

DP

1 4 5 5 0

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

UMI[®]

NOTE TO USERS

Page(s) not included in the original manuscript are unavailable from the author or university. The manuscript was microfilmed as received.

Page 25

This reproduction is the best copy available

UMI[®]

#644

SOIL ACIDITY AND BACTERIAL ACTIVITY.**
EFFECT OF ORGANIC MATTER UPON SOIL REACTION. II.*
R. E. STEPHENSON.

1920

INTRODUCTION.

Just how and why soils become acid is a problem that has not yet been explicitly solved. Neither is the effect of reaction upon the activity of soil organisms definitely understood. But it has been fairly well established that the process of nitrification once thought to be absent in acid soils, does proceed to an appreciable extent, if not perhaps sufficiently in most cases, when the supply of organic matter is adequate, for normal crop production. The process of ammonification which of course must precede nitrification is carried on by so many classes of organisms that it is not usually a limiting factor, in either acid or sweet soils, under aerobic or anaerobic conditions.

In practically all soils there must be two analytical processes, the decomposition of organic matter, and the disintegration of minerals. The importance of microorganisms in bringing about these processes is too obvious to need comment. While these processes are occurring plant growth also takes place. The general tendency of plant growth has been found to be to keep the nutrient solution nearly neutral. Crop production therefore doubtless has a tendency to prevent soils becoming acid in reaction, while the leaching of bases, has the opposite effect.

* This portion of work was completed at Iowa Experiment Station.
** Part of the work on this problem of "Soil Acidity and Bacterial Activity" has already been published. Two papers, "The Effect of Organic Matter on Soil Reaction. I." and "The Activity of Soil Acids" were published in Soil Science, another paper "Nitrification in Acid Soils" is in press at the Iowa Experiment Station. The portion of the work here published was presented to the graduate faculty of the Iowa State College of Agriculture in partial fulfillment of the requirement for the degree of Dr. of Philosophy.

UMI Number: DP14550



UMI Microform DP14550

Copyright 2006 by ProQuest Information and Learning Company.

All rights reserved. This microform edition is protected against
unauthorized copying under Title 17, United States Code.

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

The tillage given soils in producing crops of course encourages leaching, stimulates bacterial activity, and on the whole in this indirect way must tend to produce acid soils.

In mineral disintegration, with the accompanying interchange of ions, both acids and bases must be set free. Similar effects are produced when organic matter is broken down. But changes in the organic portion of the soil must occur under favorable conditions much more rapidly than changes in the mineral portion. The acids and carbon dioxide produced in organic decay hastens mineral disintegration, and therefore, increases availability of mineral plant food. But though minerals are put into solution by these processes, there is also a compensating effect, in that organic decomposition products are capable of forming insoluble compounds with the minerals disintegrated and thus preventing or at least retarding their loss by leaching.

One fact to keep in mind in regard to either organic acids or bases, is that so far as available data indicates, these products do not remain long as such. Oxidation changes, convert the nitrogen bases to nitric acid and the organic acids to carbon dioxide. Only the nitric acid produced therefore, is capable of causing a permanent direct effect upon soil reaction. Mineral bases and acids on the other hand are permanently removed from the soil only by leaching. The portion used by the plant may be expected to return to the soil.

It may be observed too, that practical experience demonstrates that soil containing sufficient organic matter remains more productive for a longer time than those soils which are low in organic matter. Loss of organic matter means a sour, soggy, unfit soil, which does not respond to tillage or commercial fertilizer. Muck and peat soils are notable exceptions but largely because

mineral elements, such as potassium and other bases were never present. And again such soils occur only under those conditions which favor large production of organic acids, and ~~disfavor~~^{do not favor} complete oxidation. These soils are therefore often highly acid, and that undoubtedly because of organic acids. But by way of contrast it must be observed that sandy soils and heavy clays, which do not contain sufficient organic matter to produce an appreciable acidity, are often highly acid and non-productive.

In this and the following work one heavy silt loam soil, one ~~soil~~ somewhat sandy, both low in organic matter, and a loam soil rather high in organic matter, were used, for the purpose of studying, changes which occur, the rate of change, and to some extent the final products of the reactions.

HISTORICAL.

Previous work to study the effect of organic matter upon the reaction of soils is very limited in amount and application. White (7) SKinner and Beatty (3) Miller (2) and Stephenson (6) found no positive evidence that the decay of organic matter in ordinary soils under conditions which would be favorable to crop production, produced any appreciable increase in the lime requirement of the soil. No argument is necessary of course, to understand that the large production of nitric acid would increase the acid reaction of the soil, or use up bases rapidly if they were present.

PLAN OF PROBLEM.

In a previous publication (6) the effect of the decomposition of albumin, casein, starch, blood, dextrose, alfalfa, and ammonium sulphate was studied on two soils. This study is continued here using materials of more general use as farm

manures in some form. Cotton seed meal, horse manure, timothy hay, clover hay, green timothy, and green clover were employed. This affords opportunity to compare the green and the more mature dried materials.

Two of the soils were used here, the one low in organic matter, rather sandy and light in color, the other dark and fairly rich in organic matter, and of the loam type. Treatments were applied at the rate of ten tons of air-dried material per acre of soil, on the basis of two million pounds of soil per acre. The coarse materials were ground and thoroughly mixed with the soils, in gallon earthenware jars. Samplings were made at intervals of 2, 5, 10, 15 and 22 weeks respectively. Two series were run, one limed and the other unlimed. Determinations were made at each sampling for the ammonia, nitrates, acidity, and residual carbonates, since these are directly connected with the effect of materials on the soil reaction. A study was made at the second sampling for the soluble non-protein nitrogen present in the soil, on one soil type. This would help to answer the question as to whether there is a tendency for the accumulation of soluble products of protein decomposition, other than nitrates and ammonia and whether there is any correlation between the quantity of nitrates or ammonia and these products.

AMMONIFICATION.

The quantity of ammonia was determined by the aeration method, using potassium carbonate to liberate the ammonia. Incidentally it may be said that the experience of the Iowa State Experiment Station with this method would lead to the conclusion that those workers who have found the method unsatisfactory, must have experienced a faulty manipulation. The aeration must stir the soil completely

to the bottom of the containing flask. This is the secret of successful operation of the method.

It may be observed that there is very little accumulation of ammonia with any of the treatments except the cotton seed meal. It has shown the greatest accumulation of ammonia at the first sampling and a greater accumulation when the soil was untreated, than when it was limed, both of which results agree with work done previously (6) with highly nitrogenous materials. There is too small an accumulation of ammonia on the untreated soils to show marked differences between limed and unlimed treatments. The same may be said of most of the other treatments, though there is a greater amount of ammonia on the unlimed soils where green manures were added. The greatest amount of ammonia is found in nearly all cases at the first sampling before nitrification is well started. There is quite a marked difference in the two soils, noticeable where the cotton seed meal is used, in that the amount of ammonia remains high on the unlimed sandy soil, throughout the test, while on the humus soil nitrification seems to have pretty well kept pace with ammonification even in the absence of lime. This is a point in favor of the argument that soils containing sufficient organic matter are more active bacteriologically, and likewise usually more productive, than soils containing less organic matter even when the total lime requirement is much greater for the organic soil.

The amount of ammonia produced may depend upon several factors. But when conditions are favorable for nitrification the ammonia is changed to nitrates almost as rapidly as produced.

TABLE 1.
AMOUNT OF AMMONIA AT THE END OF EACH PERIOD.

	1st sample	2nd sample	3rd sample	4th sample	5th sample	Averages.
	2 weeks	5 weeks	10 weeks	15 weeks	22 weeks	
	NoLime	Lime	NoLime	Lime	No Lime	Lime
Humus soil.						
Soil Alone	16.8	14.0	11.2	8.4	16.8	11.2
Cotton Seed Meal	302.4	285.6	268.8	61.6	98.0	22.4
Manure	8.4	5.6	11.2	8.4	11.2	11.2
Timothy Hay	5.6	8.4	11.2	11.2	16.8	11.2
Clover Hay	19.6	11.2	8.4	5.6	11.2	11.2
Green Timothy	44.8	11.2	14.0	5.6	16.8	11.2
Green Clover	33.6	14.0	16.8	5.6	16.8	11.2
AVERAGE.	61.6	50.0	48.8	15.2	22.8	12.8
Sandy Soil.						
Soil Alone	56.0	30.8	14.0	5.6	16.8	11.2
Cotton Seed Meal	294.8	305.2	280.0	100.8	132.5	16.8
Manure	16.8	19.6	8.4	11.2	8.4	11.2
Timothy Hay	11.2	8.4	11.2	8.4	16.8	11.2
Clover Hay	39.2	39.2	19.6	11.2	14.0	14.0
Green Timothy	58.8	47.6	33.6	16.8	14.0	8.4
Green Clover	103.6	75.6	30.8	14.0	11.2	11.2
AVERAGE.	97.2	75.2	56.8	24.0	30.5	12.0

Lime favors nitrification and at least in that indirect way indicates a retarded ammonification. Lime also increases the number of organisms, and should therefore tend to reduce the total of ammonia and nitrates in the presence of a limited supply of organic matter, because of greater nutritional demands by the increased number of organisms. When a large amount of nitrogenous organic matter is added this would perhaps not result. And since the ammonification process is the actual limiting factor under conditions which permit nitrification, the increased basicity due to the use of lime, evidently does have a retarding effect.

When averages are taken of all determinations and all treatments, there is no case on the humus soil (so called because of its higher content of organic matter) where lime has not diminished the amount of ammonia produced. On the sandy soil there are two cases, manure and timothy hay, where the reverse is true, but the results would appear to be more accidental than fundamental.

NITRIFICATION.

For the determination of nitrates the phenoldisulfonic acid method was used as modified by Davis (1). Calcium carbonate was used to flocculate the soil and secure a clear filtrate. The results are given in table II.

It is observed that the amount of nitrates increased on the untreated soils up to the last.

The cotton seed meal, in accordance with its higher nitrogen content, gave a greater accumulation of nitrates on both soils than any other treatment. Here again, the sandy soil, though starting more slowly, finally ran higher than the

TABLE II.

NITRATES AT EACH SUCCESSIVE SAMPLING.

