The Effect of Cultivation on the Availability of Soil Nitrogen in some Manitoba Soils

A Thesis

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By

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Abstract

Samples were taken from virgin and cultivated sites in each of three soil associations in the Black earth zone to study the effect of cultivation on available soil nitrogen.

The investigations have shown that cultivation affected the organic matter, nitrogen content and nitrogen distribution in one of the soils to such an extent that rate of nitrification was reduced considerably. In the other two soils cultivation caused a smaller loss in organic matter and nitrogen content and even appeared to increase nitrification of the remaining nitrogen fraction.

Field trials were conducted with ammonium sulphate and ammonium nitrate fertilizers on barley, wheat and oats. In some cases the ammonium sulphate and ammonium nitrate was supplemented with ammonium phosphate fertilizer.

Significant yield increases were obtained with ammonium sulphate fertilizer. When applied in the fall, ammonium sulphate was more effective than ammonium nitrate as a nitrogen carrier.

Acknowledgement

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I. INTRODUCTION

In recent years a good response to nitrogen fertilizer on stubble was obtained with the Cooperative Fertilizer trials carried out in Manitoba. Thus the fertilizer recommendations have shifted toward a greater use of higher nitrogen fertilizers such as ammonium-phosphate-sulphate (16-20-0) and ammonium-nitrate-phosphate (27-14-0). The reason for the increasing response with nitrogen fertilizer has as yet received very little attention in Manitoba.

Over a period of years, cultivation usually reduces the amount of nitrogen made available to the crop. This may be due to chemical effects such as a decline in total nitrogen, particularly in that fraction which is most easily nitrified. It may also be due to physical effects such as soil structure which affects aeration, an important factor in nitrate formation.

Analysis of soil samples taken by the Manitoba Soil Survey show considerable losses of soil organic matter and soil nitrogen in cultivated as compared to similar virgin soils. This appears to be the case in all the soils found in Manitoba varying of course with the cultural treatment to which the soil has been subjected.

This paper deals with the effect of cultivation on the factors responsible for the amount of available soil nitrogen.

II. REVIEW OF LITERATURE

A. Nitrification Studies

Nitrification as described by Waksman and Starkey (41) is the process of conversion of ammonia to the more highly oxidized inorganic compounds of nitrogen as nitrite and nitrate. The organisms forming nitrite from ammonia are called *Nitrosomonas* and *Nitrosococcus*. Nitrite is converted to nitrate by *Nitrobacter*.

The laboratory conditions suitable for the formation of nitrite and nitrate by nitrifying bacteria were found to be an inorganic medium containing salts of ammonia and several nutrient elements, a neutral reaction, and aerobic conditions.

The importance of pH is indicated by Halvorson and Caldwell (19). They found that the addition of calcium carbonate at four tons per acre greatly increased the nitrate producing power of an acid prairie soil. In contrast, results with two Webster high lime soils indicated that the presence of large amounts of calcium carbonate inhibited nitrification.

Bacteriological studies of field soils by Brown (7), (8), indicated that the ammonifying power, the nitrifying power and the nitrogen-fixing power of the soils are greatly affected by the crop rotation. The soils in two and three year crop rotations had greater bacterial activity than soils under continuous corn. Similar results were obtained by Gainey and Gibbs (16). The application of manure to land cropped continuously to corn and wheat greatly increased the number of bacteria. The ability of the soil to oxidize ammonia nitrogen to nitrate nitrogen was also materially increased by the application of manure or commercial fertilizer.

Martin's (24) results indicate that straw applications to a loam soil reduce nitrification and growth of the crops at least for a period. This seemed to be due to the retarded accumulation of nitrates in the soil. The results of other investigators suggest that in the presence of a large supply of carbonaceous matter nitrates are utilized by the increased numbers of micro-organisms.

A correlation between nitrification and soil productivity was found by Brown (9), Noyes and Conner (27), and Lipman (23), while a close correlation between high nitrifying power and high productivity has been observed by Ashby (3), Stevens and Withers (35), Given (18) and Gainey (15).

Allen and Bonazzi (2) found that the nitrifying capacity of a soil may or may not correlate with its crop producing power. Continuous cropping, especially without fertilization, reduced the nitrifying power of soils. Fraps (14) pointed out that the effect of cropping upon soil nitrogen was related to the amount of nitrate produced. The lack of correlation between soil productivity and its nitrifying capacity as reported in some cases may be due to determining the nitrification capacity under conditions different from those found in the field.

B. Organic Matter Losses

The carbon to nitrogen ratio in humus is usually between 10:1 and 12:1. Therefore soil organic matter can not be permanently or appreciably increased or decreased without a corresponding change in organic carbon and nitrogen. The importance of the carbon-nitrogen ratio was indicated by the results of Halvorson and Caldwell (19) on black prairie soils of southern Minnesota in which the soils with the lower carbon-nitrogen ratios had the lowest nitrate producing capacity. The optimum appeared to be around 12:1. Therefore, as stated by Waksman (40) a decrease in organic matter content accompanies depletion of soil fertility and results in a deterioration of soil structure.

Cultivation disturbs the natural organic matter equilibrium as less organic matter is usually returned to the soil and decomposition processes are speeded up by farming operations. In 1937 Caldwell, Wyatt, and Newton (10), conducted a study of the loss of organic matter and nitrogen, of soils in the three prairie provinces. They reported an average loss of 24 per cent of the organic matter and 17 per cent of the nitrogen from the 0-6 inch layer. Losses from the lower depths were not as great. The data also indicated that the average annual loss from soils cultivated for only 9 years was greater than the annual loss from soils cultivated for 28 years. This rapid loss of organic matter and nitrogen in a soil during the first few years of cultivation was also shown at the Missouri Agricultural Experiment station (21). Similar results were obtained by Stephens (34) in Oregon, Sievers and Holtz (32) in Washington, Bracken and Greaves (5) in Utah, and Gainey, Sewell, and Latshaw (17) in Kansas. Myers, et al. (26) found that the carbon and nitrogen losses were rapid following breaking but tended to approach a constant level. The nitrogen and carbon content, the cropping system used and the soil treatment employed.

Losses of organic matter and nitrogen are found to be lower in semiarid than in humid regions. This was shown by results obtained by Russell (31) in Nebraska and Swanson and Latshaw (36) in Kansas in which the humid soils had a 10 per cent greater loss than semiarid soils.

