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Nitrate nitrogen accumulation in soils as affected by soil reaction and certain treatments

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NITRATE NITROGEN ACCUMULATION IN SOILS AS AFFECTED BY SOIL REACTION AND CERTAIN TREATMENTS.

by

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INTRODUCTION

Very early in the development of agricultural science the nitrogen supply of the soil was considered one of the important factors controlling plant nutrition. The nature of soil nitrogen in its relation to plant growth received special attention in the early investigations. Because of this it was found that altho the nitrogen supply may be large enough to meet the needs of growing plants, unless the nitrogen be changed into the nitrate form it is of little value. Hence, the power of a soil to change combined nitrogen into the nitrate form has been considered in late years to be one of the most important factors affecting its fertility.

It is commonly stated in the literature that the nitrifying power of a soil bears a rather close relation to its reaction, and that the reaction most favorable to nitrification is neutral or slightly alkaline. Statements to this effect have been based partly on theory and partly on a limited amount of research. Recent investigations, however, have proved that there are many exceptions to the general assumption of a correlation between the reaction of the soil and nitrification. Moreover, it has been shown that many other

TABLE OF CONTENTS

factors such as temperature, moisture, organic matter, fertilizers, and soil type play a very important role in nitrification.

With continuous cropping the soils of many localities have had their natural supply of nitrogen, phosphorus and potash reduced to such a low degree as to render crop production unprofitable. Hence, the addition of commercial fertilizers has become necessary in recent years. There are on the market many forms of nitrogen carriers which are sold to the farmer at a high price. Considering the state of our knowledge regarding nitrification and nitrogen absorption by plants, further study of the factors affecting nitrification has seemed justified.

SCOPE OF THESIS

The primary purpose of the investigations reported in this thesis was to study the relation of soil reaction to the process of nitrification. In addition, information regarding the effect of fertilizers, cropping systems and soil type, on nitrification, in their relation to the soil reaction, was sought. Altho the nitrification process is the objective, the investigation necessarily concerns itself mainly with the accumulation of nitrates.

Part I deals with the trend of nitrate accumulation in the presence of vegetation as influenced by soil reaction, fertilizer treatment and soil type under field conditions.

The investigations were conducted under a wide range of soil conditions. The fields considered are situated on the Experiment Station and College Farms, and are as follows:

1. Special Onion Plots, lower part of Brooks (Experiment Station) Farm; soil, a fine sandy loam of the Hartford series.

2. Block R (North Soil Test), Experiment Station, near Stockbridge Hall; soil, sandy loam of Hartford series.

3. North Corn Acre, Experiment Station, east of

Block R; soil, Merrimac sandy loam.

4. South Soil Test, Experiment Station, near Flint Laboratory; soil, sandy loam of Merrimac series.

5. West Field 3 (Middle Flat), Farm; soil, Hartford sandy loam.

6. Alfalfa Longevity Test, Experiment Station, West of Experiment Station green house; soil, sandy loam of Merrimac series. A detailed description of the soils will be given.

Part II deals with the trend of nitrate accumulation as in part I, but in the absence of vegetation and under laboratory conditions.

If the investigation were approached only under the conditions described under part I the results would be subject to certain limitations due to the different nitrate needs of the plants and loss of nitrates in the drainage. Under field conditions the nitrate accumulation in a soil as found by analysis can not be the true index of nitrification due to a treatment, but is an index of the excess of nitrate found at the moment when the sampling is done above that absorbed by growing plants and microorganisms and that lost in drainage and from other causes.

REVIEW OF LITERATURE

While it has been proved again and again that lime increases crop yields, the exact function of lime in connection with plant growth is not entirely understood. The universal belief held at present is that among other effects lime assists in the microorganic activities of the soil. Among the effects is the commonly alleged benefit to nitrification. The following literature is intended to bring together the views of the different workers on the subject.

Meek and Lipman (12) working with culture solutions, found that nitrate formation depends upon the soil reaction. The range of the pH value for optimum and maximum nitrification is considerably influenced by the medium from which the nitrifying bacteria were taken. The range for the pH value for organisms taken from garden soil was 5.4 to 13.0 while that from peat soil 4.1 to 9.5.

Kruger, W. (10) reported that both CaO and $CaCO_3$ exert favorable influence on the nitrifying bacteria, independent of the aeration and fertilizer treatments of the soil.

Waksman (20) states that alkaline reaction is essential for nitrate formation. In the absence of

basic carbonates only ammonium carbonate is oxidized, while in the presence of sodium, magnesium or calcium carbonates free ammonia as well as ammonium sulfate or phosphate can be nitrified. This is due to the fact that the optimum reaction for the organisms is on the alkaline side of neutrality (pH 7.0 - 8.0). The optimum reaction for the growth of the nitrate bacteria is pH 7.1 with pH 6.5 to 7.8 as limits. Waksman quotes the explanation of A. D. Hall and associates relative to the effect of small isolated particles of $CaCO_3$ on nitrification in very acid soils.

Scales, F. M. (15) reported that the nitrifying bacteria are most active in the presence of 50 per cent of the lime requirement by the "Veitch Method" and 75 per cent by the "Chemical Lime Requirement Method". Excess of lime in the form of $CaCO_3$ was found to be toxic to the nitrifying organisms.

Vogel (19) reported that lime is beneficial to all the microorganisms of the soil. The minimum lime required for azotobacter he estimated to be 0.1 per cent.

