NITRATE STUDIES IN A MANURED AND UNMANURED SOIL UNDER A CONTINUOUS WHEAT CULTURE

by

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A Thesis submitted in Partial Fulfillment
of the Requirements for the
Degree of Master of Science
in the
Oklahoma Agricultural and Mechanical College
Department of Agronomy
May 1923

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INTRODUCTION

During recent years much study has been devoted to the influence of cropping systems and fertilizers on the soil flora. In turn, the influence of soil flora on crop production has received wide attention. The results of these investigations, however, even up to the present time are of preliminary studies and before the exact relationship of all the factors involved are discovered a great deal more experimenting will have to be done. There is no doubt but that the lower forms of flora found in the soil have an influence on the growth of higher plants.

Fertilizers have been used a number of years to produce greater yield of crops but no definite conclusions can as yet be drawn as to the relationship of the fertilizer to the soil flora for all soils under general conditions.

The purpose of this paper is to give some light to these problems from an Oklahoma soil standpoint. The work as has been carried on here has been wholly physiological rather than botanical, limiting the subject to the nitrate forming bacteria with special reference to the intensity of their work. The reason for taking up the physiological side is largely from the practical standpoint. It is thought that from the agricultural view the knowing of the extent of activity is of more value generally than

of knowing the exact organisms producing the results. However, both are important. The work was limited to nitrate production because of the high commercial value assigned to commercial nitrogenous fertilizers; also many investigations have shown that nitrogen is taken up, at least to some extent, by most plants in the nitrate form. Nitrogen also is quite commonly deficient in soils, especially where a continuous culture of grain has been grown and no straw returned or other material containing nitrogen added.

Besides these, it is known that all nitrates are soluble and if not used by the soil organisms or higher plants they are apt to be lost by leaching, as the soil has no appreciable power of fixing them.

HISTORICAL.

(6) Stevens and Withers observed that the nitrifying power of North Carolina soils was low but could be increased by cropping to legumes and by the action of stable manure.

(5) Lyon and Bizzell made a study of the relation of certain higher plants to the formation of nitrates in soils. They found evidences indicating this possible relationship. They observed that the rate of nitrification of plots of soil planted to alfalfa and timothy respectively was much more rapid in the alfalfa soil. This quality was found to persist in the soil one or two years after the crops were removed.

Under oats and millet there appeared to be an increase of nitrates during the very early stages of growth but this quickly disappeared as the growth proceeded. With the maize plant nitrates

tended to accumulate until the middle of the growing season. Another conclusion made was that the character of the plants grown may affect the rate of nitrification but not the limit of nitrate accumulation in the soil. It was also observed that changes in moisture content or temperature after early summer had no appreciable effect on the nitrates found under plants.

(3)Brown and MacIntire found a difference in the nitrate content of soil under different crops for the growing season ranging from 35.5 parts per million under maize to 1.4 parts per million under grass.

(4) Fraps shows that the nitrification test may be of value in tracing the effects of crops on the soil. It was found that cropping decreased the nitrogen which could be converted into nitrates and that this condition was fairly constant with a large number of soils worked with.

(8) Whiting and Schoonover report as a conclusion of four years work that, "The most important factor in increasing nitrate production is soil treatment. Climatic factors control the course of nitrate production, but the amount of production is dependent upon soil treatment". These investigators also observed that the cropping system had an influence on nitrate production. Where a rotation containing a legume as a green manure was followed the soil showed a marked superiority in nitrate production. They found that active organic matter greatly increased the amount of nitrates in the soil used (brown silt loam). They further report results indicating that the largest removal of nitrates from a

soil growing wheat is during the stage of rapid leaf development and maturity in the spring. In their experiments the best nitrate-producing plots supported the most rapid growth and the wheat crop began reducing the nitrate supply of these plots earlier than on the poorer nitrate producing plots.

(1) Allen and Donazzi show that with a continuous wheat culture in the 19th year on Wooster silt loam (Ohio), nitrate production is much higher on the manured plot than on the untreated plot.

(2) Brown shows that the cropping system has an influence on the bacterial activities of a soil. He observed that, in general, rotations produced a beneficial effect on the nitrifying power as compared to a continuous cropping with corn.

(7) Stewart and Greaves found under Utah conditions that the nitric nitrogen of oat land disappeared rapidly during the last few weeks of the growth of the plant.

HISTORY OF THE SOIL AND TREATMENT

The soil on which the studies presented in this paper were conducted belongs to the Kirkland series as surveyed by the United States Department of Agriculture, Bureau of Soils.* It ranges from a loam to silt loam in character. This is a common Oklahoma upland. It is characterized by having a brown to chocolate brown color, a more or less impervious hardpan subsoil, and gently rolling to level topography. The subsoil is of such an impervious nature that very little if any percolation or leaching takes place. Very often the surface drainage is not extra good, but the particular piece of land used for these experiments has a gentle slope toward the northeast which gives it fair surface drainage.

**Up to 1893 the land used in this experiment was in a virgin condition. At that time an acre was set aside for continuous culture of wheat. In 1893 the acre was divided into two sections of one-half acre each thereby creating the two plots commonly called in this paper the "manured" and "unmanured" plots. The unmanured plot has never had any material added. The only source of organic matter it has received is that left by the stubble and roots of the wheat plants. The following gives the treatment of the manured plot.

Date of Application	Rate of Application
July 1893	15 tons of manure per acre
July 1899	11 " " " " "
July 1904	18 " " " " "
Nov. 1911	24 " " " " "
Feb. 1913	12 " " " " "
July 1916	12 " " " " "
July 1920	12 " " " " "

*The Soil survey map of the Oklahoma Experiment Station Farm--United States Department of Agriculture, Bureau of Soils.

**Reported in Press BulletinNo.172; Oklahoma Experiment Station Records.

GENERAL METHODS USED

Three locations were made on each of the two plots, one near the east end, another near the west end and still another about the middle. The samples were collected in one pound tin boxes using a spatula to transfer the soil. The boxes and spatula were sterilized with alcohol.

