a greater value means alkalinity with a correspondingly lower hydrogen-ion concentration.

TABLE 2
Results of Veitch, Truog and hydrogen-ion determinations and analyses of soils on basis of acre of 2,000,000 pounds

NUMBER	SOIL TYPE	VEITCH LIME RE- QUIREMENT	TRUOG LIME REQUIREMENT	(H ⁺) IN P _H	ORGANIC CARBON	NITROGEN	CARBON - NITROGEN RATIO, N=1	PHOSPHORUS
		lbs.			lbs.	lbs.		lbs.
1	Sarpy loam.....	0	negative	7.78	22,700	1,980	11.4	2,195
2	Thurston sandy loam.....	0	negative	7.73	20,500	1,180	17.4	1,185
3	Sarpy silt loam.....	0	negative	7.68	29,983	2,590	11.6	1,481
4	Wabash silt loam.....	0	negative	7.56	53,631	4,180	12.8	1,669
5	Carrington sandy loam.....	0	negative	7.54	30,977	2,630	11.8	1,024
6	Cass fine sandy loam.....	0	negative	7.30	27,237	1,770	15.4	808
7	Jackson silt loam.....	0	negative	7.20	29,721	2,370	12.4	660
8	Clyde silty clay loam.....	0	negative	7.05	17,581	890	19.8	593
9	Wabash loam.....	0	very slight	6.86	46,137	3,800	12.2	822
10	Carrington loam.....	600	very slight	6.41	60,060	4,800	12.5	1,091
11	Lindley fine sandy loam.....	800	very slight	5.83	13,377	1,120	12.0	485
12	Hancock loam.....	1,600	slight	6.88	75,238	5,650	13.6	902
13	Carrington loam.....	2,000	strong	5.70	27,627	2,380	11.6	902
14	Knox fine sandy loam.....	2,000	slight	4.85	10,592	720	14.7	942
15	Lindley sandy loam.....	2,200	medium	5.33	12,175	890	13.7	687
16	Lindley loam.....	2,400	slight	5.51	23,478	1,740	13.5	745
17	Plainfield loam.....	2,800	slight	5.39	21,294	1,310	16.3	808
18	Cass sandy loam.....	3,000	medium	5.34	19,929	1,120	17.8	1,010
19	Buckner fine sandy loam.....	3,000	strong	5.02	37,128	3,090	12.0	889
20	Wabash silt loam.....	3,200	negative	7.30	38,493	2,980	12.9	1,736
21	Plainfield sandy loam.....	3,200	medium	5.36	23,641	1,340	17.6	808
22	Wabash fine sandy loam.....	4,000	slight	6.36	73,381	5,500	13.4	1,913
23	Carrington fine sandy loam.....	4,000	medium	5.38	37,401	2,740	13.7	943
24	Shelby loam.....	4,200	very strong	5.41	27,027	2,210	12.2	795
25	Shelby loam.....	4,400	strong	5.53	36,145	2,960	12.2	889