Bear, F. E. (2) reported that the greatest increase in soil microorganisms occurred when the pH value of the soil was 7.0. As the lime applications

increased from 250 to 5,000 pounds a consistent increase in nitrates took place. When the lime was increased to 7,500 pounds per acre a consistent decrease in nitrates followed. There was a marked increase in nitrates as the lime applications increased to 5,000 per acre, while higher applications, as high as 40,000 per acre caused but a very small increase.

Brown and Hitchcock (3) found that applications of limestone below 1.5 per cent stimulated nitrification while higher applications at a point between 1.5 and 6.1 per cent became toxic to the nitrifying bacteria.

Kellerman and Robinson (9) found that applications of lime in the forms of $CaCO_3$ as high as two per cent were favorable for the nitrifying bacteria.

Lyon and Bizzell (11) found that applications of lime until the soil was distinctly basic was beneficial to nitrification.

Temple, J. C. (18) reported that nitrification was found to take place in soils of lime requirement as high as 5,000 pounds of $CaCO_3$ per acre.

Stephenson, R. E. (17) found that application of lime from one to twenty tons per acre increased the nitrate accumulation in the soil. The greatest accumulation occurred with five tons of lime.

Potter and Snyder (13) found that lime facilitates the decomposition of organic matter in soils.

Shorey, E. C. (16) reported that lime stimulates the proper decomposition of organic matter which furnishes food for the nitrifying bacteria, and destroys the organic acids liberated by such decomposition, which may be very injurious to the organisms.

Brown and Lipman, (4) working with culture solutions and with sterilized soils found that lime applications increased the nitrification in the culture solutions and in the inoculated sterilized soils.

Withers and Fraps (22) reported that the addition of lime accelerates the nitrification of cotton seed meal and ammonium sulphate in soil. The sulphuric acid formed from the ammonium sulphate is neutralized by the lime, thus keeping conditions favorable for the nitrifying bacteria.

Whiting and Schooner (21) observed that the combined treatments of organic matter, lime and raw rock phosphate increased the nitrification of the soil much more than lime alone, organic matter alone, raw rock phosphate alone or the combined treatment of any two of the substances used.

Copson and Halversen (6) reported that the maximum nitrification in Oregon soils occurred when the pH value was 7.0 or a little above.

Fred and Graul (7) found that the kind of nitrogen and the texture of the soil are important factors in nitrification. In an acid soil organic nitrogen will nitrify more readily than $(NH_4)_2SO_4$.

Gowda, R. N. (8) observed that while raw rock phosphate brought about the greatest nitrate accumulation, acid phosphate increased the nitrifying power of the soil.

Barthel, C. E. (1) observed that nitrate formation takes place in acid, neutral and alkaline soils whether clays or loams. Nitrification of organic compounds takes place more readily than the inorganic, such as $(NH_4)_2SO_4$. Addition of CaO is of no advantage to the nitrification of animal manures but is distinctly beneficial to the nitrification of $(NH_4)_2SO_4$.

Prince and Blair (14) reported that the average nitrate accumulation in the unlimed plots with some exceptions, was greater than in the limed, but the crop yield was greater in the limed plots. The pH value of the soils was more variable in the unlimed plots than in the limed regardless of the fertilizer treatment.

Christie and Martin (5) reported that the chemical effects of CaO and $CaCO_3$ applications increase the solubility of water soluble potassium, magnesium, sulphates and phosphates.

SUMMARY OF LITERATURE

The literature reviewed indicates in general that lime promotes nitrification. To the general rule that a soil reaction neutral or above is necessary for optimum nitrification there are many exceptions which are not well understood. There is need for an extensive study of the interrelationship of soil reaction and other factors affecting nitrification.

While the problem of nitrification has been approached in many ways, very little work has been done in regard to practical application. Moreover, due to the fact that the use of commercial fertilizers have increased so rapidly in recent years, a study of their effect upon nitrification in connection with lime application has considerable practical value. Hence, the problem will be approached with that in mind.

ORIGINAL INVESTIGATIONS

METHODS EMPLOYED

PART I

A composite soil sample was taken every two weeks from the surface soil of each plot by making 20 - 25 borings to a depth of 7 inches by means of a one and one-half inch soil auger. The soil samples were at once placed in quart fruit jars, sealed and taken to the laboratory for moisture, nitrate, and hydrogen ion determinations. The phenol-di-sulphonic acid method as described in the Bureau of Soils Bulletin 31 for nitrate determination and the quinhydrone electrometric method for determining hydrogen ion concentration were used in all the work both for part I and part II. The temperature of the soils in the individual plots was also taken and recorded.

PART II

For this part of the work the soils under study were divided into 250 gram lots, received lime and fertilizer applications, brought up to 60 per cent of their water retentive capacity and then incubated at room temperature. At the end of 4 and 8 week incubation periods, samples for nitrate and hydrogen ion

determinations were taken and analyzed by the methods cited under the methods of part I. A more detailed explanation regarding the methods used in connection with this part will be given later.

SPECIAL ONION PLOTS

The soil on which the special onion plots are located is classified as Hartford sandy loam. The Hartford series includes the fine sediments deposited in the shallow waters of the glacial lake or estuary which filled the lowlands of this region within the glacial period. The field is level to gently rolling and well drained by land tiles. The soil contains more organic matter than other soils studied in this investigation.

