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The Cation Exchange Capacity of the Soils of the Tennessee Agricultural and Industrial State College Farm

Fred E. Westbrooks

THE CATION EXCHANGE CAPACITY OF THE SOILS OF THE TENNESSEE AGRICULTURAL AND INDUSTRIAL STATE COLLEGE FARM

BY

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TENNESSEE A. & I. STATE COLLEGE

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To The Committee On Graduate Study:

I am submitting to you a thesis written by Fred E. Westbrooks, entitled "The Cation Exchange Capacity of the Soils of the Tennessee Agricultural and Industrial State College Farm." I recommend that it be accepted for nine quarter hours credit in partial fulfilment of the requirements for the degree of Master of Science with a major in Agronomy.

M. F. Spaulding
Major Professor

We have read this thesis and recommend its acceptance:

W. A. Flowers
Adviser

A. W. Shute
Adviser

Accepted for the Committee

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Director of the Graduate Division

THE CATION EXCHANGE CAPACITY OF THE SOILS
OF THE
TENNESSEE AGRICULTURAL AND INDUSTRIAL STATE COLLEGE FARM

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A THESIS

Submitted to

The Committee on Graduate Study

of

Tennessee Agricultural and Industrial State College

in

Partial Fulfilment of the Requirements

for the degree of

Master of Science

Fred E. Westbrooks

August, 1947

DEDICATION

To my father and mother, Mr. Atha Westbrooks and the late Mrs. Albertha Westbrooks, whose greatest ambition was and still is that I succeed in making a contribution to civilization.

ACKNOWLEDGMENT

If gratitude should be acknowledged for favors received, the author has this opportunity, most sincerely, to thank Dr. M. F. Spaulding, head of the department of Agronomy and Dr. M. B. Towns, Professor of Physical Chemistry, at the Tennessee Agricultural and Industrial State College, for assistance rendered in this work.

Special thanks are also given to Mr. D. H. Esry, Soil Conservationist, and Mr. C. B. Brenig, assistant Soil Conservationist, for work done in connection with Figure 3 of this work.

Appreciation is expressed to other members of the Agricultural Staff for helpful criticism and suggestions.

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INTRODUCTION

The Tennessee Agricultural and Industrial State College campus and farm is composed of 320 acres of land, located just out of the city limits of North Nashville, on the Cumberland River. This farm varies from very good farm land to a small section too stony to cultivate.

During the month of February the district soil conservationist, Mr. D. H. Esry and his assistant, Mr. C. B. Brenig, along with a class of four students, under the supervision of Dr. M. F. Spaulding, made a detailed survey of the college farm.

This survey resulted in the finding of seven different soils found in different localities of the farm, and having varying degrees of slope and erosion.

The author, a member of the class of four in Soil Classification, became interested in going a step farther into the analysis of these soils; to the extent that recommendations could be made as to the liming, and fertilizing practices to be carried out on this farm.

As a basis for making the said recommendation the Cation Exchange Capacity or the Adsorptive Capacity of each type of soil found on the farm was made.

The cation exchange capacity of a soil is governed by the size of the soil particles. That is, as the soil particles increase in size the adsorptive capacity decreases. There is also significant positive correlation betewwn organic matter content and cation exchange capacity of soils. The organic fraction contributes to the adsorptive capacity just as the mineral fraction does.

Because of the above fact, the author in this problem determined the organic matter content of these soils along with the cation exchange capacity of each of the seven soils irrespective of slope or degree of erosion. This was done so as to make definite recommendations as to methods of improvement in farm management of this farm.

LITERATURE REVIEWED

Way, in 1850 (9)[1] was the first to explain soil absorption on the chemical basis: that is, calcium and ammonium (NH_4) for example, exchanged places according to chemical reaction. Liebig held the view that absorption was physical like the absorption of gases by charcoal. Since 1861, when Graham (Eng.) introduced the term "colloids" and so shaped the concept regarding them as to make possible scientific inquiry into their nature, absorption research in soil science has centered on colloidal soil materials. Van Bemmelen Hall, 1878, was the first investigator to observe the colloidal properties of the clay and humus of soil. At first, he accepted Way's chemical hypothesis of absorption, but later in 1890 he concluded that displaceable basic elements were held in soils by adsorption, that is, on the surfaces of colloidal particles.

The minute and heterogeneously despersed clay particles are electrically active, (4) ordinarily carrying a considerable electrical potential. This is due to an ionic double layer phenomenon. The inner layer is an immovable stratum of negatively charged ions (anions) that are an integral part of the surfaces, both external and internal, of the colloidal particles. The outer layer is made up of certain positive ions (cations) that are, at least in part, readily displaced (Fig. 1).

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1 Figures in Parenthesis refer to "Literature Cited," p. 32.

Thus, as the clay particle moves through its dispersive medium it is accompanied by a swarm of cations, and the farther away the more active members of this pulsating throng maintain themselves, the greater is the electrical potential of the particle. Since the charges on the particle itself are normally negative, it functions much like a simple acid radical such as Cl^- or $SO_4^=$, and will migrate to the positive pole when subjected to an electrical current.