26	Carrington sandy loam.....	4,400	very strong	5.02	28,665	1,960	14.6	741
27	Carrington silt loam.....	4,800	medium	6.04	43,680	3,670	11.9	1,387
28	Buckner loam.....	4,800	very strong	5.53	52,962	3,950	13.4	1,131
29	O'Neill loam.....	4,800	strong	5.04	33,688	3,700	9.1	1,428
30	O'Neill sandy loam.....	5,000	very strong	5.00	25,880	1,460	17.7	876
31	Lindley silt loam.....	5,200	slight	5.90	27,846	2,070	13.4	660
32	Clinton silt loam.....	5,200	medium	5.33	19,110	1,760	10.8	700
33	Waukesha silt loam.....	6,800	medium	6.00	46,137	3,480	13.2	1,495
34	Judson silt loam.....	7,600	medium	5.73	49,140	3,600	13.7	1,414
35	Carrington loam.....	7,600	strong	5.36	48,590	4,180	11.6	1,050
36	Marshall silt loam.....	8,400	medium	5.58	53,344	4,360	12.2	929
37	Tama silt loam.....	8,800	slight	5.36	36,036	2,520	14.3	902
38	Bremer silt loam.....	9,600	medium	6.20	107,452	8,380	12.8	2,074
39	Clinton silt loam.....	9,600	slight	5.53	34,343	2,680	12.8	1,100
40	Clinton silt loam.....	9,600	medium	5.36	33,961	2,730	12.5	996
41	Carrington loam.....	10,800	very strong	5.11	50,641	4,410	11.5	1,024
42	Grundy silt loam.....	11,200	medium	5.66	96,587	4,860	20.0	1,118
43	Grundy silt loam.....	12,000	strong	5.11	56,511	4,160	13.6	1,387
44	Carrington loam.....	12,800	very strong	5.14	62,244	5,190	12.0	1,145
45	Tama silt loam.....	12,800	strong	4.94	54,873	4,480	12.3	1,414
46	Putnam silt loam.....	12,800	very strong	4.84	34,944	2,820	12.4	969
47	Tama silt loam.....	13,600	medium	5.19	59,623	4,600	13.0	1,306
48	Wabash silt loam.....	14,400	strong	5.22	42,970	3,530	12.2	983
49	Wabash loam.....	18,000	strong	5.56	113,677	9,590	11.9	1,913
50	Bremer loam.....	24,000	very strong	4.55	76,767	6,200	12.4	1,684

EXPERIMENTAL RESULTS

In table 2 and graphically in figure 2 is shown the relation of the hydrogen-ion concentrations to the Veitch lime requirement of each of the fifty samples. The samples have been arranged in the table and for making up the graph in the order of increasing Veitch lime requirement. Where samples show the same lime requirement the one having the highest pH value is given first.

It will immediately be noted that there is no apparent relationship between the results of the two determinations except that all of the samples having no lime requirement, except no. 9, show an alkaline reaction as measured by the hydrogen electrode and all of the samples with lime requirements, except no. 20, show acid with the electrode. It was found that the soils with a low

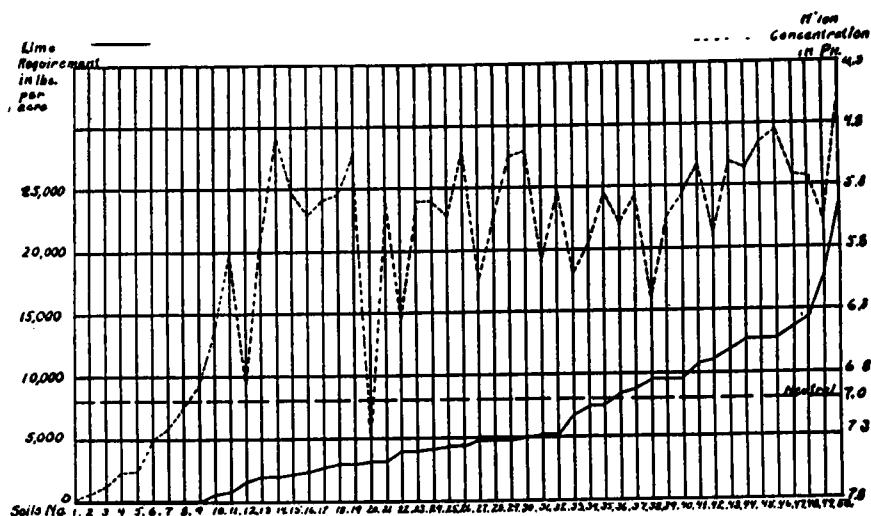


FIG. 2. RELATION OF VEITCH LIME REQUIREMENT TO HYDROGEN-ION CONCENTRATION

lime requirement had as high a hydrogen-ion concentration as those in need of the larger amounts of lime, in fact no. 14, with a lime requirement of only 2000 pounds has the highest hydrogen-ion concentration of all the samples except no. 50. Even the general trend of the line representing hydrogen-ion concentrations bears no relation to the line representing lime requirement. It is evident that in considering soils of different types there is no relation between acidity, as measured by the hydrogen electrode, and so-called "acidity," as measured by the Veitch method.

