August 1, 1948

To the Committee on Graduate Study:

I am submitting to you a thesis written by William Lawrence Parks entitled "The Relation of the Soil Reaction To Certain Other Soil Properties." I recommend that it be accepted for nine quarter hours credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

E. Winters

Major Professor

We have read this thesis
and recommend its acceptance:

Lyndon L. Seat

C. A. Bremner

Accepted for the Committee

E. G. Williams

Dean of the Graduate School

THE RELATION OF THE SOIL REACTION TO CERTAIN OTHER SOIL PROPERTIES

A THESIS

Submitted to
The Committee on Graduate Study
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

---

by

William Lawrence Parks

August 1948

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Mr. Frank Bell for collecting the samples used in this study,

The Staff of the Agronomy Department for their many helpful suggestions.

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INTRODUCTION

The purpose of this study is to determine the relation of the reaction (pH) of several Tennessee soils to the cation exchange capacity of both the organic and mineral portions of the soil, the percent organic matter, the percent clay and the percent base saturation.

Many investigators (3, 5, 7, 19)[1] have shown that the soil reaction is a function of the nature of the soil acid at the same percent base saturation and that titration curves of soil colloids that have weathered under similar conditions and to approximately the same extent are quite similar. Thus, some relation does exist between the nature of the colloid and the pH at various degrees of saturation.

Accurate methods of evaluating the acidity relationship of the soil are of practical significance as many soil management practices and crop adaptations are either directly or indirectly correlated with the soil reaction.

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[1] Figures in parenthesis refer to "Literature Cited," page 22.

MATERIALS AND METHODS

The soils used in this study represent the surface samples (0 to 6 in.) of fifteen different soil series found in Tennessee. These samples were collected in 1947 by Mr. Frank Bell of the Agronomy Department and are part of a collection used for the study of the lime requirement. The samples were air dried, pulverized to pass through a 20 mesh sieve and stored in paper containers in the laboratory.

The Memphis, Paden, Eupora, and Almo series are found in West Tennessee. The Decatur and Guthrie series are found in the Highland Rim Area and also in the East Tennessee Valley. The remainder of the series studied are found in the East Tennessee Valley. Additional information concerning the different samples is given in Table I.

In this study the cation exchange capacity was determined by a slight modification of the ammonium acetate method described by Peech, et al (18). The total exchangeable bases were determined by a modification of the Bray and Wilhite method as described by Piper (21). The organic matter content was determined by the chromate oxidation method as described by Walkley (25) with slight modifications by Peech, et al (18). The percent clay was determined by a modification of the pipette method as described by Baver (6) and Piper (21). The organic matter content of the soils studied was not oxidized previous to the determination of the percent clay.

TABLE I

THE PHYSIOGRAPHIC POSITION, DRAINAGE, AND COLOR OF THE SOILS STUDIED

Lab. No.	Series Name	Physiographic Position	Drainage*	Color (Surface)
2	Bruno	Upland	4	Grayish Brown
3	Talbott	Upland	4-3	Brownish Gray
4	Paden	Alluvium	3	Brownish Gray
5	Almo	Terrace	1	Light Gray
6	Memphis	Upland	4	Brownish Gray
8	Cumberland	Terrace	4	Brownish Red
9	Tellico	Upland	4	Brownish Red
10	Dewey	Upland	4	Grayish Brown
11	Jefferson	Colluvial	4	Brownish Gray
12	Eupora	Colluvial	3-2	Brownish Gray
13	Litz	Upland	6	Light Brown
14	Etowah	Upland	4	Grayish Brown
18	Decatur	Upland	4	Brown
19	Guthrie	Colluvial	1	Light Gray
22	Clarksville	Upland	4	Gray

*Numbers under drainage indicate the following conditions: 1-Poorly drained; 2-Imperfectly drained; 3-Moderately well drained; 4-Well drained; 6-Excessive external drainage

In determining the exchange capacity of the mineral portion of the soil the organic matter was removed by treating the soil with hydrogen peroxide, using a method similar to that outlined by Truog, et al (24). Pre-treatment of the soil with hydrochloric acid was necessary to remove manganese (1). The peroxide treated soil was then titrated with calcium hydroxide to a pH of 7 which would closely approximate the exchange capacity.