In 1925 plots 87, 88, 105-N, 106-N, 106-S, 107-N, 108-N, 108-S and 127 were started for the study of the effect of lime upon onion growth. All plots received every year 4-8-4+ fertilizer at the rate of 2,500 pounds to the acre. The ingredients of the fertilizer were:

Sodium nitrate	134.9 pounds
Mono-ammonium phosphate (commercial)	188.4 "
Animal tankage	491.2 "
Acid phosphate	502.1 "
Muriate of potash	200.5 "

+Figures refer to NH_3, P_2O_5, and K_2O respectively.

Lime was added to the plots only at the beginning of the experiment. The plots under consideration were grouped and treated as follows:

Field plot number	Lime[+] treatment
125 and 127	None
87 " 105-N	2 Tons per acre
88 " 107-N	4 " " "
106 " 108-N	6 " " "
106 " 108-N	7 " " "

+"Agricultural" lime (about 60% CaO) used.

Samples for nitrates and pH value determinations were taken every two weeks from July 13, 1927 to August 24, 1927. The results are given in table I and figure 1, pages 15 and 16.

Table I.

Special Onion Plots.

(A) Nitrates; p.p.m. NO_3 Dry soil — (B) Acidity In Terms Of pH.

Treatment	July		August		Aver-age	July		August	
	13	27	10	24		13	27	10	24
No Lime	167.0	273.0	214.8	244.5	224.8	5.59	5.54	5.56	5.56
2 Tons Lime	122.0	142.8	136.2	149.0	137.5	5.86	5.73	5.78	5.81
4 Tons Lime	164.5	172.5	116.2	216.3	167.3	5.93	5.93	6.04	6.05
6 Tons Lime	183.0	170.5	116.0	156.3	156.5	6.31	6.28	6.41	6.36
7 Tons Lime	155.6	193.2	117.0	220.2	171.5	6.34	6.21	6.29	6.40

(C) Moisture Percentage, Dry Weight Basis — (D) Soil Temperature in Degrees Fahrenheit

Treatment	July		August		Aver-age	July		August		Average
	13	27	10	24		13	27	10	24	
No Lime	38.3	34.2	36.9	42.3	37.9	69	66	58	68	65.3
2 Tons Lime	33.2	35.6	37.9	38.2	36.3	69	67	58	68	65.5
4 Tons Lime	36.2	35.5	37.7	39.6	37.3	69	67	58	68	65.5
6 Tons Lime	37.3	36.9	38.3	40.8	38.3	69	66	58	68	65.3
7 Tons Lime	37.7	37.0	38.9	40.1	38.4	69	66	58	68	65.3

DISCUSSION OF RESULTS

From the data and graphs it may be seen that at the time of the first sampling, the maximum nitrate accumulation was brought about by 6 tons of lime. It may also be seen that there was an increase of nitrate accumulation in the soil as the lime applications increased from 2 to 6 tons, and that there was a marked decrease of nitrates as the lime application was increased from 6 to 7 tons. While there was a marked increase in nitrates as the lime applications increased, the nitrate accumulation in the no-lime plot was almost as great as that of the 6-ton lime plot, which had the highest nitrate accumulation brought about by lime.

The results of the second determination show that there was an increase of nitrates as the lime application increased from 2 to 4 tons, no increase from 4 to 6 tons, and an increase as the lime application was increased from 6 to 7 tons. The no-lime plot showed a much greater nitrate accumulation than that of the lime treated plots.

The maximum nitrate accumulation, at the time of the third sampling was brought about by 2 tons of lime, while there was practically no difference in nitrate

accumulation in the plots that received 4, 6 and 7 tons of lime. The no-lime plot had, by far, the greatest nitrate accumulation.

At the time of the last sampling the no-lime plot had the greatest nitrate accumulation. The maximum nitrate accumulation in the lime plots was brought about by 4 and 7 tons of lime, both having about the same amount of nitrates. Likewise the minimum nitrate accumulation was brought about by 2 and 6 tons of lime applications.

In regard to the pH value of the soil during the time from the first to the last sampling, there was a gradual increase as the lime applications increased. The range of the pH value of the soils at the time of each sampling was as given in table I (B).

CONCLUSIONS

The nitrate determinations show greater nitrate accumulation in the no-lime plots. This does not necessarily mean that in the limed plots there was less nitrification, for it was noted, and later supported by yield data, that the onions in the limed plots had better growth. This may explain the greater nitrate accumulation in the unlimed as compared with the limed plots.

Altho the pH value of a soil is greatly influenced by lime applications, it does not necessarily follow that as the pH value increases by the addition of lime an increase of nitrates will result.

SOUTH SOIL TEST

This field was set aside by the Experiment Station at the same time and for a similar purpose as the North Soil Test or Block R. The fertilizer treatment of this field is essentially the same as that given for Block R, page 26. The soil is classified as Merrimac sandy loam. The plots in connection with this work have received no fertilizer since the experiment started, except in the year 1922 when all plots received a uniform treatment of manure and commercial fertilizer. Lime was applied on all the plots in 1899 and in 1904 at the rate of one ton per acre, and again in 1907, one-half ton per acre. After 1907 no lime was applied on plot 5, while plot 6 received yearly 800 pounds of lime per acre until 1923, when the lime applications were discontinued. Various tilled crops and hay were grown until 1924 when the field was seeded with a mixture of grasses, clover and alfalfa. The relatively high proportion of alfalfa on the limed plot has been noticeable for several years.

