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METHODS FOR THE QUANTITA-
TIVE DETERMINATION OF
SOIL ACIDITY

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A COMPARISON OF DIFFERENT METHODS FOR THE
QUANTITATIVE DETERMINATION OF SOIL ACIDITY

By

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THE PROBLEM IN ITS RELATIONS

The occurrence of acid soils and the potent influence which an acid condition has upon vegetation have only in the last comparatively few years come to be duely recognized by investigators and students in agriculture. In any analysis of a soil today a determination of its acidity is considered as one of the most important. An analysis would be considered quite incomplete without it. However, various methods are used for this determination and a comparison of these is the object of this study.

Before taking up these methods it will be well to bring to mind the important facts regarding acid soils and soil acidity in general, including their occurrence, its causes, its affects upon the soil fertility and upon vegetation, as well as the treatment for its correction or prevention.

OCCURRENCE OF ACID SOILS

In speaking of the prevalance of acid soils, Wheeler (1) of the Rhode Island Experiment Station says, "The experience of the experiment stations of Virginia, Maryland, Rhode Island, Massachusetts and of farmers in many parts of the united States

furnish abundant evidence in support of the idea that a deficiency of carbonate of lime exists frequently in this country and that acid upland soil may not be uncommon", and again, "A dangerous degree of acidity or at least a fatal lack of carbonate of lime appears to exist in upland and naturally well-drained soils, and is not confined to muck and peat swamps and very wet lands as most American and many other writers seem to assume, in view of which it appears that the test for acidity should be more generally applied to such lands."

Whitson (2) states that "tests in Wisconsin have shown the existence of acidity in both virgin and cultivated soils; in clay, sand, clay loam and marsh soils. He also says that "Except under unusual conditions of origin, such as an arid climate, or where affected by glacial action, sandy soils are as a rule acid." Hilgard (3) speaks of the sour, sandy soils of the Mississippi coast belt and acid sandy pine lands of the Southern states. From Schulz (4), Deherain (5), Storer (6) and others we have descriptions of the "Saure Sandboden" of Germany, the acid, sandy soils of France, the "Sour Land of Alaska and the sour "Veld" of South Africa. We conclude therefore that acid soils are of common occurrence, that they are met with in all regions having a humid climate, and that they are not restricted to any particular type of soil.

CAUSES OF ACIDITY IN SOILS

A sour soil indicates the presence of unneutralized acids. The acidity may result from either chemical or biological processes or both and depends upon one or several of many factors. Some of the factors are: the presence of large amounts of vegetable matter and poor drainage, a lack of bases or alkaline carbonates which is largely determined by the origin of the soil or by the depletion through cropping, cultivation and leaching and the use of certain fertilizers.

Engle (7) says in speaking of sour soils, "This sourness is generally due to the production of free organic acids of the humus acid type and is possessed by many peaty soils where the amount of organic matter is excessive." Detner (8) states that not all soils which are excessively rich in humus are acid and on the contrary that sandy soils sometimes give an acid reaction.

Hilgard (9) remarks that, "It has been long known that after long continued cultivation, soils originally neutral or slightly basic reaction become acid." Wheeler (10) also states that, "The removal of plants from the soil and the use of certain fertilizers doubtless exhaust the lime and other basic ingredients of the soil more rapidly than would be the case were nature allowed to take her course," and that soils originating from mica, schist and granite and have a large percentage of silicates are commonly acid, also that "Wet locations lack bases with which the organic acids being formed can combine.