C. Nitrogen Distribution

A considerable portion of the nitrogen-containing compounds found in soil organic matter are proteinaceous in character. Although attempts to isolate intact proteins from soils have not been generally successful, a treatment with acid or alkali similar to that used to hydrolyze proteins will liberate a variety of amino acids as well as ammonia. A part of the ammonia nitrogen is presumed to be derived from acid amides. On the basis of the amounts of these products it has been estimated by Bremner (6) and Kojima (22) that one third to three fourths of the organic nitrogen in a mineral soil and a muck soil may be in proteinlike combination.

Morrow and Gortner (25) determined the nitrogen distribution in several organic (peats) and mineral soils and found that in the two kinds of soil the range in percentage of total nitrogen in the various forms was similar. In the data reported the proportion of amide nitrogen was consistently somewhat higher and the nonbasic amino nitrogen slightly lower in the mineral soils. Similarly, Bremner (6) reported that the amount of amino nitrogen as determined by the ninhydrin reaction, after acid hydrolysis, varied from 24 per cent of the total nitrogen in a cultivated mineral soil containing 0.10 per cent nitrogen to 37 per cent in a fen soil containing 2.38 per cent nitrogen. Rendig (30) studied the nitrogen fractions of comparable virgin and cultivated soils. He found that the content of nonbasic amino nitrogen, as a percentage of the total nitrogen, was lower in the cultivated than in the virgin soil. The cropped soil also contained a lower percentage of amide nitrogen and a higher percentage of nitrogen that was not extracted by the hydrolyzing treatment. The results by these investigators indicates that the amino nitrogen is susceptible to decomposition while the amide nitrogen is more resistant.

Early work of Winogradsky and his colleague Omeliansky as cited by Waksman and Starkey (41) indicated that some organic materials may completely inhibit nitrification. Such substances as glucose, peptone, asparagine, glycerol, and urea were distinctly injurious in concentrations of 0.2 to 1.0 per cent. Shreiner and Skinner (33) found that organic nitrogenous compounds appeared to be as beneficial to plants as nitrates and were able to replace the nitrates in part. They did find that the soil constituents such as picoline and carboxylic acid were moderately harmful and the related uvitonic acid decidedly so. Tyrosine, picoline, piperidine, and pyridine were also found to be toxic while neurine and guanidine were decidedly so. Beneficial constituents were found to be nucleic acid, hypoxanthine, xanthine, guanine, creatinine, creatine, histidine and arginine. Choline was moderately beneficial. Nitrates do not last over from season to season but the organic compounds can do so and hence constitute an important source of available soil nitrogen. The nitrogen fraction in the soil is important since the organic nitrogen compounds differ in the ease with which they can be decomposed to produce available soil nitrogen.

A high total nitrogen content in a soil was found by Whiting (43) to be conducive to rapid nitrification and was usually accompanied with a high water-soluble nitrogen content. Similarly, a high content of easily hydrolyzable nitrogen was related to a rapid nitrification if unencumbered with cellulose. Green plant materials were found to nitrify more rapidly than dry plant materials of the same age and kind. Legumes were more readily nitrified than non-legumes indicating that species of plant grown and serving as the crop residue can affect the availability of soil nitrogen.

III. SOILS USED

Surface samples of virgin and cultivated soil were selected from the Newdale, Stockton and Red River soil associations. The virgin and cultivated samples were selected so that they were comparable with respect to texture, drainage, and topography.

The samples from the Newdale association, a clay loam soil, were taken at the southern outskirts of Basswood. The samples from the Stockton association, a very fine sandy loam, located in south central Manitoba were obtained a quarter of a mile south of Melbourne. The samples from the Red River association were taken from the Morris associate at a location 0.9 miles west of Smith Siding on highway 23.

These soils are described in more detail in the Manitoba Soil Survey Reports (12), (13), (11).

The cultural history of the three soils indicated that the cultivated samples had been under cultivation for 50 to 60 years.

IV. LABORATORY INVESTIGATIONS

A. Rates of Nitrification

(1.) Method

One-hundred-gram samples of the six soils were ground to pass a 1 mm. sieve and placed in glass jars. Two moisture contents, 60 and 90 per cent of field capacity were maintained in the soils during incubation. The soil was incubated at inside and outside temperatures. The inside temperature was the temperature in the laboratory which was fairly uniform at 72° F. The outside temperature was obtained by incubation of the soil samples outdoors thereby giving a closer representation of soil temperature under field conditions. The outside temperature during the incubation period of May 5th to June 30th, 1955, was a mean of 60° F. The samples were incubated for periods of 3, 7, 14, 28, and 56 days. The experiment was replicated four times. Thus there were two samples from each association (virgin and cultivated), two moisture contents, two temperatures, five incubation periods and four replicates making 160 flasks for each soil association. At the end of the respective incubation periods the soil nitrification was stopped by drying the soil at 55° C.

The nitrate nitrogen was determined by the phenoldisulphonic acid method of Harper (20). Fifty grams of soil was used in this determination. A 250 ml. solution of 0.02 N copper sulfate was used to extract the nitrates. One hundred and fifty millilitres of the colored extract was treated with 0.2 gm. of calcium hydroxide, 0.5 gm. of magnesium carbonate and one half teaspoon of charcoal to remove the soluble organic matter and give a colorless extract. This was filtered and the first 20 ml. of filtrate discarded. A 5 to 10 ml. aliquot of the filtrate, depending on the nitrate content, was evaporated to dryness. The residue was dissolved in 3 ml. of phenoldisulphonic acid, diluted with water and the nitrate color developed with 4 N ammonium hydroxide. The solution was then diluted to 100 ml. and color intensity determined using the Coleman Universal spectrophotometer. Nitrate concentration in the solution was determined by comparison of spectrophotometer readings with a standard curve made using potassium nitrate. The concentration of nitrogen as nitrate was calculated as ppm. of the oven dry weight of soil.

(2.) Results and Discussion

Results on nitrate production upon incubation of the soil samples are given in Table 1. Analysis of variance of these data is presented in Tables 2, 3, and 4.

With all the soils studied the rate of nitrification was significantly affected by temperature, incubation period, type of soil (virgin and cultivated) and moisture content. The virgin clay loam had a greater rate of nitrate increase than the cultivated clay loam soil. In the very fine sandy loam slightly more nitrate was released from the virgin than from the cultivated sample but the difference was not as great as in the clay loam soil. Results with the clay soil show that the cultivated sample produced more nitrate nitrogen than the virgin sample.

The fact that temperature significantly affected the rate of nitrification may be of practical significance. The generally low temperature that occurs in the spring in Manitoba soils may explain in part the low rate of nitrification and therefore the response of crops to nitrogen fertilization.