The soil of this field is classified as Merrimac sandy loam. It is glacial till reworked by wind and water. The drainage here is good. The field is gently rolling toward the west.

Samples for nitrate and pH value determinations were taken every two weeks, July 11 to August 22. The results of these determinations together with graphic presentations are given on pages 22 and 23.

Table II.

South Soil Test

Date of Sampling	A Nitrates; p.p.m. NO_3 Unlimed	Limed	B Acidity in terms of pH Unlimed	Limed	C Moisture Percent Dry Basis Unlimed	Limed	D Temperature-Degrees F Unlimed	Limed
July 11	tr	tr	6.48	6.64	17.7	20.8	71	70
July 25	6.1	9.0	6.83	7.32	17.7	20.7	72	72
August 10	tr	3.2	6.48	6.89	22.6	23.9	71	69
August 22	tr	3.7	6.64	7.31	20.3	20.3	68	69
Average	1.25	3.8			19.6	21.4	70.5	70.0

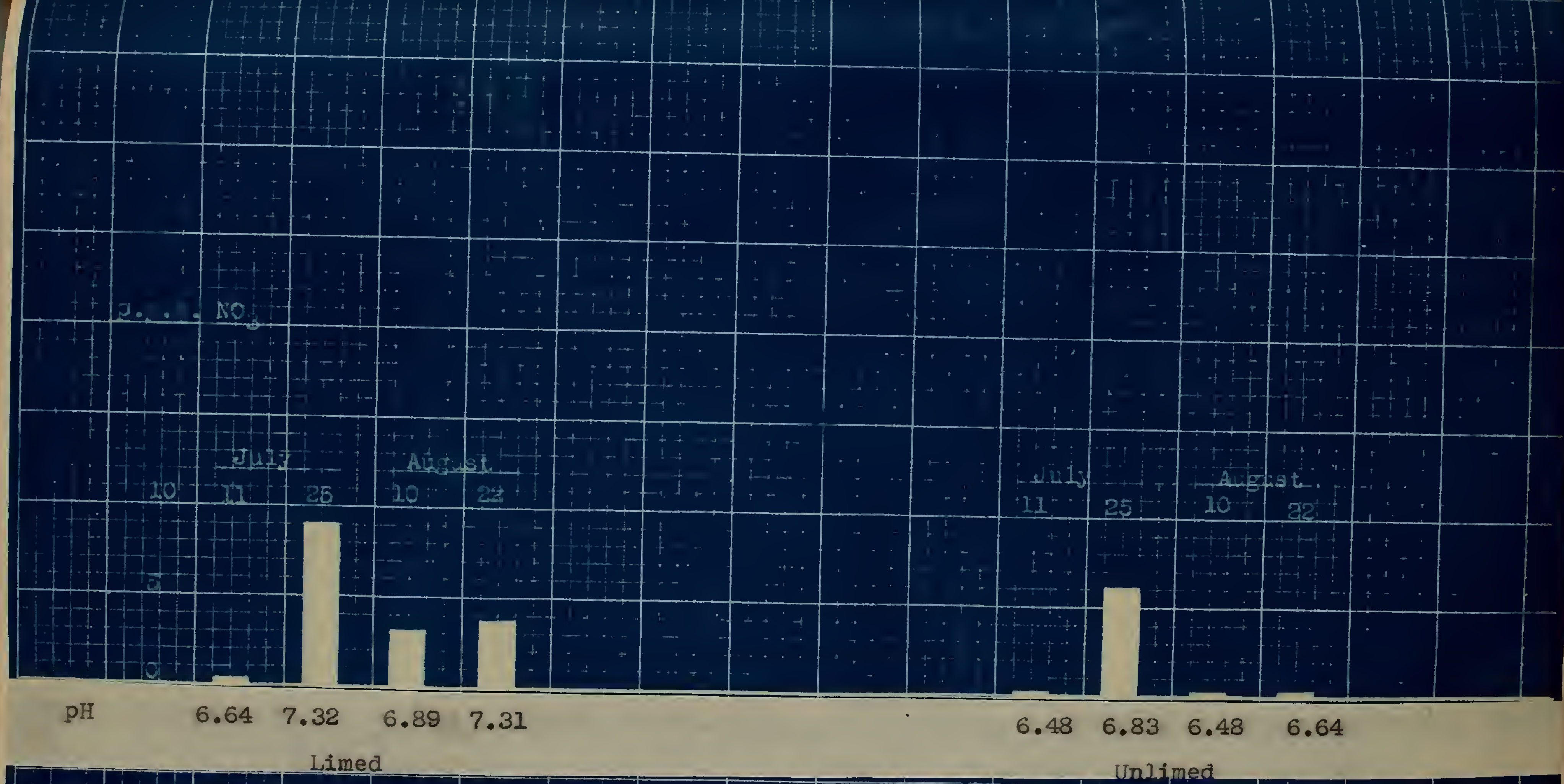

Figure 2, South Soil Test

DISCUSSION OF RESULTS

From table II given on page 22 and graphs on page 23, it will be seen that at the time of the first sampling there were only traces of nitrates in both limed and unlimed plots, a condition commonly found in growing sod.

At the time of the second sampling, while the nitrate accumulation was greater in the limed plot, in both the limed and unlimed plots the accumulation was greater than at the first sampling. This may be explained by the fact that the day after the first sampling the hay was cut so that accumulation took place while there was not enough vegetative growth to remove the nitrates during the following two weeks from the time of cutting.