For convenience in designation the individual particle is spoken of as an <u>Acidoid</u>, a <u>Micelle</u> or a <u>Nucleus</u>.

It is now evident that the micalike clay particles are composed of two distinct parts: the inner porous, and enormously larger insoluble acidoid or micelle, and the outer and more or less dissociated swarm of cations with variable amounts of water of hydration. Since these adsorbed cations are usually rather easily displaced, they are spoken of as exchangable ions. This replacement, called ionic exchange or cation exchange or more commonly base exchange, is one of the most important of all soil phenomena. (figure 1)

While all sorts of cations may thus be loosely held by the adsorptive power of the clay nuclei, certain ones are especially prominent (Figure 2). For a humid-region clay, these in the order of their numbers are H^+ and Ca^{++}, first; Mg^{++}, second; and K^+ and Na^+, third. For well drained arid-region soil, the order of the exchangable ions is Ca^{++} and Mg^{++}, first; Na^+ and K^+, next; and H^+ least.

Two general types of atomic sheets (4) constitute the individual units or molecules that build up the complicated clay particles. One is a Silica sheet ($2SiO_2.H_2O$) and the other alumina ($Al_2O_3.3H_2O$). These sheets probably are held together by an Oxygen linkage to form the individual molecules. As might be suspected, various kinds of clay are possible because of differences in the number of these lattice sheets and also because of substitutions therein of metallic cations such as iron, magnesium, calcium, and the like. Under certain conditions even Aluminum and Silicon may substitute each other. As a result clays may vary not only mineralogically and chemically but also in respect to such physical characteristics as size and shape of particles, and the amount and effectiveness of the interfaces.

Two groups of clays are commonly recognized (4,8,11): the kaolin and the montmorillonite. The molecule of the former are thought to be composed of two sheets or plates, one of silica and one of alumina. Such clays are therefore said to have a 1 to 1 type of crystal lattice. Since the molecules are apparently held together rather tightly, the internal interface is much restricted. Therefore, the two representations of the kaolin group, kaolinite and halloysite, do not exhibit colloidal properties of an unusual high order.

The second general group of clays, the montmorillonite, apparently is composed molecularly of two silica sheets and one of alumina. It is,therefore, considered as having a 2 to 1 type of crystal lattice. Of the three common representatives of the group, montmorillonite, beidelite, and montronite, the two first mentioned apparently are found in soils in largest amounts. The molecules of these clays are less firmly linked together than those of kaolin group and they are usually farther apart.

An unusually large amount of internal interface is thus exposed and molecules of water and the cation of various substances may force themselves between the sheet like molecules. As a result adsorption is more marked than in the case of kaolin clays, and other colloidal properties, such as plasticity, cohesion, and especially base exchange, are greatly in evidence.

Hendricks and Alexander (3) states that while all of the clay minerals show cation exchange, montmorillonite has considerably the greater capacity, which is of the order of 1.0 M. E. per gram. The value for the micalike mineral is about 0.2 M. E. per gram, and that for kaolinite is less than 0.1 M. E. per gram. Although these quantities do not vary greatly they are not sufficiently constant to serve as more than a rough check of mineral composition. Each mineral, however, differs in the order of ionic replacement at equivalent concentrations. The availability of the sites for cation exchange, furthermore, show a different dependence upon ionic size for the several minerals. The nature of the exchange site also influences the manner in which the cation hydrates.

The importance of the Cation Exchange Capacity of a soil cannot be easily overestimated. Lyon and Buckman (4) recognizes Marshall's statement: "next to photosynthesis, base exchange is the most important chemical reaction in the whole domain of Agriculture." Considering the influence of ionic exchange on the physio-chemical condition of soils, on the availability of nutrients to micro organisms and higher plants on the loss of soluble constituents in drainage, and on the effectiveness of lime and commercial fertilizers, the reason for such a statement is readily understood.

It is probable that higher plants, possibly by contact replacement, can make ready use of at least a part of the exchangable constituents of soils. The nutritional importance of base exchange is therefore undoubted.

The cation exchange capacity, or the base exchange, or ionic exchange capacity, as it is often called, according to results of investigations, (9) may be defined as the displacement of basic elements (including Hydrogen) that are chemically combined insoluble soil compounds by other basic ions and hydrogen when soil materials are brought in contact with salt, base, and acid solutions. These cations are governed by the chemical "electromotive series" and "mass action." An example of this is sodium (Na^+) easily replaced by Calcium (Ca^{++}), Calcium by hydrogen (H^+) and ammonium ions (NH_4^+).

Cation Exchange (9,12) is recognized as a most important fundamental or principle of soils. In it are found explanations for several important soil phenomena or conditions including soil acidity and alkalinity, friability of some clays, fixation of Potassium (K^+) and Ammonium (NH_4^+), and non fixation of nitrate nitrogen NO_3^-).