In collecting the samples of soil, the surface inch was removed, then the soil from an area about 12" by 8" was dug up to a depth of 6 inches. This was thoroughly mixed and a sample taken.

The samples were taken to the laboratory. Moisture determinations were made and nitrates determined immediately. One hundred gram samples of soil calculated on a moisture-free basis were used in making the nitrate determinations. In each of these determinations water equal to twice the weight of the dry soil was added along with 2 grams of calcium hydrate. They were then vigorously shaken for twenty minutes. At the end of this time they were filtered and an aliquot portion of each taken and nitrates determined by the phenol-di-sulphonic acid method, using a Schreiner colorimeter and aqua ammonia as an alkali.

For the nitrification tests one hundred gram samples of soil calculated on a moisture-free basis were weighed out and placed in sterilized glass tumblers. To each of these one hundred milligrams of ammonia sulfate were added. The samples were then made up to a moisture content of 25 percent and incubated for a period of four weeks. At the end of this period the nitrates were determined as stated above.

Nitrate incubation studies were carried on under various con-

ditions, namely, in the greenhouse, open room, and out-doors.

In the nitrate percolation tests 100 gram samples of soil were placed in glass percolators and the nitrates present leached out by using 500 cubic centimeters of water for each sample. These percolators were allowed to incubate for a period of three months and at regular one month intervals the nitrates were leached out and determined.

NITRIFICATION UNDER GREENHOUSE CONDITIONS

These tests were conducted for a period of two months; each individual test covering a period of one month. The samples were placed under as near as possible optimum temperature for the development of plant life. The test eliminates the influence of the growing wheat plant in removing nitrates during the period of incubation. A relative index of the nitrifying power of the different soil treatments is thus obtained.

Table 1. gives the results of these experiments. It was found as a general average for two months that the manured plot produced a much larger quantity of nitrates than the unmanured plot. During the first month the difference was not so wide as during the second month, but the total quantity of nitrates present at the end of each test showed the manured plot contained almost twice as much nitrates as the unmanured plot.

During the first month the nitrates in the manured plot gained 104% over its initial content, while the unmanured plot gained 133% over its initial content. The initial content of the manured plot was more than twice that of the unmanured plot.

For the second month the manured plot gained 368% over its initial nitrate content, while the unmanured plot gained but 46%. In this case the initial content was practically the same, although a little higher in the manured plot.

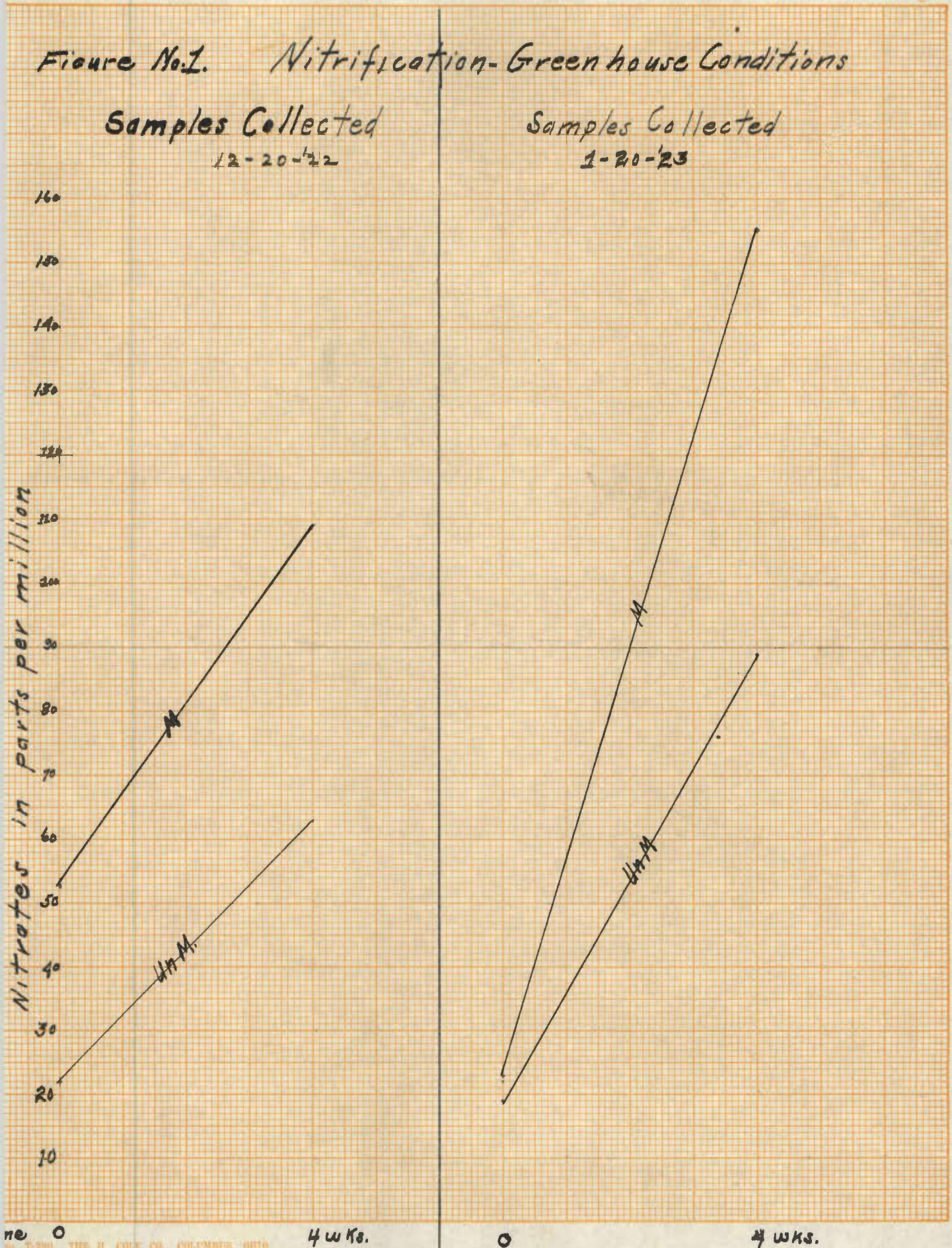
As a general average for the two months the nitrates produced under the manured and unmanured treatments compare 93.93 to 32.63 respectively, or 1.88 times higher for the manured soil.