The pH-percent saturation relationship was determined as follows: Ten gram samples of hydrogen soil were treated with increasing increments of .04 normal calcium hydroxide, diluted to a final volume of fifty milliliters, and allowed to stand for forty-eight hours (22). The soil suspension was then reduced to a paste by filtration and the pH determined with a Beckman glass electrode assembly.

The detailed procedures used in this study are given in the appendix, page 24.

DATA AND OBSERVATIONS

The results of the pH, cation exchange capacity, total bases, percent organic matter and percent clay determinations are given in Table II. The cation exchange capacity of the soils studied varied from 3.9 me. for a light textured soil to 14.7 me. for a heavy textured soil. The clay content of the soils varied from 7.9 to 44.4 percent and the mineral colloids accounted for 46 to 98 percent of the total cation exchange capacity. The organic matter content of the soils varied from 1.00 to 3.94 percent and accounted for 2 to 54 percent of the total cation exchange capacity. The total base content varied from 0.60 to 7.70 me.

The mineral cation exchange capacity and the organic cation exchange capacity are given in Table III; certain data from Table II are repeated there-in for convenience of comparison. The mineral cation exchange capacity varied from 2.3 to 14.0 me. while the organic cation exchange capacity varied from 0.2 to 3.4 me.

The pH values of the soils at various degrees of calcium saturation are given in Table IV and a graph of this relationship is shown in Figure I.

TABLE II

THE pH, EXCHANGE CAPACITY, TOTAL BASES, PERCENT SATURATION, PERCENT ORGANIC MATTER AND THE PERCENT CLAY OF 15 SURFACE SOIL SAMPLES

Lab. No.	Soil Type	pH	Cation Exch. Cap. M.E.	Total Bases M.E.	Percent Saturation	Percent Org. Matter	Percent Clay
2	Bruno loamy sand	6.10	3.9	2.77	74.6	1.00	7.9
3	Talbott silty clay	5.65	13.7	7.70	56.3	3.42	29.2
4	Paden loam	5.05	6.1	3.45	56.6	1.20	11.2
5	Almo silt loam	5.90	9.4	6.40	68.1	1.93	16.9
6	Memphis silt loam	6.05	6.0	5.36	89.3	1.04	12.8
8	Cumberland silty clay loam	5.25	9.9	4.00	40.4	2.44	30.4
9	Tellico clay	4.50	14.7	4.02	27.3	3.10	44.4
10	Dewey silt loam	5.50	7.8	3.66	45.8	2.04	22.3

THE pH, EXCHANGE CAPACITY, TOTAL BASES, PERCENT SATURATION, PERCENT ORGANIC MATTER AND THE PERCENT CLAY OF 15 SURFACE SOIL SAMPLES(continued)

Lab. No.	Soil Type	pH	Cation Exch. Cap. M.E.	Total Bases M.E.	Percent Saturation	Percent Org. Matter	Percent Clay
11	Jefferson silt loam	4.45	9.7	0.60	6.2	3.94	19.0
12	Eupora loam	5.30	6.0	2.45	48.3	1.27	12.0
13	Litz silt loam	5.10	10.0	2.06	20.6	2.20	20.0
14	Etowah loam	6.50	8.2	6.70	81.7	2.30	18.5
18	Decatur silty clay loam	5.20	10.2	3.80	37.3	2.06	32.8
19	Guthrie loam	4.50	4.7	1.20	25.5	1.55	13.1
22	Clarksville loam	5.20	6.3	1.77	28.1	3.49	10.6

TABLE III

THE MINERAL, ORGANIC AND TOTAL CATION EXCHANGE CAPACITIES, PERCENT ORGANIC MATTER AND THE PERCENT CLAY OF 15 SURFACE SOIL SAMPLES

Lab. No.	Soil Type	Cation Exch. Cap. M. E.	Mineral Cation Exch. Cap. M. E.	Percent Clay	Organic Cation Exch. Cap. M. E. (by Difference)	Percent Organic Matter
2	Bruno loamy sand	3.9	2.3	7.9	1.6	1.00
3	Talbott silty clay	13.7	9.8	29.2	2.9	3.42
4	Paden loam	6.1	4.8	11.2	1.3	1.20
5	Almo silt loam	9.4	7.8	16.9	1.6	1.93
6	Memphis silt loam	6.0	4.4	12.8	1.6	1.04
8	Cumberland silty clay loam	9.9	8.8	30.4	1.1	2.44
9	Tellico clay	14.7	14.0	44.4	0.7	3.10
10	Dewey silt loam	7.8	7.0	22.3	0.8	2.04