Adolf Meyer (11) in discussing fertilizers makes a very interesting and important classification relating to the effect that each has upon the alkalinity or acidity of a soil. His classification is in part as follows:

1. Physiologically Neutral.

Calcium Sulphate (Gypsum)

Magnesium Sulphate

Sodium Chloride (Common Salt)

Superphosphate

Potassium Nitrate (This approaches closely group 3)

2. Physiologically Sour.

Potassium Chloride (Muriate of Potash)

Ammonium Sulphate

Potassium Sulphate

German Potash Salts in General

3. Physiologically Basic.

Calcium Carbonate

Wood Ashes

Caustic Lime

Potassium Carbonate

Undissolved Calcium Phosphate

Sodium Nitrate (Nitrate of Soda)

Bone Meal

Meyer also states in connection with this that, "Bases are withdrawn by plants from humates and silicates rendering the soil acid." Hall (12) makes this important note regarding

subsoils. "Another source of sterility is the presence of unoxidized iron salts in the soil; many clay subsoils are colored dark blue or green by double ferrous silicates like glauconite or by finely divided pyrites. Until these materials become oxidized to ferric hydrate, the soil remains sterile, particularly is this the case with iron pyrites, which in the form of marcosite easily oxidizes to yellow ferrous sulphate and sulphuric acid. Cultivation with a free use of lime or chalk is the best means of ameliorating such soils which always show an acid reaction."

EFFECT OF ACIDITY UPON FERTILITY

Acidity affects the fertility of the soil by furnishing an antiseptic property that retards the decomposition of the organic matter and that hinders the fixation of nitrogen by legume and other bacteria. The process of nitrification is also very slow in acid soils, and available phosphates are commonly deficient.

EFFECTS OF ACIDITY UPON VEGETATION

The potent influence that an acid condition in a soil has upon the growth of many plants has been strikingly demonstrated by numerous experiments. In many cases it parallels the effect of acidity in the culture media for bacteria, completely preventing the growth of certain classes. It is interesting to note what many investigators say in regard to the influence of acid soils upon vegetation. Stutzer (13) says,

"A large amount of acids in soils is injurious to all cultivated plants." Hubener (14) states that, "Hardly anything has so great an influence upon the character of the vegetation as the condition of the humus." Schultz (15) speaks of the sandy soils of Germany as sour and unfit for economical production of plants. In his "How Crops Feed" Johnson (16) says, "A soil that is fit for agricultural purposes contains little or no acids, except carbonic acid and oftentimes show an alkaline reaction with litmus paper." From Hilgard's (17) description of the sour sandy soil of the Mississippi Coast Belt we have this statement: "An analysis shows the soil to be sour and extremely poor, especially in its lime and phosphates. Its herbaceous vegetation consists exclusively of very small-seeded "Calcifuge" plants (sedges, orchids, juncus, etc.)." A paragraph in Whitson (18) and Walster's "Notes on Soils", is so admirably put that we include it here in full. "Not all plants are injuriously affected by an acid condition of the soil. One of our weeds, usually known as the common sorrel (*Rumex Osetosella*) prefers acid soils, and its presence is practically a sure indication of an acid condition. The presence of the common horsetail rush (*Equisetum*) also indicates acidity. Cranberries and certain of the marsh rushes are also able to thrive under acid conditions. Of the cultivated crops, red clover, alfalfa, and sugar beets are peculiarly sensitive to acidity, while corn, oats, potatoes, and alsike clover are not so badly affected.

Alsike clover has often made a good stand on fields too acid for the growth of red clover. Large yields of potatoes have been obtained on acid soils, where of course there were suitable amounts of potash and phosphate present."

CORRECTION FOR SOIL ACIDITY

Sour or acid soils can be corrected by neutralizing the acidity present with some basic oxide or alkaline salt, such as wood ashes, caustic lime, potassium carbonate, limestone, dolomite, etc. However, the treatment universally recommended is lime carbonate. The old and popular maxim, "A limestone country is a rich country" stands unchallenged. Hilgard (19) says, "The current neutralization of the humus acids is unquestionably the cardinal advantage of calcareous lands", and Wheeler (20) expresses much the same thought in this fashion: "The fault of many soils is a lack of basic ingredients to which the noxious compounds which may partly or wholly give rise to the acid reaction is attributable." Pichard (21) notes, in speaking of the acid sandy soil of Brittany that lime increased the yield of fodder beets from 6,315 Kilograms to 24,000 and 37,000, an increase of three to six times.

