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VARIATIONS IN SOIL REACTION AFFECT NITRIFICATION

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In some of the earliest studies on nitrification, it was found that the reaction of the soil exerted a profound influence on the occurrence of the process. In strongly acid soils, frequently no nitrate formation took place, and as the acidity increased, the process proceeded more and more slowly. It was further noted that additions of lime to acid soils would stimulate the action of the nitrifying bacteria and a greater production of nitrates would occur.

Many investigations have confirmed the earlier results on the effects of lime on nitrification. In practically all cases the application of lime to acid soils has led to a stimulation in nitrification, due either to a neutralization of the acids present in the soil, which may have been limiting the process, or to a stimulation in the activities of the organisms, or possibly to certain secondary effects of the lime, such as improved physical conditions in the soil, the elimination of competing species of organisms, or the liberation of available bacterial food constituents through chemical action. It is generally conceded that one of the reasons for the beneficial effects of liming on crop yields is the stimulation in desirable bacterial activities engendered by the lime.

But contrary to the earlier conclusions, it has been found in more recent studies that nitrification often occurs in soils which show an acid reaction according to the usual tests. In other words it appears that while liming does increase nitrification, the process may proceed in soils which are quite acid in reaction. The limiting acid reaction has been variously placed by investigators and apparently it varies under different soil conditions. Probably a pH of 3.9 to 4.5 is a fair estimate of the usual maximum acidity for the nitrifying bacteria. However, there is no question but that the buffering in soils will bring about a variation in the point at which the acidity becomes so toxic that the nitrification process ceases. Soils with a high content of buffer substances will permit of the occurrence of the process at a much higher acid reaction than those with low buffer content. There is a further explanation of nitrification in acid soils, suggesting that nitrate formation takes place

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in such soils in the films surrounding the small isolated particles of calcium carbonate which may occur distributed through an acid-reacting soil. There is also the possibility that the nitrifying bacteria may gradually become adapted to greater acidity, and finally grow fairly well under very acid conditions. In such a case there would certainly be a maximum acidity beyond which the organisms could not be induced to grow even by a most careful attempt at an adaptation.

Under ordinary soil conditions, when the acidity is not great and average buffering occurs, there is no question but that nitrification occurs quite extensively, in spite of an acid reaction. But liming brings about an increase in nitrate production and to the extent that this greater nitrate content is utilized by plants, the increase will prove economic and will be reflected in greater crop yields.

A number of investigations have shown a close relationship between crop yields and the nitrifying power of the soil.[1 2] It becomes of special significance, therefore, to study the nitrifying process and to determine the influence of the soil reaction upon the rate and extent of nitrification. Only through such work can the optimum soil reaction for crop growth be accurately determined without an actual measurement of the crop yield after a seasons' growth.

The literature on the subject of the effects of liming is extensive and no reference will be made here even to the more important papers. The previous discussion summarizes all the work available.

In these tests a series of plots on the Agronomy Farm of the Iowa Agricultural Experiment Station were employed. The treatments were as follows:

Plot. No.	Treatment
421	Check
422	100 pounds per acre of 0-12-0
423	100 pounds per acre of 2-12-6
424	100 pounds per acre of 2-12-0
425	100 pounds per acre of 0-12-6
401	Check
402	300 pounds per acre of 0-12-0
403	300 pounds per acre of 2-12-6
404	300 pounds per acre of 2-12-0
405	300 pounds per acre of 0-12-6
601	Check
602	600 pounds per acre of 0-12-0
603	600 pounds per acre of 2-12-6
604	600 pounds per acre of 2-12-0
605	600 pounds per acre of 0-12-6

1 Brown, P. E. 1915. Bacterial Activities and Crop Production. Iowa Agr. Exp. Sta. Rsch. Bul. 25.

2 Gainey, P. L. and Gibbs, W. M. 1916. Bacteriological Studies of a Soil Subjected to Different Systems of Cropping for 25 Years. Jour. Agr. Rsch. 6: 953.

The soil type on which these plots are located is a typical Carrington loam, an extensive upland soil in the Wisconsin drift soil area. The series was begun in 1923, and treatments were made three years prior to the carrying out of the tests reported here, only one application of the various fertilizers having been made. The crops grown during the period were oats, clover and corn, the plots being in corn the year of the tests.

The plots were sampled on September 17 and October 21, and the samples were tested for nitrifying power and reaction. In sampling, three samples were drawn to a depth of six inches from each plot, at different points well distributed over the plots. From the three samples a composite was made and the tests were made on these composites.

In the nitrification tests, four 100 gram portions of soil from each plot were weighed out in tumblers. To two of these tumblers of each soil, 100 mgs. of ammonium sulfate were added. The moisture content of all the soils was adjusted to the optimum with distilled water and kept optimum by regular additions. The cultures were incubated for thirty days at room temperature. At the conclusion of the incubation period, the nitrate content was determined by the phenoldisulfonic acid method.

The hydrogen ion concentration of the soils was determined on the samples at the October 21 sampling. The results of the reaction and nitrifying power determinations are given in table I. The nitrates produced in the check soil are subtracted from the total to give the amount produced from the ammonium sulfate.

There are some interesting comparisons possible from the data given, the results being relatively similar on the samples taken at the two dates. On October 21, the soils showed a higher nitrifying power than on September 17, but the relations among the differently treated plots are very similar.