THE MINERAL, ORGANIC AND TOTAL CATION EXCHANGE CAPACITIES, PERCENT ORGANIC MATTER AND THE PERCENT CLAY OF 15 SURFACE SOIL SAMPLES(continued)

Lab. No.	Soil Type	Cation Exch. Cap. M. E.	Mineral Cation Exch. Cap. M. E.	Percent Clay	Organic Cation Exch. Cap. M. E. (by Difference)	Percent Organic Matter
11	Jefferson silt loam	9.7	7.9	19.0	1.8	3.94
12	Eupora loam	6.0	4.1	12.0	1.9	1.27
13	Litz silt loam	10.0	7.7	20.0	2.3	2.20
14	Etowah loam	8.2	6.2	18.5	2.0	2.30
18	Decatur silty clay loam	10.2	10.0	32.8	0.2	2.06
19	Guthrie loam	4.7	3.5	13.1	1.2	1.55
22	Clarksville loam	6.3	2.9	10.6	3.4	3.49

TABLE IV

THE pH AT VARIOUS DEGREES OF SATURATION OF 15 SURFACE SOIL SAMPLES

Lab. No.	Soil Type	Percent Saturation										
		0	20	40	60	80	100	120	140	160	180	200
		pH Values										
2	Bruno loamy sand	3.67	----	4.70	5.85	6.90	7.05	7.30	7.80	8.20	9.10	----
3	Talbott silty clay	3.70	4.38	5.20	6.20	6.85	7.20	7.70	8.35	8.85	9.40	9.80
4	Paden loam	3.60	4.05	4.60	5.60	6.35	7.05	7.50	8.00	8.50	9.10	9.63
5	Almo silt loam	3.40	3.85	4.43	5.50	6.58	7.10	7.49	8.32	9.05	9.60	10.00
6	Memphis silt loam	3.50	----	4.50	5.50	6.57	7.20	7.60	8.15	8.88	9.60	10.08
8	Cumberland silty clay loam	3.70	4.20	4.73	5.45	6.30	7.00	7.56	8.02	8.40	8.78	9.17
9	Tellico clay	3.24	3.58	4.24	4.75	5.95	6.70	7.20	8.00	8.52	9.08	9.50
10	Dewey silt loam	3.65	4.15	4.75	5.65	6.20	6.85	7.15	8.00	8.50	8.77	9.10

THE pH AT VARIOUS DEGREES OF SATURATION OF 15 SURFACE SOIL SAMPLES(continued)

Lab. No.	Soil Type	Percent Saturation										
		0	20	40	60	80	100	120	140	160	180	200
		pH Values										
11	Jefferson silt loam	4.00	4.50	5.38	5.70	6.25	6.70	7.15	7.55	8.00	8.25	8.80
12	Eupora loam	3.60	3.95	4.60	5.85	6.35	6.85	7.35	7.85	8.50	9.05	9.35
13	Litz silt loam	3.45	3.95	4.85	6.15	6.90	7.40	8.10	8.80	9.40	9.70	10.40
14	Etowah loam	3.70	4.35	5.05	5.85	6.35	6.90	7.40	7.90	8.35	8.80	9.20
18	Decatur silty clay loam	3.70	4.10	4.70	5.50	6.30	6.85	7.55	7.95	8.40	8.75	9.00
19	Guthrie loam	3.40	3.88	4.50	5.20	6.00	6.50	6.90	7.40	8.00	8.80	9.35
22	Clarksville loam	3.72	4.32	5.05	5.55	6.00	6.35	6.75	7.10	7.50	7.95	8.40