Deherain (22) states that, "Clover culture, which was formerly unknown, was rendered possible by the use of lime, transformed Limonsin, France, which had been in a miserable state for centuries, to a state of prosperity." Hopkins (23),

speaking of lime in relation to acidity has this to say:
"The chief and usually the only justifiable reason for applying lime to soils to correct or neutralize soil acidity. The fermentation and decay of nearly all forms of organic matter is accompanied by the formation of acids. x x x x x x. Souring is usually the first stage in the process of decay of organic matter." "The process termed nitrification by which the nitrifying bacteria transforms the insoluble nitrogen in manure and plant residues into soluble nitrate nitrogen, the form in which it becomes available as plant food, is greatly promoted by the presence of limestone and retarded by acid conditions."

QUALITATIVE TESTS FOR ACIDITY AND THE REQUIREMENTS OF LIME IN A SOIL

There are two simple qualitative tests for acidity and the lime requirement in soils. One is a test for carbonate and of which Hopkins (24) speaks as follows: "A positive test for carbonates in the soil precludes the presence of soil acidity, because the carbonates are easily decomposed by acids with the liberation of carbonic acid which breaks down into water and gas (carbon dioxide). Consequently the carbonates, such as calcium and magnesium carbonate, serve as mild alkalis in the presence of which soil acidity cannot exist. To test for carbonates in the soil, make a shallow cup of a ball of soil and pour in a few drops of concentrated hydrochloric

acid. If carbonates are present, a reaction occurs with the liberation of carbon dioxide, which appears as gas bubbles, producing foaming or effervescence." Heating will increase this reaction. However, Hilgard (25) remarks that, "All advantages of calcareous soils are secured with percentages of lime far below those in which the slightest effervescence can be perceived." The second test is that with litmus paper, in which a permanent change in the color of the paper from blue to red indicates directly the presence of free or unneutralized acids. According to Wheeler (26) even free carbonic acid is capable of permanently reddening blue litmus paper. The test may be performed in various ways. If the soil is moist a slit may be made in it with a clean knife blade, the paper placed in this slit and the soil pressed back onto it. After a few minutes the paper is examined and its color, if red or pink, will indicate an acid soil. The same test can be made by placing the paper between two halves of a ball of fresh soil, which are pressed firmly upon it. If the soil must be wetted only neutral water can be used and preferably distilled water. An objection to this method has been raised by those who hold that the change of color in the paper may be due to the absorption of the litmus by the soil in contact with the paper. This objection is avoided by the use of a method recommended by Dr. Kellerman of the U.S. Bureau of Plant Industry, whereby a shallow dish is used and the litmus paper is separated from

the soil above and below by neutral filter paper. Results of the Wisconsin Soil Survey field tests for acidity by the litmus paper method, are, with but very few exceptions, in agreement with the laboratory determinations for lime requirement. The litmus test does not indicate, however, the degree of acidity of a soil nor the amount of lime necessary for its neutralization. For this more elaborate methods must be used. A review of such methods is attempted in the next paragraphs.

REVIEW OF METHODS FOR THE QUANTITATIVE DETERMINATION OF SOIL ACIDITY

The Veitch (27) Method.

The method worked out and used by F.P. Veitch is as follows: A preliminary test is first made on three ten gram samples of soil. To each sample 50 or 60 c.c. of distilled water and different amounts of standard lime water is added, as 10, 20, and 30 c.c. They are evaporated to dryness, and transferred to stoppered Jena flasks with about 100 c.c. of water and let stand over night with occasional shaking. 50 c.c. of the clear supernatant liquid from each flask is then placed in Jena beakers with a few drops of phenolphthaleine and boiled until a pink color appears, or in case where no color develops, to a volume of 5 c.c. Then with two of treated soils, one of which has been rendered alkaline by the added lime water and the other of which is still acid,

as guides a number of fresh 10 gram portions of soil is prepared. Lime water is added as before, except that the amount added to a dish differs from that of another by only one or two centimeters. They are then dried, transferred, allowed to stand and filtered exactly as before. The smallest amount of lime water which gives the characteristic pink color with phenolphthaleine is taken as the acidity equivalent of the soil and from the data obtained the lime requirement of the soil may be calculated.