The lower rate of nitrification in the virgin clay soil may be due to the presence of carbonaceous matter, such as grass roots. Numerous investigators suggest that in the presence of a large supply of carbonaceous matter, nitrogen is utilized by the increased number of micro-organisms and therefore is not converted to nitrate.

Table 1: Nitrate increase during incubation

Soil	Temperature	Moisture in % of field capacity	Nitrate content at start	Increase of nitrate-N in ppm. over initial nitrate content at: 3 days	7 days	14 days	28 days	56 days
Newdale C.L.-V *	inside	60	2.9	25.9	33.0	36.6	37.4	53.1
Newdale C.L.-C *	inside	60	8.0	9.1	10.5	14.4	14.0	18.3
Newdale C.L.-V	inside	90	2.9	23.7	39.0	48.7	51.1	56.9
Newdale C.L.-C	inside	90	8.0	10.7	12.1	12.0	26.0	1.7
Newdale C.L.-V	outside	60	2.9	16.3	23.2	32.7	32.9	28.6
Newdale C.L.-C	outside	60	8.0	9.1	10.1	11.1	9.5	11.0
Newdale C.L.-V	outside	90	2.9	19.0	24.4	34.6	33.6	36.9
Newdale C.L.-C	outside	90	8.0	6.6	6.6	10.4	13.8	18.3
Stockton V.F.S.L.-V	inside	60	2.9	11.1	12.6	19.0	22.6	20.1
Stockton V.F.S.L.-C	inside	60	7.1	7.3	9.7	15.9	17.9	18.7
Stockton V.F.S.L.-V	inside	90	2.9	11.0	16.9	21.1	27.4	24.6
Stockton V.F.S.L.-C	inside	90	7.1	8.0	11.4	20.0	20.4	22.4
Stockton V.F.S.L.-V	outside	60	2.9	5.9	10.9	12.7	11.9	15.9
Stockton V.F.S.L.-C	outside	60	7.1	5.0	7.0	11.3	9.2	13.9
Stockton V.F.S.L.-V	outside	90	2.9	4.9	13.2	14.2	13.1	19.4
Stockton V.F.S.L.-C	outside	90	7.1	5.0	4.8	10.8	11.2	14.4
Red River C.-V	inside	60	2.3	8.0	10.7	18.2	48.5	34.0
Red River C.-C	inside	60	13.9	10.2	21.2	26.7	35.6	45.1
Red River C.-V	inside	90	2.3	13.0	10.8	17.8	24.5	45.0
Red River C.-C	inside	90	13.9	22.1	27.1	34.7	36.6	53.9
Red River C.-V	outside	60	2.3	0.1	4.8	15.2	14.7	10.2
Red River C.-C	outside	60	13.9	1.3	1.7	26.2	17.6	24.4
Red River C.-V	outside	90	2.3	1.8	7.2	18.3	16.5	13.2
Red River C.-C	outside	90	13.9	2.5	8.9	24.5	27.4	30.1

V: virgin

C: cultivated

Table 2: Analysis of variance of data from the nitrification study with Newdale clay loam soil.

Source	S.S.	D.F.	M.S.	F
Temp.	2203.0	1	2203.0	144.9 **
Times	4079.1	4	1019.7	67.1 **
Types	20050.2	1	20050.2	1318.9 **
Moisture	290.8	1	290.8	19.13 **
Temp. x time	178.9	4	44.7	2.94 *
Temp. x types	921.1	1	921.1	60.6 **
Temp. x moisture	21.4	1	21.4	1.41
Times x types	1538.5	4	384.6	25.3 **
Times x moisture	277.2	4	69.3	4.56 **
Types x moisture	195.2	1	195.2	12.84 **
Temp. x times x types	642.7	4	160.7	10.57 **
Temp. x times x moisture	582.4	4	145.6	9.58 **
Temp. x types x moisture	58.5	1	58.5	3.85
Times x types x moisture	148.8	4	37.2	2.45 *
Temp. x times x types x moisture	176.8	4	44.2	2.91 *
Error	1826.1	120	15.2	
Total	33190.7	159	208.7	

* Significant at the 5 per cent level.

** Significant at the 1 per cent level.

Table 3: Analysis of variance of data from the nitrification study with Stockton very fine sandy loam soil.

Source	S.S.	D.F.	M.S.	F.
Temp.	1498.2	1	1498.2	325.7 **
Times	2750.2	4	687.6	149.5 **
Types	398.2	1	398.2	86.6 **
Moisture	119.4	1	119.4	25.95 **
Temp. x time	252.3	4	63.8	13.86 **
Temp. x types	1.5	1	1.5	0.33
Temp. x moisture	38.6	1	38.6	8.39 **
Times x types	64.6	4	16.2	3.52 **
Times x moisture	47.1	4	11.8	2.57 *
Types x moisture	8.9	1	8.9	1.93
Temp. x times x types	55.4	4	13.9	3.02 *
Temp. x times x moisture	4.7	4	1.2	0.26
Temp. x types x moisture	4.2	1	4.2	0.91
Times x types x moisture	26.9	4	6.7	1.46
Temp. x times x types x moisture	18.4	4	4.6	1.00
Error	554.1	120	4.6	
Total	5842.7	159	36.7	

* Significant at the 5 per cent level.

** Significant at the 1 per cent level.

Table 4: Analysis of variance of data from the nitrification study with Red River clay soil.

Source	S.S.	D.F.	M.S.	F.
Temp.	8271.3	1	8271.3	562.7 **
Times	13858.2	4	3464.5	235.7 **
Types	1855.0	1	1855.0	126.2 **
Moisture	513.3	1	513.3	34.9 **
Temp. x time	2118.7	4	529.7	36.0 **
Temp. x types	93.1	1	93.1	6.33 *
Temp. x moisture	24.6	1	24.6	1.67
Times x types	493.2	4	123.3	8.38 **
Times x moisture	462.7	4	115.7	7.87 **
Types x moisture	409.0	1	409.0	27.8 **
Temp. x times x types	253.1	4	63.3	4.30 **
Temp. x times x moisture	295.6	4	73.9	5.02 **
Temp. x types x moisture	58.2	1	58.2	3.95 *
Times x types x moisture	304.3	4	76.1	5.17 **
Temp. x times x types x moisture	577.5	4	144.4	9.82 **
Error	1766.5	120	14.7	
Total	31354.3	159	197.2	

* Significant at the 5 per cent level.