At the time of the third and fourth samplings the nitrate accumulation was about the same in the limed plot and only traces in the unlimed.

In regard to the pH value of the two plots under consideration there does not seem to be great difference between that of the unlimed plot 5 and that of the limed plot 6. This shows that the residual effects of the lime added in, and before, 1907 were manifested in the pH value of plot 5.

The following conclusions are drawn.

1. Nitrates do not accumulate to a great degree in soils covered with sod containing a fair proportion of alfalfa.

2. Altho the nitrate accumulation was very small in both limed and unlimed plots, that of the limed plot was appreciably greater than that of the unlimed.

3. The considerable nitrate accumulation in both limed and unlimed plots at the time of the second sampling is attributed to the reduced vegetative growth during the time from the first to the second sampling.

BLOCK R

For thirty-six years prior to 1922, Block R was known as the "North Soil Test" and was used for growing truck and field crops under a fixed fertilizer program. To the lower (west) half of the field lime was added from time to time in addition to the fertilizer so that by 1916 it had received, in all, four and one-half tons of lime. After 1916 no more lime was added. In 1922 an orchard of apples, peaches, grapes and red raspberries was planted on the field. The old fertilizer program was continued with the exception of the bone-black which was replaced by acid phosphate when the orchard was planted. The present fertilizer program for plots sampled is given below.

Plot	Fertilizer treatment in lbs. per acre (annual)	
2	Sodium Nitrate	160 pounds
3	Acid phosphate	320 "
4	Check	
5	Potassium chloride	160 "
9	Acid phosphate	320 "
	Potassium chloride	160 "
10	Sodium nitrate	160 "
	Acid phosphate	320 "
	Potassium chloride	160 "
11	Gypsum	800 "
12	Check	

Table III (A) Nitrates (p.p.m. NO_3) Dry Soil Basis

Date of Sampling	Limed July 9	Limed July 23	Limed August 6	Limed August 20	Unlimed July 9	Unlimed July 23	Unlimed August 6	Unlimed August 20	Average Limed	Average Unlimed
Plot 2 - N	97.10	112.80	93.50	36.85	153.32	170.20	161.50	38.90	80.1	105.0
Plot 3 - P	16.00	31.60	43.20	11.10	15.40	35.27	42.70	6.98	25.5	25.1
Plot 4 - Check	16.20	39.55	31.15	11.80	20.61	31.20	23.03	4.80	26.4	20.0
Plot 5 - K	16.50	31.07	22.38	8.48	9.01	23.80	30.50	3.93	19.8	16.8
Plot 9 - P K	7.82	7.84	13.08	20.75	8.43	16.60	20.50	3.47	12.4	12.3
Plot 10 - N P K	24.90	40.83	29.90	12.95	42.88	52.55	36.10	6.47	27.2	34.5
Plot 11 - Gypsum	21.82	52.90	67.30	17.55	14.80	24.90	17.50	5.11	39.9	15.8
Plot 12 - Check	26.83	106.60	43.20	24.90	13.70	10.20	22.63	4.50	50.4	12.8

Table III (B) Moisture Percentage, Dry Soil Basis

Date of Sampling	Limed July 9	Limed July 23	Limed August 6	Limed August 20	Unlimed July 9	Unlimed July 23	Unlimed August 6	Unlimed August 20	Average Limed	Average Unlimed
Plot 2 - N	25.94	26.50	26.34	25.71	28.95	24.92	26.03	26.34	26.1	26.6
Plot 3 & P	28.37	26.66	26.34	27.15	26.34	23.92	24.38	25.47	27.1	25.0
Plot 4 - Check	29.12	28.04	27.63	27.80	26.42	24.92	25.79	25.39	28.2	25.6
Plot 5 - K	29.28	26.66	27.06	27.23	25.47	23.15	24.46	25.79	27.6	24.7
Plot 9 --P K	27.15	25.47	25.71	25.94	22.25	19.05	21.29	21.65	26.1	23.6
Plot 10 - N P K	27.55	24.30	25.87	24.77	31.23	19.90	21.80	21.43	25.6	23.6
Plot 11 - Gypsum	26.90	24.69	25.71	26.42	22.10	20.34	20.85	22.32	25.9	21.4
Plot 12 - Check	28.45	27.71	27.71	28.04	21.36	20.92	22.10	23.00	28.0	21.9

BLOCK R

Table IV (A) Acidity in Terms of pH

Date of Sampling		Limed July 9	Limed July 23	Limed August 6	Limed August 20	Unlimed July 9	Unlimed July 23	Unlimed August 6	Unlimed August 20
Plot 2	N	6.10	5.85	5.76	6.22	5.30	4.75	5.13	5.23
Plot 3	P	6.21	6.28	5.86	6.29	4.90	4.61	4.85	4.87
Plot 4	Check	6.28	6.40	6.10	6.19	4.87	4.58	4.75	4.68
Plot 5	K	6.14	6.29	6.12	6.17	4.83	4.60	4.74	4.85
Plot 9	P + K	6.24	6.31	6.14	6.24	4.78	4.68	4.74	4.80
Plot 10	N+P+K	6.36	6.28	6.28	6.24	5.03	4.85	4.95	5.03
Plot 11	Gypsum	5.98	6.09	6.05	6.10	4.85	4.82	4.78	4.78
Plot 12	Check	6.40	6.40	6.21	5.97	4.66	4.41	4.58	4.58