Table No. 1. Nitrification ___ Greenhouse Conditions
(Nitrates expressed in parts per Million)

Plot Location and * Treatment.	December 20–January 20			January 20–February 16			2 mos. Average	
	Nitrates			Nitrates			Nitrates	General average for Treatment Plot.
	Present at Start.	Present at End.	Produced	Present at Start.	Present at End.	Produced	Produced	
1 M E	70.83	152.00	81.17	26.40	177.33	150.93	116.05	
1 M C	50.65	79.00	19.35	26.40	126.00	101.60	60.47	93.93
1 MW	30.66	98.00	67.34	16.80	160.00	143.20	105.27	
2 Un E	33.72	101.00	67.28	30.00	126.00	96.00	81.64	
2 Un C	17.16	50.00	32.84	14.50	90.80	76.30	54.57	55.63
2 Un W	16.24	39.50	23.16	13.00	51.20	36.20	30.66	
Average								
Manured	53.71	109.67	55.95	23.20	155.11	131.91		93.93
Unmanured	22.41	63.50	41.09	19.17	89.33	70.16		55.63
Ratio of manured to unmanured:	1.36					1.73		1.66

* : M E = East end of manured plot — Un E = East end of unmanured plot.
: M C = Central part of manured plot — Un C = Central part of manured plot.
: M W = West end of manured plot — Un W = West end of unmanured plot.

Fioure No.1. Nitrification- Greenhouse Conditions



NITRIFICATION IN OPEN ROOM CONDITIONS

To get a measure of the nitrifying power of each soil when under less favorable conditions, samples were collected from each plot, made up to 25% moisture and placed in an open room to incubate. These experiments were run for two months, samples being placed to incubate each month. Table 2. gives the results of these experiments.

Under these conditions the largest quantity of nitrates was found in the manured soil. The manured soil contained at the end of the first month over twice the amount of nitrates present in the unmanured soil. Although the total amount was much greater in the manured soil, nitrification proceeded faster in the unmanured plot when measured by the initial quantity present in each soil. The total gain in production of nitrates on the manured plot was 1.48 times that of the gain on the unmanured plot for the first month. As a general average for the two months the manured plot produced under open room conditions 2.24 times as much nitrates as the unmanured plot.

Table No. 2. Nitrification Open Room Conditions.
(Nitrates in P. P. M)

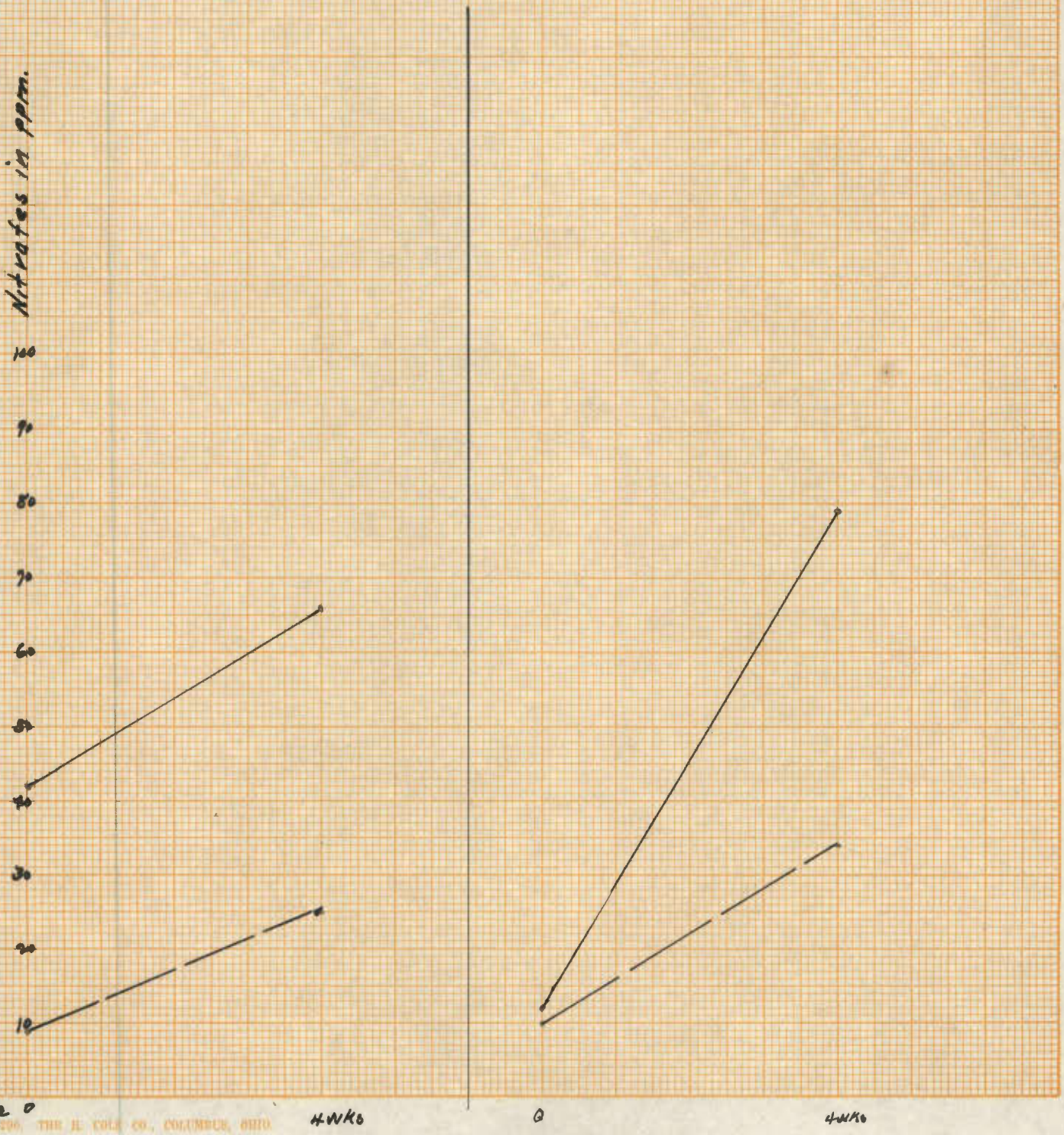
Plot, Location, and Treatment	February 16 March 16 Nitrates			March 16 --April 14 Nitrates			2 Mons. Total. Nitrates Produced	2 Mos. Average.	General average for plot and Treatment
	Present at Start	Present at End	Produced	Present at Start	Present at End	Produced			
1 M E	52.00	73.53	21.53	26.66	123.33	94.67	162.20	56.10	
1 M C	50.66	71.11	20.45	6.00	62.00	56.00	76.45	38.22	45.11
1 M W	26.00	54.05	26.05	4.00	54.00	50.00	76.05	39.02	
2 Un E	10.00	30.00	20.00	3.33	32.80	29.47	49.47	24.73	
2 Un C	10.00	22.22	12.22	17.50	36.40	16.90	31.12	15.56	20.14 XX
2 Un W	9.00	24.00	15.00	40.00(?)	19.00	-21.00	-6.00	*	
Average									
Manured	42.89	66.23	23.34	12.22	79.11	66.89			45.11
Unmanured	9.67	21.41	15.74	10.41 XX	34.60 XX	24.16 XX			20.14 XX
Ratio of manured to Unmanured	1.46					2.76			2.24