	1st sample		2nd sample		3rd sample		4th sample		5th sample		Averages.	
	2 weeks		5 weeks		10 weeks		15 weeks		22 weeks			
	no lime	lime	No Lime	Lime	No lime	Lime	No lime	Lime	No lime	Lime	No Lime	Lime
Humus Soil												
Soil Alone	28.6	19.1	63.5	68.8	38.9	95.9	52.3	112.0	50.0	121.1	46.7	83.4
Cotton S.Meal	33.0	45.7	98.3	243.2	214.8	309.0	302.4	289.9	324.0	316.0	194.5	240.8
Manure	14.2	7.3	21.4	23.8	37.8	57.8	36.7	61.8	74.5	104.1	36.9	50.9
Timothy Hay	trace	trace	trace	trace	trace	20.5	trace	35.5	22.8	67.4	4.5	24.7
Clover Hay	40.6	58.9	67.8	92.5	80.3	129.5	86.3	133.5	116.7	170.8	78.3	117.0
Green Timothy	45.6	51.5	100.4	83.9	180.5	125.0	141.1	93.8	181.4	121.4	129.8	94.9
Green Clover	69.4	78.1	109.7	122.0	234.1	319.1	181.5	168.1	284.6	201.0	175.8	177.6
AVERAGE	33.1	37.2	65.9	90.6	112.3	150.9	114.3	127.8	150.6	155.9	95.2	112.8
Sandy Soil												
Soil Alone	17.7	16.6	58.6	72.4	85.0	58.8	97.6	73.1	81.6	103.8	68.1	65.9
Cotton S.Meal	9.4	7.3	112.2	138.3	167.9	229.4	267.6	400.2	312.4	457.4	173.9	246.5
Manure	11.2	19.1	38.2	52.1	53.1	62.4	61.1	48.8	61.4	89.8	45.0	54.4
Timothy Hay	trace	trace	trace	trace	trace	14.8	trace	41.5	21.3	50.3	4.2	21.3
Clover Hay	11.5	15.1	63.6	97.1	83.5	69.5	90.7	122.0	123.1	152.4	74.5	91.2
Green Timothy	12.1	23.3	66.1	86.6	100.7	82.4	92.0	88.0	105.3	144.3	75.2	84.9
Green Clover	16.4	13.7	86.0	109.3	153.3	117.9	147.3	135.5	207.4	183.7	122.1	112.0
AVERAGE.	11.2	13.6	60.7	79.4	90.9	90.7	108.0	129.9	130.3	168.8	80.4	96.6

5
bettersoil. On both soils the greatest amount of nitrate was found at the last sampling, the first two samplings on the sandy soil showing less than the untreated soil. In most cases lime increased the nitrification of cotton seed meal.

The addition of stable manure caused a decrease in the amount of nitrates present in most cases, probably because of an increased number of organisms greater than the accompanying addition of easily nitrifiable material.

Timothy hay had the same effect as stable manure but to a much more marked degree. Little nitrifiable material was added in the timothy but considerable energy material was provided, and the organisms used most of the nitrates for nutritional purposes. The nitrates began to show at about the same time on both soils but never ran nearly so high as on the untreated soils. Lime again stimulated nitrification. The green timothy in contrast to the dry, stimulated nitrification at once on both soils, and the greatest accumulation of nitrates was found at the last sampling and in the presence of lime.

Dry clover also caused a stimulation of nitrification from the first, producing the greatest effect at the last sampling, and usually greater in the presence of lime. The green clover had a somewhat greater effect than did the dry, and maximum nitrification was induced sooner.

When averages of all samplings and all treatments are taken, the humus soil shows greater nitrification in the presence of lime in every case except one and this is for green timothy. There is very little difference for the green clover. When the sandy soil is considered the soil alone produces slightly less

of the nitrates on the limed series. Every treatment except one, and in this case it is green clover, has shown greater nitrification in the presence of lime. Apparently the lime does not affect the nitrification of the green material as much as some of the dried materials. The greatest amount of nitrates is found at the last sampling, while the greatest amount of ammonia is usually found at the first sampling which is logical enough.

The sum of the nitrates and ammonia is shown in the table following.

TABLE III.
NITROGEN SUMMARY. SUMMARY OF AMMONIA AND NITRATES.

	1st sample		2nd sample		3rd sample		4th sample		5th sample		Average.	
	2 weeks		5 weeks		10 weeks		15 weeks		22 weeks			
	N. lime	Lime	N. lime	Lime	N. lime	Lime	N. lime	Lime	N. lime	Lime	No	Lime
Humus soil.											Minus	Minus
Soil Alone	45.5	33.1	74.7	77.3	55.7	107.2	63.6	131.1	61.2	134.5	60.1	Soil
C.S.Meal	335.5	331.3	367.1	304.8	312.9	331.4	338.2	309.5	346.1	330.0	339.9	279.8
Manure	22.6	13.0	32.6	33.3	49.3	69.0	50.8	73.0	88.5	115.3	48.7	*11.4
Tim. Dry	5.6	8.4	11.2	11.2	16.8	31.6	11.2	41.1	34.0	78.6	15.7	*44.4
Clover Dry	79.2	70.1	76.5	98.1	91.5	140.6	91.9	144.7	127.7	170.8	93.4	33.3
Tim. Green	90.4	62.7	114.4	89.5	197.3	136.1	152.2	105.0	192.6	132.6	149.4	89.3
Clover Green	103.1	92.1	126.5	127.6	250.9	330.3	192.7	176.5	295.8	209.4	193.8	133.7
AVERAGE											128.7	134.0
Sandy Soil.												
Soil alone	73.8	37.4	72.6	78.0	101.8	70.0	117.2	84.8	95.6	117.8	92.2	77.6
C.S.Meal	404.2	312.5	392.2	239.1	300.4	246.2	418.8	422.6	326.4	477.0	368.4	276.2
Manure	28.0	38.7	46.6	63.4	61.5	73.7	69.5	57.2	72.6	101.0	55.6	*36.6
Tim. Dry	11.2	8.4	11.2	8.4	16.8	26.1	14.0	52.7	32.5	139.9	17.1	*75.1
Clover Dry	50.8	54.3	143.2	107.3	97.6	83.5	101.9	130.4	139.8	171.4	106.7	14.5
Tim. Green	70.9	70.9	99.7	103.4	114.7	90.8	103.2	101.4	110.9	149.9	99.9	7.7
Clover Green	114.0	89.3	116.8	123.3	164.5	129.1	158.5	146.7	212.6	189.3	153.3	61.1
AVERAGE											127.6	89.2

*These are omitted in taking final averages.

The table shows the largest combined production of nitrates and ammonia with cotton seed meal, followed by green clover, green timothy, horse manure, and dry timothy, the latter two producing considerably less than the soil alone. The general effect of the lime was to decrease the total of nitrates and ammonia found, especially where there is any large production. When averages are taken of all treatments and samplings, however, there is slightly more of the combined nitrates and ammonia on the humus soil in the presence of lime, while the reverse is true of the sandy soil. When the organic treatments alone are considered the results are reversed again. Thus no conclusions are justified.

ACIDITY RESULTS.

The lime requirement on the soils differently treated are given in Table IV. The method used was that previously described (5). The acid soil was brought into contact with pure calcium carbonate, and the aeration and shaking continued for 10 hours before titrations were made. The double-titration was performed using methylorange and phenol-phthalein as indicators.

There is little to be said in regard to the effect of the various treatments upon the lime requirement of the soils. The general tendency has been to reduce rather than to increase it. A large production of ammonia reduces the lime requirement, and when nitrification has occurred the opposite effect results, which is very logical.

Table V brings out this point when the cotton seed meal treatment is studied, comparing the effect of ammonification and nitrification upon the decrease or increase of the lime

TABLE IV.

LIME REQUIREMENT OF THE VARIOUSLY TREATED SOILS IN TONS PER 2000000# SOIL.											
	2	5	10	15	22	More or less than the soil alone					
	weeks	weeks	weeks	weeks	weeks	12	2	3	4	5	
Humus Soil	Tons	Tons	Tons	Tons	Tons						
Soil alone	:3.90	:4.20	:3.85	:3.80	:3.80						
C. Seed Meal	:3.65	:3.65	:4.45	:4.25	:4.55	+0.25	+0.55	+0.60	+0.45	+0.75	
Manure	:3.80	:4.25	:3.60	:3.40	:3.80	+0.10	+0.05	+0.25	+0.40	+0.00	
Nature Timo.	:4.05	:4.15	:3.55	:3.35	:3.55	+0.15	+0.05	+0.30	+0.45	+0.25	
" Clover	:3.85	:4.15	:3.65	:3.25	:3.95	+0.05	+0.05	+0.20	+0.55	+0.15	
Green Timo.	:4.10	:4.45	:3.70	:3.65	:3.95	+0.20	+0.25	+0.15	+0.15	+0.15	
Green Clover	:3.65	:4.00	:3.25	:3.20	:3.85	+0.20	+0.20	+0.60	+0.60	+0.05	
Sandy Soil.											
Soil Alone	:3.20	:2.60	:2.35	:2.40	:2.35						
C. Seed meal	:1.70	:2.15	:2.15	:2.50	:2.45	+0.50	+0.45	+0.20	+0.10	+0.10	
Manure	:2.20	:2.35	:2.10	:2.65	:1.75	+0.00	+0.25	+0.25	+0.25	+0.60	
Nature Timo.	:2.20	:2.30	:1.80	:2.05	:1.75	+0.00	+0.30	+0.55	+0.35	+0.60	
Nature Clover	:2.15	:2.30	:1.90	:1.80	:1.75	+0.05	+0.30	+0.45	+0.60	+0.60	
Gr. Timothy	:2.55	:2.65	:2.25	:2.30	:2.00	+0.35	+0.05	+0.10	+0.10	+0.35	
Gr. Clover	:1.70	:2.65	:1.90	:1.90	:1.85	+0.50	+0.05	+0.45	+0.50	+0.50.	

requirement of the treated soil over the untreated.

Table V.

Difference of ammonia and nitrates on unlimed soils compared with effect of treatment on lime requirement.

<u>Humus soil.</u>					
Ammonia	302.4	268.8	98.0	86.8	32.0
nitrates	<u>33.0</u>	<u>98.3</u>	<u>214.8</u>	<u>302.4</u>	<u>324.0</u>
Difference	+269.4	+170.5	-116.8	-215.6	-292.0
" of lime requirement	-0.25	-0.55	+0.60	+0.45	+0.75
<u>Sandy soil.</u>					
Ammonia	394.8	280.0	132.5	151.2	14.0
Nitrates	<u>9.4</u>	<u>112.2</u>	<u>167.9</u>	<u>267.6</u>	<u>312.4</u>
Difference	+385.4	+168.8	-35.4	-116.4	-298.4
" of lime requirement	-0.50	-45.0	-0.20	+0.10	+0.10

The above table shows that though there is not a close agreement between the difference of ammonia and nitric acid produced on the soils treated with cotton seed meal, the tendency is for the soil to show a greater or smaller lime requirement according as there is more or less of the nitrogen present in the basic or acid form. None of the other treatments contain sufficient nitrogen to make comparison significant.