To the inquiring mind a question immediately arises. What is the magnitude of this all important property, or in technical terms, what is the exchange capacity of silicate clays or soils?

Before dealing with cation exchange capacity which is simply another term for the relative adsorptive power of a clay; the method of expressing its magnitude must be explained. The unit is a milliequivalent (M.E.) and it is defined as "one milligram of hydrogen or the amount of any other ion that combines with or displaces it." Milliequivalents, when applied to soils are usually expressed on the basis of 100 grams of dry substance (4).

Thus if a clay has a total exchange capacity of one milliequivalent it is capable of adsorbing and holding one milligram of hydrogen (H+) or its equivalent for every 100 grams of dry substance.

As might be expected, the exchange capacity of soil clays exhibit a wide range since a number of different clay minerals are always present and their proportionate amounts markedly vary with conditions of climate and soil material. Lyon and Buckman (4) states that in clays extracted from Iowa soils, the exchange capacities of montmorillonite hydrous mica and kaolin were in the order of 100, 30, and 10 milliequivalents respectively.

It is thus easy to see why the clay complex of southern soils, dominated as they are by kaolin minerals should have a low exchange capacity ranging perhaps between 20 and 30 milliequivalents. On the other hand the clays functioning in the soils of the middle west where hydrous mica and montmorillonite are prominent have a much higher base exchange capacity ranging from 50 to possibly 100 milliequivalents, depending on the conditions.

The practical significance of the above statements is far reaching. Clays differ markly in their base exchange properties. Hence, soils also will differ widely in this all important capacity, not only because they possess different amounts of clays but also because the clay is a fertility factor of tremendous importance.

The cation exchange capacity deals primarily with the colloidal material in soils. There are two types of colloidal material in the soil (6,4): namely, mineral and organic. In some ways their influences are similar, in other respects, decidedly antagonistic.

The mineral colloid is made up of complex silicates normally gel-like in character, and highly plastic and cohesive. The residues is low in plasticity and cohesion. Both types of colloidal matter, however, have high adsorption, are markedly dynamic, and are active catalytic agents.

The lack of inorganic colloidal matter in sandy soils has certain obvious advantages (4,10): looseness, friability, good aeration and drainage, and easy tillage. By the same token the lack of inorganic colloidal matter in sandy soils has certain obvious disadvantages: excessive drainage and excess aeration.

One of the outstanding characteristics of the colloidal complexes of the soil both mineral and organic is the capacity of adsorbing cations. Rich and Obenshain (6) presents data to show that: 1. There is a close relationship between the cation exchange capacity and the organic content of the soils studied. As the organic matter present increased, the milliequivalent increased. They also found that fertilizer and crop practices which tended to increase crop yields also tended to increase soil organic matter and cation exchange capacity. 2. There was a significant positive correlation between organic matter content and cation exchange capacity of the soil. The organic fraction seemed to be of greater importance than the mineral fraction in contributing to the cation exchange capacity of this soil. 3. Where farm manure was applied, exchangeable calcium, magnesium potatium, and cation exchange capacity were increased significantly.

Whitt and Baver (12) found that when the milliequivalent of exchangeable hydrogen per 100 grams are plotted as a function of the average diameters of the particles the exchange capacity increases with decreasing particle size. This increase in exchange capacity is usually considered as being due to an increase in the surface per gram and hence to a greater number of exchange points per unit weight of material.

There are several methods of determining the cation exchange capacity of a soil. Bower and Truog (2) found that the results for cation exchange capacity of montmorillonite and Miami clays when determined by means of the monovalent cations, sodium (Na^+), potassium (K^+), Hydrogen (H^+), and Ammonium (NH_4^+) are in good agreement with the results obtained by titration curve method. When the exchange capacity results for the divalent cations are compared, it is noted that the cations which form the weakest base give the highest values. The stronger base forming cations, barium (Ba^{++}) and strontium (Sr^{++}) give results only very slightly higher than the true exchange capacity. While weaker base forming cations, calcium (Ca+ +), magnesium (Mg), and manganese give much higher results. Since monovalent cations do not give high results for exchange capacity, the values obtained by means of ammonium (NH_4) represents the true exchange capacities of the clays.

Sieling (7) states that a knowledge of base exchange capacity of soils is of considerable help in diagnosing lime and fertilizer needs.

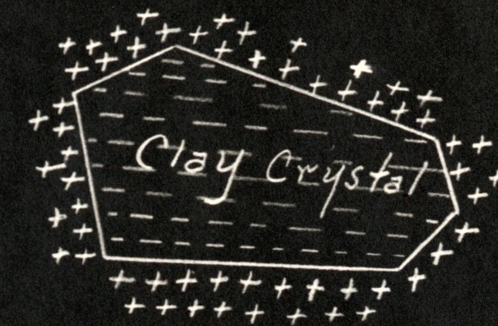

Fig.1 Diagrammatic representation of colloidal clay crystal with its lamellar nucleus or micelle. its innumerable negative charges, and its swarm of exchangeable cation. Under the influence of an electric current such a particle will move toward the positive electrode.