The fertilizer treatments showed some influence on nitrification in most cases, but in some instances the differences were not very large, especially with the larger applications. Thus in the first group of plots when 100 pound applications of the various fertilizers were applied, all the treatments stimulated nitrification, the 0-12-6 apparently having the greatest effect. The effects were very similar at both dates of sampling.

But noting the pH of the soils, it will be seen that the soil from the plot receiving the 0-12-6 fertilizer had a higher pH than the others, being almost neutral in reaction, while the check plot was the most acid. Thus it is quite evident that the reaction of the soil

Table I — Nitrification
(Mgs. of Nitrate Nitrogen per 100 Grams of Soil)

PLOT. NO.		SEPTEMBER 17TH		OCTOBER 21ST		pH
421	$(NH_4)_2SO_4$	2.58	2.05	7.12	5.33	5.3
421	Check	0.53		1.79		
422	$(NH_4)_2SO_4$	3.14	2.72	7.80	5.40	5.5
422	Check	0.42		2.40		
423	$(NH_4)_2SO_4$	2.76	2.33	8.00	6.05	5.6
423	Check	0.43		1.95		
424	$(NH_4)_2SO_4$	3.24	2.73	11.44	9.52	5.9
424	Check	0.51		1.92		
425	$(NH_4)_2SO_4$	10.00	9.31	20.00	17.56	6.8
425	Check	0.69		2.44		
401	$(NH_4)_2SO_4$	11.00	10.38	20.70	18.78	7.2
401	Check	0.62		1.92		
402	$(NH_4)_2SO_4$	7.56	6.97	18.46	16.52	6.9
402	Check	0.59		1.94		
403	$(NH_4)_2SO_4$	6.33	5.50	14.28	12.37	6.2
403	Check	0.83		1.91		
404	$(NH_4)_2SO_4$	5.03	4.53	11.10	9.52	6.1
404	Check	0.50		1.58		
405	$(NH_4)_2SO_4$	2.70	2.20	7.80	6.16	5.5
405	Check	0.50		1.64		
601	$(NH_4)_2SO_4$	5.73	5.22	13.66	12.28	6.3
601	Check	0.51		1.38		
602	$(NH_4)_2SO_4$	6.11	5.55	14.84	12.90	5.7
602	Check	0.56		1.94		
603	$(NH_4)_2SO_4$	8.31	7.87	16.58	14.55	6.8
603	Check	0.44		2.03		
604	$(NH_4)_2SO_4$	5.84	5.27	14.64	12.39	5.7
604	Check	0.57		2.25		
605	$(NH_4)_2SO_4$	5.40	4.78	13.54	10.94	5.5
605	Check	0.62		2.60		

had more effect than the treatment and probably the difference in pH is mainly, if not entirely responsible for the greater nitrifying power.

In the next group of plots the check or untreated soil showed the highest nitrifying power at both dates and it might be concluded that the 300 pounds of the various fertilizers had depressed nitrification. This was certainly not the case. The check soil was neutral, showing a pH of 7.2 while the other soils in the group were increasingly acid. The decrease in nitrifying power was absolutely parallel to the decrease in pH in the series of treated soils. Undoubtedly here, the reaction of the soil was so important that its effect overshadowed the influence of the fertilizers and gave the appearance of a depressive effect from the treatments. Certainly nitrification in soils and measurements of the nitrifying power are affected very definitely by the reaction of the soils.

In the third group of plots where 600 pounds of the fertilizers were added, the fertilizers seemed to have some effect at least in certain cases. But again the reaction seems most significant. Thus the soil from the plot receiving the 2-12-6 fertilizer showed the highest nitrifying power but it was also the highest in pH. The soil receiving the 0-12-6 was lower in nitrification than the check, but here the pH was lower. In two of the plots, the pH was slightly lower than the checks but in these cases the nitrification was increased slightly. However, here the difference was slight. The results might be interpreted to mean that in these soils the applications had overcome the injurious effects of reaction and gave some increase in nitrification.

It is apparent again, however, that the reaction of the soil is of large influence on the nitrification results and the effects are so great, that the applications of fertilizers, which might otherwise have shown beneficial effects not only do not increase nitrification but may actually decrease the nitrifying power. Where the reaction is favorable, the effects of the fertilizers may apparently be much greater than is actually the case.

These data as a whole show very clearly the significant effects of the reaction of the soil on its nitrifying power. Apparently when the differences in pH are not very great, the influence of greater acidity may be quite large, and where wide variations occur, the reaction of the soil may overshadow the effects of soil treatments. If the treated soils are more acid, nitrification will be reduced and fertilizer treatments which would ordinarily stimulate the process will have no effect. It should be emphasized that the greater acidity in the fertilized soils is not a result of fertilization but a natural variation in soil reaction in such a soil type as the Carrington loam which is closely associated with the Clarion loam, a type containing lime in the subsoil.

It should certainly be concluded that measurements of nitrification or the nitrifying power of treated soils should include tests of reaction or hydrogen ion concentration if the results are to be correctly interpreted. If the reaction varies the treatments will probably show no effect. With wide variations and especially high acidity the nitrification process will be reduced in spite of the treatment which, of course, in some cases may reduce the injurious effects of the acidity. Further it is not impossible that the treatments may entirely overcome acidity effects. This may of course, be interpreted to mean that the reaction or acidity limits possible beneficial effects from the treatments.

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