Table IV (B) Soil Temperature in Degrees F

Date of Sampling		Limed July 9	Limed July 23	Limed August 6	Limed August 20	Unlimed July 9	Unlimed July 23	Unlimed August 6	Unlimed August 20	Average Limed	Average Unlimed
Plot 2	N	60	67	59	59	58	66	60	60	61.3	61.0
Plot 3	P	60	68	60	60	58	66	60	59	62.0	60.8
Plot 4	Check	60	67	62	59	58	67	60	59	62.0	61.0
Plot 5	K	60	66	60	59	59	66	59	59	61.3	60.8
Plot 9	P+K	60	68	60	60	59	68	60	59	62.0	61.5
Plot 10	N+P+K	60	67	60	59	60	68	60	59	61.5	61.8
Plot 11	Gypsum	61	68	60	60	60	69	60	59	62.3	62.0
Plot 12	Check	61	66	60	59	59	68	61	59	61.5	61.8

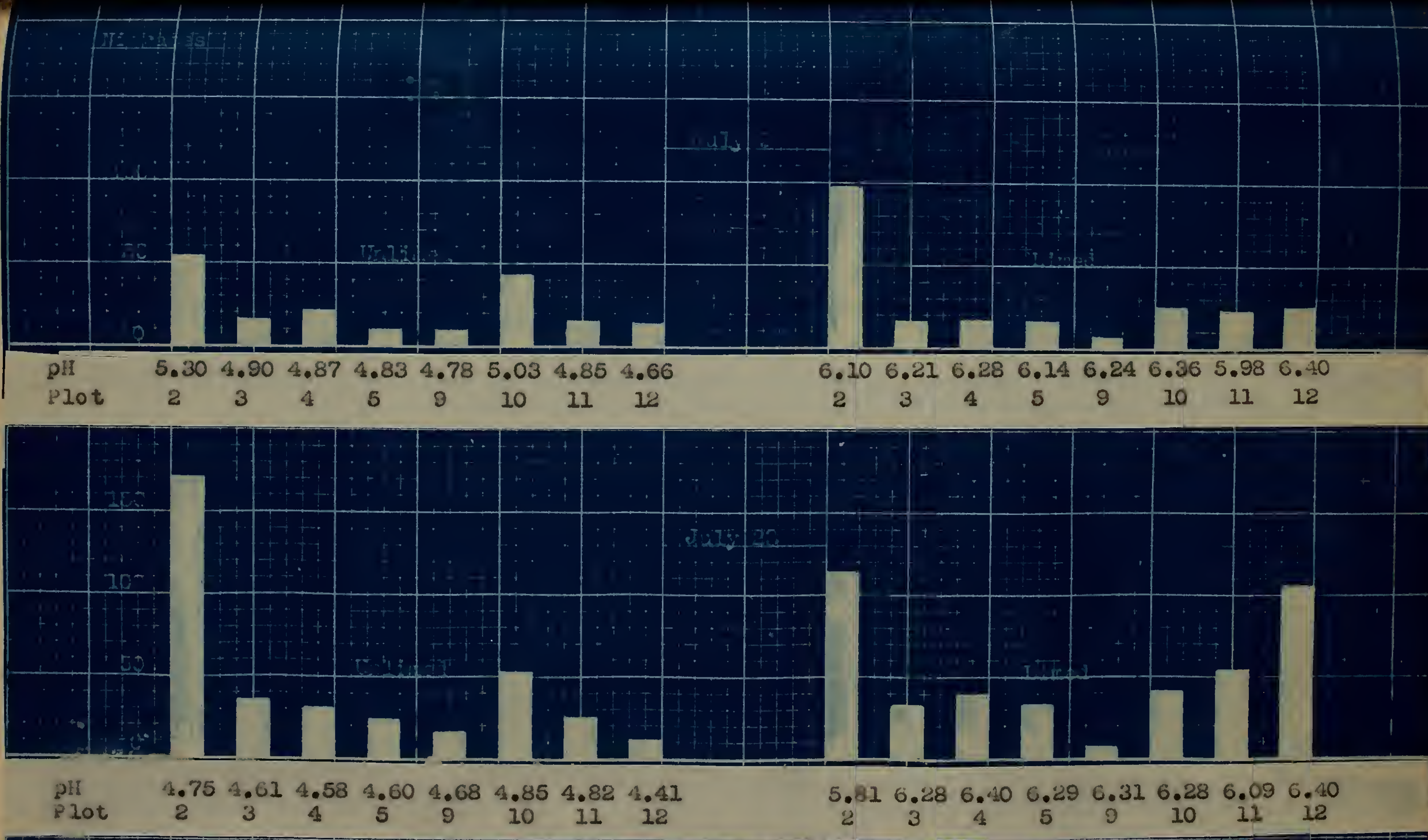

Figure 3, Block R

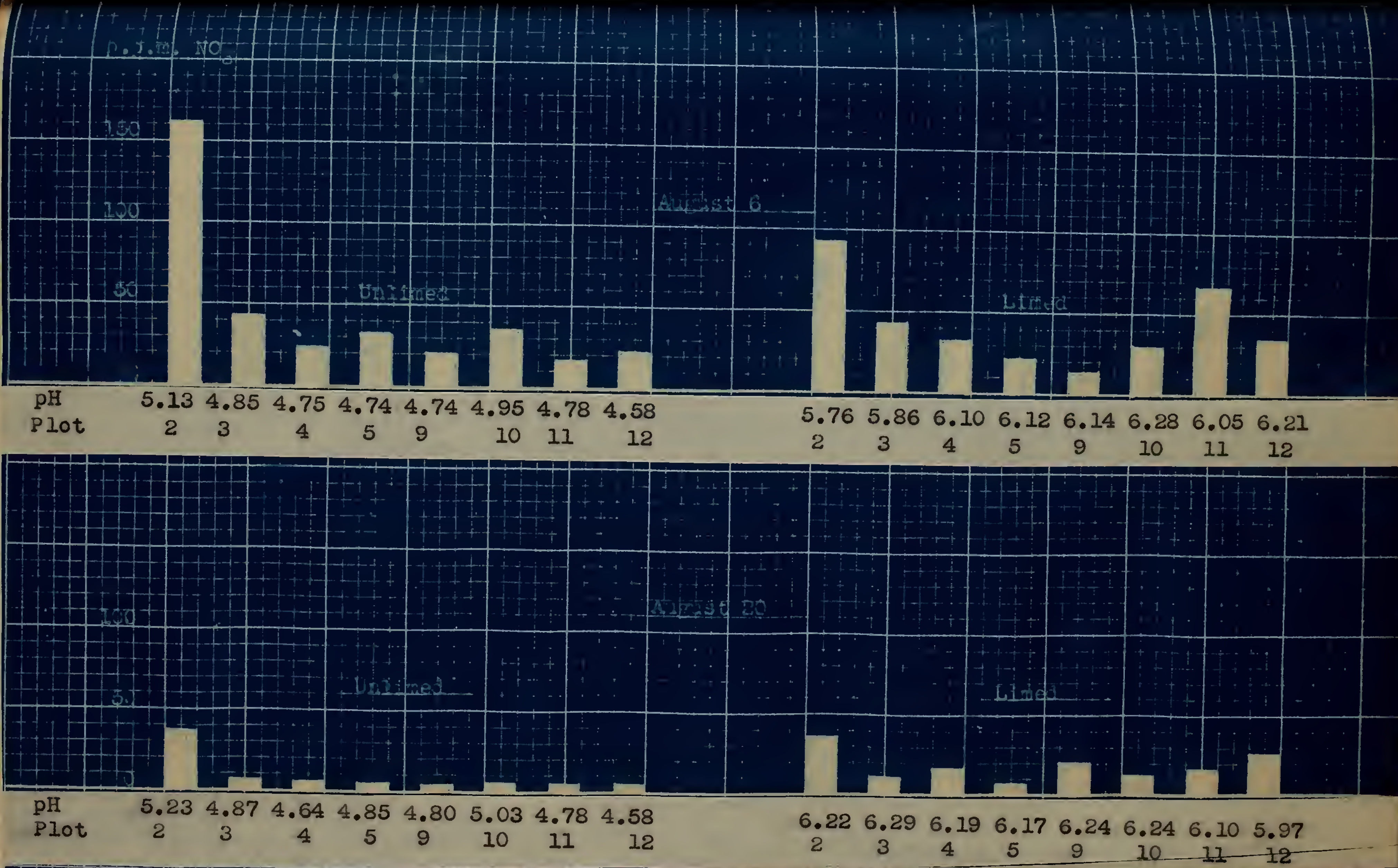

Figure 4, Block R

The soil of this field represents a transition between the Merrimac and Hartford series, but is more like the Hartford than the Merrimac. In texture it is a sandy loam. The drainage is good. The entire field slopes gently toward the west.

Samples for nitrate and pH determinations were taken every two weeks from July 9 to August 20. The results of these determinations together with their graphic presentation are given on pages 27, 28, 29 and 30.

From the data and graphs given on pages 27, 29 and 30 it may be seen that at the time of the first sampling the nitrate accumulation in the unlimed half of plots 4 and 10 were greater than in the limed portion.

At the time of the second sampling the unlimed plots 2, 9 and 10 had greater nitrate accumulation than the limed. The nitrate accumulation in the other plots was greater in the limed portion.

At the time of the third sampling the nitrate accumulation was greater in the limed plots with the exception of plots 2, 3 and 9 which had a greater nitrate accumulation in the unlimed portion of the plots.

At the time of the last sampling the accumulation was distinctly in favor of the limed plots with the

exception of plot 2 where the nitrates of the limed and unlimed portions of the plot were about the same.

From the above discussion it is evident that there was a wide variation in nitrate accumulation in the limed and unlimed portions of the plots at the time when the samples were taken. If the average of the four nitrate determinations is now taken into consideration, a clearer idea may be had regarding the nitrate accumulation in the limed and unlimed plots.

Referring to the last two columns of table I, page 27, it will be seen that the nitrate accumulation of plots 2 and 10 was greater by 25 and 7 p.p.m. respectively in favor of the unlimed plots. The relationship here between the accumulated nitrates of the limed and unlimed portions may be explained on the basis of added fertilizer nitrogen. Plant growth on the unlimed portions, especially of plot 2 which has received only nitrogen for many years, was apparently insufficient to utilize as much nitrate as that on the limed half of the same plot.