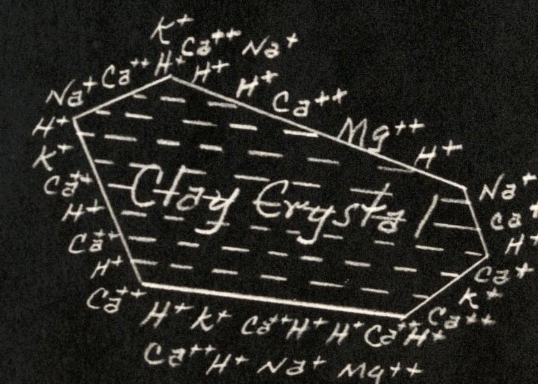

Fig.2 Diagram of a clay crystal showing the various cation that usually occupy the exchange complex. Note that Ca and H ions are dominant. No attempt has been made to indicate the numerous adsorbed molecules of water.[1]

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[1] T. L. Lyon and H. O. Buckman, The Nature and Properties of Soils, pp. 70-71.

METHODS AND MATERIALS

A composite sample was taken from each plot labeled: 10-Huntington, 21-Maury, 40-Lindside, 42-Dickson, 61-Maury, 81-Dunning, and 83-Melvin, irrespective to the slope and the degree of erosion. A two inch soil auger was used in securing the samples. A minimum of six borings was made in each plot. The sample was taken from the first one to six inches of the top soil. The respective samples were mixed thoroughly and placed in the agronomy laboratory to air dry.

After the soil had completely air dried, it was put on a table in the agronomy laboratory and well pulverized in preparation for the analysis.

ANALYSIS

The determination of the moisture content was done as follows: (1)

1. Weigh 2 grams of soil in crucible.
2. Place in oven at 105 degrees C for 5 hours.
3. Cool in desiccator and weigh.
4. Calculate results.

The determination of the organic matter content was done as follows: (1)

1. Take soil and crucible from the determination of moisture content.
2. Place crucible with soil in muffle furnace at 600 degrees C for 1 hour.
3. Cool in desiccator and weigh.
4. Calculate the results.

The determination of the cation exchange capacity was done as follows: (5)

1. Saturate 50 grams of soil sample with 250cc of N Ammonium acetate solution PH 7.0. Stir well and allow to stand over night at room temperature.

2. Filter through a 15 cm Whatman No. 44 filter paper and leach with further portions of Ammonium Acetate, allowing one portion to leach completely before repeating.
3. Wash the soil repeatedly with 60% alcohol until the excess of ammonium acetate is removed. (This may be done by adding a small quantity of Ammonium chloride to the first lot of alcohol used for washing and then leaching with alcohol until the filtrate gives no test for chloride. When free from chloride discard the alcohol washings).
4. Then remove the adsorbed ammonium by washing once with 0.1 N Potassium sulfate and continuing with N Potassium Sulfate, until one litre of filtrate has been collected.
5. Transfer an aliquot of the filtrate to a litre Erlenmeyer flask. Add 2-3 grams of magnesia and distil the ammonia into a measured amount of 0.05N hydrochloric acid.
6. Titrate the excess of hydrochloric acid with 0.05N sodium hydroxide using methyl red as indicator.
7. The total amount of ammonia adsorbed by the soil and displaced by the potassium sulfate corresponds to the total cation exchange capacity of the soil.

RESULTS

Soil number 10 (figure3) is classified as being a well drained brown first bottom Huntington soil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February, 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 1 Moisture Content

No. of Sample	Wt. of Soil before heating	Wt. loss on heat	% of Moisture
1	2.0196g	.0446g	2.20
2	2.0900g	.0462g	2.21
3	2.0920g	.0468g	2.23
Ave.&dev.			2.21 ± .01

Table 2 Organic Matter Content

No. of Sample	Original wt. of sample	Wt. loss on heating	% of organic matter
1	2.0196g	.1024g	5.07
2	2.0900g	.1046g	5.00
3	2.0920g	.1050g	5.02
Ave.& dev!			5.03 ± .03

Table 3 Cation exchange capacity

No.of sample	M. E. per 100g soil
1	29.85
2	29.00
3	30.00
Ave. & dev.	29.62 ± .41

Soil number 21 (Figure 3) is classified as being a brown blue grass Maury soil, with permeable subsoil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 4 Moisture Content

No. of sample	Wt. of soil before heat	Wt. loss on heat	% of moisture
1	2.0002g	.0528g	2.64
2	2.0004g	.0530g	2.65
3	2.0008g	.0533g	2.66
Ave. & dev.			2.65 ± .06

Table 5 Organic Matter Content

No. of sample	Original wt. of sample	Wt. loss on heating	% of Organic Matter
1	2.0002g	.1161g	5.80
2	2.0004g	.1165g	5.82
3	2.0008g	.1158g	5.79
Ave. & dev.			5.80 +- .01