* Less than at the start.
XX Excluding "Un W"
(?) Abnormal.

Figure No. 2 Nitrification - Open-room Conditions

Samples Collected
2-16-23
—— manured.
— — Unmanured.

Samples Collected
3-16-23



COMPARISON OF NITRATE PRODUCED UNDER ROOM AND GREENHOUSE CONDITIONS

Under greenhouse conditions nitrates were produced in much greater quantity for both soil treatments. The total for the two months under greenhouse temperature for the manured soil was 187.86 parts per million as compared to 111.16 for the unmanured. Corresponding figures for open room conditions are 90.23 and 40.30. Although the amounts were larger for the greenhouse temperature the general ratios of nitrate production under the two conditions for the two soil treatments bore out a similar fact that the manured soil had a greater nitrifying power. Under the greenhouse temperature the average ratio was 1.68 while for the open room temperature the ratio was 2.24. These comparisons are shown in Table 3.

(Table No. 3) Nitrates Produced. Summary of Greenhouse and Open Room Conditions.
(Nitrates Expressed in P. P. M)

Plot and Treatment	Dec. - January			January & February			February 16 - March 16			March 16 - April 14		
	Greenhouse Temperature						Open Room Temperature					
	Nitrates			Nitrates			Nitrates			Nitrates		
	PRESENT at Start	Present at end	Produced	Present at beginning	Present at end	Produced	Present at beginning	Present at end	Produced	Present at Start	Present at end	Produced
1 M E	70.65	152.00	81.17	26.40	177.33	150.93	52.00	73.53	21.53	26.66	121.33	94.67
1 M C	59.65	79.00	19.35	26.40	126.00	101.60	50.66	71.11	20.45	6.00	62.00	56.00
1 M.W	30.66	96.00	67.34	16.80	160.00	143.20	26.00	54.05	28.05	4.00	54.00	50.00
2 Un E	33.72	101.00	67.28	30.00	126.00	96.00	10.00	30.00	20.00	3.33	32.80	29.47
2 Un C	17.16	50.00	32.84	14.50	90.80	76.30	10.00	22.22	12.22	17.05	36.40	18.90
2 Un W	16.34	39.50	23.16	13.00	51.20	36.20	9.00	24.00	15.00	40.00	19.00	-21.00
Average: Manured			55.95			131.91			23.34			66.89
Unmanured			41.09			70.16			15.74			24.18 xx
Ratio Manure to Unmanured			1.36			1.88			1.48			2.76

* Less than at Start

xx Excluding Un W.

NITRIFICATION DURING THE DRY SEASON

The activity of the nitrifying organisms during the dry seasons of the year was studied by collecting samples during July, raising them to optimum moisture content and placing them to incubate for a period of three weeks under open room conditions. The temperature during this period was rather high. Often it was as much as 90 F. or more in the shade during the day time. The temperature of the night ranged about 70 F. The soils were collected when the moisture content was about one-half that of optimum growth condition.

The results of this experiment are shown in Table 4. This table shows that nitrifying organisms were present and when moisture conditions are made favorable nitrification took place more rapidly than during the winter months under open room conditions. During the month February 16 to March 16, 1923 the manured plot contained at the end but 66.23 parts of nitrates per million, (Table 2) while for the three weeks ending July 24, 1923 99.50 parts of nitrates per million were found in the same soil. The unmanured soil gave very similar results.

As to the comparative power of the two treatments, the manured soil was much superior to the unmanured. At the end of the experiment the manured soil contained 99.50 parts per million to the unmanured soil's 57.16 or 1.74 times as much nitrate nitrogen.

(Table No. 4)

Nitrification during the Summer. Nitrates present at the end of 3 weeks incubation July 1-24, 1922.

(Nitrates express in parts per Million)

Plot No.	Location	Treatment	Moisture content at sampling	Sample 1	Sample 2	Averages
1	East end	Manured	13.84 %	120.00	50.00	99.50
1	West end	Manured		106.00	120.00	
2	East End	Unmanured	11.96 %	66.66	60.00	57.16
2	West End	Unmanured		46.00	54.00	
Ration of manured to Unmanured						1.74

GREENHOUSE VERSUS OUTDOOR NITRIFICATION

To get a further index of the nitrifying power of the two soil treatments a comparison was made of the nitrates produced under greenhouse and outdoor conditions. The outdoor samples were placed north of a building so as to be out of the direct rays of the sun. The greenhouse samples were placed under as near optimum temperature as possible for the development of nitrates. Table 5 shows the comparison . This table shows the greenhouse conditions gave the highest amount of nitrates for both treatments, yet the ratio existing for the nitrifying power of the two treatments remains about constant. This determination was made during the time the wheat in the field made some of its most pronounced growth as is shown below

	Height of Wheat in Field		
Treatment	At Beginning	One-half of period of incubation	End of Incubation
Manured	7inches	14 1/2 inches	25 inches
Unmanured	3 1/2 inches	8 1/2 inches	16 inches

The outdoor conditions then existing are shown to be favorable to growth in general.