Hopkins' (28) Method.

The method recommended by Cyri G. Hopkins of the University of Illinois is as follows: A 100 gram sample of soil is placed in a 400 c.c. wide mouthed bottle, 250 c.c. normal potassium nitrate solution is added and the bottle stoppered and shaken in a shaking machine for three hours or every five minutes by hand and let stand over night, when 125 c.c. of the clear supernatant liquid is drawn off, boiled for 10 minutes to expel the carbon dioxide, cooled, and titrated with standard sodium hydroxide solution (of which 1 c.c. is equivalent to 4 grams of calcium carbonate), using phenolphthaleine as indicator. The result from the titration must be multiplied by $3\frac{1}{2}$, according to the following explanation by Hopkins. "The acids and acid salts of the soil are difficultly soluble in water, but by titrating with a salt solution, as potassium nitrate, a double decomposition takes place,

carrying acidity into solution. An equilibrium is reached, however, before this reaction runs to an acid, and if, after having drawn off 125 c.c. to titrate, 125 c.c. of fresh potassium nitrate are added to the bottle and the bottle again shaken for three hours, 125 c.c. drawn off will give a titration which is more than half of the first. By continuing this process until the last 125 c.c. shows practically no acidity, we have a series of titrations, the sum of which represents the total acidity of the 100 grams of soil. It has been found by working with a number of different soils that as an average the sum of such a series is two and one half times the first titration. Consequently when the sodium hydroxid is made up so that 1 c.c. is equivalent to 4 milligrams of carbonate, and 125 c.c. (which represents 50 grams of soil) are titrated, each 0.1 c.c. required to neutralize corresponds to 1 milligram of calcium carbonate required by the 100 grams of soil, or to 0.001 per cent of calcium carbonate required by the soil tested."

The Albert (29) Method.

Robert Albert has developed the following method:

A 20 to 50 gram sample of soil is boiled with a known amount of magnesia, lime or baryta and an excess of an ammonium salt. The liberated ammonia is absorbed in a definite amount of standard acid and estimated by titrating with sodium alizarmsulphonate or cochineal as indicator. The dif-

ference in amounts of ammonia liberated by the alkaline earths alone and with the soil represents the acidity of the soil.

Tacke's (30) Method.

The method prepared by Tacke and improved by Suchting is based on the supposition that free acids in the soil gives free carbon dioxide in contact with calcium carbonate. This method has been used almost exclusively for peat soils. Ten to fifty grams of soil are mixed with a little water contained in a flask and an accurately weighed quantity (about 4 grams) of calcium carbonate is added and the carbon dioxide evolved is removed by means of a current of hydrogen with constant stirring of the mass and absorbed in a definite amount of standard potassium hydroxide and titrated or collected in a Geisseler's bulb containing potassium hydrate and weighed. Dilute hydrochloric acid is then added and the carbon dioxide evolved determined as before. The sum of these results should equal the carbon dioxide calculated in the calcium carbonate added to the soil. If the sum of the carbon dioxide formed by decomposition of organic matter and in accurate analysis this should be allowed for. The weighing of the carbon dioxide evolved from the soil before adding the hydrochloric acid and the amount calculated from the calcium carbonate added represents the carbon dioxide expelled by the acids of the soil and from this the lime requirement of the soil can be calculated.

STATEMENT OF THE CONDITIONS AND METHOD OF CONDUCTING
THE EXPERIMENTS

Soils Used.