In table 2 and figure 3, the results of Truog tests as related to hydrogen-ion concentrations are shown. In figure 3 as in figure 2, the samples are arranged in order of increasing lime requirement. This was done by laying the test papers in a row and arranging them according to the intensity of color. The arrangement was checked by three other observers. The points on the

curve indicating very slight, medium, strong and very strong acidity were determined by selecting the test papers corresponding to the colors on the Truog chart (21). Lines connecting these points, representing the acidity of intervening samples, give a fairly regular curve for the Truog tests.

From figure 3 it is evident that here again there is no definite relationship between the results obtained by the Truog test and the hydrogen electrode. It will be noted, however, that there is somewhat better correlation than in figure 2. All the samples with no lime requirement show alkaline by the electrode method and all those in need of lime show acid. Also it is very evident that the general trend of the hydrogen-ion line is more nearly parallel to the Truog test line than it was to the Veitch test line. Apparently the Truog method has more of a tendency to indicate the strength of the acids than has the Veitch test.

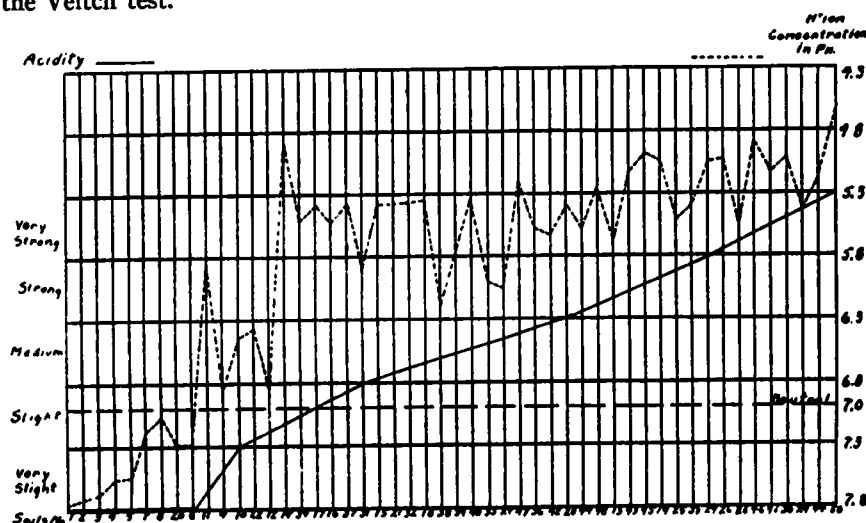


FIG. 3. RELATION OF TRUOG ACIDITY TO HYDROGEN-ION CONCENTRATION

Considering both tests, however, the conclusion is necessarily reached that lime requirement is not very closely related to the strength of the soil acids when soils of various types are compared. When this lack of relationship became evident an explanation for it was sought.

The soils were separated into four classes, silt loams, loams, fine sandy loams and sandy loams according to texture. One silty clay loam, no. 8, was included with the silt loams. The samples in each class were arranged according to increasing lime requirements by both methods and plotted in figures 4 and 5. It is readily seen from these diagrams that texture has a great influence on the relation between the lime requirement and hydrogen-ion concentration. With the finer textured soils the trend of the lines representing the two determinations is nearly parallel and the lines are not far apart. This is especially true of the Truog tests. It will be noted, too, that the finer

soils include the ones with the higher lime requirement. In the case of the coarser textured samples the lines are very far apart. These have rather low lime requirement but very high hydrogen-ion concentration. Even though