(Table 5)

Comparison of Nitrification Under Greenhouse and Out door Temperature (April 1-30, 1923)

(Nitrates expressed -parts per million)

Plot, Treatment and Location	nitrates present at start	Greenhouse Temperature (nitrates produced)	Ratio of manured to Unmanured	Out Door Temperature nitrates produced	Ratio of Manured to Unmanured.
1 M S	6.25	124.95	3.03	60.48	2.88
1 M C	6.25	137.75		51.08	
1 M W	7.50	152.50		82.50	
2 Un S	4.00	54.00		25.60	
2 Un C	6.28	45.72		23.32	
2 Un W	4.86	37.14		18.47	

A summery of the nitrification experiments given in Table 8 indicates that the manured plot is far superior to the unmanured plot in producing nitrates. As a general average from December 1922 to May 1923 the manured plot averaged 104.53 parts per million nitrates to 47.73 parts per million for the unmanured plot. This gives a ratio of 1 to 2.19 in favor of the manured plot. At no time during the period was the nitrification for the unmanured plot equal to that for the manured plot.

(TABLE 6)

Nitrification ___Summary of all Conditions giving total nitrates present
(Nitrates expressed in parts per Million)

PLOT	Dec. & Jan. greenhouse	Jan. & Feb. greenhouse	Feb. & Mar. open room	Mar. & Apr. open room	Apr. & May outdoors	April & May greenhouse	General average	General Average per plot	Ratio
1 M E	144.00	202.66	73.53	136.66	66.67	131.20	120.67		
1 M C	80.00	120.00	71.11	70.00	57.33	144.00	90.24	104.53	
1 M W	100.00	140.00	54.05	44.00	90.00	160.00	102.67		
2 Un E	120.00	132.00	30.00	33.60	29.60	60.00	63.23		
2 Un C	50.00	92.00	22.22	36.80	29.60	52.00	46.83	47.73	
2 Un W	35.00	46.00	24.00	20.00	23.33	42.00	33.17		
1 M E	160.00	152.00	----	104.00					
1 M C	78.00	136.00	80.00	54.00					
1 M W	96.00	160.00	60.00	62.00					
2 Un E	82.00	120.00	___	32.00					
2 Un C	50.00	89.60	29.09	36.00					
2 Un W	44.00	54.40	16.50	16.00					
Ratio	1.72	1.73	2.60	2.71	2.58	2.82	2.19		

A STUDY OF THE NITRATE CONTENT OF THE FIELD SOIL DURING THE DORMANT STAGE OF THE WHEAT

This test was started at about the time the wheat began to show stoppage of growth for the fall. At this time the wheat on the manured plot had stooled fairly well and although not having a large growth was much ahead of the unmanured plot.

Table 7 shows the nitrates found in the soil from this time up to the time that spring growth started. For the most part this table shows a small activity of the nitrifying organisms at this period. The amount of nitrates in the plots remained fairly constant during the period as a general average, although the results of January nineteenth were low for the manured plot and the results of January twelfth high for the unmanured plot. Causes for these discrepancies cannot be accounted for unless it was that during the few days preceding January twelfth unusually warm weather occurred which might not only have stimulated the activity of the nitrate organisms for that time but also started the wheat somewhat, as the determination on January nineteenth showed unusually low results on the manured plot, and somewhat low results on the unmanured plot.

The lowering of the results on February sixteenth was most likely due to the starting of the activity of the wheat plant, because on March second a general lowering of the nitrates on the manured plot took place, although this can hardly account for the low results on the unmanured plot. From about this time on, the nitrates in the manured plot began to reduce in amount due to

rapidity of plant growth in relationship to the activity of the nitrate producing organisms. The general reduction began on the unmanured plot at a later date.

A further comparison (Table 8) of the two month, January and February, shows that although very little nitrates were formed, the wheat on the manured plot was in a much better state so far as nitrates were concerned to start off spring growth. As a general average the manured soil contained at least twice as much nitrates as the unmanured soil at the beginning of the month of February.

On the sixteenth of February the analysis showed the manured soil containing more than four times the nitrates present in the unmanured soil. It is possible, though, that spring growth, which was evident a few days following by the outward appearance of the wheat, had actually started at this time. In any case the nitrates present were in greater quantities during these months in the manured soil.

(TABLE No. 7)

Nitrates Present During Dormant Stage of Wheat
(Nitrates expressed in parts per Million)