The same soils, seven in number, were used in all the different determinations throughout the experiment. All of them gave an acid reaction with litmus paper. They were designated by numbers from one to seven and are so indicated in all the following tables.

Soil No. 1 is from the Griswold Farm near West Salem, LaCrosse County, Wisconsin. It is a silt loam soil of secondary loessial origin, eight to ten feet deep and contains a high per cent of organic matter. The land is level but well drained. Originally it supported a heavy growth of hardwoods such as maple and white oak. This soil is very acid as a result of long time cropping but is highly fertile. It has been well fertilized with the manure of a large dairy herd continually fed on concentrated feedstuffs. For years the soil has had good tillage and care.

Soil No. 2 is from the town of Longwood, Clark County in the west central part of Wisconsin. It represents the surface eight inches of the soil in the N.W. $\frac{1}{4}$ of the S.E. $\frac{1}{4}$, Section 23, Township 28, Range 2 West, 4th P.M. and is classified as the Colby Loamy Clay, a loamy clay with very little stone; gently sloping and well drained. It originally supported a dense growth of hardwoods, hemlock and much pine. The area which this soil represents was cleared and seeded

to timothy some twenty years ago and used for meadow purposes by a lumber company. The last five years it has been cropped to oats and corn. Sample No. 3 is the subsoil corresponding to sample No. 2 and represents the subsoil from 8 to 24 inches below the surface.

Sample No. 4 is also a Colby Clay from Clark County and represents the surface eight inches from the N.W. $\frac{1}{4}$ of the S.W. $\frac{1}{4}$, Section 26, Township (Hixon) 29, Range 2 West, 4th P.M. This field is nearly level, but its even slope allows it to be drained by dead-furrows. It has been cropped fifteen years, chiefly to timothy and clover with a crop of oats every fourth or fifth year. In 1910 it was cropped to corn. Sample 5 is the corresponding subsoil to No. 4 taken from a depth of from 8 to 24 inches.

Samples No. 6 and 7 are the soil and subsoil from the E. $\frac{1}{2}$ of the S.E. $\frac{1}{4}$, Section 5, Township 31, Range 10 East, 4th P.M. near the village of Antigo, Langlade County, Wisconsin. It is known as the Ackley Gravelly Clay, a clay and gravel grading into a wet hard pan. The land is quite level and was formerly a very wet tamarack swamp. It is now drained by ditches, and has been cleared and cropped to meadow three years, followed in 1910 by a crop of oats.

No. 1 was shipped in a barrel and was in a loose condition. The other samples were in small sacks of about 3 to 5 pounds, and were so baked and hard that grinding was necessary.

The Moisture Content of each sample was as follows:

No. 1 -	14.5	per	cent	of	the	dry	weight.
No. 2 -	4.7	"	"	"	"	"	"
NO. 3 -	2.3	"	"	"	"	"	"
No. 4 -	2.7	"	"	"	"	"	"
No. 5 -	2.2	"	"	"	"	"	"
No. 6 -	3.2	"	"	"	"	"	"
No. 7 -	2.0	"	"	"	"	"	"

This was, of course, allowed for in calculating the acidity estimates or lime requirements in all determinations.

DESCRIPTION OF THE EXPERIMENTS AND THE DATA OBTAINED

Determination by the Veitch Method.

The determinations by the Veitch method were made in exact accordance with the conditions set forth in the review of the method above, except that six instead of three portions of soil were used. Great care was taken to avoid contamination by alkalis or acids from the air or from the water. In this as in all the following determinations, duplicate determinations were made as checks. When duplicates did not agree the results were discarded. Three determinations were made and the results were surprisingly similar in each case for the same soil.

From the amounts of standard calcium hydroxide used, the lime requirement for each soil was calculated to parts per million.