RESIDUAL CARBONATES.

The residual carbonates were determined by decomposing the remaining limestone with dilute acid, and titrating the carbon dioxide liberated, in the same way as the titration was made in the lime requirement determinations. The results are given in Table VI.

Lime was applied at the rate of 7 tons on the more acid soil and 6 tons on the other soil using pure carbonate. This was intended to give a sufficient excess that nitrification would not exhaust it, which proved to be true.

The data shows that in most cases the organic materials have tended to protect the lime applied to the soil. The notable exception is the cotton seed meal, which on account of the large

RESIDUAL CARBONATES ON TREATED SOILS. EXPRESSED IN TONS PER ACRE.

	1	2	3	4	5	1	2	3	4	5
	Tons	Tons	Tons	Tons	Tons					
Unus										
Soil Alone	3.40	2.55	2.00	1.95	1.35					
C.S.Meal	4.95	2.55	1.20	1.25	0.55	+1.55	+0.00	-0.80	-0.70	-0.80
Manure	4.10	2.85	2.45	1.90	2.05	+0.70	+0.30	+0.45	-0.05	+0.70
Dry. Tim.	4.35	2.90	2.35	2.10	1.90	+0.95	+0.35	+0.35	+0.15	+0.55
Dry. Clov.	4.15	3.05	2.30	2.10	2.15	+0.75	+0.50	+0.30	+0.15	+0.80
Gr. Tim	4.05	3.20	2.50	2.30	2.15	+0.65	+0.65	+0.50	+0.35	+0.80
Gr. Clov.	4.20	3.00	2.95	2.50	2.45	+0.80	+0.45	+0.95	+0.55	+1.10
Sandy Soil										
Soil Alone	2.80	2.55	2.45	2.55	24.0					
C.S.Meal	3.90	2.35	1.70	1.20	0.85	+1.10	-0.20	-0.75	-0.35	-1.55
Manure	2.95	2.70	2.65	2.60	2.40	+0.15	+0.15	+0.20	+0.05	+0.00
Dry Tim.	3.25	2.75	2.45	2.60	2.35	+0.45	+0.20	+0.00	+0.05	-0.05
Dry. Clov.	3.30	3.00	2.75	2.90	2.50	+0.50	+0.45	+0.30	+0.35	+0.10
Gr. Tim.	2.80	2.55	2.50	2.40	2.30	+0.00	+0.00	+0.05	-0.15	-0.10
Gr. Clov.	4.25	3.30	3.00	3.00	2.85	+0.45	+0.75	+0.55	+0.45	+0.45

production of nitric acid, has used up the carbonates nearly completely. All of the treatments helped to save limestone until nitrification occurred, as noted by the fact that minus quantities do not appear with but three exceptions until the last two samplings.

SOLUBLE NON-PROTEIN NITROGEN.

The method used was in general that used by Potter and Snyder (4). The soil was extracted with one percent hydrochloric acid, the limed and the unlimed alike. The nitrate nitrogen and the ammonia nitrogen were distilled off by the Devarda Reduction method. The residue from this reduction was then treated with sulphuric acid and the total nitrogen determined in the usual way. This latter gave the unknown soluble non-protein nitrogen of the acid extract.

The acid extracted soil was next extracted with 1.75 percent sodium hydroxide, for two hours (shaking) and the extract clarified by centrifuging for 5 minutes at 30,000 R.P.M. The extract was then neutralized with sulphuric acid, and acidified with tri-chlor-acetic acid sufficiently to give $2\frac{1}{2}$ per cent of the latter. The precipitate was then filtered off and another aliquot of the filtrate taken for determination of the nitrogen by the micro method.

Soluble non-protein materials should apparently be largest in amount when decomposition was most active. But the question would be, do these compounds, doubtless of peptide character tend to accumulate in appreciable amounts, or does ammonification and nitrification proceed at once

TABLE VII.
HUMUS SOIL AFTER FIVE WEEKS

RESULTS ARE EXPRESSED IN PARTS PER MILLION. SOLUBLE NON-PROTEIN NITROGEN.						
TREATMENT.	UNKNOWN					
	NON-PROTEIN N.					
	In H. CL.		In Alkaline			
	Extract		extract.		TOTAL UNKNOWN N.P.N.	
	No Lime	Lime	No Lime	Lime	No Lime	Lime
Soil Alone	23.33	26.00	245.5	246.5	268.83	272.50
Cotton S. Meal	195.99	44.66	310.5	287.5	506.49	355.16
Manure	32.66	11.33	246.5	218.0	278.16	229.33
Timothy	28.66	29.99	232.0	253.0	260.66	282.99
Clover	233.3	26.00	260.5	244.0	283.83	270.00
Green Timothy	35.33	30.00	266.0	253.0	301.33	283.00
Green Clover	28.66	19.60	277.3	253.3	305.96	272.90

When the decomposition has started. In other words should the soluble nitrogen be found primarily as ammonia and nitrates or also in more complex forms. Previous study has shown that plants are capable of using more complex forms of nitrogen than nitrates and ammonia, and if they occur to any extent in ordinary soils, there may be conditions when such complex compounds function as direct sources of plant food.

The results show in every cases but one (timothy) that the application of lime has diminished the total unknown soluble non-protein nitrogen. The nitrates and ammonia though soluble non-protein nitrogen are not included in this data. A reference to table III, shows that this is the same general tendency as observed in the production of ammonia. There is one noticeable fact and that is that none of the organic treatments have as marked an effect upon the amount of unknown S.M.P.N. as they have on the nitrates and ammonia. This indicates as does also the data of Potter and Snyder (4) that in the decomposition of proteins of the soil the degradation products rather rapidly undergo complete change to the simpler state of ammonia and nitrate. The products except the more resistant forms possibly polypeptids of some degree of complexity apparently do not accumulate to a large extent, and the nitrogen of the soil must exist mostly as the more complex and resistant forms or else as the simplest possible products of decomposition. Ordinarily of course, nitrates and ammonia are removed from the soil almost as rapidly as produced and are not therefore found in large amounts at any one time. The soluble non-proteins such as are

found in this study are therefore probably present at any definite time in perhaps five or even ten times the amount of ammonia and nitrates present.

Another question to consider is the possible effect of such compounds on the reaction of the soil. Be they acids or bases, or both as they probably are, they are not found in sufficient quantity to exert a marked effect upon reaction. Such materials and others, however, doubtless exercise a buffering effect and help to reduce the hydrogen-ion concentration to some extent

GENERAL DISCUSSION.

This experiment was continued for 159 days, or about 22 weeks. It is not presumed that there would be no changes after this time, but rather that such changes as occurred previous to this would determine whatever effects were to be produced by the different treatments on the activity of soil organisms or the reaction of the soil.

The materials used contained the following percents of nitrogen in ascending scale, dry timothy, 0.693; manure, 1.24; green timothy, 1.28; dry clover, 2.30; green clover, 2.82; and cotton seed meal 6.96 percents respectively. The poorer soil contained 0.116, and the better soil about twice as much or 0.238 percent of nitrogen. The amounts of nitrogen found as ammonia and nitrates were for the most part in the same order as the percents of nitrogen contained in the materials used.

No definite conclusions may be drawn from a limited study, but in general it seems that the essential soil organisms are active in soils of at least moderately strong

acidity. The data indicates again also that the decay of organic materials under aerobic conditons does not produce an appreciable acidity except where nitric acid is formed in nitrification.

SUMMARY.

1. The lime requirement of neither soil was increased by the organic treatments except in those cases where there was a large production of nitric acid.

2. Ammonification is apparently greater in the absence of lime, partly perhaps due to the fact that nitrifying organisms have been less active.

3. Lime has generally stimulated nitrification.

4. The sum of ammonia and nitrates is usually greater on the unlimed soil when treated with nitrogenous organic materials. This is doubtless partly due to the increased number of organisms in the presence of lime and the consequent greater consumption of nitrates and ammonia by the organisms.

5. When ^{such} ~~non-nitrogenous~~ sources of energy were supplied as in the case of horse manure and timothy hay, nitrification and ammonification were reduced below that of the untreated soil.

6. The green materials were somewhat more readily attacked than the dried materials. There was greater production of ammonia and nitrates partly however because of the fact that these materials were richer in nitrogen than the mature plants.

7. The soluble unknown non-protein ^{Nitrogen} determined at the second sampling on the more fertile soil, when the activity

of the organisms were nearly the maximum, showed, little effect due to the various organic treatments. The cotton seed meal was the only treatment which gave any large increase over the untreated soil.

8. In all cases but one, the unlimed treatments gave a higher non-protein nitrogen content than the limed.

BIBLIOGRAPHY.

- (1) Davis, C. W. 1917. Studies on the phenol-disulphonic acid method for determining nitrates in soils. In Jour. Indus. Engin. Chem., Vol. 9, No. 3, p 290.
- (2) Miller, M.F. 1917. Work and progress of the agricultural experiment station. In Mo. Agr. Exp. Sta. Bul. 147, pp. 50.
- (3) Skinner, J.T. and Beattie, J.H. 1917. Influence of fertilizers and soil amendments on soil acidity. In Jour. Amer. Soc. Agron. V.9, No. 1, p 25-35.
- (4) Snyder, R.S. and Potter, R.S. 1918. Soluble non-protein nitrogen of the soil. In Soil Sci. Vol. 6, No. 6, pp441-448
- (5) Stephenson, R.E. 1918. Soil Acidity Methods. In Soil Sci. Vol. 6, No. 1 pp 33.
- (6) Stephenson, R.E. 1918. The effect of organic matter on soil reaction. In Soil Sci. Vol. 6, No. 6, p 413-439.
- (7) White, J.W. 1918. Soil acidity and green manures. In Jour. Agric. Res. Vol. 13, No. 3, p 171.

EFFECT OF ORGANIC MATTER ON SOIL REACTION. III.*

INTRODUCTION.

In this series of treatments the organic materials were applied at the same rates as before (10 tons) except where dried blood and straw were mixed and then blood was used at the rate of ten tons, with 5 and 10 tons of straw. Precipitated carbonate of lime was added to the limed treatments at the uniform rate of 5 tons per acre. The materials used were soybean hay, green rape, oat straw, green soybean hay, (pods removed) dried blood and a mixture of blood and oat straw, all these in both limed and unlimed series. The green materials were dried, as were also the other materials and ground as finely as was convenient before adding to the soil. The soils used in this study was rather heavy and compact, and poor in organic matter, an acid silt loam taken from the W.Va. Experiment Station.