Table 6 Cation exchange capacity

No. of sample	M.E. per 100g soil
1	22.02
2	21.87
3	21.86
Ave. & dev.	21.92 +- .07

Soil number 40 (Figure 3) is classified as being a medium drained first bottom Lindside soil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 7 Moisture Content

No. of sample	Wt. of soil before heating	Wt. Loss heating	% of moisture
1	2.0010g	.0549g	2.74
2	2.0006g	.0550g	2.75
3	2.0030g	.0560g	2.79
Ave. & dev.			2.76 ± .02

Table 8 Organic Matter Content

No. of sample	Original wt. of soil	Wt. loss heating	% of Organic Matter
1	2.0010 g	.1219 g	6.09
2	2.0006 g	.1218 g	6.08
3	2.0030 g	.1222 g	6.10
Ave. & dev.			6.09 ± .01

Table 9 Cation Exchange Capacity

No. of sample	M.E. per 100g of soil
1	37.97
2	37.69
3	37. 78
Ave. & Dev.	37.81 ± .10

Soil number 42 (Figure 3) is classified as being a medium drained brownish gray soil with a compact layer (pan) in the subsoil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 10 Moisture Content

No. of sample	Wt. of soil before heating	Wt. loss heating	% of moisture
1	2.4508g	.0520g	2.12
2	2.3980g	.0510g	2.12
3	2.3060g	.0500g	2.14± .02

Table 11 Organic Matter Content

No. of sample	Original wt of soil	Wt. loss heating	% of Organic Matter
1	2.4508g	.1670g	6.81
2	2.3980g	.1630g	6.79
3	2.3060g	.1611g	6.98
Ave. & dev.			6.86 ± .08

Table 12 Cation exchange capacity

No. of sample	M. E. per 100g of soil
1	25.51
2	25.33
3	25.38
Ave. & dev.	25.41 ± .07

Soil number 61 (Figure 3) is classified as being land too stony to plow, Maury Soil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 13 Moisture Content

No. of sample	Wt. of soil before heating	Wt. loss heating	% of moisture
1	2.0026g	.0404g	2.01
2	2.0021g	.0402g	2.01
3	2.0030g	.0410g	2.05
Ave. & dev.			2.02 ± .02

Table 14 Organic Matter Content

No. of sample	Original wt. of soil	Wt. loss heating	% of Organic Matter
1	2.0026g	.1390g	6.94
2	2.0021g	.1387g	6.93
3	2.0030g	.1395g	6.97
Ave. & dev.			6.95 ± .02

Table 15 Cation Exchange Capacity

No. of sample	M. E. per 100g of soil
1	20.35
2	20.59
3	20.89
Ave. & dev.	20.61 ± .18

Soil number 81 (Figure 3) is classfied as being a dark colored wet Dunning soil. This classification was given by district soil conservation department located in Nashville, Tennessee, February 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 16 Moisture Content

No. of Sample	Wt. of soil before heat	Wt. loss heating	% of moisture
1	2.0012g	.0732g	3.65
2	2.0081g	.0790g	3.93
3	2.0020g	.0760g	3.79
Ave. & dev.			3.79 ± .09

Table 17 Organic Matter Content

No. of sample	Wt. original of soil	Wt. loss on heat	% of Org. Matter
1	2.0012g	.1736g	8.68
2	2.0081g	.1742g	8.68
3	2.0020g	.1740g	8.69
Ave. & dev.			8.68 ± .003

Table 18 Cation Exchange Capacity

No. of sample	M. E. per 100g of soil
1	23.91
2	23.96
3	24.41
Ave. & dev.	24.09 ± .21

Soil number 83 (Figure 3) is classified as being poorly drained gray first bottom Melvin soil. This classification was given by the district soil conservation department located in Nashville, Tennessee, February, 1947. The color, parent material, and type and depth of subsoil were the bases on which the classification was made.

Table 19 — Moisture Content

No. of sample	Wt. of soil before heat	Wt. loss on heat	% of moisture
1	2.0292g	.0408g	2.01
2	2.0200g	.0404g	2.00
3	2.0299g	.0481g	2.37
Ave. & dev.			2.13 ±.16

Table 20 — Organic Matter Content

No. of sample	Wt. original of sample	Wt. loss on heating	% of Organic Matter
1	2.0292g	.1338g	6.59
2	2.0200g	.1330g	6.58
3	2.0299g	.1340g	6.60
Ave. & dev.			6.59 ± .01

Table 21 — Cation Exchange Capacity

No. of samples	M. E. per 100g of soil
1	39.35
2	39.21
3	39.28
Ave. & dev.	39.28 ± .05

DISCUSSION

The soils of this area belong to one of the two great soil groups of the United States, known as the pedalferic group. That is, it is a soil located in the Humid region of the United States. These soils have undergone leaching and oxidation and contain an abundance of iron and aluminum.