<u>Sample</u>	<u>Weight of Soil</u>	<u>Pounds of Calcium Carbonate Required</u>
No.1	1,000,000 lbs.	1,980
No.2	1,000,000 "	792
No.3	1,000,000 "	1,188
No.4	1,000,000 "	990
No.5	1,000,000 "	1,584
No.6	1,000,000 "	3,960
<u>No.7</u>	<u>1,000,000 "</u>	<u>1,188</u>

Hopkins' Method.

In the determination with the Hopkins' Petit Method, 100 grams of the soil were used, and all conditions as set forth in the review of the method above were closely adhered to, except that in the titrations, potassium hydroxide was used in place of sodium hydroxide.

The average results of four duplicate determinations is given below in terms of pounds of calcium carbonate necessary to neutralize the acidity in a million pounds of soil.

<u>Sample</u>	<u>Weight of Soil</u>	<u>Weight of Calcium Carbonate</u>
No.1	1,000,000 lbs.	277 lbs.
No.2	1,000,000 "	1,277 "
No.3	1,000,000 "	1,635 "
No.4	1,000,000 "	173 "
No.5	1,000,000 "	2,435 "
No.6	1,000,000 "	2,435 "
<u>No.7</u>	<u>1,000,000 "</u>	<u>1,049 "</u>

Robert Albert Method.

In the determination by this method, 50 gram portions of soil were placed in Kjeldahl flasks with 150 c.c. of a 0.1 per cent solution of calcium hydroxid and 100 c.c. of N/10 ammonium sulphate solution. A blank, that is the flask without any soil, but with the stated amounts of solution was used as a check in each determination. The flasks were connected with a distilling battery and the ammonia liberated at boiling by the calcium hydroxid not used up by the soil, was collected in flasks containing known quantities of standard sulphuric acid. The boiling was continued until the liquid distilled over gave no test for ammonia, and the amount of ammonia liberated from each flask determined by titration. The difference between that liberated from the blank and from each of the other flasks would indicate the amount of acidity in each of the 100 gram portions of soil, and from which the lime requirement was calculated in parts per million.

<u>Sample</u>	<u>Weight of Soil</u>	<u>Weight of Calcium Carbonated required</u>
No.1	1,000,000 lbs.	1,960 lbs.
No.2	1,000,000 "	1,505 "
No.3	1,000,000 "	2,099 "
No.4	1,000,000 "	495 "
No.5	1,000,000 "	2,594 "
No.6	1,000,000 "	2,913 "
<u>No.7</u>	<u>1,000,000 "</u>	<u>970 "</u>

Tacke's Method.

The apparatus used for the quantitative determination of acidity by Tacke's method consisted of a Kipp generator containing zinc and sulphuric acid for generating hydrogen and a carbon dioxide apparatus for purifying the carbon dioxide liberated by the action of the soil acids on a part of the calcium carbonate added. The carbon dioxide was forced through this apparatus by a stream of hydrogen from the Kipp generator and collected in a Geisseler's Bulb containing potassium hydroxide. This process was allowed to go on for two hours to assure a complete action between the calcium carbonate and soil acids. The amount of carbon dioxide liberated during the process was shown by the increase in the weight of the bulb. This carbon dioxide may not be due entirely to the action of the soil acids but also to decomposition of organic matter; therefore an excess of dilute hydrochloric acid is at this stage added to the soil and the carbon dioxide of the remaining calcium carbonate collected in the bulb and weighed. The excess of the sum of these determinations above the amount calculated in the calcium carbonate represents the product of decomposition. The carbon dioxide resulting from the action of the soil acids can then be found by difference, and the lime requirement calculated.

Owing to some fault in the apparatus or some other cause not discovered, the results obtained were quite inconsistent; and since time did not allow a repetition of a sufficient number

of determinations to afford data of any dependable value, we do not here include them.

COMPARISON AND DISCUSSION OF THE DIFFERENT METHODS
WITH REGARD TO THE RESULTS OBTAINED

The lime requirement calculated in parts of calcium carbonate for a million pounds of soil from the results of the different determinations is shown in the table below.