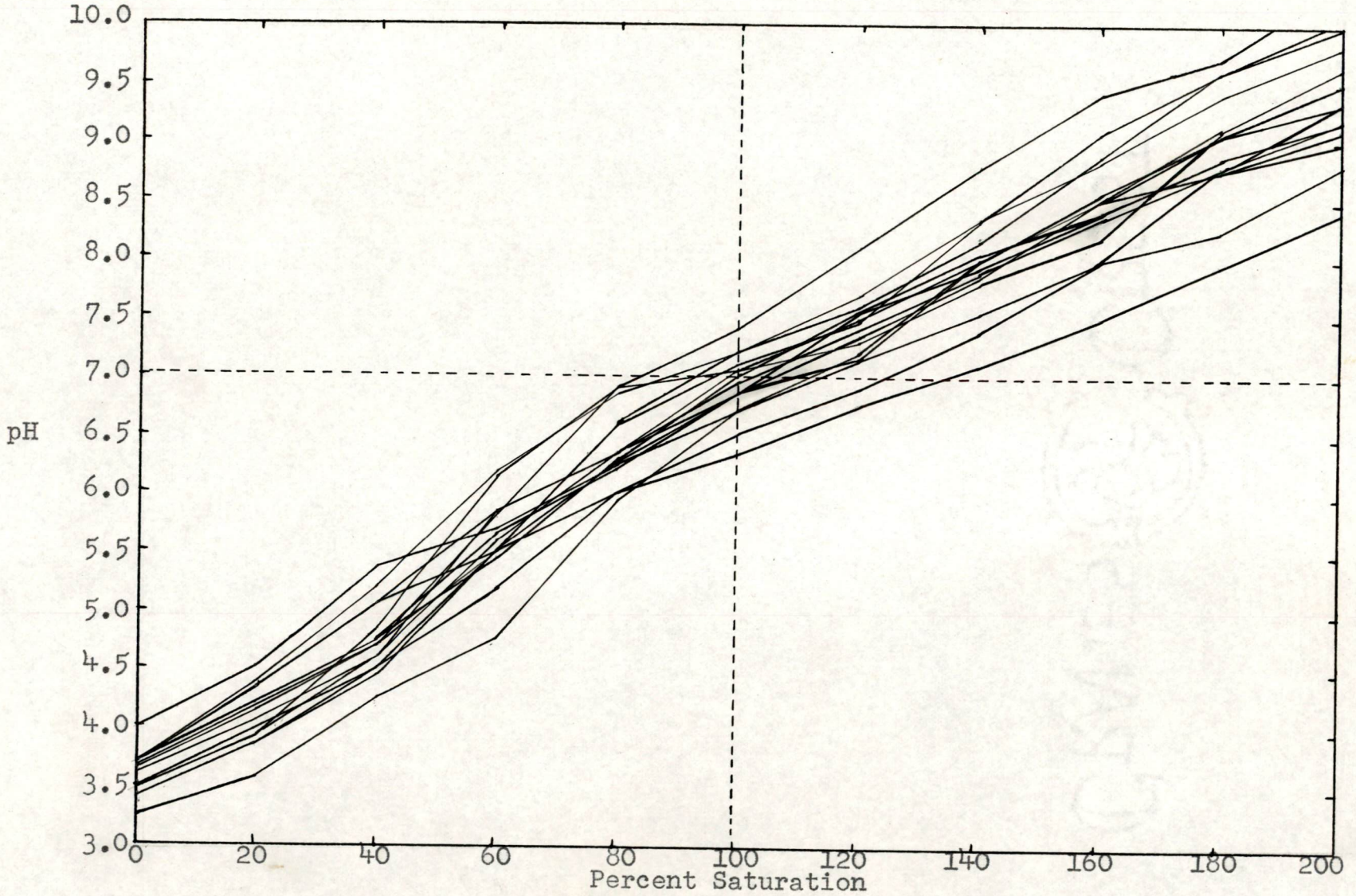

Figure I
The pH-Percent Saturation Relationship

DISCUSSION

The soil reaction (pH) has been used widely as a guide in estimating the lime requirement of the soil. Its reliability may depend upon how well it is correlated with other soil properties (19), the season in which the soil sample is taken (16) and the method used in determining the pH (23).

Soils that vary in cation exchange capacity may vary in the amount of lime required to change the soil reaction one pH unit. The Tellico clay soil which has an exchange capacity of 14.7 me. required 3.0 me. of calcium per hundred grams of soil to bring about a pH change from 5.7 to 6.35, while the Bruno loamy sand which has an exchange capacity of 3.9 me. would need only 0.4 me. of calcium per hundred grams of soil to bring about a similar change in pH values. Thus, when using the soil reaction as a guide in determining the lime requirement, the cation exchange capacity of the soil must be either directly or indirectly considered.