The A. & I. State College farm is located in Middle Tennessee, in the physiographic region known as the central basin. The central basin is the most important physiographic region of Tennessee as far as fertility of the land and density of population are concerned. This region developed on soluble Ordovician limestone is a gently undulating elliptical plain lying lengthwise across the state but almost wholly within it. The area of the basin is about 5,500 square miles, and its altitude is 500 to 700 feet above sea level. The basis is extremely irregular in outline, for it is entirely surrounded by the highland rim, 400 or more feet higher.

The soil of this region belongs to the soil group of the United States known as the Maury-Hagerstown area. The soils of this area are dominantly heavy textured consisting mainly of silt and clay, high in mineral plant nutrients and organic matter. These soils are medium to strongly acid in reaction. Soils of this region are expected to be of the hydrous mica clay nature with a cation exchange capacity of approximately 20 to 30 M. E. per 100 grams of soil.

Soil labeled Number 10 (Fig. 3) is classified as being a well drained brown first bottom Huntington soil. It appears in four different plots on the farm all of which are 0 to 2 percent slope, and has slight sheet erosion with less than 25% of top soil removed, with the exception of one plot which is 7 to 12 percent slope and moderate sheet erosion with 25 to 75 percent of top soil removed.

The organic content of this soil is 5.03. This indicates that this is a mineral soil. The moisture content of the soil in this problem is significant, in that it gives a rough indication of the particle size.

The cation exchange capacity of this soil is 29.62 milliequivalents per 100g. This indicates that this soil has the capacity to react as the hydrous mica clays.

Soil number 21 (Fig. 3) is classified as being a brown blue grass maury soil with permeable subsoil. It appears in nine different plots, with three different slopes. Five plots have slopes from 2 to 7 percent; three plots have slopes from 7 to 12 percent; and one has a slope from 12 to 20 percent. The degree of erosion ranges from 25 to 75 percent to over 75 percent of top soil removed by moderate sheet erosion.

The organic content of this soil is 5.80 percent, which indicates that this is a mineral soil. This is slightly higher than soil number 10.

The cation exchange capacity of this soil is 21.92 M. E. per 100 grams of soil. It is believed that the cation exchange capacity is lower in 21 than is 10 because 21 has more soil washed away than 10: Therefore, in collecting the samples more of the B horizon or the subsoil was taken. It has been found that subsoils have a lower cation exchange capacity than top soils. Were it not for the added organic content the exchange capacity might have been much lower.

Soil number 40 (Fig. 3) is classified as being a medium drained first bottom Lindside soil. It appears in two different plots. One plot has a 0 to 2 percent slope, and one has a 2 to 7 percent slope. The degree of erosion is plus erosion.

The organic content of this soil is 6.09 percent. The percentage of organic matter content in this soil is higher than in either number 10 or 21. This is thought to be due to the fact that this land is not as well drained as the other two soils mentioned, thus retarding the decomposition of the organic matter in the soil.

The cation exchange capacity of this soil is 37.81 milliequivalents per 100g of soil. The high milliequivalents in this soil is thought to be due to the high content of organic matter contained therein.

Soil number 42 (Fig. 3) is classified as being a medium drained brownish grap Dickson soil, with a compact layer (pan) in the subsoil. This soil appears in two different places, each one being located on the top of a narrow ridge. The slope of one is from 2 to 7 percent, and the other from 7 to 12 percent. The degree of erosion is moderate sheet erosion with over 75% of the top soil removed.

The organic matter content of this soil is 6.86 percent. The organic matter content of this soil is somewhat higher than No. 40. This is thought to be due to the fact that drainage here is not as extensive as in several other plots, and the decomposition of the organic contents has not been as extensive.

The cation exchange capacity of this soil is 25.41 milliequivalent per 100 grams of soil. The milliequivalent of this soil is thought to be lower than number 40 because the presence of the compact layer (pan) in the subsoil indicates that the finer soil particles have leached out of the surface soil leaving a greater proportion of coarse particles. The coarse particle soil has a lower milliequivalent per 100 grams of soil than does the small particles thus explaining the low results found.

Soil number 61 is classified as being land too stony to plow. It is a maury stony soil: this type of land only comprises one area. The slope is from 12 to 29 %, and the degree of erosion is moderately severe sheet erosion. This land at present is in pasture.

The organic matter content of this soil is 6.95 percent. Since no cultivation has gone on to hasten decomposition of the organic matter, it is understandable why a pasture soil would be this high in organic matter content.

The cation exchange capacity is 20.61 milliequivalents per 100 grams of soil. This is somewhat low as compared to other plots but is thought to be due to the coarse texture of the soil and to the state of activity of the organic content.

Soil number 81 (Fig. 3) is classified as being a dark colored wet dunning soil. This soil appears in two plots each having a 0 to 2 percent slope and plus erosion. This area remains wet longer than the surrounding land, as it is lower.

The organic matter content of this soil is 8.68 percent. This is higher than any other plot on the farm, and is thought to be due to the amount of water contained on this soil. Water tends to cool the soil, thus retarding the decomposition of the organic matter.