** Significant at the 1 per cent level.

B. Organic Matter Determination

(1.) Methods

(a.) Wet Combustion Method

The procedure for the wet combustion method is developed from methods of Adams (1) and Waynick (42) and modified by O. G. Caldwell in the laboratory of the Soils Department University of Manitoba.

The total carbon was determined by oxidizing a 1 gm. soil sample with 55 ml. of a chromic-sulphuric acid mixture. The carbon dioxide evolved was dried by passing it through a sulphuric acid bath and over calcium chloride and magnesium perchlorate crystals. Any chlorides present were removed by passing the gas over amalgamated zinc. The carbon dioxide was collected in a tared Nesbitt tube containing Ascarite. The weight of carbon dioxide evolved was converted to carbon.

The inorganic carbon was determined by digesting 2 gm. of soil with approximately 60 ml. of 1:10 hydrochloric acid. The carbon dioxide evolved was drawn through an absorption train consisting of a tube of Dehydrite and calcium chloride. The carbon dioxide was then collected in a Nesbitt tube containing Ascarite. Carbon dioxide was removed from the air entering the digestion flask by bubbling it through concentrated sodium hydroxide. The weight of carbon dioxide collected in the Nesbitt tube was converted to inorganic carbon.

The difference between the total and inorganic carbon gives the organic carbon content. The organic carbon when multiplied by the Van Bemmelen factor of 1.724 (Waksman (39)), gives an empirical organic matter content.

(b.) Loss on Ignition

The loss on ignition method of Rather (29) involved the removal of minerals from the soil which lose weight on ignition. This was done by successive digestions with 2.5 per cent hydrochloric acid and 2.5 per cent hydrofluoric acid.

One gram of soil of 1 mm. size was digested with two 50 ml. portions of water for 5 minutes on a boiling water bath. The water extract which contains water soluble organic matter was concentrated and saved for addition to the residue remaining after acid treatment. In soils with more than 3 per cent calcium carbonate two digestions (5 minutes each) were made on the residue with 20 ml. of 2.5 per cent hydrochloric acid, and 30 ml. of water. The soil residue was then subjected to a series of 6 digestions with 10 ml. of 2.5 per cent hydrochloric acid, 10 ml. of 2.5 per cent hydrofluoric acid and 30 ml. of water. The soil residue was washed with water and added to the concentrated water extract. This was evaporated to dryness and brought to constant weight at 100°C. The sample was then ignited at 960°C. and the loss in weight was multiplied by 100 to give the percentage of organic matter in the soil.

The soil nitrogen was determined by a modified Kjeldahl-Gunning-Arnold (4) method. One gram of soil was weighed into a Kjeldahl flask and digested for 30 minutes in 10 gm. of potassium sulphate, 0.3 gm. of copper sulphate, 0.7 gm. of metallic mercury and 25 ml. of concentrated sulphuric acid. After cooling, 200 ml. of water and 25 ml. of 8 per cent sodium hyposulphite solution were added. Sixty millilitres of concentrated sodium hydroxide and a few pieces of zinc metal were added and the ammonia released was distilled into an excess of 0.1 N sulphuric acid. The excess acid was back titrated with standard 0.1 N sodium hydroxide.

The carbon-nitrogen ratios were calculated by dividing the per cent organic carbon by the per cent nitrogen.

(2.) Results and Discussion

The results of the organic matter and nitrogen determinations are presented in Table 5. Nitrate increase in the soil in relation to nitrogen content are presented graphically in Figures 1, 2, and 3.

In the wet combustion method an empirical factor is used to convert the organic carbon to organic matter. The organic carbon percentage in organic matter varies and hence, this factor is only approximate. For this reason the loss on ignition method which determines organic matter directly was used. The results indicate that the factor of 1.724 was too small for converting the organic carbon to organic matter. A factor of 2.0 would have given results in better agreement with the loss on ignition method. In the discussion the organic matter figures referred to will be from the loss on ignition method.

A decline of 50.8 per cent for nitrogen, 51.2 per cent for organic carbon and 49.6 per cent for organic matter was obtained in the clay loam soil. The very fine sandy loam had a smaller loss amounting to 34.4 per cent for nitrogen, 30.0 per cent for organic carbon and 25.0 per cent for organic matter. Losses of nitrogen, organic carbon and organic matter were slight for the clay soil and amounted to 9.1, 30.1, and 15.8 per cent, respectively.

The effect of cultivation was not as great on the clay soil as on the other two soils. This may be attributed to cultural practices, texture, and erosion differences of the three soil types.

Figure 1, shows the relation of the nitrate increase to total nitrogen content in the clay loam soil. The virgin clay loam soil, not only had a greater per cent of total nitrogen than the cultivated clay loam, but a greater percentage of the nitrogen present nitrified under all comparable conditions. In the very fine sandy loam the cultivated soil nitrified a greater percentage of the nitrogen present (Figure 2). However, the difference in total nitrogen content between the virgin and cultivated soils was not as great. Similarly, in the clay soil in which the difference in total nitrogen content between the cultivated and virgin soil was small, a greater percentage of the total nitrogen was nitrified by the cultivated soil (Figure 3). From this it would appear that where the total nitrogen loss had not been too severe, cultivated soils would nitrify a greater percentage of the total nitrogen present. This may be due to better conditions for nitrification such as aeration, carbon-nitrogen ratio etc. in cultivated soils. Temperature affected the percentage of total nitrogen nitrified in a similar manner in all soils. The higher temperature caused a greater percentage of the nitrogen to be nitrified.

Table 5: Nitrogen and organic matter content of the soils

Soil	1 % Total Carbon	2 % Inorganic Carbon	3 % Organic Carbon	4 % Nitrogen	5 Carbon Nitrogen Ratio	6 Organic Matter By Wet Combustion	7 % Organic Matter By Loss On Ignition	8 % Organic Carbon In: Organic Matter	9 Organic Carbon Conversion Factor
			1 - 2		3 ÷ 4	3 x 1.724		3 as % of 7	7 ÷ 3
Newdale C.L.-V *	7.01	0.02	6.99	0.61	11.5:1	12.05	13.33	52.44	1.907
Newdale C.L.-C *	3.51	0.10	3.41	0.30	11.4:1	5.86	6.72	50.74	1.971
Stockton V.F.S.L.-V	3.20	nil	3.20	0.32	10.0:1	5.52	6.35	50.39	1.984
Stockton V.F.S.L.-C	2.24	nil	2.24	0.21	10.7:1	3.86	4.76	47.06	2.125
Red River C.-V	5.62	0.67	4.95	0.44	11.3:1	8.53	10.50	47.14	2.121
Red River C.-C	3.46	nil	3.46	0.40	8.7:1	5.97	8.84	39.14	2.555