<u>Soil</u>	<u>Veitch's</u>	<u>Hopkins'</u>	<u>Albert's</u>
No.1	1,980	277	1,960
No.2	792	277	1,505
No.3	1,188	1,635	2,099
No.4	990	173	495
No.5	1,584	2,435	2,594
No.6	3,960	2,435	2,913
<u>No.7</u>	<u>1,188</u>	<u>1,049</u>	<u>970</u>

Expressed in tons required for 2,000,000 pounds of soil which* represents the weight of the plowed soil of an acre of average land to a depth of 6 2/3 inches the results are:

<u>Soil</u>	<u>Veitch's</u>	<u>Hopkins'</u>	<u>Albert's</u>
No.1	1.98 tons	0.28 tons	1.96 tons
No.2	0.79 "	0.28 "	1.50 "
No.3*	1.19 "	1.64 "	2.10 "
No.4	0.99 "	0.17 "	0.50 "
No.5	1.58 "	2.44 "	2.59 "
No.6	3.96 "	2.44 "	2.91 "
<u>No.7*</u>	<u>1.19 "</u>	<u>1.09 "</u>	<u>0.97 "</u>

*Hopkins' "Soil Fertility", p. 59.

In the study and interpretation of the results shown in the table above, it should be noted that Numbers 3, 5, and 7 are the respective subsoils of 2, 4, and 6, and that compared with their respective soils they contain relatively less organic matter. From this it is clear that the soils containing the higher per cent of organic matter were not in all cases the most acid. The acidity of the subsoils, though low in organic matter themselves, may, however, in part be due to the organic matter of their corresponding soils, a result of leaching, and yet soil No. 6 which next to No. 1 contains the highest per cent of organic matter, has a subsoil (No.7) lower in acidity than either of the subsoils of Numbers 3 and 5, corresponding to soils No. 2 and 4 which are low in organic matter.

With these differences of the several soils in mind, let us now make a comparison of the several methods from the results obtained. It is at once apparent that the results obtained by the different methods do not agree throughout. In Soil No. 1, both Veitch's and Albert's methods show a lime requirement of nearly two tons, while Hopkins' method shows it to be less than one-third of a ton. But going farther, we note the soils showing the least acidity by Veitch's method are Numbers 2, 4, and 7. This agrees with Albert's method. In Hopkins' method, however, we find an exception in Soil No. 1. Again taking the soils showing the highest amount of acidity, we find that Hopkins' and Albert's methods agree,

while an exception occurs in Veitch's in the case of Soil No.1. On the whole, however, the results of the different methods seem relatively to agree.

Comparing Veitch's method with Hopkins' method in more detail, we find that the soils Numbers 1, 2, 4, and 6 show a higher degree of acidity by the former method than the latter. With the subsoils, Numbers 3, 5, and 7, this is not the case, but almost the direct opposite is indicated. From these facts it seems that a high per cent of organic matter has an influence upon the results by Veitch's method. A conclusion which is much strengthened by the high acidity indicated by this method in Soils Numbers 1 and 6, both of which are high in organic matter, and which in the case of No. 6 seems also to be reflected in its subsoil, No.7, which under Veitch's method shows the relatively high lime requirement of 2,380 pounds as against 2,180 pounds by the Hopkins' and 1940 pounds by Albert's method. The differences between the results of Albert's method and those of Veitch, however, are not so great as between those of Hopkins' and Veitch's. In fact, as compared with Hopkins', the results of Albert's method also seems to reflect a response to the presences of organic matter as shown in the following comparisons.