It is generally accepted that the pK value of all soil colloids varies inversely with the exchange capacity and the degree of dissociation of the colloids (5, 10). Anderson and Byers (3) have shown that it is possible to distinguish the neutralization curves of the colloidal acids of one Great Soil Group from those of another. Assuming that the degree of dissociation of all the exchangeable metal ions and the pK

value are reasonably constant for any group of similar soils, Peech and Bradfield (19) have shown how the relationship between the pH of the soil and the degree of base saturation may be readily calculated. Once the degree of base saturation and the cation exchange capacity or the exchangeable hydrogen are known, the lime requirement can be readily estimated from the pH value with a fair degree of accuracy.

Accurate and quick methods for determining the soil reaction (pH) are now in use (23) but the methods for determining the exchange capacity are rather lengthy. For this reason many investigators (4, 14, 17, 20) have attempted to determine the relation between cation exchange capacity and other soil properties which are more easily determined. Morgan (14) found the exchange capacity of Connecticut soils to be reasonably consistent with soil type. An examination of the data in Table II will show that the lighter textured soils have the lower cation exchange capacities while the soils of heavier texture have higher exchange capacities. Thus, when pH is known, texture may be used as a rough guide in estimating liming needs of soils where the general relation of texture to exchange capacity is known.

The Relation Between Percent Clay and Mineral Cation Exchange Capacity

A high correlation was observed between the percent clay and the mineral cation exchange capacity of the soils studied. The exchange capacity per hundred grams of clay was calculated for each soil from the data in Table II and these values are given in Table V. The exchange capacities of the soil clay varied from 26 to 46 me. per hundred grams with an average of 34 me. Other investigators (5, 10) have shown that the mineral cation exchange capacity varies directly with the silica-sesquioxide ratio of the mineral colloid. This suggests that the silica-sesquioxide ratio of the mineral colloids of the soils studied is approximately the same and that approximately the same type clay predominates. However, due to the long time required to determine the percent clay and the cation exchange capacity, they would be of little value in rapid estimation of lime requirements of soils. Once the type of clay mineral is known, the texture of a soil sample may be used to estimate its exchange capacity.

The Relation Between Percent Clay and Total Cation Exchange Capacity

Some correlation between the percent clay and the total cation exchange capacity can be observed from the data in Table II. In several cases the correlation is poor, particularily for the light textured soils where the organic

TABLE V

THE CATION EXCHANGE CAPACITY OF CLAY
AND ORGANIC MATTER

Lab. No.	Soil Series	M.E. Per 100 Gr. of Clay	M.E. Per 100 Gr. of Organic Matter
2	Bruno loamy sand	29	160
3	Talbott silty clay	36	84
4	Paden loam	42	109
5	Almo silt loam	46	83
6	Memphis silt loam	34	154
8	Cumberland silty clay loam	29	45
9	Tellico clay	31	23
10	Dewey silt loam	31	39
11	Jefferson silt loam	41	46
12	Eupora loam	34	150
13	Litz silt loam	38	105
14	Etowah loam	34	87
18	Decatur silty clay loam	30	9
19	Guthrie loam	26	77
22	Clarksville loam	27	97
	Average	34	84

colloid is responsible for most of their exchange capacity. Perhaps this is caused by variations in the percent organic matter and in the nature of the organic colloid (2, 15). Mitchell (13) found that the organic matter from different soils varied greatly in cation exchange capacity. McGeorge (9) showed that different organic compounds had different cation exchange capacities. Muller (15) observed that the nature of the organic matter affects its exchange capacity and that the degree of decomposition is more or less correlated with the cation exchange capacity. The exchange capacities of the organic colloids of the soils used in this study ranged from 9 to 160 me. per hundred grams. The conclusions of the workers just quoted may explain this wide variation in exchange capacities.

The organic matter content of Tennessee soils is relatively low and quite variable within this low range. Even in cases where the organic colloid accounts for a large percent of the exchange capacity, the total exchange capacity is still relatively low.

Morgan (14) found that the cation exchange capacity of most Connecticut soils was influenced more by organic matter than by clay content and that correlations between percent clay and cation exchange capacity were obscured by variations in organic matter. Similar relations would not be expected to occur in most soils of the Red-Yellow Podzolic region as

the organic matter content is usually lower than that of the Connecticut soils due to a higher annual temperature.