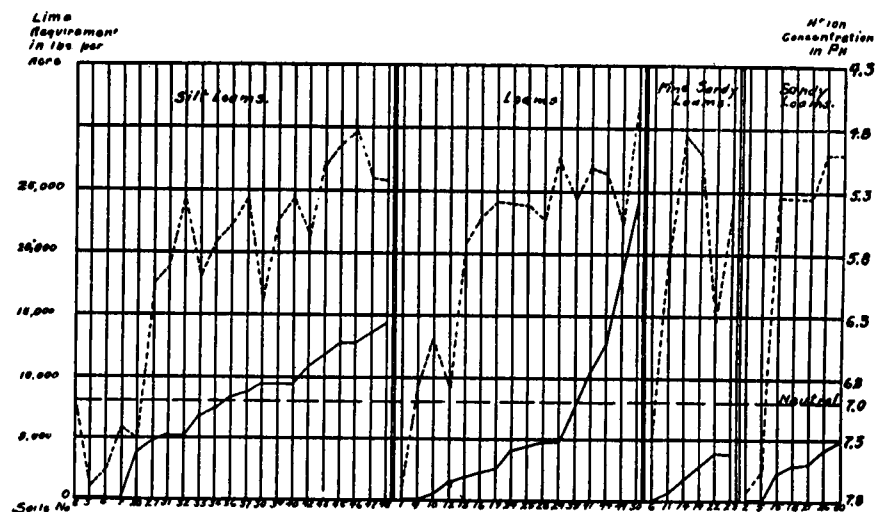


FIG. 4. RELATION OF VEITCH LIME REQUIREMENT TO HYDROGEN-ION CONCENTRATION AS AFFECTED BY SOIL TEXTURE

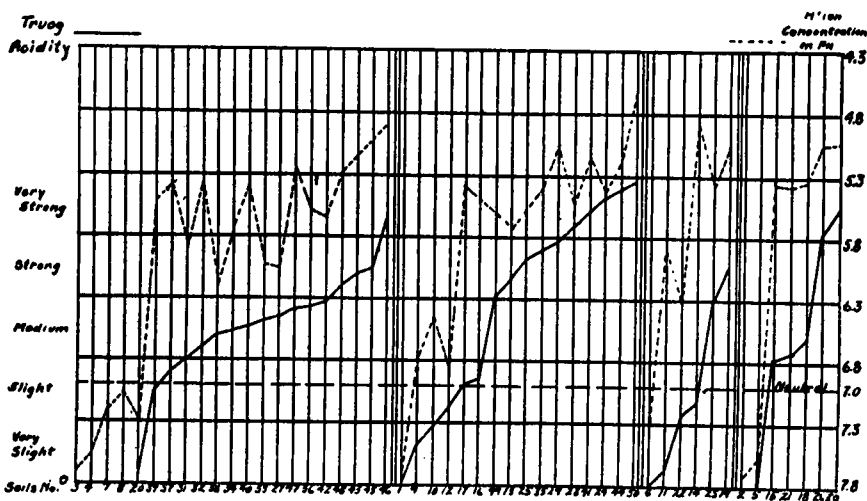


FIG. 5. RELATION OF TRUOG ACIDITY TO HYDROGEN-ION CONCENTRATION AS AFFECTED BY SOIL TEXTURE

texture explains some of the irregularities in the relationship between the two determinations, there is evidently some other factor which has even greater influence, since the line representing hydrogen-ion concentration is still very uneven. This is quite pronounced in the case of both tests.

When a line representing the organic carbon content¹ of each soil is drawn in, as in figure 6, the influence of organic matter on the intensity of the acidity is very evident. When the organic matter content is very low, the hydrogen-ion concentration is very high and when the organic content runs very high the hydrogen-ion concentration as compared to the lime requirement is very low. These relationships are very strikingly true in samples 12, 14, 15, 18, 22, 32, 38, 42, 46 and 49.