The total period of incubation was 125 days, samplings being made at intervals of 2, 5, 10, and 18 weeks respectively. In addition to the determinations made in the study of previous series, hydrogen-ion determinations were made upon all treatments.

AMMONIFICATION.

The aeration method was again used for ammonia. The results are shown in the following table, expressed as parts per million of nitrogen.

Only the blood possessed a high nitrogen content and therefore it is the only material which caused a great production of ammonia.

Lime produced no marked effect in the ammonification of any of the materials until the third sampling when it caused appreciable reduction which effect was still emphatic in the last sampling. This may have been due to two causes. The lime may have caused greater numbers of organisms to grow, and the greater

AMOUNT OF AMMONIA AT THE END OF EACH PERIOD.

TREATMENT	1st sample		2nd sample		3rd sample		4th sample		Averages	
	2 weeks		5 weeks		10 weeks		18 weeks			
	NoLime	Lime	NoLime	Lime	NoLime	Lime	NoLime	Lime	No Lime	Lime.
Silt Loam Soil	:	:	:	:	:	:	:	:	:	:
Soil Alone	: 36.0	: 50.0	: 32.0	: 34.0	: 60.0	: 5.6	: 16.0	: 12.0	: 36.0	: 2.54
Soybean Hay	: 94.0	: 106.0	: 107.0	: 106.0	: 92.4	: 8.7	: 36.0	: 8.0	: 82.4	: 57.2
Green rape	: 182.0	: 168.0	: 178.0	: 132.0	: 36.4	: 8.7	: 64.0	: 4.0	: 115.1	: 78.2
Green S. Bean Hay	:	:	:	:	:	:	:	:	:	:
Oat straw	: 48.0	: 68.0	: 40.0	: 56.0	: 16.9	: 22.2	: 12.0	: 8.0	: 29.2	: 38.5
Blood	: 52.0	: 20.0	: 24.0	: 16.0	: 13.8	: 5.6	: 10.4	: 8.0	: 25.1	: 12.4
Blood & 5 TStraw	: 342.0	: 282.0	: 566.0	: 425.0	: 546.0	: 361.2	: 328.0	: 54.0	: 445.5	: 287.3
" "10 T "	: 242.0	: 316.0	: 424.0	: 400.0	: 336.2	: 43.2	: 440.0	: 48.0	: 360.5	: 201.8
AVERAGES	: 226.0	: 300.0	: 396.0	: 306.0	: 288.4	: 26.8	: 366.0	: 32.0	: 319.1	: 166.2
	: 169.4	: 180.0	: 247.9	: 209.7	: 190.1	: 68.1	: 179.5	: 23.1	: 196.7	: 120.2

numbers of organisms caused greater consumption of ammonia. The principal cause no doubt was that lime permitted greater nitrification, and most of the ammonia had been changed over to nitrate. The data shows that this had occurred.

The oat straw depressed ammonification just as it did nitrification, in most cases below that of the untreated soil, which would indicate that it was a suitable source of energy for bacterial activity.

Green soybeans likewise have depressed ammonification below that of the soybean hay but partly because of the fact that its nitrogen content was lower. Green rape on the other hand stimulated ammonification next to the dried blood. The green rape, however, contained a little less nitrogen than the soybean hay, though more than the green soybeans.

Straw mixed with blood had little consistent effect upon ammonification. However, the ammonia produced by the combined application of blood and straw was seldom greater and often less than that produced from the blood alone.

There were individual cases where the limed treatments produced more ammonia than the unlimed but when averages of all treatments (omitting the soil alone) and of all samples, are taken, the unlimed treatments have produced a greater quantity of ammonia. The difference is quite marked at later samplings where nitrification is well under way.

NITRIFICATION.

Nitrates were determined by the colorimetric method as before. The results are shown in Table II, expressed as parts of nitrogen per million of soil.

TABLE II.

NITRATES AT EACH SUCCESSIVE SAMPLING.

TREATMENTS	: 1st sampling:	2nd sample	: 3rd sample	: 4 th sample:	Averages.						
	: 2 weeks	: 5 weeks	: 10 weeks	: 18 weeks							
	:NoLime:	Lime	:No Lime:	Lime:	NoLime	:Lime:	Nolime:	Lime:	Nolime:	Lime	
ilt Loam	:	:	:	:	:	:	:	:	:	:	:
Soil Alone	: 19.6	: 23.0	: 24.8	: 33.3	: 38.4	: 54.6	: 65.3	: 113.8	: 37.0	: 56.2	
S. Bean Hay	: 25.9	: 25.7	: 28.8	: 37.9	: 71.8	: 181.1	: 122.6	: 195.3	: 62.3	: 110.0	
Gr. Rape	: 76.1	: 96.6	: 79.0	: 75.1	: 120.5	: 234.1	: 260.3	: 188.7	: 133.9	: 148.6	
Gr. S. Bean	: 42.5	: 27.2	: 388.5	: 39.7	: 83.5	: 108.2	: 175.7	: 109.0	: 172.5	: 71.0	
Oat Straw	: 19.8	: trace	: 19.6	: 4.6	: 26.3	: 18.2	: 38.6	: 38.9	: 26.1	: 15.4	
Dried Blood	: 14.2	: 9.1	: 24.6	: 40.7	: 149.1	: 485.5	: 353.3	: 611.1	: 135.3	: 286.6	
od & 5TStraw	: 8.6	: trace	: 17.8	: 37.1	: 160.3	: 380.9	: 332.7	: 640.0	: 129.8	: 264.5	
" 10T "	: trace	: trace	: 59.1	: 59.8	: 156.9	: 492.5	: 413.0	: 575.4	: 157.2	: 281.2	
VERAGES	: 26.7	: 22.7	: 88.2	: 42.1	: 109.8	: 271.5	: 242.3	: 336.9	: 116.7	: 168.3	

The data shows that the accumulation of nitrates has increased at each successive sampling with all treatments and no treatments, both limed and unlimed. In general there has been greater nitrification in the presence of lime. This is more noticeable after the first sampling and with the nitrogen rich materials. Lime apparently had the opposite effect where oat straw was used. Straw used with blood retarded nitrification at first but later there was little or no retardation. The maximum amount of nitrates occurs at the last sampling in most cases.

Apparently the green soybeans began to nitrify more quickly than did the soybean hay. Green rape likewise stimulated nitrification to an appreciable extent at once.

Nitrification apparently scarcely occurred in the presence of oat straw until the third and fourth samplings. In no case was there as much nitrate as on the untreated soil.

Nitrification was slow in starting when blood and straw were mixed but by the end of 10 weeks there was an appreciable accumulation of nitrates on the treated soils over the untreated. Apparently the addition of straw had no marked effect upon the nitrification of dried blood.

When averages of all treatments and all samplings are taken (omitting the untreated soil) it is observed that nitrification was slow in starting where straw and blood and mixtures of the two were used, but the blood straw mixtures finally ran high. Lime in these cases seems to have retarded the beginning of the nitrifying process, but perhaps more organisms were present where lime was added and they were consuming such nitrates as were produced.

NITROGEN SUMMARY.

TABLE III.

sum of nitrates and ammonia

TREATMENT.	2 weeks		5 weeks		10 weeks		18 weeks		Average.	
	No Lime	Lime	No Lime	Lime	No Lime	Lime	No Lime	Lime	No Lime	Lime
Silt Loam Soil:									minuss	minus
Soil Alone	55.6	73.0	57.3	67.3	98.4	59.9	81.3	125.8	73.1	81.5
Soybean hay	120.0	131.8	130.8	144.0	164.2	189.8	158.6	203.3	173.4	70.3
Green Rape	258.1	264.6	257.0	207.1	156.9	242.8	324.3	192.7	249.1	176.0
Green S. Bean	90.5	95.2	78.5	95.7	100.4	130.4	187.7	117.0	114.3	41.2
Oat Straw	71.8	20.0	43.6	20.6	40.1	23.8	49.1	46.9	51.2	-21.9
Dried Blood	356.2	291.1	590.6	492.7	745.1	846.7	681.1	665.1	580.8	507.7
Blood & 5T Straw:	250.6	316.0	441.8	437.3	496.5	424.1	777.7	687.9	491.7	418.6
" " 10T "	226.0	300.0	455.0	365.8	445.3	519.2	779.0	607.4	477.2	404.1
AVERAGE.	196.1	202.7	336.1	251.8	299.9	339.6	421.8	360.0	301.1	286.3

The nitrogen summary shown in the table, indicates that the average total of nitrates and ammonia has been greatest in most cases for the treated soils, when not limed, but that the reverse is true for the untreated soil. Whether the difference may be due to numbers of organisms and the consequent utilization of parts of the nitrogen changed, on treated limed soils cannot be stated, though it seems probable. Experience has shown that in nearly every case a carbohydrate material such as straw which is poor in nitrogen, has given a decrease in ammonia and nitrates over the soil alone, either limed or unlimed. Since ammonia and nitrate forms of nitrogen are by-products of the attempt of the organism to secure sufficient energy this is to be expected. Table IV.

LIME REQUIREMENT.

The data shows that in nearly every case the lime requirement was less when organic matter was added to the soil. The greatest effect is usually at the first sampling. This is especially marked with the dried blood which produced large amounts of ammonia. Next to blood, soybean hay produces the greatest effect, next is green rape, and last is oat straw producing the least effect. Thus it seems that nitrogenous materials by their production of ammonia, and perhaps by other reactions reduce the lime requirement of soils. The effect has been more marked and consistent on this rather heavy soil than on the lighter soils previously studied. Carbohydrate materials have much smaller effects.

It is shown also that the limed soils have a capacity for decomposing limestone, even after 18 weeks standing with excess lime. This would indicate that acid soils react with carbonate

ACIDITY (LACKE.)

TABLE IV.

LIME REQUIREMENT OF VARIOUSLY TREATED SOILS, TONS PER 20000000 #.