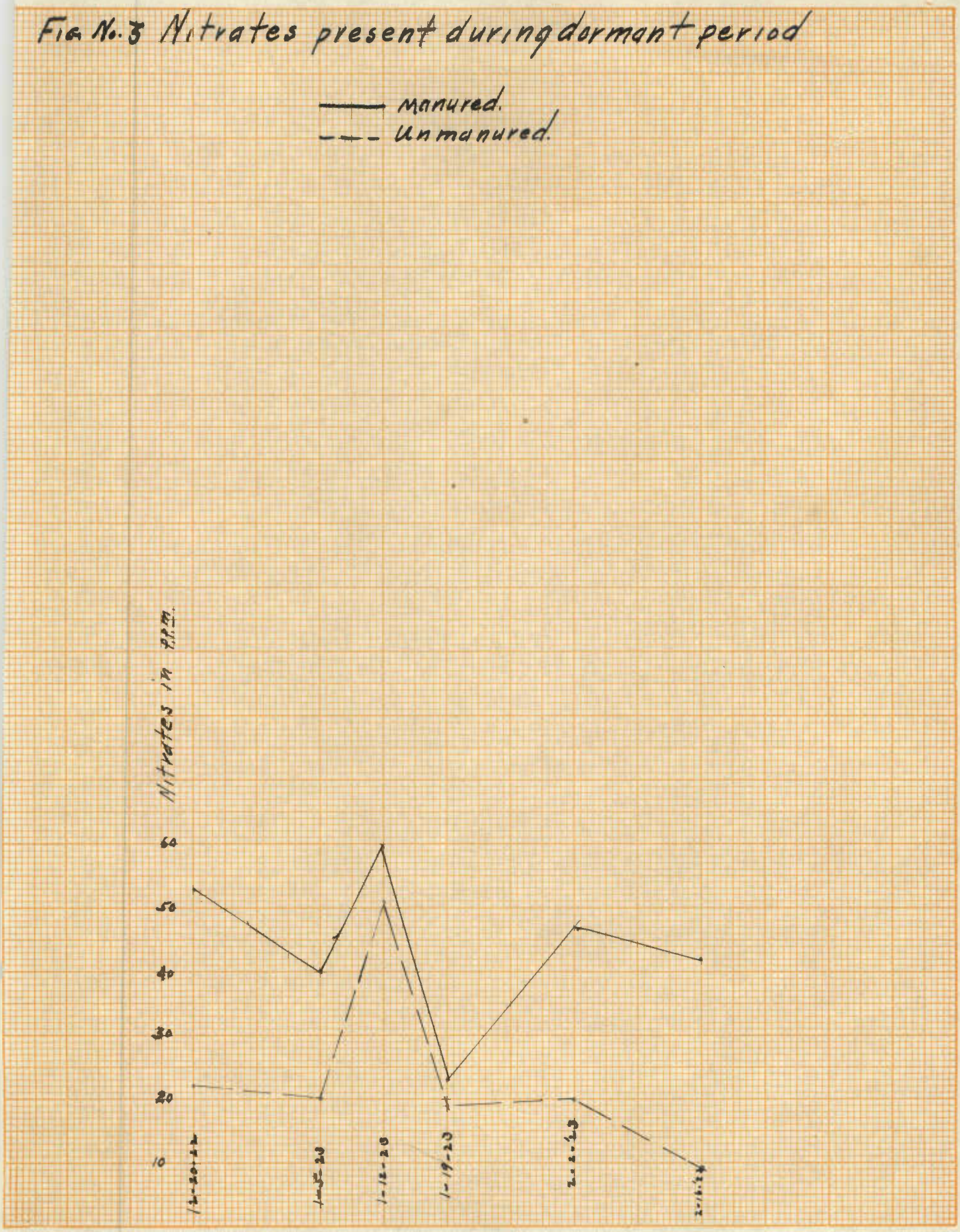
Plot, and Location	Dec. 20 1922	Jan. 5: 1923	Jan. 12: 1923	Jan. 19: 1923	Feb. 2: 1923	Feb. 16: 1923	Average of: Location	Average: of Plot:
1 M E	70.63	32.17	44.65	26.40	43.33	52.09	46.23	
1 M C	59.65	35.65	76.00	36.40	60.00	50.66	51.72	43.47
1 M W	30.66	31.11	57.33	16.80	36.00	26.00	33.48	
2 Un E	33.72	29.56	56.00	30.00	35.00	10.00	32.38	
2 Un C	17.16	14.76	52.00	14.50	12.50	10.00	20.15	25.84
2 Un W	16.34	17.63	48.33	13.00	12.50	9.00	19.00	
Averages:								
1 Manured:	53.71	40.64	59.99	25.20	47.11	42.60	___	43.47
2 Unmanured	22.41	20.72	51.11	19.17	20.00	9.67		25.84
Ratio of manured to Unmanured								1.82

(TABLE No. 8)

Comparison of Nitrates present during January and February
(Nitrates expressed in P. P. M)

Plot, Treatment and Location	JANUARY				FEBRUARY			
	5th.	12th	19th	Average	2nd.	16th.	Average	
1 M E	32.17	44.65	26.40	34.41	45.33	52.00	48.66	
1 M C	35.65	76.00	26.40	46.66	60.00	50.66	55.33	
1 M W	54.11	57.33	16.80	42.75	36.00	26.00	31.00	
2 Un E	29.56	56.00	30.00	36.52	35.00	10.00	11.25	
2 Un C	14.76	52.00	14.50	27.09	12.50	10.00	11.25	
2 Un W	17.83	45.23	13.00	25.35	12.50	9.00	10.75	
Average:								
Manured	40.64	59.99	23.20	41.26	47.11	42.89	45.00	
Unmanured	20.72	51.11	19.17	30.32	20.00	9.67	14.83	
Ration of manured to Unmanured				1.36			3.03	

Fig No. 3 Nitrates present during dormant period



NITRATES PRESENT IN THE SOIL DURING THE EARLY MONTHS OF WHEAT GROWTH

This part of these experiments (Table 9) shows that the nitrates were rapidly reduced during the early spring growth of the wheat plant. Not only was there a rapid reduction but the quantity of nitrates present reduced to a very small amount. During this period the following data were secured refarding the rapidity of wheat growth.

On March twentieth the height of the wheat on the manured plot averaged 3 1/ inches, while the unmanured wheat averaged but 2 1/2 inches. The manured wheat practically covered the ground while the unmanured wheat barely covered the drill lines. The height on March twenty-ninth showed the manured wheat averaged 7 inches, while the unmanured wheat averaged 3 1/2 inches. April fourteenth showed 14 1/2 inches for the manured and 8 1/2 inches for the unmanured wheat while on April twenty-fifth the manured averaged 25 to 16 inches for the unmanured.

Considering these growths and the amount of nitrates present in the soil (Table 8 and 9) the results indicate that the wheat plant removed nitrates from the soil rapidly during this period.

The data also shows that the larger amount of total nitrates present in the manured soil (Table 7) at the beginning of spring growth most likely had an influence in the greater growth of the wheat plant on this plot over that of the wheat on the unmanured plot.