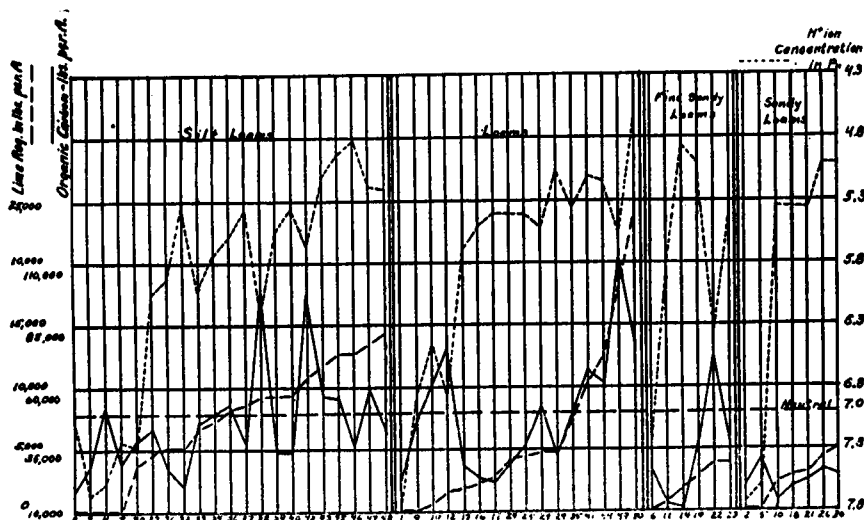


FIG. 6. RELATION OF VEITCH LIME REQUIREMENT AND HYDROGEN-ION CONCENTRATION IN SOILS OF SIMILAR TEXTURE TO ORGANIC CARBON CONTENT

DISCUSSION OF RESULTS

From the brief outline of results given, it is evident that the Veitch method does not in any way indicate the intensity of the acidity. It may measure the amount of lime which will be taken up by a soil but this seems to have little relation to the strength of the soil acids. The Truog test in a slight measure does indicate the strength of the acids. In figure 7 the Veitch, Truog and hydrogen-ion determinations are plotted together. From this graph it seems that the results of the Truog test are a combination of the other two determinations. With low lime requirement and high hydrogen-ion concentration, the Truog test shows a higher lime requirement than the Veitch, and the opposite is true. Truog (22) has demonstrated this by the use of his acidity method and claims a superiority for practical use for his test in that it gives what he terms "crop-injurious acidity."

¹ The analyses of these soils were made by Mr. J. T. Auten for the Soil Survey reports; the author wishes to express his appreciation to Mr. Auten for the use of his results.

That soil acids do not accumulate in the coarser textured soils to so great an extent as in the heavier soils but that those that are present are stronger, is clearly shown. Both the amount and strength of the acids present can be explained by the content of clay and silt particles in the individual soils. These particles are made up of the more finely divided silicates, hence are more readily weathered to form large quantities of acid silicates which can react with lime water to show apparent acidity. The coarser material of the lighter soils is not so subject to weathering, as was shown by Brown and Johnson (3) who found that grinding the coarser soils reduced the lime requirement; thus acid silicates do not accumulate to so great an extent in these lighter soils. Then too, much of the coarse material consists of silica, SiO_2 ,

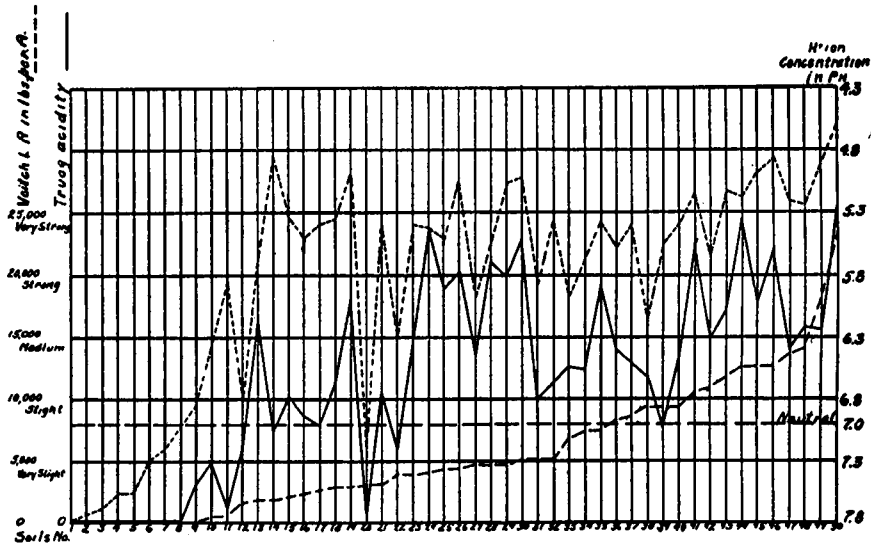


FIG. 7. RELATION OF VEITCH, TRUOG AND HYDROGEN-ION DETERMINATIONS

which is too inert to react with lime water. Hence the greater source of potential acidity is found in the heavier soils.