V: virgin

C: cultivated

Figure 1. NITRATE INCREASE AS RELATED TO TOTAL SOIL NITROGEN AT OUTSIDE AND INSIDE TEMPERATURES AND AT A MOISTURE CONTENT OF 60 % OF FIELD CAPACITY IN A NEWDALE CLAY LOAM SOIL

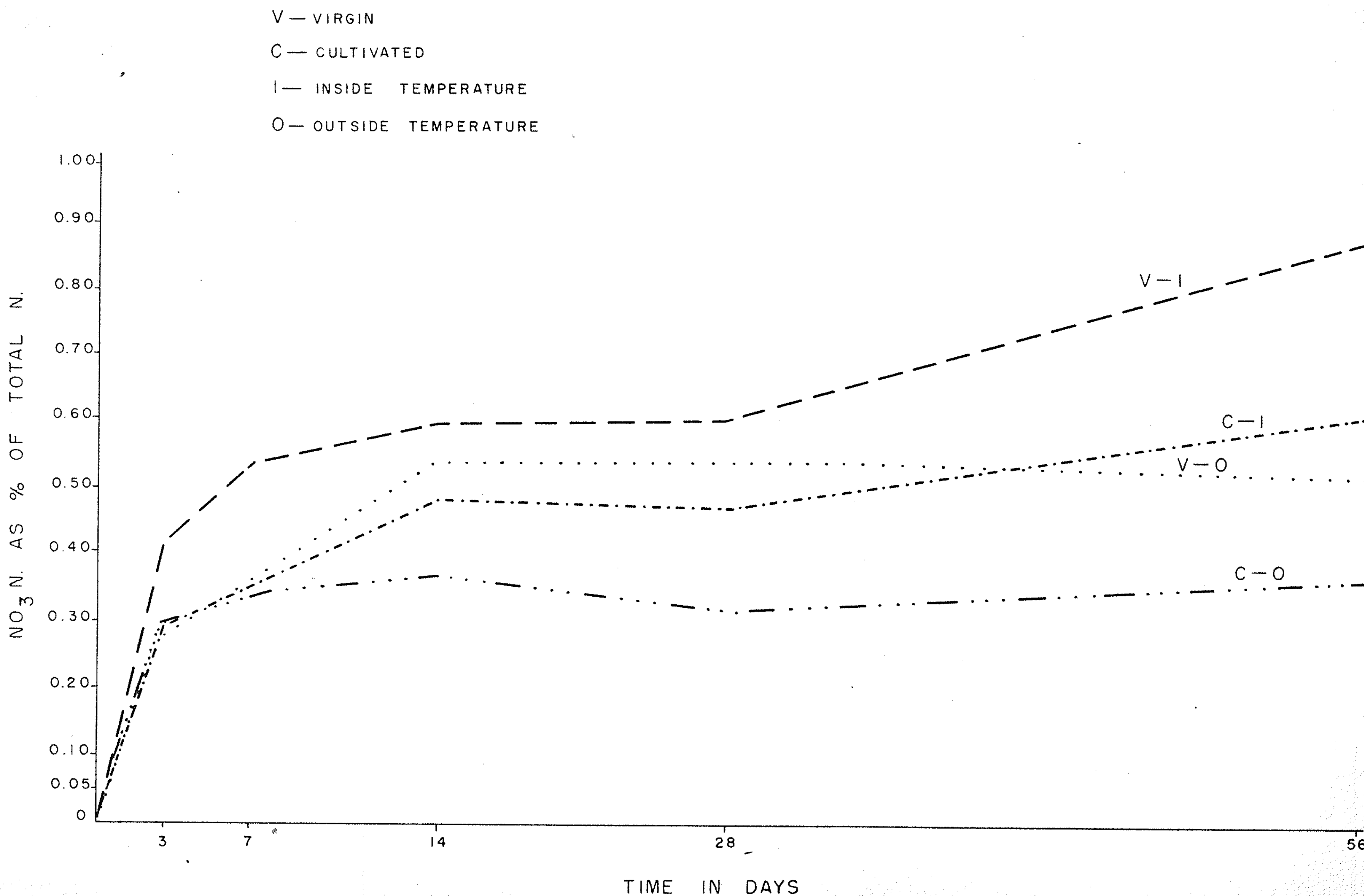


Figure 2. NITRATE INCREASE AS RELATED TO TOTAL SOIL NITROGEN AT OUTSIDE AND INSIDE TEMPERATURES AND AT A MOISTURE CONTENT OF 60 % OF FIELD CAPACITY IN A STOCKTON VERY FINE SANDY LOAM SOIL