	2 weeks:	5 weeks:	10 weeks:	18 weeks:	More or less than soil alone			
					1	2	3	4
Clay Soil.								
soil alone	3.35	2.95	3.10	3.10				
soil limed	0.95	0.55	0.45	0.65				
S. Bean Hay	2.00	2.60	2.60	3.10	-1.35	-0.35	-0.50	+0.00
Limed	0.35	0.95	0.60	0.80	-0.60	+0.40	+0.15	+0.15
Green rape	2.10	2.50	2.65	3.20	-1.25	-0.45	-0.45	+0.10
Limed	0.60	0.80	0.55	.90	-0.35	+0.25	+0.10	+0.25
Green S. Beans	1.85	2.85	2.65	3.00	-1.50	-0.10	-0.45	-0.10
Limed	0.45	0.95	0.55	0.60	-0.50	+0.40	+0.10	-0.05
Oat Straw	2.65	2.60	2.65	2.85	-0.70	-0.35	-0.45	-0.25
Limed	0.45	0.85	0.75	0.65	-0.50	+0.30	+0.30	+0.00
Blood	2.00	1.80	2.00	2.95	-1.35	-1.15	-1.10	-0.15
Limed	0.35	0.90	0.65	1.35	-0.60	+0.35	+0.20	+0.70
Straw:								
Blood & 5T	1.85	2.65	1.90	3.05	-0.50	-0.30	-1.20	-0.05
Limed	0.35	1.05	0.80	1.50	-0.60	+0.50	+0.35	+0.85
Straw:								
Blood & 10 T	1.70	2.20	2.05	3.00	-0.65	-0.75	-1.05	-0.10
Limed	0.40	1.20	0.90	1.40	-0.55	+0.65	+0.45	+0.75

of lime beyond the neutral point, or that for lack of sufficiently intimate contact, all the acids have not yet been neutralized. There is perhaps no such thing as completion of the reaction. There are doubtless always slowly soluble acids or acid salts capable of decomposing the carbonate.

It is worthy of note too that the organic treatments seem to have increased the capacity of the soil to react with lime, when they were applied with the lime, though the reverse was true when they were used alone.

There is a rather close correlation between changes in soil reaction, and the nitrogen changes as shown by the following table. This is especially noticeable on the blood treatments where there is sufficient nitrogen added to produce a measurable effect upon the reaction.

Table V.
Difference of ammonia and nitrates on unlimed soils compared with the effect of the treatment on soil reaction.

SILT LOAM SOIL	1.	2.	3.	4.
Blood treatment only.				
3 Ammonia	270.0	462.0	390.0	378.0
Nitrates	7.8	33.8	155.4	366.3
Excess (N.H ₃)	+ 262.2	+ 428.2	+ 234.6	+ 11.7
P _H on blood	6.33	7.00	6.46	5.41
" Increase over untreated soil	+ 1.62	+ 2.12	+ 1.68	+ 0.54

This data shows a close correlation between the excess of ammonia over nitrates and the true acidity or P_H values of the soils, and would signify that the bacteriological changes which were occurring were effecting the soil reaction to an appreciable extent.

The same thing is shown in Table VI on all treatments, taking summation effects as before.

Table VI.

Nitrogen changes and the effect on soil reaction summarized.

ALL TREATMENTS TO LIME.	1	2	3	4
	No lime	No lime	No lime	No lime.
Ammonia	169.4	247.9	190.1	179.5
Nitrates	26.7	88.2	109.8	242.3
Difference	+142.7	+159.7	+80.3	-62.8
P _H values	6.01	6.23	5.97	5.17
" Increase over untreated soil	+1.10	+1.35	+1.19	+ .29

Table VII.

Residual carbonates on treated soils at the various samplings expressed as tons per acre.

	1	2	3	4: More or less than soil alone.				
					1	2	3	4
Clay Soil								
Soil alone	2.55	2.20	1.40	0.90				
S. Bean Hay	3.15	2.40	1.05	1.05	+0.60	+0.20	-0.35	+0.15
Green Rape	3.15	2.10	1.20	0.45	+0.60	-0.40	-0.20	-0.45
Gr. S. Bean	3.25	2.00	1.45	1.00	+0.70	-0.20	+0.05	+0.10
Oat Straw	3.20	1.85	1.40	0.95	+0.65	-0.35	+0.00	+0.06
Blood	3.15	3.05	0.60	0.00	+0.60	+0.85	-0.80	-0.90
Blood & 5T Straw	3.70	3.20	1.05	0.00	+1.15	+1.00	-0.35	-0.90
Blood & 10T Straw	3.60	3.20	0.70	0.0	+1.05	+1.00	-0.70	-0.90

RESIDUAL CARBONATES.

The data shows that the organic matter has protected the carbonates until there was considerable nitrification. All organic treatments caused a marked saving of carbonates at the first sampling. At the last sampling those treatments where there was much nitrogen to produce nitric acid, nearly or completely exhausted the carbonates present. Even the untreated soil has reacted slowly and continually and would perhaps have used up all the limestone after sufficient time, even though there ^{was} ~~were~~ no leaching.

This data would indicate that excessive nitrification might become a positive factor in contributing to soil acidity. Nitrates being soluble however will not accumulate and in the process of leaching basic material is permanently removed from the soil.

HYDROGEN ION CONCENTRATION.

The hydrogen-ion concentration was determined at each sampling on all of the treatments with the hydrogen electrode apparatus.

TABLE. VIIITable showing P_H of different treatments.

					: More or less than soil alone.			
	1.	2.	3.	4	1	2	3	4
Clay soil	4.91	4.88	4.78	4.88	:	:	:	:
Soil alone	:	:	:	:	:	:	:	:
" & 5 T. Lime	7.62	7.72	7.65	7.60	:	:	:	:
S. Bean & Straw	6.03	5.89	5.50	5.02	+1.12	+1.01	+0.72	+0.14
" " & Lime	7.74	7.64	7.41	7.51	+0.12	-0.08	-0.24	-0.03
Green Rape	6.03	6.05	6.17	4.78	+1.12	+1.17	+1.39	-0.10
Gr. Rape & Lime	7.66	7.65	7.42	7.53	+0.04	-0.07	-0.23	-0.07
Gr. S. Beans	5.81	5.58	5.34	5.17	+0.90	+0.70	+0.56	+0.29
Gr. S. B. & Lime	7.74	7.64	7.60	7.74	+0.12	-0.08	-0.05	+0.14
Oat Straw	5.21	5.07	5.41	5.00	+0.30	+0.19	+0.63	+0.12
O. Straw & Lime	7.48	7.60	7.66	7.71	-0.14	-0.12	+0.01	+0.11
Blood	6.48	7.17	6.55	5.43	+1.57	+2.29	+1.77	+0.55
Blood & Lime	7.71	7.91	7.22	7.60	+0.09	+0.19	-0.43	+0.60
" & Straw 5 T.	6.28	7.10	6.58	5.38	+1.37	+2.22	+1.80	+0.50
Bld & Str. 5 T.	:	:	:	:	:	:	:	:
and lime	7.74	7.76	7.34	7.54	+0.12	+0.04	-0.31	-0.06
Bld. & Str 10 T.	6.24	6.74	6.24	5.44	+1.33	+1.86	+1.46	+0.56
" " " "	:	:	:	:	:	:	:	:
and Lime	7.65	7.76	7.36	7.61	+0.03	+0.04	-0.29	+0.01

The lime requirement according to the Tacke method was a little more than three tons. To take care of acids which might be produced in the decomposition of organic material, an excess of two tons was used. The data shows that this is sufficient to give a slightly alkaline soil either with or without organic treatments (the smaller the P_H value the more acid the soil). Every organic treatment without lime has diminished the true acidity of the soil, the highly nitrogenous materials most, as was also true of the lime requirement. The oat straw has the least effect. In the presence of lime, however, the organic treatments have a rather slight effect in reducing the hydrogen-ion concentration at first, and by the third sampling the effect is the reverse in nearly every case, though the increase in hydrogen-ion concentrations is again not large. By the fourth

sampling the effects are quite erratic. In nearly every case where lime was not used, however, the organic treatments have reduced the acidity somewhat.

GENERAL DISCUSSION.

The materials used in this study were such as are common crop residues or fertilizers. In order of increasing nitrogen content they run, oat straw 1.05, green soybeans, 2.41; green rape, 3.43; soybean hay, 3.63; dried blood, 13.93 per cent. The five ton application of limestone proved to be scarcely enough to take ^{care} of the natural soil acidity plus that produced in nitrification, as shown by the data.

The lime requirement shown by the Lacke method on this soil was about 3 tons. Shaking and aeration was continued for only 5 hours, however, in this and the remaining work, partly for convenience and partly because of the fact that a limited amount of work had shown the lime requirement indicated by a five hour run was sufficient that when that quantity of lime was added to the soil and allowed to stand for a short time with optimum moisture conditions a practically neutral reaction was produced as shown by hydrogen-ion determinations.

These results of the effect of carbohydrate materials upon nitrification have a practical bearing which is worthy of consideration. Experience has shown that the plowing under of green manures such as rye, the heavy use of straw and other refuse, often causes disappointing yields from the crop immediately following. This may result not alone because of effect produced upon the rise of capillary water, or because, the crop has exhausted the water supply previous to plowing under, but oftentimes no doubt, because such materials have furnished the soil organisms with easily available sources of energy and

nitrification does not proceed rapidly enough to supply the crop with nitrates. Thus the immediate crop suffers nitrogen starvation, though perhaps later crops might be much benefited.

SUMMARY.

1. Oat straw again reduced nitrification and ammonification below that of the untreated soil.
2. A mixture of straw and blood reduced the total nitrogen found in the form of ammonia and nitrates below that of the blood treatment alone. Ten tons of straw with the blood caused a somewhat greater reduction than the 5 ton application.
3. All the treatments reduced the lime requirement indicated by the Tacke method, until nitrification had taken place.
4. Lime requirements run on the limed soils showed that these treated soils were always capable of reaction with more lime, though an excess of two tons of lime-stone had been applied. This shows that the soils contain acids which are very slowly reactive, and that they will perhaps react with limestone beyond their neutral point.
5. The residual carbonates, where blood was applied, were completely exhausted at the last sampling.
6. The hydrogen-ion determinations show that in practically every case the organic treatments reduced the true acidity. In some cases, on the contrary, both lime and organic treatments did not give as alkaline a soil as did the lime alone.
7. Changes in soil reaction especially on the blood treated soils, follow very closely, the deficit or excess of ammonia over nitric nitrogen, indicating that these processes may become factors influencing the production of acid soils.

BUFFERING IN SOILS.

Practically all soils possess perhaps some degree of buffering, that is they are able to react with either base or alkali to a certain extent, without very much change in hydrogen-ion concentration. The degree of buffering and the rate of change of reaction with increasing amounts of base or acid will depend very much upon soil type, as the following data will show.