On the other hand, the quantity of fine material present affects the strength of the acids in two ways. First, it is a recognized fact that coarser, more open soils are more easily and rapidly weathered and leached than the heavier soils. Thus the bases in the finer particles in the sandy soils will be more nearly completely removed than in the finer textured soils. This would affect the strength of the soil acidity in that the degree of removal of base would determine the amount of hydrogen-ions liberated. This may be illustrated by the titration curve for phosphoric acid where each of the acid salts, KH_2PO_4 and K_2HPO_4 , gives rise to a definite hydrogen-ion concentration as is shown by Clark and Lubs (4). Thus the different acid salts formed in the weathering of the silicates would give rise to different hydrogen-ion concentrations; the less the amount of base present in each molecule the more intense would be

the acidity. Hence, with sandy soils which would be more highly weathered, we would expect a higher hydrogen-ion concentration.

The second effect might be due to "buffer" action of the clay. Several acid salts show this property, an ability to resist changes in hydrogen-ion concentration on the addition of acids or alkalis. This, too, is illustrated by the action of the phosphate salts in the experiment referred to above. When either of the acid phosphates are present, additions of potassium hydroxide have little effect on the pH value of the solution until all the salt present is changed over to another form. In soils the acid silicates may act as "buffers." This effect would be proportional to the amount of silicates present and their degree of weathering, which in turn would depend on the texture of the soil. In a soil containing more clay, consequently more silicates in a less weathered condition, the buffer effect would be greater. Hence, the accumulation of nitric, sulfuric and organic acids, and even the greater weathering and consequent hydrogen-ion liberation of some of the soil particles, would affect the hydrogen-ion concentration of the heavier soils less than the sandier ones.

The influence of the organic matter also may be explained by its "buffer" action. Organic materials are known to possess a very considerable "buffer" action, as has been shown by Clark and Lubs (4). Thus, with soils containing the larger amounts of organic carbon, we would expect to find the hydrogen-ion concentration very markedly depressed, while with smaller quantities no such effect would be obtained.

The older statements, that soil acidity was due entirely to organic acids, seem to be quite definitely discredited by these results, since the larger amounts of organic matter depress rather than increase the acidity. These statements are further contradicted when the carbon-nitrogen ratio, a widely adopted measure of the decomposition of organic matter, is plotted against the acidity, as in figure 8. It is very evident that the carbon-nitrogen ratio bears no relation to the acidity, hence, the oxidation of the organic matter with the supposedly consequent accumulation of organic acids can not be a cause of soil acidity in these soils. It must be noted, however, that these are mineral soils and the same would not hold true for peats and mucks.

Since the acidity could not be explained by the presence of organic acids, it was sought to prove it was due to weathering and subsequent removal of bases. The only index to such action available at present was the phosphorus content. This is only a rough index and its value was recognized as questionable. However, in these soils, all formed from similar materials, although laid down by different agencies at different times, the amount of phosphorus present should be, in general, proportionate to their loss of bases. Plotting this against the acidity and knowing it could in no way be a cause for acidity but only an approximate index to the cause in soils of similar texture, the results as shown in figure 9 were obtained. Here it is seen that where the phosphorus content is high, showing supposedly less weathering and loss of bases, the intensity of acidity is much less. This not only indicates that soil

acidity is due to weathering with subsequent loss of bases and the consequent formation of acid silicates, but substantiates the reasons given previously as to why the coarser soils are more intensely acid than the finer ones.