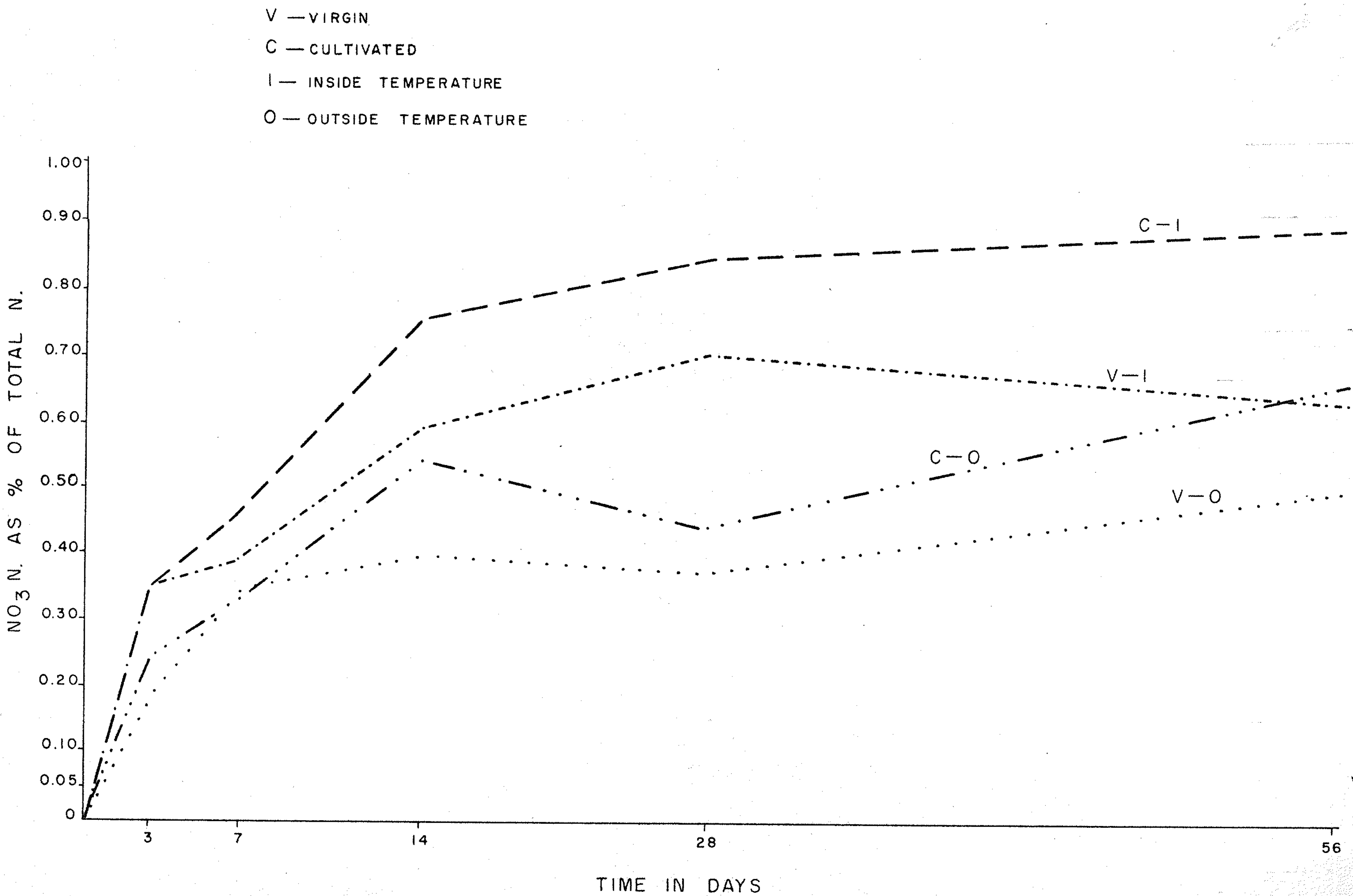
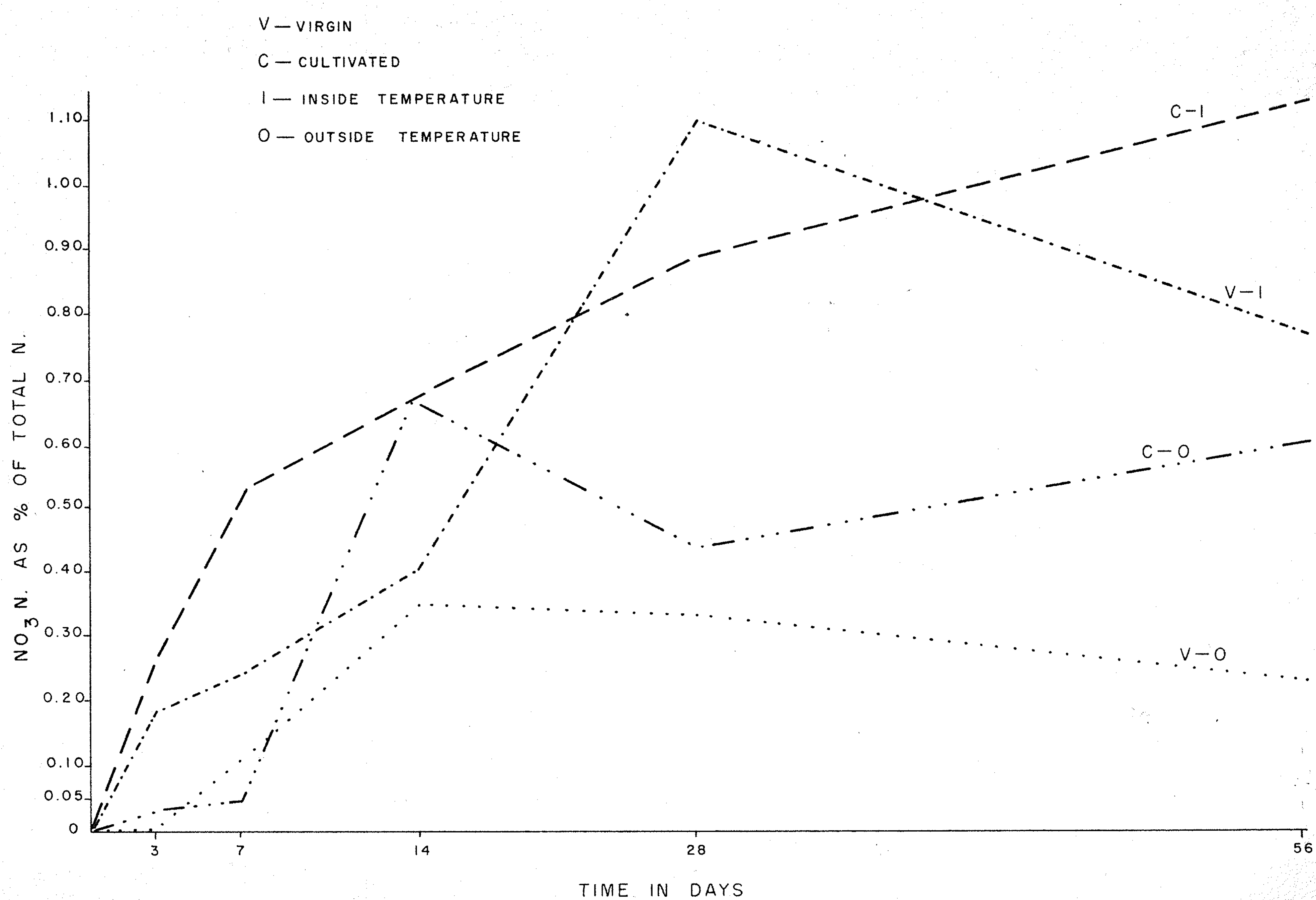


Figure 3. NITRATE INCREASE AS RELATED TO TOTAL SOIL NITROGEN AT OUTSIDE AND INSIDE TEMPERATURES AND AT A MOISTURE CONTENT OF 60 % OF FIELD CAPACITY IN A MORRIS CLAY SOIL



C. Determination of Nitrogen Distribution

(1.) Method

Fractionating methods similar to those used for protein analysis have been used to determine the nitrogen distribution, that is, the proportions of various forms of nitrogen in soils. The methods used by Rendig (30) and most other investigators involves the use of the Van Slyke (38) gas analysis method. The method used in this investigation is one described by Parker, Sowden and Atkinson (28) from which five nitrogen fractions were obtained.