TABLE I.

TABLE SHOWING TREATMENTS AND THE HYDROGEN-ION CONCENTRATIONS
OF THE INCREMENTS CORRESPONDING.

	Alone P.H.	CA(OH) ₂ 1000#	CA(OH) ₂ 2000#	CA(OH) ₂ 4000#	CA(OH) ₂ 8000#	CA(OH) ₂ 16000#	CA(OH) ₂ 32000#
A. (Muck)	4.5	0.2	0.3	0.2	0.6	0.3	0.7
B. (Fine Sand)	5.1	0.1	0.3	0.7	1.0	1.0	0.1
C. (Red Clay)	5.0	0.2	0.2	0.7	0.8	0.7	0.9
D. (Coarse Sand)	5.8	0.6	0.9	0.5	0.4	0.3	0.8
E. (Mucky Loam)	4.6	0.1	0.1	0.3	0.9	1.2	0.5
F. (Neutral Soil)	7.0	0.3	0.3	0.3	0.3	0.2	
G. (Alkaline Soil)	7.9	0.3	0.0	0.0	0.2	0.1	

Five grams of the above soils were treated with $\frac{1}{50}$ Ca(OH)₂ equivalent to the various amounts of lime per acre of 2,000,000 pounds of soil, evaporated to dryness on the steam bath taken up with 20 c.c. of water, allowed to stand over night, and the hydrogen-ion concentration determined with a hydrogen electrode apparatus. The acid treated soils were managed in the same way, $\frac{1}{125}$ H₂SO₄ being used.

The above data shows that the rate of change of reaction with increasing increments of lime is very different for the different soils. The muck soil shows highest buffering, the sand

the least as would be expected. The neutral and alkaline soils do not change very greatly showing that they have little capacity for buffering against base.

The data below shows the effect of acid treatments.

TABLE II.

SHOWING TREATMENTS AND CORRESPONDING H-ION CONCENTRATIONS
BY INCREMENTS CORRESPONDING TO TREATMENTS.

SOIL	Alone P.H.	H ₂ SO ₄ 1000#	H ₂ SO ₄ 2000#	H ₂ SO ₄ 4000#	H ₂ SO ₄ 8000#	H ₂ SO ₄ 16000#
A. (Muck)	4.5	0.4	0.2	0.2	0.2	0.4
B. (Fine Sand)	5.1	0.6	0.3	0.5	0.5	0.4
C. (Red Clay)	5.0	0.4	0.2	0.4	0.5	0.4
D. (Coarse sand)	5.7	1.0	0.4	0.8	0.4	0.3
E. (Mucky Loam)	4.5	0.3	0.3	0.3	0.3	0.3
F. (Neutral)	7.0	0.1	0.1	0.3	0.3	2.0
G. (Alkaline)	7.9	0.1	0.0	0.2	0.0	0.0

As was true of buffering against bases, the organic soils show greater capacity for buffering against acids. The sandy soil shows less buffering, and the neutral and alkaline soils, show great apparent buffering perhaps due to the presence of excess bases.

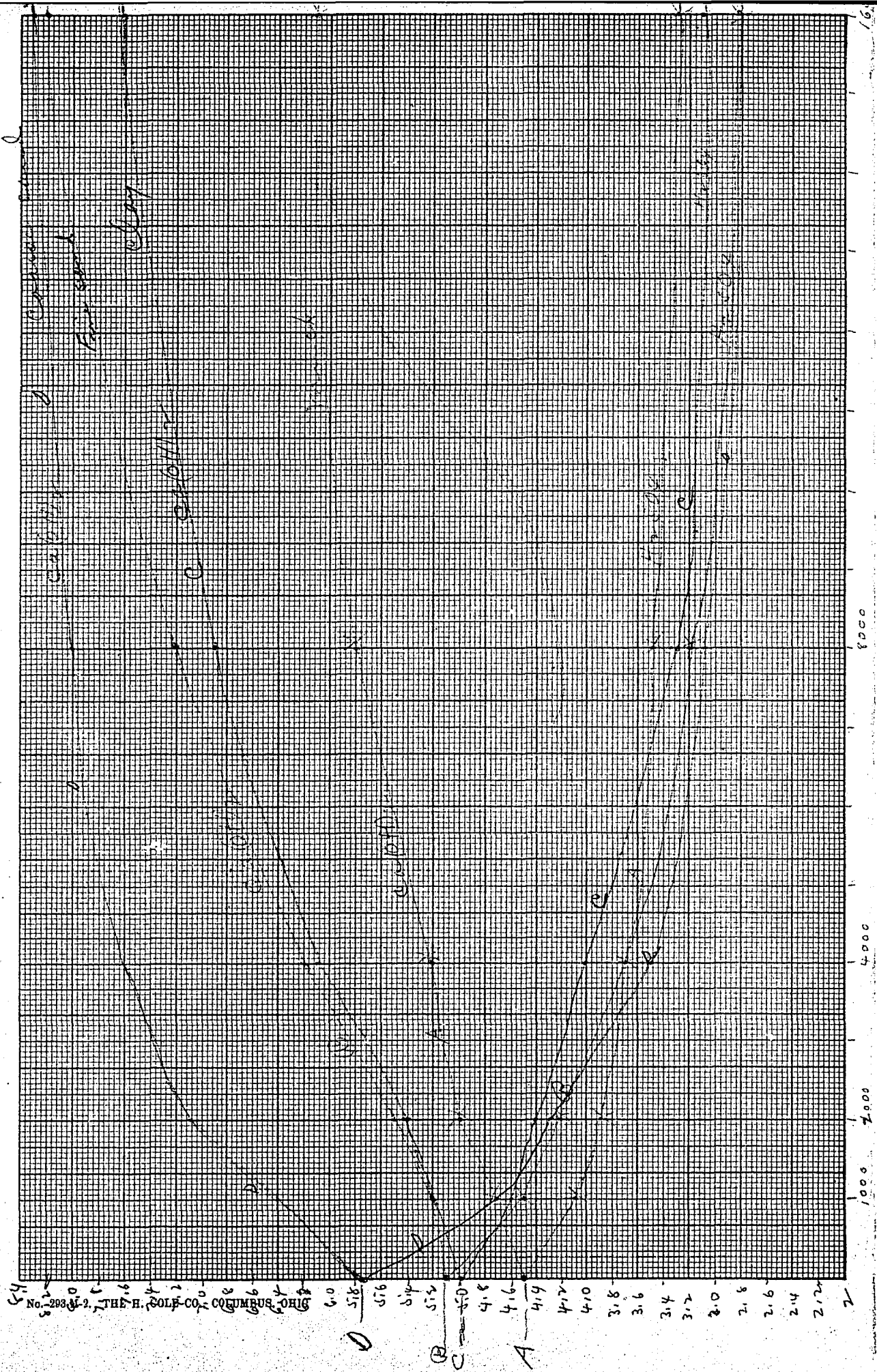
In general mucky or organic soils should show high buffering, clays less, and sands least buffering. The protein materials of the organic soils, and the acid silicates of clayey soils are doubtless responsible for most of the buffer action of such types. Sands, containing perhaps little of either, are not usually highly buffered.

The highly buffered soils should show not only less change

with the first treatments of base or acid but should continue to resist change of reaction longer when larger treatments are given. The initial reaction will of course be a factor to consider on this point. But it is worthy of note that the soils A and C which are most acid to start with yet show the greatest capacity for buffering against acid.

It might be supposed that since soils tend naturally to become acid the capacity for buffering against acids would be more or less exhausted. It is demonstrated that this is true to a limited extent only. While the first application of acid causes a comparatively large change in reaction, it is observed that there is a marked buffering which continues to be manifested with the highest treatments. The acid soils likewise however, have a greater capacity for base buffering.

These facts are best brought out by means of graphs, which show the rate of change by the degree of curvature. Soil A has a curve much less steep than the other soils, soil D having much the most abrupt slope. The acid curves for B and D reach a final point nearly together, though starting quite widely separated. Soil A which is by far the most acid, never rises to as high an acidity as soil D which is much the least acid. Soil A is a muck, while soil D is a sand and this difference in buffering capacity could be predicted, though such an extreme effect may seem extraordinary.