(TABLE No 9)

NITRATES PRESENT DURING THE FIRST 2 MONTHS OF THE SPRING GROWING SEASON
(Nitrates expressed in parts per Million)

Plot, Treatment and Location	MARCH 2nd	MARCH 16th.	MARCH 26th.	APRIL 14th.	APRIL 26th	Average for the 57 days Period
1 M E	25.71	26.66	6.25	50.00	7.50	23.22
1 M C	66.66	6.00	6.25	4.60	5.00	17.74
1 M W	12.00	4.00	7.50	9.60	4.25	7.47
2 Un E	21.50	3.33	4.00	3.40	2.50	6.05
2. Un C	25.33	17.50	6.25	3.40	2.33	10.57
2 Un W	7.60	40.00	4.85	5.60	4.00	18.41
Ratio of Manured to Unmanured						1.62

SUMMARY OF NITRATES PRESENT IN THE SOIL

Table 10 gives the summary of nitrates present in the soil for the two treatments. It also gives the amounts of moisture present in the soil at each sampling time.

A rather distinct line of demarcation for the lowering of the nitrate content of the manured soil is shown. Up to March second the average amount of nitrates present was between 40 and 50 parts per million with but one exception. After this date the nitrates lowered considerably as the growth of wheat occurred.

On the unmanured plot the general reduction of nitrates took place at a later date. Up to March sixteenth the general nitrate content was about twenty parts per million. The nitrate determination on March twenty eighth marked the beginning of the general nitrate reduction for this treatment. Growth data previously given along with this show the backward development of the wheat on the unmanured plot as compared to that on the manured plot.

(TABLE No. 10)

NITRATES FOUND IN THE SOIL

(Expressed as NO_3 in P. P. M)

Plot and Location	Dec. 20 1922	Jan. 5 1923	Jan. 12 1923	Jan. 19 1923	Feb. 2 1923	Feb. 16 1923	Mar. 2 1923	Mar. 16 1923	Mar. 28 1923	Apr. 14 1923	Apr. 28 1923
1 M E	70.63	32.17	44.65	26.40	85.33	52.00	25.71	26.66	6.25	50.00	7.50
1 M C	59.65	35.65	76.00	26.40	60.00	50.66	66.66	6.00	6.25	4.80	6.00
1 M W	30.66	54.11	57.33	16.80	36.00	26.00	12.00	4.00	7.50	9.60	1.25
2 Un E	33.72	20.56	86.00	30.00	35.00	10.00	21.50	3.33	4.00	3.40	1.50
2 Un C	17.16	14.76	52.00	14.50	12.50	10.00	25.33	17.30	6.25	3.40	.33
2 Un W	16.34	17.68	45.33	13.00	12.50	9.00	7.60	40.00	4.66	5.60	1.00

MOISTURE PRESENT AT TIME OF SAMPLING (EXPRESSED IN PER CENT MOISTURE FREE BASIS)

1 M E	16.69	13.54	10.00	13.36	27.23	16.14	18.00	22.00	15.65	22.99	25.53
1 M C	19.03	15.40	12.19	12.56	25.69	16.80	13.30	21.94	16.70	25.62	24.21
1 M W	16.67	14.21	10.25	10.49	21.55	17.64	12.50	21.39	13.79	26.19	26.96
2 Un E	19.95	12.54	9.65	10.27	21.26	17.90	16.10	22.16	15.51	22.14	24.93
2 Un C	14.09	12.79	15.53	11.16	19.11	17.00	13.20	19.65	13.11	21.03	25.91
2 Un W	14.79	12.67	16.19	11.65	20.41	15.89	16.20	16.15	13.51	20.79	25.88

Average of Nitrates found: (Expressed in P. P. M)

1 Manured	53.71	40.64	59.99	32.20	47.11	42.69	34.79	12.22	6.67	21.46	15.58
2 Unmanured	20.48	21.72	51.11	19.17	20.00	9.67	17.47	20.27	5.05	4.13	2.94

Average Moisture content. (Expressed in per cent)

1 Manured	16.26	14.38	10.83	12.10	24.19	16.19	14.60	22.79	15.31	24.26	25.27
2 Unmanured	16.27	12.73	13.69	11.09	20.27	16.93	15.17	20.06	13.91	21.32	25.57