Twenty five grams of soil was digested in 6 N hydrochloric acid for 24 hours under a reflux condenser. After cooling, the residue and acid hydrolyzate were separated with the centrifuge. The soil residue containing the hydrochloric acid insoluble nitrogen was dried and nitrogen determined by the Kjeldahl method. To the hydrochloric acid hydrolyzate 2 ml. of toluene was added as a preservative and the solution diluted to 1000 ml. with water. An aliquot of this acid hydrolyzate was taken and Kjeldahl nitrogen determined giving the total hydrochloric acid soluble nitrogen. Another aliquot of the acid hydrolyzate was made alkaline with calcium hydroxide and the ammonia released was determined by distillation into standard acid. The liquid remaining after distillation was centrifuged to separate the calcium hydroxide precipitate containing the humin nitrogen from the supernatant liquid containing the amine nitrogen. Nitrogen in these fractions was determined by the Kjeldahl method.

A further test for available soil nitrogen was carried out using a method developed by Truog (37). In this determination 0.5 gm. of 0.5 mm. soil was oxidized using a 1 gm. mixture consisting of 20 parts of potassium permanganate, 80 parts of anhydrous sodium carbonate and 150 ml. of ammonia free water. A small piece of paraffin was added to prevent foaming. The flask was placed on the distillation rack and brought to a boil in exactly five minutes, and boiled for five minutes. The distillate, which contains the nitrogen liberated as ammonia was distilled into 20 ml. of ammonia free water. The distillate was transferred to a 100 ml. volumetric flask, 2 ml. of Nessler's solution was added to develop the color and the resulting mixture diluted to 100 ml. with water. The color comparison was made on the spectrophotometer. The ppm. nitrogen was calculated from a graph made using standard solutions of ammonium sulphate.

(2.) Results and Discussion

The results of the nitrogen fractionation are presented in Table 6.

The cultivated soil samples contained a slightly higher percentage of nitrogen that was not extracted by the hydrolyzing treatment. The difference between the virgin and cultivated samples amounted to 2.30 per cent in the clay loam, 1.95 per cent in the very fine sandy loam and 0.91 per cent in the clay soil. Similarly, the percentage of the total nitrogen found in the amine fraction was higher in the virgin than in the cultivated clay loam and clay soils. In the very fine sandy loam there was little difference. The humin nitrogen fraction was consistently higher in the cultivated samples, particularly in the clay soil. These results are in agreement with those reported by Rendig (30), Bremner (6), and Morrow and Gortner (25).

The available nitrogen as measured by weak oxidation was found to be higher in the virgin samples in all cases. The virgin clay loam with a higher rate of nitrification than the cultivated clay loam also had a larger amount of available nitrogen. The virgin and cultivated very fine sandy loam soils which produced nitrate at about the same rate had a slightly greater amount of available nitrogen. In the clay soil, although the cultivated sample produced more nitrate nitrogen, the virgin sample had a slightly greater amount of available nitrogen. Some of the available nitrogen in the virgin clay may have been used by soil organisms in decomposing organic matter present in the form of grass roots. This may account for the discrepancy between the amount of available nitrogen as measured by weak oxidation when compared to nitrate accumulation.

Table 6: Nitrogen fractions.

Soil	HCL in-soluble-N		HCL soluble-N		NH3-N		Humin-N		Amine-N		Available
	% N	% Total-N	% N	% Total-N	% N	% Total-N	% N	% Total-N	% N	% Total-N	N in ppm.
Newdale C.-V *	0.23	37.70	0.39	63.90	0.12	19.67	0.06	9.84	0.19	31.15	292
Newdale C.-C *	0.12	40.00	0.18	60.00	0.05	16.67	0.05	16.67	0.06	20.00	178
Stockton V.F.S.L.-V	0.07	21.86	0.25	78.13	0.10	31.25	0.04	12.50	0.12	37.50	198
Stockton V.F.S.L.-C	0.05	23.81	0.16	76.19	0.05	23.81	0.03	14.29	0.08	38.10	170
Red River C.-V	0.15	34.09	0.30	68.18	0.13	29.555	0.04	9.09	0.12	27.27	244
Red River C.-C	0.14	35.00	0.27	67.50	0.13	32.50	0.08	20.00	0.05	12.50	210

V*--virgin

C*--cultivated

V. FIELD INVESTIGATIONS

(1.) Outline of Fertilizer Trials

Fertilizer trials with ammonium sulphate (21-0-0) at rates ranging from 100 to 300 pounds per acre were conducted on various farms in Manitoba. Both fall and spring applications of fertilizer were made. Fall applications of ammonium nitrate were also made at a rate comparable in nitrogen to the ammonium sulphate. In some cases the nitrogen applications were supplemented by ammonium phosphate (11-48-0). The nitrogen fertilizers were applied with a lime spreader prior to seeding in the spring of 1955. The fall applications were made in 1955, just prior to freeze-up. The ammonium phosphate was drilled in with the seed using the farmer's fertilizer attachment. The spring applications of nitrogen fertilizer were made in 10 foot strips across the ammonium phosphate treatments. These nitrogen strips were replicated at 10 intervals throughout the length of the ammonium phosphate treatments. The fall applications of nitrogen fertilizer in 1955, were made in 10 foot strips the length of the field. The ammonium phosphate was applied in the spring of 1956 on top of these nitrogen strips. Check strips were left between every consecutive nitrogen treatment. The fields used were from one quarter to one half mile long and had grown a cereal crop for one or more years since it was last summer fallowed.

Yields were obtained by taking ten one-square-yard samples at regular intervals throughout the length of each treatment. These samples were threshed, weighed and the yields calculated in bushels per acre.

(2.) Experimental Results

Tables 7 and 8 give the yield data obtained in 1955 and 1956, respectively. The yield data on the checks are the average of all checks found on that farm. The yields from each fertilizer treatment can be compared to the mean check yield at the top of each farm column. The calculation used to obtain the fertilizer yield figures in Tables 7 and 8 is as follows: actual treatment yield divided by the adjacent check yield times the average check yield. Thus yields of any fertilized strip can be compared statistically to their adjacent checks in order to show whether or not yield differences are significant.

Average yields of check plots were extremely low in 1955 due to unfavorable weather conditions such as a wet spring and intense heat at maturing time. The fertilizer effects are probably not as large as they would have been under more normal conditions.