44
No. 2
3

08-11-30

THE N. 6

24-25

CO-2

၆၈၅၂၀၆

7-0110

5.5

576

513

4.5

416

414

4.0
3.8

3.6

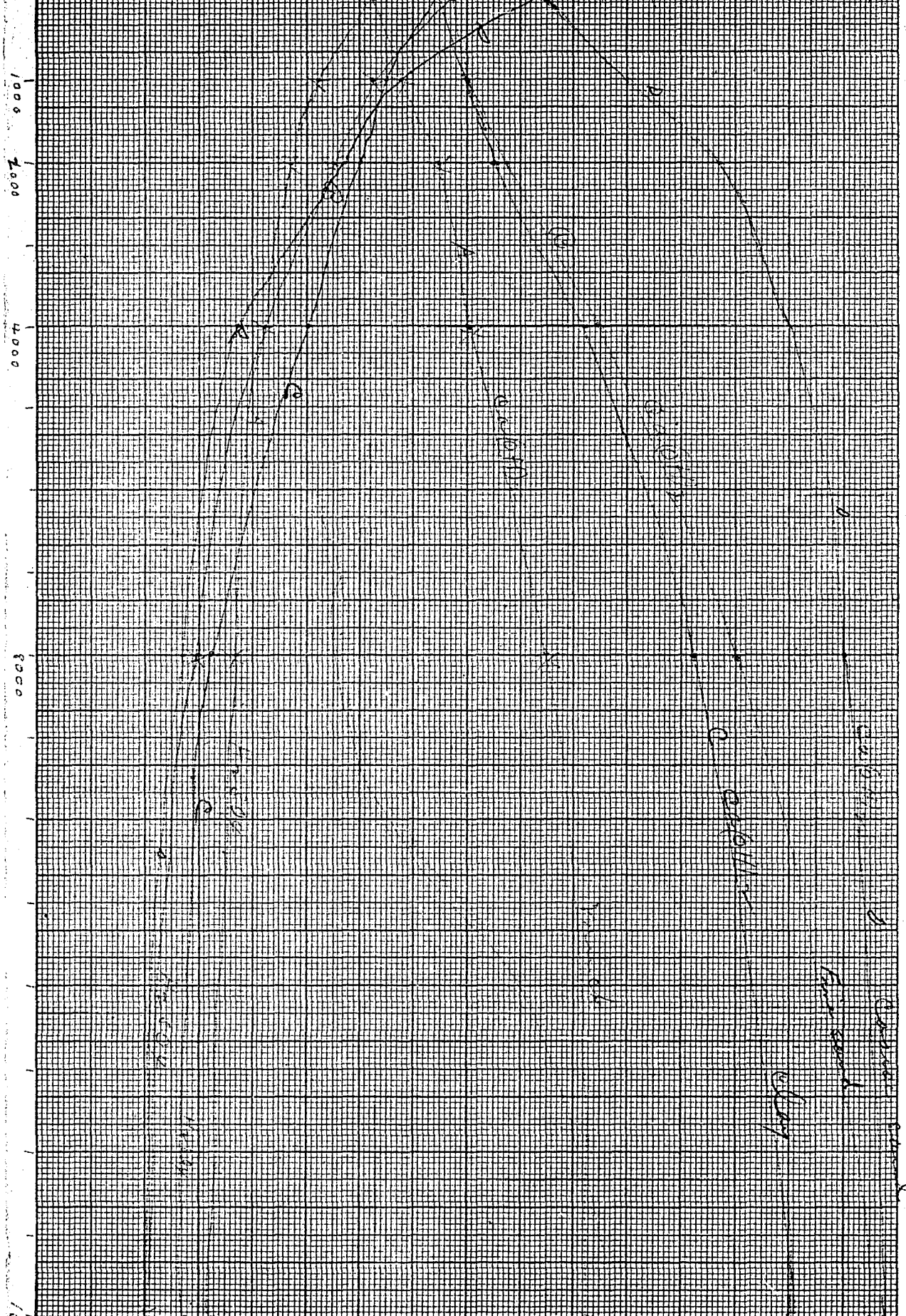
3.4
3.2

2.0
2.1

2.6

2.14
2.20

2



03

5

Figure 1

4

Age Group	Percentage of Respondents
18-29	65%
30-49	70%
50-69	75%
70+	85%

10

1

5

10

5000

100

1



Year	Percentage of Respondents (%)
1997	65
1998	75
1999	70
2000	85
2001	90
2002	95
2003	100
2004	100



10



The above data has considerable significance in various ways. It demonstrates what practical experience has already indicated, that soils may be quite acid when total lime requirement is measured, and yet have a comparatively low active acidity. Ordinary soil acidity methods measure the capacity of the soil for decomposing lime, rather than its true acidity or hydrogen-ion concentration. Soils high in organic matter may be able to take up large amounts of limestone, when a great part of this acidity has been overshadowed by amphoterics substances.

Highly buffered soils may also permit vigorous bacterial activity, because the buffering effect keeps down the hydrogen-ion concentration to a point which is not destructive of the soil organisms. A soil on the other hand which is not buffered, has a higher hydrogen-ion concentration though a smaller total lime requirement, and organisms are not very active because of the deleterious effects of the unbuffered acids.

The importance of hydrogen-ion concentration biologically may be shown, by the following data taken from Fred's ^{work} (2) with the legume bacteria. Only the acid limits are given, but perhaps the alkaline limit would be nearly as far above neutrality which would mean a wide variation for some organisms and only a quite narrow one for others.

1. Alfalfa and sweet clover	Acid limit	P _H	5.0
2. Garden pea, field pea, vetch	"	"	4.8
3. Red Clover and common beans	"	"	4.3
4. Soybeans and velvet beans	"	"	3.4
5. Lupines	"	"	3.2
6. Limits of growth of Azotobacter about	P _H		6.6 to 8.8

Many soil organisms are even more sensitive to reaction than some of the common legume organisms, and thus the true acidity of soils is doubtless the determining factor for the

biological changes which are to occur. No data can be given here for the reaction permitting mold growth but it is known that they endure high degrees of acidity and probably no soil under ordinary treatment is ever too acid for their activity.

THE NATURE OF SOIL ACIDITY. HYDROGEN-ION STUDIES.

The following preliminary study was made using tumblers of soils treated in various ways to determine the effect of the treatment upon hydrogen-ion concentration. In each case 100 grams of dry soil was used, and the moisture content kept at the optimum (50% saturation). One series was treated with ammonium sulphate at the rate of one ton per acre, and lime in increasing increments 1, 3, 5, 7, 9, 12 and 20 tons per acre of 2000,000 pounds of soil. The results are given below in P_H values.

TABLE III.

THE P_H VALUES FOR THE VARIOUS TREATMENTS. INCUBATED SIX WEEKS.

Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
$(NH_4)_2SO_4$	$(NH_4)_2SO_4$	$(NH_4)_2SO_4$	$(NH_4)_2SO_4$	$(NH_4)_2SO_4$	$(NH_4)_2SO_4$	$(NH_4)_2SO_4$	$(NH_4)_2SO_4$
0	1 ton	3 ton	5 ton	7 ton	9 ton	12 ton	20 ton
5.08	4.88	4.98	5.67	7.27	7.86	7.91	7.91
							7.96

The lime requirement of the untreated soil determined by a 5 hour Tacke run, was 3.2 tons per acre. It will be observed that the ammonium sulphate alone increased the acidity as would be expected of a physiological acid salt which has been nitrified. The increased acidity is not overcome by the one ton treatment of calcium carbonate, but is more than overcome by the 3 ton treatment. A neutral reaction is not secured however until 5 tons are applied when it runs beyond neutrality. After 9 tons is applied there is only a small increase in alkalinity, and with 20 tons the P_H is not quite 8.

In the next table similar results are presented with an organic nitrogenous application, albumin, at the rate of about $1\frac{1}{2}$ tons or approximately the equivalent of the one ton of ammonium sulphate in nitrogen content.

TABLE IV.

PH VALUES WITH ALBUMIN TREATMENTS.

Only Soil	Soil ; Albumin	Soil ; Albumin	Soil ; Albumin	Soil ; Albumin	Soil ; Albumin	Soil ; Albumin	Soil ; Albumin	Soil ; Albumin	Soil ; Albumin
Lime 0	Lime 0	Limelt	3 ton	5 ton	7 ton	9 tons	12 ton	20 ton	
PH 5.08	4.76	5.27	6.07	7.84	7.96	7.91	7.91	8.02	

The results are very similar to those obtained with ammonium sulphate. Accidentally or otherwise the albumin caused a slightly greater acidity when lime was not applied to the soil but in most cases it was less. In other words the same amount of lime permitted less acidity or more alkalinity when albumin was used than when an equivalent in ammonium sulphate was used. This results perhaps because not only was nitric acid produced from ammonium sulphate but sulphuric acid remained. When albumin was nitrified if any other acid was produced it was in smaller quantity or of weaker ionization than was the sulphuric acid from the ammonium sulphate.

In the next table the soil alone is given the various lime treatments and the hydrogen-ion determined.

TABLE V.

PH VALUES WITH VARIOUS LIME APPLICATIONS ON SOIL ALONE.

SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL
Lime 0	Limelt	3 ton	5 ton	7 ton	9 ton	12 ton	20 tons	
PH 4.70	4.91	6.55	7.69	7.68	7.96	8.05	8.26	

Evidently there must have been some variation in the soil as this sample seems to be more acid originally. The 3 ton treatment is not quite neutral while the 5 ton treatment is alkaline. Apparently about 4 tons or a little more than the indicated Tacke requirement is necessary to give a neutral soil. The 20 ton

treatment runs above 8 PH which is rather alkaline for a limestone treatment.

In the next series acids were added equivalent respectively to the nitric and sulphuric acids which would result if the ammonium sulphate were completely nitrified.

TABLE VI.

Soil :	Acid :	Acid :	Acid :	Acid :	Acid :	Acid :	Acid :	Acid :	Acid :
Only :	Soil :	Soil :	Soil :	Soil :	Soil :	Soil :	Soil :	Soil :	Soil :
Lime0 :	0	:1 ton :	3 ton :	5 ton :	7 ton :	9 ton :	12 ton :	20 ton :	
PH4.71	3.91	:4.31 :	6.15 :	7.25 :	7.55 :	7.55 :	7.69 :	7.79 :	

The acids increase the acidity but the five ton treatment of limestone gives a somewhat alkaline soil. The higher treatments do not cause as great an alkalinity as where nothing but lime is added to the soil, even when a large excess of lime is present.

Another series was treated with ammonium sulphate and mineral and organic acids. Sulphuric and citric acids were used in equivalent amounts.

TABLE VII.

AMMONIUM SULPHATE				:	ALBUMIN			
Soil :	Soil :	Soil :	Soil :	:	Soil :	Soil :	Soil :	Soil :
1 Ton	H ₂ SO ₄	H ₂ SO ₄	citric acid	:	H ₂ SO ₄	H ₂ SO ₄	citric acid	Albumin
H ₂ SO ₄	3 ton	3 ton	10 ton	:	3 ton	5 ton	7 ton	Alone
4.21	3.85	3.62	5.22	:	4.36	3.65	4.69	4.76

It is very evident that the ten tons of citric acid in conjunction with the ammonium sulphate did not increase the true acidity of the soil. In fact it is much less. Neither did the seven tons used with the albumin cause any increase. But the sulphuric acid evidently caused quite a marked increase in every case, the increase being somewhat proportional to the amount applied. The three ton application of sulphuric did not have so great an effect in the presence of albumin as with ammonium

sulphate but the five ton treatment had nearly as great an effect.

Another series was run using citric acid on the soil alone.

TABLE VIII.

SOIL	SOIL	SOIL	SOIL	SOIL	SOIL
	Citric	Citric	Citric	Citric	Citric
	acid	acid	acid	acid	acid
	3 ton	5 ton	7 ton	9 ton	10 ton
4.71	5.02	5.33	5.40	5.14	5.33

It is very evident again that the organic acid has not increased the acidity of the soil, and the largest application has no more effect than the smaller ones.

These results are in accord with the contention that organic acids do not accumulate in soils under any conditions favorable to crop production. It is very evident that the organic acid used here has oxidized rapidly enough to remove all cause for suspicion that ordinary acid soils might owe this characteristic to citric acid produced from the decay of organic matter. The results agree also with those of Stemple, who use citric, oxalic, and acetic acids. It is possible of course that more stable and active organic acids than citric might be produced, and that there might be conditions when such acids would contribute to the causing of an acid soil.

SOURCE OF ORGANIC ACIDS AND MINERAL.

