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STUDIES ON METHODS OF MEASURING THE NITRATE ASSIMILATING POWER OF SOILS

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The work of many investigators has demonstrated the fact that nitrate nitrogen disappears from soils to which organic materials of a high carbon-nitrogen ratio have been added. Doryland [2] in 1916 claimed that soils have a definite nitrate consuming power and that additions of organic matter such as straw, dextrose, or other soluble sugars stimulated the disappearance of the nitrates. He attributed this disappearance to the fact that the nitrates were assimilated by microorganisms but not lost from the soil.

The fact that microorganisms thus enter into competition with the higher plants for soil nitrates makes it desirable to study the factors involved with a view to ascertaining whether or not they can be controlled to any extent. Assuming that soils have a definite nitrate consuming power which can be altered by different treatments, it is conceivable that some method might be devised whereby this consuming power can be measured, at least under specific conditions. Murray [3] in his studies of the effect of straw on soils, in 1921 attempted to measure their nitrate assimilating capacity. He added finely chopped straw in amounts of 0.1 to 5.0 percent and 50 mgm. of sodium nitrate to 100 grams of soil in tumblers. He found that 1.0 percent of straw caused a loss of soil nitrates but his incubation period was rather long and this makes comparisons with the work reported in this paper rather difficult. Smith [4] in 1928 reported results using a soil culture method for determining the nitrate assimilating power of a soil. In this paper some additional data are presented along the same line.

The nitrate content of a soil at any time is undoubtedly the resultant of a number of different microbiological processes. Chief among these activities are nitrification, which tends to increase the nitrate content of the soil, and nitrate assimilation, which tends to

1 The authors express their appreciation of the reading and correction of the manuscript by Dr. P. E. Brown.

2 Doryland, C. J. T. 1916. The Influence of Energy Material upon the Relation of Soil Microorganisms to Soluble Plant Food. N. D. Agr. Exp. Sta. Bul. 116: 319-401.

3 Murray, T. J. 1921. The Effect of Straw on the Biological Soil Processes. Soil Sci. 12: 233-259.

4 Smith, F. B. 1928. The Nitrate Assimilating Power of the Soil and Some Nitrate Assimilating Soil Bacteria. Proc. Iowa Acad. Sci. V. 35. (In press.)

decrease the nitrate content. In order to measure the nitrate assimilating power of a soil with any degree of accuracy, it is very desirable to devise some means whereby the other processes involved can be kept at a minimum. Many investigators have found that cellulose and certain soluble carbonaceous organic materials arrested or inhibited nitrification in solution and soil cultures. An attempt was made in the following experiments to retard nitrification by additions of straw, dextrose and starch. 100 gram equivalents of air dry soil were weighed out into tumblers sufficient for 4 sets of 40 tumblers each. Set 1 was left untreated, to set 2 was added 2 percent of finely ground straw, to set 3, 2 percent of dextrose, and to set 4, 2 percent of starch. These materials were all well mixed with the soil. Each set was then divided into 4 like groups of ten tumblers each to be incubated 1, 2, 3 and 4 weeks respectively. Each group of 10 tumblers was then divided into 5 series to which were added 0.0, 5.0, 10.0, 15.0, and 20.0 mgm. of nitrate nitrogen so that all treatments were made in duplicate. These were all incubated at optimum moisture and temperature for the allotted time and the nitrates determined by the phenol-disulphonic acid method. The amount of nitrate assimilated was calculated as the difference between the amount remaining and the amount added plus the original nitrate content of the soil. In cases where a negative assimilation is indicated, there was an increase in the amount of nitrates, due to nitrification.

Before this work was completed, a new set of tests was prepared using a one week incubation period. The same treatments were followed as above except that a soluble form of starch was substituted for the insoluble form. The data obtained from this latter group are given in table I. The data for the original four groups are given in tables II, III, IV and V.

It was hoped that an analysis of the data obtained would provide an answer for the following questions which have arisen during this study: (1) How long should the incubation period be

Table I — Milligrams Nitrate-N. Assimilated per 100 Grams Dry Soil After One Week *

Treatment	Soil Alone	Soil + 2% Straw	Soil + 2% Dextrose	Soil + 2% Soluble Starch
No treatment	-1.85	1.28	1.28	1.28
5.00 mgms. NO_3-N.	-0.39	6.28	6.28	6.28
10.00 mgms. NO_3-N.	-0.34	10.39	9.44	11.28
15.00 mgms. NO_3-N.	0.93	10.60	13.58	16.28
20.00 mgms. NO_3-N.	5.18	10.63	9.38	17.08

* Soil contained 1.28 mgm. NO_3N. per 100 gm. soil in beginning.