The cation exchange capacity of this soil is 24.09 milliequivalents per 100 grams of soil. This is lower than would be expected on a soil containing 8.68 percent organic matter content but it is believed that the low exchange capacity is due to large partions of coarse material being brought down by erosion from adjacent plots, and coarse particle soils having a lower milliequivalent per 100 grams of soil than fine particles have influenced the results greatly. It is also thought that the state of decomposition of the organic matter has influenced the cation exchange capacity.

Soil number 83 (Fig. 3) is classified as being a poorly drained gray first bottom Melvin soil. This soil only comprises one area. The slope is 0 to 2 percent and has plus erosion.

The organic matter content of this soil is 6.59 percent. The organic matter content is high possibly because the plot is poorly drained and the decomposition of organic matter has been retarded.

The cation exchange capacity of this soil is 39.28 milliequivalent per 100 grams. This is also high but is thought to be due to the large amount of organic matter content plus the fact that this plot, having plus erosion and being subject to floods has had small particles of soil deposited there during the flood periods.

SUMMARY AND CONCLUSIONS

The most outstanding facts revealed by this study are that:

1. The moisture content of these soils ranged from 2.02 in Maury Stony (61) to 3.79 percent in the Dunning (81).
2. The organic matter content of these soils ranged from 5.03 in the Huntington to 8.68 percent in the Dunning (81).
3. The cation exchange capacity of these soils ranged from 20.61 in the Maury Stony to 39.28 M. E. per 100 grams of soil in the Melvin (83).

The following conclusions were made:

SOILS

1. In soils having a low moisture content, a high organic matter content, and cation exchange capacity, the high cation exchange capacity is due to the high percentage of organic matter.

2. In soils with a low organic matter content, high moisture content, and high cation exchange capacity, the high cation exchange capacity is due primarily to the size of the particles.

3. In soils with a low moisture content, high organic matter content, and low cation exchange capacity, the cation exchange capacity would have been much lower had it not been for the high organic matter content.

4. In soils with a high moisture content, high organic content, and high cation exchange capacity, the high cation exchange capacity is due both to the mineral fraction and the organic fraction.

5. In soils with a high moisture content, high organic matter content, but low in cation exchange capacity, it is thought that the organic matter in this soil is in a state of disintergration, but has not reached the stage of decomposition; whereas, it can contribute to the cation exchange capacity. However, when this stage of decomposition is reached, the cation exchange capacity will be raised accordingly.

6. Additional study is needed before the full explanation of the reason as to why the soil having high organic content and high moisture content still has a relatively low cation exchange capacity.

RECOMMENDATIONS

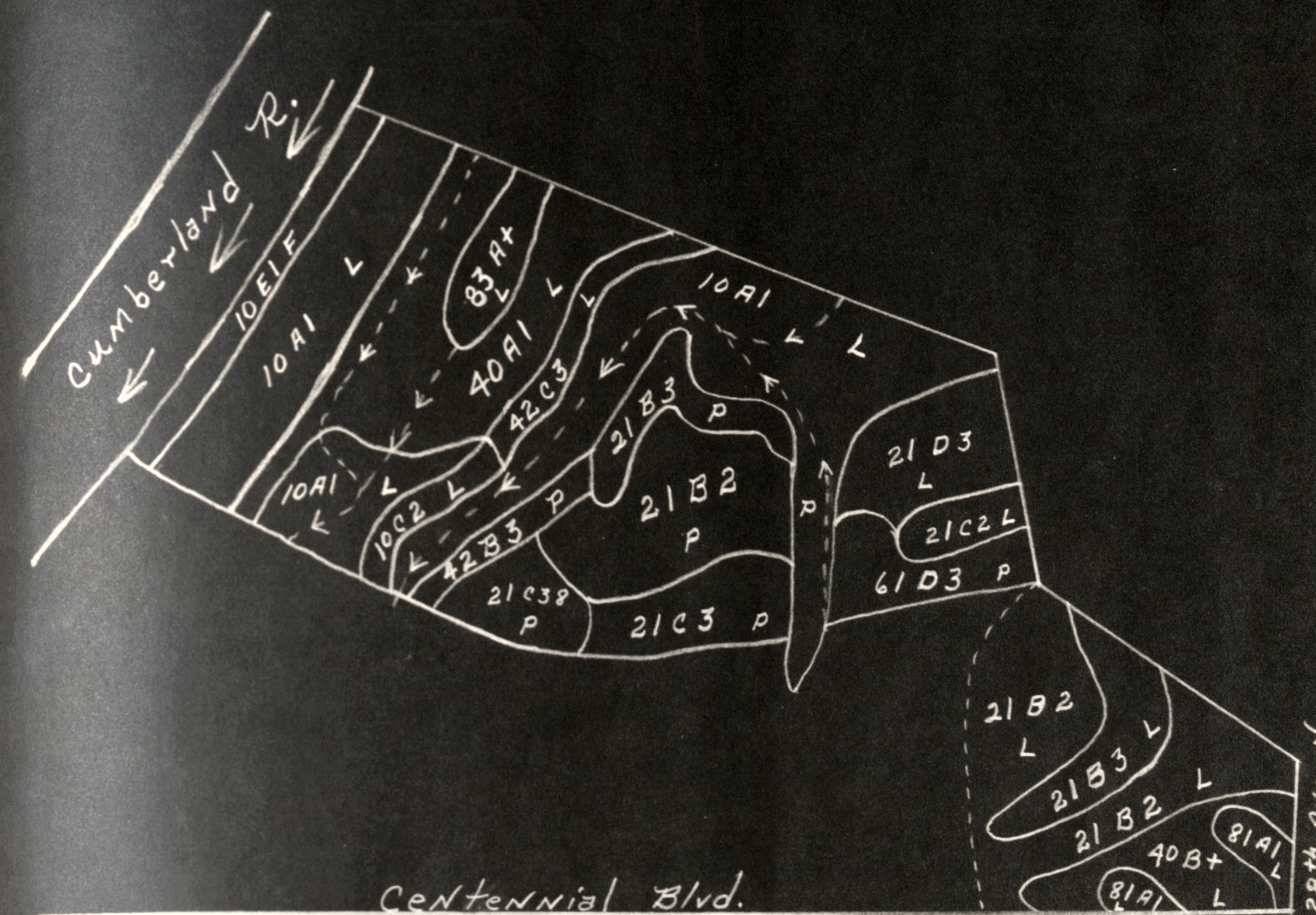
THE FOLLOWING RECOMMENDATIONS ARE MADE:

1. According to the cation Exchange capacity found, Soils numbered 83 Melvin and 40 Lindside (Fig. 3) are capable of utilizing larger amounts of commercial fertilizers than other soils on the farm. The quantity used on the other Soils should be in the following order, from large to small amounts: No. 10 Huntington, 42 Dickson, 81 Dunning, 21 Maury, and 61 Maury Stony.

2. To soils number 10 Huntington, and 21 Maury, organic matter should be added in the form of green manure, barnyard manure, plant residue, or any other form available.

3. When limed, the calcium will remain in soils with high cation exchange capacity longer than in soils with low cation exchange capacity. The leaching of calcium will be in the following order: the least will be in soil 83 Melvin, followed by 40 Lindside, 10 Huntington, 42 Dickson, 81 Dunning, 21 Maury, and 61 Maury Stony, in that order.

It is believed that the above information will be of great assistance in the management of the Farm at the TENNESSEE AGRICULTURAL AND INDUSTRIAL STATE COLLEGE.



(Fig.3) Tennessee A. & I. State College Farm as classified by the district soil conservation department Nashville, Tennessee - February 1947

10 - Huntington
21 - Maury
40 - Lindside
42 - Dickson
61 - Maury
81 - Dunning
83 - Melvin

UTILITARIAN SOIL CONSERVATION LEGEND
Davidson County, Tennessee

SOIL GROUPS

10. Well Drained brown first bottom soils.
20. Brown or Reddish brown silt loams low in phosphate.
21. Brown blue grass soil with permeable subsoil.
30. Cherty soils with yellow subsoil.
31. Cherty soils with reddish subsoil.
32. Well drained chert free surface soils with yellow or reddish subsoil.
40. Medium drained first bottom soils.
42. Medium drained brownish gray soils with a compact layer (Pan) in the subsoil.
50. Dark colored bluegrass soils with yellow plastic subsoil.
51. Brownish gray soils with reddish plastic subsoil.
53. Grey soils with yellow plastic clay subsoils.
55. Shallow bluegrass soils with yellow and grey plastic clay subsoil.
61. Land too stony to plow.
62. Low phosphate stony soils where lowing is possible.
63. Moderately deep silty clay loam soils with shaley or sandy high phosphate subsoils.
65. Cherty phosphatic soils with greyish brown surface and permeable subsoil.
66. Shallow soils over shale.
68. Stony bluegrass soil where plowing is possible.
80. Wet soils of the stream terraces.
81. Dark colored wet soils.
83. Poorly drained grey first bottom soils.

EROSION SYMBOLS

- − Unclassified erosion
- \+ Recent accumulations
- 1. Slight sheet erosion- less than 25% of top soil removed.
- 2. Moderate sheet erosion 25 to 75% of top soil removed.
- 3. Moderately severe sheet erosion-over 75% of top soil removed.
- 4. Severe sheet erosion-sheet erosion into subsoil.
- 5. Very severe sheet erosion-sheet erosion into parent material.
- 6. Occasional gullies.
- 7. Frequent gullies.
- 8. Very frequent or destructive large gullies.

Note: Gullies too large to be crossed by tillage implements are indicated by encircling the symbol.

LAND USE

1 - crop land
p - pasture
pb-Brushy pasture
X -Idle Land
F -Woodland
H -Non-agricultural

SLOPE LEGEND

A - 0 - 2 percent
B - 2 - 7 "
C - 7 -12 "
D -12 -20 "
E -20 -30 "
F -Over 30 "

SEQUENCE OF SYMBOLS

soil type -- slope --Erosion

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