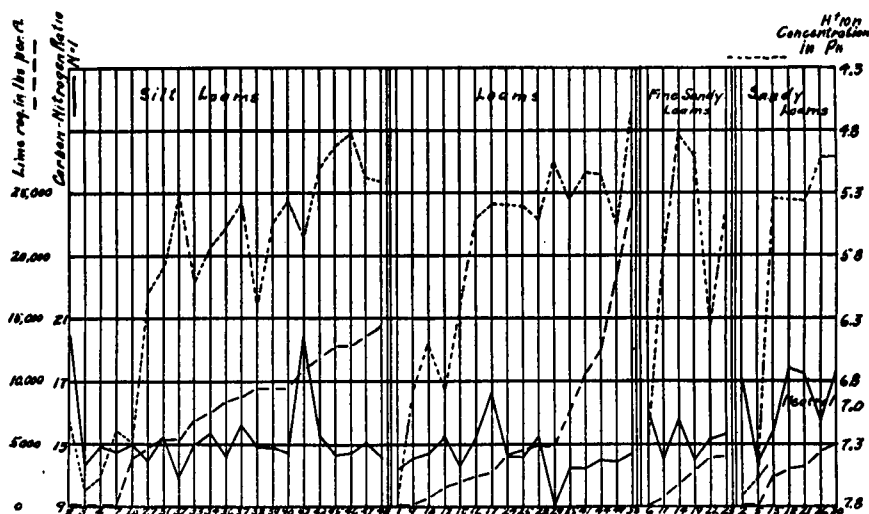


FIG. 8. RELATION OF VEITCH LIME REQUIREMENT AND HYDROGEN-ION CONCENTRATION IN SOILS OF SIMILAR TEXTURE TO CARBON-NITROGEN RATIO

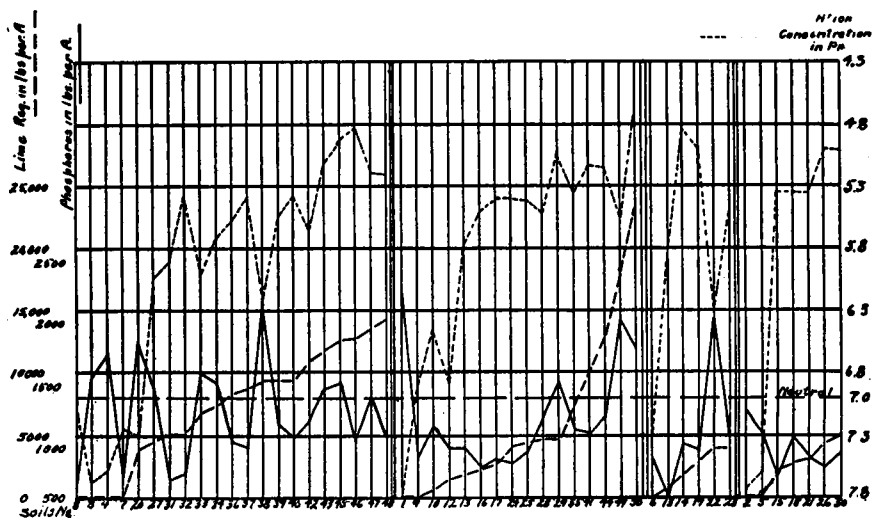


FIG. 9. RELATION OF VEITCH LIME REQUIREMENT AND HYDROGEN-ION CONCENTRATION IN SOILS OF SIMILAR TEXTURE TO PHOSPHORUS CONTENT

From all these considerations, it is plainly evident that, in soils as a whole, the apparent quantity of acid or the lime requirement has no relationship to the intensity or strength of acids present or the hydrogen-ion concentration.

This substantiates the inferred conclusions of Joffe (11) that sands and clays vary in relation between these two factors. However, for soils of the same type, that is, the same texture, age, formation, and color or organic-matter content, the two factors may bear a close relationship to each other. This explains the conclusions of Blair and Prince (1) who found that there was a definite relation between the lime requirement and hydrogen-ion concentration, working on the series of plots at the New Jersey station.

SUMMARY

Working with fifty samples of widely varying types it was found that:

1. As a whole there was no relation between the lime requirement as determined by the Veitch method and the hydrogen-ion concentration as measured by the hydrogen electrode.

2. The Truog method of measuring the lime requirement gave results which were a combination of the Veitch lime requirement and the hydrogen-ion concentration.

3. In soils of similar type there is a relation between the apparent quantity of acids and the strength of the acids.

4. Soil acidity in mineral soils is apparently due to weathering and leaching rather than the accumulation of organic acids.

5. Clay particles and organic matter act as "buffers" to keep the hydrogen-ion concentration down.

The buffer effect of these two materials is being further studied, as is also the proof of the statement that soil acidity is due to the weathering and leaching and consequent formation of acid silicates.

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