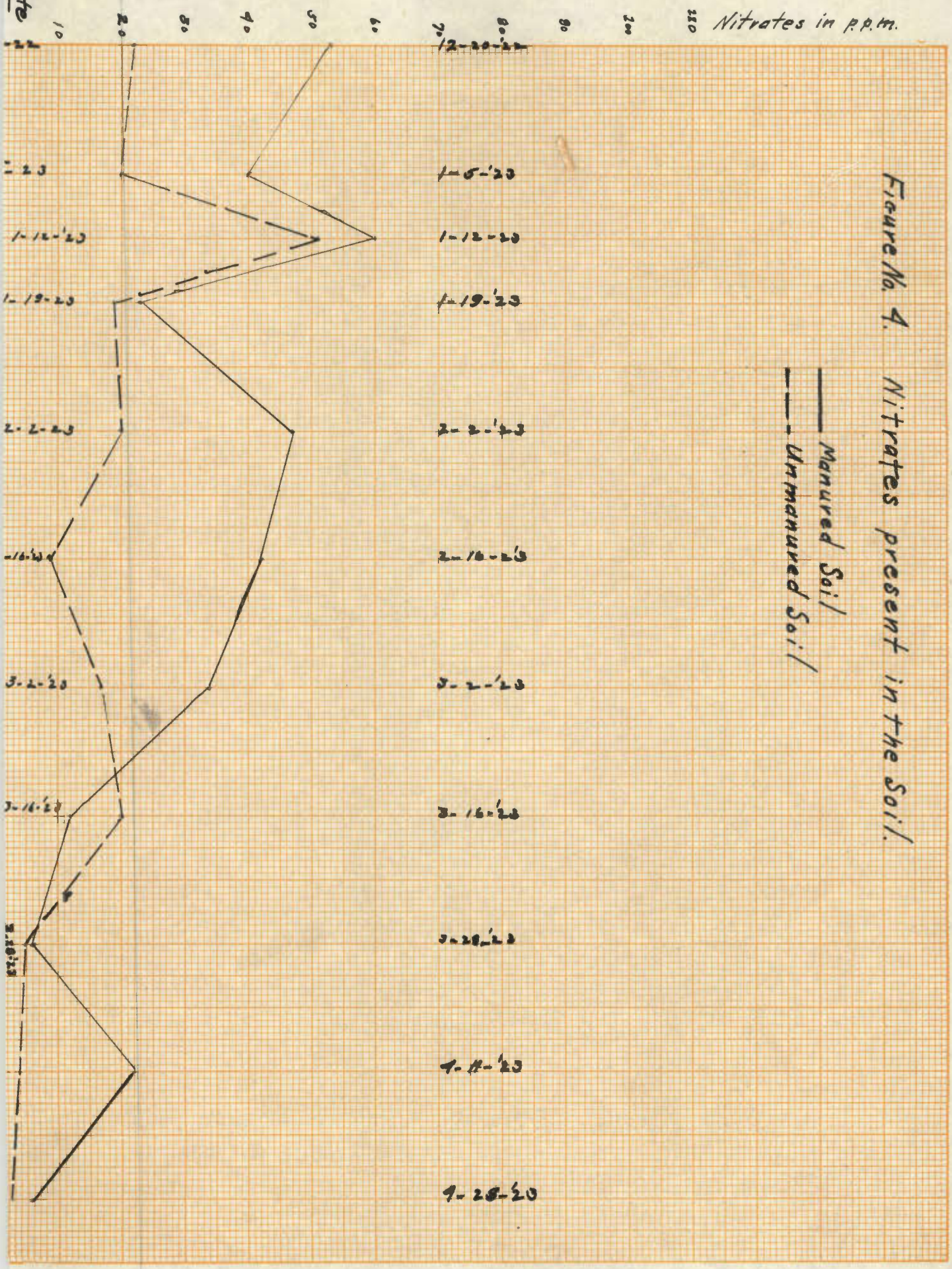


Figure No. 4. Nitrates present in the Soil.

NITRATES LEACHED OUT BY PERCOLATION

This test was conducted under open room conditions. It shows the production of nitrates in the two soils where the influence of the wheat plant is removed. At the beginning of the experiment the nitrates present were leached out with 500 c.c. of distilled water, and the determinations made as given in Table II. This table shows that the manured soil produced 1.10 times as much nitrates during the 3 months as did the unmanured soil. The moisture content of the percolators was not regulated. At the end of each percolation the soil was left in a more or less saturated condition and by the time the one month period was up for the next leaching the soil had fallen below the optimum moisture content for the growth of plants.

Table II.

Nitrates Leached Out by Percolation
(nitrates expressed in parts per million)

Treatment	Jan. 1	Feb 9	Mar. 9	Apr. 6	3 months average
Manured	1465	180	150	190	173.3
Unmanured	6.00	215	120	135	156.6
Rates of Manured to Unmanured					1.10

SUMMARY

1. Nitrates were produced in much larger quantities in the manured soil.

2. Nitrification experiments conducted in the greenhouse showed that the manured soil produced 1.68 times more nitrates than the unmanured soil for a period of two months.

3. Nitrification experiments conducted under open room conditions showed that the manured soil produced 2.24 times as much nitrates as the unmanured soil for a two months average.

4. Nitrification experiments conducted under open room conditions during July with optimum moisture present showed the manured soil produced 1.74 times the amount of nitrates produced by the unmanured soil.

5. Nitrification was greater under greenhouse conditions than outdoors for both manured and unmanured soils. Similar ratios existed in both cases favoring the manured soil.

6. The nitrates present in the soil for the two treatments during the dormant period showed the manured soil contained 1.82 times that of the unmanured as the general average for the two and one-half month period.

7. Spring growth started later on the unmanured plot as shown by both the height of the wheat and nitrates present in the soil.

8. The general average nitrate content for the manured soil was higher than that of the unmanured soil.

9. The percolation test showed 1.16 times the development of nitrates in the manured plot as in the unmanured plot for three months average production.

10. The manured soil was superior to the unmanured soil under all conditions studied, namely, nitrates present, nitrification and moisture retention and plant growth as they influence nitrates in general.

11. The amount of nitrates present in the soil under either treatment rapidly reduces as soon as spring growth of the wheat begins.

BIBLIOGRAPHY.

1. Allen A. R. and Bonazzi, A.

1915 On nitrification
Ohio Agr. Expt. Sta. Tech. Bul. 7

2. Brown, P. E.

1912 Bacteriological studies of field soils. 11 Effects of continuous cropping and various rotations.
Iowa Agr. Expt. Sta. Res. Bul. 6

3. Brown, B. E. and MacIntire W. H.

1910 Seasonal nitrification, soil moisture, and lime requirements in four plats receiving sulfate of ammonia.
Pennsylvania Agr. Expt. Sta. Rpt. 1909-1910

4. Fraps, G. S.

1921 Relation of soil nitrogen, nitrification and ammonification to pot experiments.
Texas Agr. Sta. Expt. Bul. 283

5. Lyon, T. L. and Bizzell J. A.

1913 Some relations of certain higher plants to the formation of nitrates in soils.
Cornell Univ. Agr. Expt. Sta. Memoir 1

6. Stevens and Withers

1912 Studies in Soil Bacteriology: V. The nitrifying and ammonifying powers of North Carolina soils.
Centr. of Bakt. (etc) 2 abt. Bd. 34 187-203
Original not read.

7. Stewart, Robert and Greaves J. E.

1909 A study of the production and movement of nitric nitrogen in an irrigated soil.

8. Whiting A. R. and Schoonover W. R.

1920 Nitrate production in field soils in Illinois.

Ill. Agr. Expt. Sta. Bul. 225