The pH-Percent Saturation Relationship

Pierre and Scarseth (20) concluded that as far as the soil reaction is concerned, the relation between the exchangeable bases or the exchangeable hydrogen and the total exchange capacity is far more important than is the knowledge of any one of these values considered alone. Peech and Bradfield (19) suggest that the relationship between pH and degree of base saturation is sufficiently valid to permit its use in determining the lime requirements of soils having the same type clay mineral. Morgan (14) found a definite relation between the pH and degree of base saturation in his work with Connecticut soils. The data in Table IV show that up to a pH of 7 (or 100 percent saturation), most of the soils have approximately the same pH at the same percent saturation. Above 100 percent saturation, variations in the pH values among the samples are somewhat greater probably due to variations in carbon dioxide concentration in the soil systems. This variation in carbon dioxide concentration could be caused by differences in the partial pressure of carbon dioxide in the laboratory atmosphere on different days (8).

Mehlich (11, 12) concluded that the base saturation-pH relationship of the soil colloids is a constant and specific characteristic for each mineral and is not altered by cation

exchange capacity or buffer capacity of the soil. Since the soils included in this study seem to have approximately the same type clay, the pH-percent saturation relationship may be used as a guide in estimating lime requirements for soils of similar texture.

SUMMARY

The following determinations were made on surface samples of fifteen Tennessee soil series: The pH; total bases; percent base saturation; total cation exchange capacity; exchange capacity of both the organic and mineral portions of the soil; the percent clay; the percent organic matter; and titration curves from 0 to 200 percent saturation. The relations between these data were studied from the point of view of making accurate estimations of the lime requirement of soils by simple procedures.

The total cation exchange capacities varied from 3.9 to 14.7 me. per hundred grams, the cation exchange capacities of the mineral colloids varied from 26 to 46 me. per hundred grams, the cation exchange capacities of the organic colloids varied from 9 to 160 me. per hundred grams, the total bases varied from 0.60 to 7.70 me. per hundred grams, the percent organic matter varied from 1.00 to 3.94 percent, and the percent clay varied from 7.9 to 44.4 percent.

A high correlation was found between the percent clay and the mineral cation exchange capacity; the relation between the percent clay and the total cation exchange capacity was more variable. Thus, some relation exists between texture and total cation exchange capacity and texture may be used as a fair guide in estimating the exchange capacities of similar soils within a region. A very low correlation was

found between the percent organic matter and the organic cation exchange capacity.

The pH-percent saturation relationship is similar for the soils studied and this relationship, therefore, may be used as a guide in estimating lime requirements for soils of similar texture.

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LITERATURE CITED

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APPENDIX

ANALYTICAL PROCEDURES

Cation Exchange Capacity

Weigh out 50 grams of air-dry 2-mm. soil into a 250 ml. Erlenmeyer flask and add 100 ml. of N ammonium acetate solution buffered at pH 7. Stopper, shake the flask for several minutes, and allow to stand overnight. Transfer the contents of the flask to a Buchner funnel fitted with a moist 9.0 cm. Whatman No. 42 filter paper and filter, applying gentle suction. Leach the soil with an additional 400 ml. of N ammonium acetate, adding small portions of ammonium acetate at a time and using gentle suction, so that the leaching process will require not less than 1 hour. Retain the leachate for the determination of total exchangeable cations.

Wash out the excess of ammonium acetate from the ammonium saturated soil on the Buchner funnel remaining after the extraction of the exchangeable cations with 200 ml. of methyl alcohol, using small portions of alcohol at a time and draining well between each addition.

After washing the soil with alcohol to remove the excess of ammonium acetate, extract the adsorbed ammonium by leaching the soil with 300 ml. of .005 N acidified 10 percent sodium chloride solution, adding small portions at a time and draining well between each addition. Transfer the sodium chloride extract to a Kjeldahl flask, add 25 ml. of N sodium hydroxide and distill 200 ml. into 50 ml. of 4 percent boric acid solution. When the distillation of ammonia is complete, remove the absorption flask and titrate with standard hydrochloric acid, using bromo cresol green indicator. Compute the total number of milliequivalents ammonium salt received. This figure multiplied by 2 gives the exchange capacity in milliequivalents per 100 grams of soil.