*Table II — Milligrams Nitrate-N. Assimilated After One Week, Per 100 Grams Dry Soil**

Treatment	Soil Alone	Soil + 2% Dry Oats Straw	Soil + 2% Dextrose	Soil + 2% Starch
No treatment	-8.88	1.28	1.28	1.28
5.00 mgms. NO_3-N.	-10.12	6.28	6.28	5.23
10.00 mgms. NO_3-N.	0.93	9.43	11.28	5.34
15.00 mgms. NO_3-N.	2.03	12.05	16.28	6.13
20.00 mgms. NO_3-N.	2.38	12.18	17.67	9.30

* Soil contained 1.28 mgms. NO_3N. per 100 gms. dry soil in the beginning.

Table III — Milligrams Nitrate-N. Assimilated Per 100 Grams Dry Soil After Two Weeks

Treatment	Soil Alone	Soil + 2% Dry Oats Straw	Soil + 2% Dextrose	Soil + 2% Starch
No treatment	-1.21	1.28	1.28	1.28
5.00 mgms. NO_3-N.	-0.86	6.28	6.28	6.28
10.00 mgms. NO_3-N.	-1.22	11.00	11.28	9.08
15.00 mgms. NO_3-N.	0.58	13.14	14.00	7.11
20.00 mgms. NO_3-N.	1.28	14.66	19.24	12.26

Table IV — Milligrams Nitrate-N. Assimilated Per 100 Grams Dry Soil After Three Weeks

Treatment	Soil Alone	Soil + 2% Dry Oats Straw	Soil + 2% Dextrose	Soil + 2% Starch
No treatment	-1.10	1.28	1.28	1.28
5.00 mgms. NO_3-N.	0.23	6.28	6.28	6.28
10.00 mgms. NO_3-N.	0.18	11.28	11.28	11.28
15.00 mgms. NO_3-N.	-1.36	13.72	14.53	10.85
20.00 mgms. NO_3-N.	4.83	15.73	18.00	10.88

Table V — Milligrams Nitrate-N. Assimilated Per 100 Grams Dry Soil After Four Weeks

Treatment	Soil Alone	Soil + 2% Dry Oats Straw	Soil + 2% Dextrose	Soil + 2% Starch
No treatment	-1.55	1.28	1.28	1.28
5.00 mgms. NO_3-N.	0.18	6.28	6.28	6.28
10.00 mgms. NO_3-N.	-0.52	11.28	11.00	11.28
15.00 mgms. NO_3-N.	1.08	14.34	13.92	13.53
20.00 mgms. NO_3-N.	3.28	16.20	16.08	13.42

extended in order to get the most consistent results? (2) How much nitrate should be added? (3) Should some form of organic matter be added and if so, what form is best suited to the study?

The data in all cases where no organic matter was added are erratic and difficult of interpretation. These data are the most inconsistent of all obtained and indicate that incubation of the soil alone is not as desirable a method of procedure as incubation with some organic matter added. In practically all cases with organic matter added, where only 5 mgm. of nitrate were used, this nitrate was all assimilated in one week's incubation period. From this it can be concluded that either a shorter incubation period than one

week or a larger amount than 5 mgm. of nitrate is necessary for good results. In most cases with the 3 or 4 weeks incubation period, all the nitrate added up to 10 mgm. was assimilated. This indicated that if only 10 mgm. nitrate are to be added, then a very short incubation period should be used.

Where a soluble form of organic matter was added, the nitrate assimilating power appeared to be somewhat higher than where an insoluble form of organic matter was used. Yet the consistency of the results obtained from the straw indicates that the results secured from this method might be just as useful for comparative purposes as the results secured when a more soluble form of organic matter was used. A study of the tables indicates that the amount of nitrate assimilated may be increased in three different ways: by using a very soluble form of organic matter, such as soluble starch, by increasing the amount of nitrate added, or by extending the incubation period. As stated above there may be no advantage in using the more soluble form of organic matter. Where the incubation period was limited to one or two weeks, additions of 20 mgm. of nitrates did not show much greater assimilation than 15 mgm. additions. From this it might be concluded that for this type of soil, 15 mgm. per 100 grams of soil is sufficient. Although the amount of nitrates assimilated is slightly increased by extending the incubation period to 3 and 4 weeks, it is not increased in proportion to the extra time. The increased opportunity for the interference of other factors with the longer time would seem to make it desirable to limit the incubation period to not over two weeks, and there is a possibility that less than one week would be preferable.

It is admitted that the results so far obtained are of interest mainly as being indicative of certain tendencies which need further verification. They do show, however, quite conclusively that soils have a definite nitrate assimilating power which may be favored by additions of organic matter. The data also indicate that it may be possible to measure this nitrate assimilating power and correlate it with other microbiological activities. It is planned to continue the work with a view to supplementing the information already obtained.

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