From whence arises the acidity of ordinary agricultural soils has long been a somewhat perplexing problem. It is generally believed at the present time that most of the acidity except perhaps that in peat and muck soils arises from some mineral source. The leaching of bases and the consequent accumulation of acid silicates and aluminosilicates is doubtless responsible for a considerable portion of acidity. The practice of using certain commercial

fertilizers, such as ammonium sulphate has caused an acid condition of some soils. Thus the accumulation of sulphuric, hydrochloric, or nitric acids even in small amounts could cause a marked increase in the harmful effects of an acid soil, because such acids are highly ionized and would therefore give a high hydrogen-ion concentration to soils. A small amount of such acids would undoubtedly do more injury than larger amounts of either acid silicates or organic acids.

It may be easily demonstrated that soils contain acids of very variable strengths, the more active ones reacting at once and the very slowly active ones, only after a much longer period of contact with limestone and water. This may be due to the fact that the acids are very slowly soluble, or it may be partly because of hydrolytic actions which take place slowly. The following data showing the varying degrees of activity of soils acids is taken from a previous work.

TABLE IX.

LIME REQUIREMENT AT INTERVALS OF THREE HOURS.				
Soil No.	LIME			
	3 hrs.	6 hrs	9 hrs	total
1. Loam	5000 lbs.	6100 lbs.	6500 lbs.	6500 lbs.
Increase	:	:1100 "	: 500	:
Percent of total	: 77.0	: 17.0	: 6.0	: 100
3. sandy loam	:3700	:5100	:6200	: 6200
Increase	:	:1400	:1100	:
Percent of total	: 59.7	: 22.6	: 17.7	: 100
4. Sand	: 800	:1100	:1100	: 1100
Increase	:	: 300	: 6	:
Percent of total	: 72.7	: 27.3	: 0	: 100
5. Miomi Silt	:1800	:2300	:2500	: 2500
Increase	:	: 500	: 200	:
percent of total	: 72.0	: 20.0	: 8.0	: 100.

These results show that from 60 to 80 percent of the acidity based upon a total 9 hour run, reacted during the first three hours, while there yet remained six to 18 per cent to react during the last three hours of the run, except for the sand which was not very acid. Soils have been run a much longer period than this and have been found to react slowly even after several days run. One muck soil with a lime requirement of 15,200~~0~~ pounds at the end of three hours ran to 25,400~~0~~ pounds at the end of a 23 hour period. A soil of this type is however quite different from the ordinary soil, and doubtless the organic matter, or organic acids have a part to play in its reaction.

THE LOSS OF BASES BY SOILS.

It is not presumed that soils become acid so long as they contain bases equivalent to the acids. But the question may arise, do acids increase in quantity or ^udo bases diminish in quantity and thus leave a surplus acidity, and if either or both takes place in what manner does it occur?

The bases such as sodium, potassium, and calcium must be held originally in some chemical combination, undoubtedly with a silicate or alumino-silicate, to form a salt or acid salt. This gives a salt of a strong base and a weak acid and should therefore by hydrolysis give up a free base. That such is true has been demonstrated experimentally as shown by the following data from Steiger's work (1) with various natural silicates.

TABLE X.

Table showing alkalinity of natural silicates

NAME	FORMULA	Percent of combined alkali	Equivalent of Na ₂ O in Solution in percent
Pectolite	$\text{Ca}_2(\text{SiO}_3)_3 \text{NaH}$	9.11	0.57
Muscovite	$\text{Al}_3(\text{SiO}_4)_3 \text{KH}_2$	10.0	0.32
Natrolite	$\text{Al}_2(\text{SiO}_4)_3 \text{Na}_2 \text{H}_4$	15.79	0.30
Lintonite	$\text{Al}_6(\text{SiO}_4)_6 (\text{CaNa}_2)_3 \cdot 7\text{H}_2\text{O}$	5.92	0.29
Phlogopite	$\text{Al}(\text{SiO}_4)_3 \text{Mg}_3 \text{KH}_2$	9.32	0.22
Laumnite	$\text{Al}_2\text{SiO}_4 \text{Si}_3\text{O}_8 \text{Ca} \cdot 4\text{H}_2\text{O}$	1.00	0.18
Lepidolite	$\left\{ \text{KH}_2\text{Al}_3(\text{SiO}_4)_3 \right.$ $\left. \text{K}_3\text{Li}_3(\text{AlF}_2)_3 \text{Al}(\text{Si}_3\text{O}_8)_3 \right\}$	13.00	0.18
Elaeolite	$\text{Al}_3(\text{SiO}_4)_3 \text{Na}_3$	21.17	0.16
Henlandite	$\text{Al}_6(\text{Si}_3\text{O}_8)_6 (\text{CaNa}_2)_3 \cdot 16\text{H}_2\text{O}$	2.0	0.13
Orthoclase	KAlSi_3O_8	16.0	0.11
Analcite	$\text{NaAlSi}_3\text{O}_8 \cdot \text{H}_2\text{O}$	14.0	0.10
Oligoclase	$\left\{ \text{AlNaSi}_3\text{O}_8 \right.$ $\left. \text{Al}_2\text{CaSi}_2\text{O}_8 \right\}$	9.18	0.09
Albite	$\text{AlNaSi}_3\text{O}_8$	12.10	0.07
Wernerite	$\left\{ \text{Ca}_4\text{Al}_6\text{Si}_6\text{O}_{25} \right.$ $\left. \text{Na}_4\text{Al}_3\text{Si}_9\text{O}_{24}\text{Cl} \right\}$	11.09	0.07
Leucite	KAlSi_2O_6	21.39	0.06
Stilbite	$\text{Al}_2\text{Si}_4\text{O}_{10}(\text{CaNa}_2)_2 \cdot 6\text{H}_2\text{O}$	1.00	0.05
Chabazite	$\text{Al}_2\text{Si}_4\text{O}_{10}(\text{CaNa}_2)_2 \cdot 6\text{H}_2\text{O}$	7.10	0.05

These results were obtained by placing 0,5 gram samples in 500 C.C. water and maintaining at a temperature of 70° C. for a month. It is to be expected that in the soil it might go on even more readily, since the base would be leached as liberated unless per chance it reacted with some acid or protein decomposition product to form an insoluble salt. Why all bases do not leach with about equal readiness cannot be stated but potassium seems about the least readily leached and calcium most readily leached. When several hundred pounds^{of} limestone may be leached out in a single year it is not strange that a soil may become rather acid and unproductive in time for that reason.

There is therefore nothing more logical than that with increased weathering there should come increased acidity. As long as base rich minerals are tightly cemented together or enclosed within the interstices of a resistant granite or other mineral, they are mechanically protected and saved from waste. But they are likewise saved from any useful function in the soil either as direct plant food or as a neutralizing agent. Virgin soils are not only more likely to contain many minerals rich in unleached bases but they contain much organic matter in the process of decay and therefore in a condition to react with, and to prevent the leaching of base. With the exhaustion of the organic matter there is the accompanying loss of base and therefore a nonproductive sour soil.

Experimental data shows that practically any type of soil may become acid. But the acidity of different soil types behaves in a different way as may be shown also experimentally. A sandy soil is likely to become acid readily because there is not sufficient organic matter to prevent leaching of such bases

as may occur naturally or may be applied artificially.

There would probably be little acidity due to organic acids, because there would be little organic matter in such a soil and because conditions would likely be very favorable to the oxidation of such organic acids as might possibly develop. Mineral acids such as the acid silicates, and the stronger sulphuric and hydrochloric acids from the application of certain fertilizers would likely cause the injurious soil reaction. On a clay soil more acid alumino-silicates, would be probable. Loam soils and those of yet higher organic content might contain organic acids, or at least organic compounds capable of combining with bases. Such soils remain productive in spite of such acidity as may develop because necessary bases for plant growth have been prevented from leaching and because the organic matter itself is an important source of the essential plant food, nitrogen. In the growth of legumes, however, it is not perhaps a question of nitrogen content, but more likely a question of reaction and a supply of mineral plant food, including not only the bases potassium and calcium, but also phosphoric acid.

GENERAL DISCUSSION.

There are many factors which influence directly or indirectly the reaction of soils. It is not a question of the production of acids but a question of the capacity of the soil to resist changes in reaction caused by the acids produced.

Buffering may be effected by both mineral and organic compounds. Silicates of bases would be capable of neutralizing strong acids. Which is in fact a buffering effect. Some of the alumino-silicates no doubt react with either acid or base

and therefore function doubly toward saving base, and toward reducing the true acidity. The amino acids, and many more complex products of protein degradation react in the same manner. The ionization constants for the amino acids as either acids or bases are very low but of about equal strength which makes them ideal buffers. This explains why organic soil and clayey soils should show greater power to resist changes in reaction.

Grain size is of course an *important* factor in determining its reaction, especially with mineral soils. The smaller the grain size the more difficult it is to prevent water logging, and therefore the more difficult to maintain conditions favorable to the oxidation of organic acids or other harmful products. Though coarse grained soils readily become acid it is perhaps usually with a somewhat different type of acidity. Rahn (3) has already demonstrated the close relationship between grain size, moisture content, and bacterial activity. This relationship has its influence also upon reaction changes.

SUMMARY.

1. Highly organic soils and clays exhibit a degree of buffering, while coarse sands show little of this capacity.
2. Sulphuric acid, or a physiologically acid salts such as ammonium sulphate cause a change toward increased hydrogen-ion concentration in soils. Citric acid did not increase the true acidity.
3. Ammonium sulfate caused a greater increase in acidity than did its nitrogen equivalent of albumin.
4. When nitric and sulphuric acids were added to the soils in amounts equivalent to the acidity which might be produced from the complete nitrification of ammonium sulfate a greater

increase was produced in the hydrogen-ion concentration of the soil than where the ammonium sulphate was used.

5. A large excess of pure lime carbonate (20 tons) brought the P_H value to only a little more than 8.0 which seems to be about the limit of alkalinity produced by limestone.

ACKNOWLEDGEMENT.

The work reported in this publication was begun at Iowa State College. The latter two portions were planned and completed after the author was located at West Virginia University. Acknowledgements are extended to Dr. P.E. Bown of Iowa State College and to Prof. R. M. Salter of West Virginia University for helpful suggestions in planning and interpreting the work.

BIBLIOGRAPHY.

1. Clark, F.W. 1900, contributions to Chemistry and Minerology. U.S. Geol. Survey, Bul. 167, p. 156.
2. Fred, E.B. and Davenport Audrey, 1918, Influence of Reaction on Nitrogen-assimilating Bacteria. In Jour. Agr. Res. V.14, No. 8. p 317.
3. Rahn, Otto, 1912. The Bacterial Activity in Soils as a Function of Grain Size and Moisture Content. In Mich. Tech. Bul. No. 16.