Significant yield increases were obtained in every case for barley. Wheat showed no significant increase at 100 pounds ammonium sulphate but did at higher application rates. The application of ammonium phosphate in addition to ammonium sulphate significantly increased wheat yields as compared to checks but not as compared to ammonium sulphate treatment alone. Barley yields were greater where ammonium sulphate and ammonium phosphate were both used than where ammonium sulphate was applied alone. Oat yields were not affected to any great extent at the lower rates but significant yield increases were obtained at the high ammonium sulphate applications.

Crop yields in general were considerably higher in 1956 than in 1955 due to favorable growth conditions during most of the season.

Wheat did not respond to any great extent to the application of nitrogen. Barley and oats gave profitable yield increases with applications of ammonium sulphate. Where a good crop stand was obtained without fertilizer, applications of ammonium sulphate at rates above 200 pounds per acre reduced yields by causing severe lodging. The application of ammonium phosphate tended to alleviate the severity of lodging. Fall applications of ammonium sulphate gave larger yield increases than fall applications of ammonium nitrate, presumably because it is less susceptable to loss by leaching.

Table 7: Average yields in bushels per acre of barley, wheat and oats in 1955 as affected by ammonium sulphate (21-0-0) and ammonium phosphate (11-48-0).

Ammonium phosphate # / acre	Ammonium sulphate # N / acre	Barley Farm 1	Barley Farm 2	Barley Ave. Yield	Wheat Farm 3	Oats Farm 4
0	0	4.9	25.7	15.3	13.3	23.0
0	20	7.9**		7.9	14.4	25.6
0	30	10.4**	33.7*	22.1	16.9**	
0	40	13.6**		13.6	17.3*	27.8
0	60	17.7**	37.5**	27.6	16.3*	32.4**
40	0	5.8	27.4	16.6	13.5	
40	20	8.2**		8.2	15.6	
40	30	12.6**	41.0 **	26.8	14.9	
40	40	17.8**		17.8	16.7**	
40	60	23.2**	48.0 **	35.6	17.6*	
60	0	8.0**	36.9 **	22.5	14.2	
60	20	13.5**		13.5	15.3	
60	30	13.4**	46.5**	30.0	17.1**	
60	40	15.7**		15.7	16.2**	
60	60	24.7**	47.1**	35.9	18.5**	

* Significant yield increases with adjacent check plot at 5 per cent level.
** Significant yield increases with adjacent check plot at 1 per cent level.

Farm 1 - Red River Clay
Farm 2 - Dauphin Clay
Farm 3 - Red River Clay
Farm 4 - Marquette Clay

Table 8: Average yields in bushels per acre of barley, wheat, and oats in 1956 as affected by ammonium sulphate (21-0-0), ammonium nitrate ($33\frac{1}{2}$-0-0) and ammonium phosphate (11-48-0).

Ammonium phosphate # / acre	Nitrogen fertilizer # / acre	Barley Farm 1	Barley Farm 2	Barley Farm 3	Barley Ave.	Wheat Farm 4	Oats Farm 5
0	none	31.7	32.7	16.5	27.0	37.8	59.2
0	100# 21-0-0		27.6		27.6		
0	200# 21-0-0	51.4**	34.8	20.8**	35.7	38.0	59.4
40	100# 21-0-0	39.5**	38.4		36.0		73.9*
40	200# 21-0-0	53.9**	37.0	24.0**	38.3	42.2	77.4**
40	300# 21-0-0	48.2**	27.2		37.7	42.1**	91.3**
40	125# $33\frac{1}{2}$-0-0	35.0	36.3		35.7	42.5	73.1*

* Significant yield increase over adjacent plot at 5 per cent level.
** Significant yield increase over adjacent plot at 1 per cent level.

Farm 1 - Dauphin clay
Farm 2 - Dauphin clay
Farm 3 - Marquette clay
Farm 4 - Banks very fine sandy loam
Farm 5 - Newdale clay loam

VI. SUMMARY

The investigations carried out on three soils in Manitoba and reported herein were undertaken for the purpose of determining the effect of cultivation on the availability of soil nitrogen. This information was necessary in an attempt to explain the response obtained at present with nitrogen applications.

Comparative virgin and cultivated samples of three soils common to Manitoba were used in this study. The soils used were a Red River clay (Morris Associate), a Stockton very fine sandy loam and a Newdale clay loam.

Laboratory studies were made to determine the rate of nitrification, organic matter content, nitrogen content, and the nitrogen distribution. The investigations have shown that cultivation affected the organic matter, nitrogen content and nitrogen distribution in the clay loam soil to such an extent that rate of nitrification was reduced considerably. In the very fine sandy loam and clay soil, cultivation had caused a smaller loss in organic matter and nitrogen and appeared to increase nitrification of the nitrogen fraction remaining.

The field investigations involved a study of the effect of ammonium sulphate on cereal crop yields. The ammonium sulphate was applied both in spring and in fall at varying rates. In some cases the ammonium sulphate was supplemented by ammonium phosphate. Fall applications of ammonium sulphate and ammonium nitrate were compared. Both nitrogen carriers gave significant yield increases but ammonium sulphate appears to be more effective than ammonium nitrate if fertilizer application is to be made in the fall of the year.

VII. CONCLUSIONS

1. The most rapid accumulation of nitrates occurs in the first 14 days of incubation.
2. The rate of nitrification is significantly affected by temperature, incubation period, type of soil (virgin or cultivated) and moisture content.
3. Cultivation was responsible for a large decline in organic matter, organic carbon and nitrogen content. The clay loam soil was affected more than the very fine sandy loam and clay soils. The difference of losses may be attributed to differences in cultural practices, soil texture and degree of erosion on the three soil types.
4. Where the loss of organic matter and nitrogen was large, rate of nitrification was more than proportionally reduced. However, where organic matter and nitrogen content have not been seriously reduced by cultivation the rate of nitrification tends to be higher in the cultivated than in the virgin soils.
5. The amine nitrogen, being easily decomposed, is readily lost when a soil is subjected to cultivation while humin and unhydrolyzable nitrogen, being fairly resistant, remain.
6. The amount of available nitrogen as measured by weak oxidation with potassium permanganate is higher in virgin than in cultivated soils.
7. The weak oxidation test for available nitrogen is no indication of more rapid nitrification in virgin soils as compared to cultivated soils except where the difference

in total nitrogen is large.

8. Significant yield increases of cereal grains grown on non-fallow land can be obtained with ammonium sulphate applied at rates of 150 to 200 pounds per acre.

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