Total Exchangeable Cations

Transfer the ammonium acetate leachate from determining the exchange capacity to a 600 ml. beaker and evaporate to dryness on a hot plate at a temperature that will not cause brisk boiling or spattering. Then place the beaker with contents on a wire gauze containing an asbestos center and heat with a bunsen flame for 30 minutes or until the contents of the beaker become gray or white. Cool and add a known quantity of 0.1 N HCl. Warm and remove all material from the bottom of the beaker with a rubber policeman and titrate the excess HCl with o.1 N NaOH. The milliequivalents of HCl used multiplied by 2 gives the exchangeable cations per 100 grams of soil.

Percent Organic Matter

Transfer a weighed quantity of soil (ground to pass a 0.5 mm. sieve) containing 10 to 25 mg. of organic carbon into a 500 ml. Erlenmeyer flask, and add 10 ml. of N potassium dichromate. Then add rapidly 20 ml. of conc. sulfuric acid, directing the stream into the solution. Immediately swirl vigorously by hand for one minute and let the flask stand on a sheet of asbestos for about 30 minutes. Then add 200 ml. of water, 8 to 10 drops of o-phenanthroline ferrous complex and titrate to end point with approximately 0.5 N ferrous sulfate that has been checked against the dichromate. The addition of 20 ml. of 80 percent phosphoric acid to soils high in iron content will give a clearer end point. If more than 8 ml. of the available 10 ml. of potassium dichromate is reduced, the determination should be repeated with less soil.

Percentage of organic matter in the soil sample is equal to:

$$\frac{(\text{Milliliters of 1 N } K_2Cr_2O_7 \text{ reduced}) \quad (0.69)}{\text{Weight of sample in grams}}$$

Percent Clay

Weigh out 10 grams of hydrogen soil into a 500 ml. Erlenmeyer flask and add 0.1 N sodium hydroxide to 120 percent saturate the soil. Transfer the contents of the flask to a soil dispersion stirrer and stir for 10 to 15 minutes. Return the soil suspension to the flask and dilute to 300 ml. Shake for 4 hours each day in a reciprocal shaker for two days. Transfer the contents of the flask to a liter graduate and dilute to 1 liter, mix well and let stand. At the end of eight hours pipette a 25 ml. aliquot at 10 cm. depth using an aspirator bottle so as to take 40 seconds or more in obtaining the aliquot. Transfer the aliquot to a tared weighing bottle, evaporate to dryness at 105° C. and weigh. The difference in weight multiplied by 400 gives the percent clay.

Hydrogen Soil

Weigh out about 50 grams of soil into a 250 ml. Erlenmeyer flask and add about 100 ml. of approximately 0.1 N HCl. Stopper, shake well and let stand overnight. Transfer the contents of the flask to a Buchner funnel fitted with a moist 9.0 cm. Whatman No. 42 filter paper and leach with an additional 500 ml. of approximately 0.1 N HCl, adding small portions at a time and draining well between each addition.

Wash with distilled water until all traces of chloride ions are removed and finally with 200 ml. of methyl alcohol

using the same technique for washing as in the leaching with HCl.

Percent Saturation-pH Relationship of the Soil

Weigh out 10 gram samples of hydrogen soil into 50 ml. Erlenmeyer flasks. Add 0.04 N calcium hydroxide to obtain the desired percent saturation, dilute to 50 ml. and let stand for 48 hours, shaking frequently. The soil suspension is then reduced to a paste by transferring to a filter paper and the pH determined with a Beckman glass electrode.

Exchange Capacity of the Clay Portion of the Soil

Place 20 grams of soil into a 250 ml. Erlenmeyer flask and add 100 ml. of approximately 0.1 N HCl, shake well and allow to stand overnight. Transfer the soil to a Buchner funnel fitted with a moistened filter paper and leach with an additional 400 ml. of approximately 0.1 N HCl. Wash with distilled water to remove excess chloride ions and transfer the 20 gram sample to a 400 ml. tall beaker. Add water and stir to obtain a paste. Then add 5 ml. of 30 percent hydrogen peroxide, stir well, cover with a watch glass and allow the reaction to proceed in the cold for two hours or even overnight. Place the beaker on a hot plate or water bath at a temperature of about 40°C. for another two hours. Then if not to dryness, remove the watch glass cover and evaporate to dryness at a higher temperature if necessary. Repeat as long as there is a reaction when the peroxide is added; usually about three treatments are adequate.

Take the peroxide treated soil and obtain a hydrogen soil by the procedure outlined previously and determine the exchange capacity by titrating with standard calcium hydroxide to a pH of 7, using the same procedure as in determining the pH-percent saturation relationship.