Taking the results from the surface soils of which No.1 and No.6 are relatively high in organic matter we have:

<u>Soil</u>	<u>Albert's</u>		<u>Hopkins'</u>
No.1	1.96 tons	against	.28 tons
No.2	1.50 "	"	.28 "
No.4	0.50 "	"	.17 "
<u>No.6</u>	<u>2.91 "</u>	<u>"</u>	<u>2.44 "</u>

Also comparing the results from the subsoils, all of which are low in organic matter, we have:

<u>Soil</u>	<u>Albert's</u>		<u>Hopkins'</u>
No.3	2.10 tons	against	1.64 tons
No.5	2.59 "	"	2.44 "
<u>No.7</u>	<u>0.97 "</u>	<u>"</u>	<u>1.09 "</u>

It is evident therefore, that the soils high in organic matter show a higher acidity with Albert's method than with Hopkins' method, though not to such an extent as they do by Veitch's method. The reason for these differences is not clear to our mind. However, we are inclined to attribute them to the continued high temperature to which the soils are necessarily subjected in Veitch's and Albert's methods. In Hopkins' method the soils are at the room temperature throughout; only a portion of the soil solution being boiled to drive off the carbon dioxide. This high temperature in the two former methods would it seems result in a more active and further decomposition of the organic matter, and would also

tend to liberate more completely the acids held mechanically in the humus and organic bodies.

In comparing the results of the different methods in a general way, we see that the results obtained by Albert's method indicate, on the whole, a higher lime requirement than do the results from the other methods. This, we think, is due to the further liberation of ammonia from the ammonium sulphate than that actually replaced by the calcium of the lime not used up by soil acids. We base this conclusion upon the following observations.

The reader will recall that in connection with this method blanks were used as a basis from which the acidity was calculated. These blanks contained 150 c.c. standardized calcium hydroxid and 100 c.c. N/10 ammonium sulphate. The blanks were connected with the distilling battery as were the soil preparations, and the ammonia evolved by the action of the calcium hydroxid and boiling was collected in flasks containing 100 c.c. N/10 sulphuric acid. When the drippings from the condenser showed no further test for ammonia, the contents of these flasks were titrated with standard potassium hydroxid to ascertain the amount of ammonia evolved. In the case of the blanks this should be exactly equivalent to the calcium hydroxid added, provided the action was complete with an excess of the ammonium sulphate present and also providing that no ammonia was evolved except that which was replaced by the calcium of the lime water. It was found,

however, that this was not the case; a larger amount of ammonia having been distilled over than what was equivalent to the lime water added.

These titrations were also compared with those of 100 c.c. of standard lime water added directly to 100 c.c. of N/10 sulphuric acid.

100 c.c. of N/10 sulphuric acid plus the ammonia evolved was neutralized with 10.1 c.c. of standard potassium hydroxid (KOH), while 100 c.c. sulphuric acid plus 150 c.c. of lime water required 12.3 c.c. standard potassium hydroxid to become neutral. This indicates that ammonia equivalent to 2.2 c.c. of standard potassium hydroxide had been evolved, besides the amount equivalent to the lime water added. Whether an exactly similar evolution of an excess of ammonia takes place in the presence of the soil we had no means of ascertaining. If the action is similar in both cases it will have no influence upon the acidity determination. However, if this action is less in the presence of the soil, it will appear in the results of the acidity determinations and would show the lime requirement too high.

THE CONCLUSIONS SUMMARIZED

1. The methods compared do not agree throughout as to the amount of lime that each shows to be required for a certain soil.

2. As regards to showing the relative acidity between different soils, the methods show a general harmony.

3. Soils having a high percent of organic matter show a higher acidity with Veitch's and Albert's methods than with the Hopkins-Petit method. This we attribute to the continued high temperature to which the soils are necessarily subjected in the first two methods, resulting in a more active and further decomposition of the organic matter.

4. The results obtained with Albert's method indicate on the whole a higher lime requirement than do the results of the other methods, except in case of soils very high in organic matter, where Veitch's method shows the highest acidity. This general high lime requirement shown by Albert's method is probably due to the liberation of some ammonia from the ammonium sulphate, besides that actually replaced by the calcium of the lime not taken up by the soil acids.

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