The accumulation of plots 4, 5, 11 and 12 was greater by 6, 3, 24 and 38 p.p.m. in favor of the limed plots. There was no essential difference in nitrates in the limed and unlimed portions of plots 3 and 9.

While the data given above represent the nitrate

accumulation they do not represent the true nitrification in the soils considered. The accumulation is the net result of several factors which must be taken in consideration before the true nitrification in a soil is determined. Plant growth is one of the greatest factors that limit nitrate accumulation. While the figures show that in some plots, and particularly in plot 2, the accumulation was greater in the unlimed plots, the plant growth, with few exceptions, was greater in the limed plots. This fact may account for the lower accumulation that was found in the limed portion of some plots.

Conclusions:

1. The general effect of additions of lime and fertilizers to an acid soil on the accumulation of nitrates in the presence of growing plants, is to cause an increase in nitrates.

2. To this general rule there are exceptions. In the experiment of Block R, exceptions were noted with plots 2 and 10, both of which receivd added nitrogen. Since plant growth was poorer on the unlimed portions of the plots, particularly of plot 2, this relation can be explained on the basis of a smaller removal of nitrates.

3. When lime is used without fertilizer, with

gypsum, or with muriate of potash in a soil, it has a tendency to increase nitrate accumulation.

4. When lime is used with acid phosphate, or with acid phosphate and muriate of potash in a soil, it has no effect upon the nitrate accumulation.

5. Although no lime has been used on the limed plots since 1916, its residual effects are still very evident. The high pH of the limed portion of the plots ranging from 5.76 - 6.40 and the low pH of the unlimed portion of the plots ranging from 4.41 - 5.30, support this statement.

NORTH CORN ACRE

Prior to 1891 it was thought, and the idea was supported by some experimental data, that the commercial fertilizers at that time on the market contained too much phosphoric acid and not enough potash for good corn yield. In 1891 the Massachusetts Experiment Station undertook to test this point on an acre field of Merrimac sandy loam. There were four plots of equal size; plots 1 and 3 received a high phosphate fertilizer, approximately 4-16-6, while plots 2 and 4 received one high in potash, approximately 4-4-12.

With some exceptions that were made from time to time the fertilizer treatment of the plots was as follows:

	For Plots 1 and 3	For Plots 2 and 4
Sodium nitrate	30.0 pounds	50.0 pounds
Dried blood	30.0 "	--
Dried ground fish	37.5 "	50.0 "
Acid phosphate	273.0 "	50.0 "
Muriate of potash	37.5 "	62.5 "

The above fertilizers were used on the plots at the rate of one ton to the acre every year, except as follows:

In 1925 no fertilizer was used; plot 4, in addition to the above fertilizer, received 400 pounds of basic slag per acre for the years 1907 to 1919 inclusive; potash was omitted from plots 1 and 3 from 1918 to 1920 and from plot 4 since 1924. Moreover, the acid phosphate in plots 1 and 3 was cut down to only 28 pounds per acre since 1919 so that a study of the residual effects of potash and acid phosphate could be made in the plots under question.

All plots received lime at the rate of one ton per acre in 1900 and again in 1907. In 1921 the north half of all the plots received lime at the rate of two tons to the acre. No more lime was added to any of the plots after 1921. For further details regarding the fertilizer treatments of these plots see Experiment Station annual reports.

A four year rotation of two years of corn followed by two years of grass and clover has been the practice.

The soil of this field is classified as Merrimac sandy loam. It is glacial till reworked by water and wind. Its drainage is good. The field is gently rolling toward the Northwest.

Samples for nitrate and pH value determinations were taken every two weeks from July 11 to August 22. The results obtained from these determinations together with graphic presentation are given on pages 40 - 42.

DISCUSSION OF THE RESULTS

From the data and graphs given on pages 40 and 42 it may be seen that at the time of the first sampling the nitrate accumulating in the limed plots was considerably greater than that in the unlimed plots with the exception of plot 3. The nitrates of the limed and unlimed portions of plot 3 were about the same. Moreover, there was considerable difference in the nitrate accumulation between plots of similar treatment, plots 1 and 3 and 2 and 4 in the limed and unlimed portions of the plots, except in the limed portions of 2 and 4 where the nitrates were about the same. However, the average of the two high potash plots, 2 and 4 in the limed and unlimed plots was greater than the average of the two high phosphate plots 1 and 3.

At the time of the second sampling the nitrate accumulation in the limed plots was greater than that of the unlimed by only about 35 p.p.m. for the four plots. In the limed, as well as in the unlimed plots, the nitrate accumulation was greater in the high potash plots, 2 and 4, than in the high phosphate plots 1 and 3.

At the time of the third sampling there was no

appreciable difference between the accumulation in the limed and unlimed portions of the plots.

At the time of the last sampling, again the sum of the nitrates in the four limed plots was greater but more erratic, than the sum of the nitrates in the four unlimed. For the first time the average of the two high phosphate plots, during the time from the first to the last sampling, showed a little better nitrate accumulation than the high potash plots and this occurred in the unlimed portions of the plots. As for the limed plots the high potash (plots 2 and 4) again showed a greater nitrate accumulation than the high phosphate plots 1 and 3.

The pH value of the soils, both in the limed and unlimed portions of the plots, was rather high and uniform as it may be seen from table V-B, page 40 and graphs on page 42. The range of the limed plots was 5.88 - 6.50 and that of the unlimed plots 5.59 - 6.29.

From the results of the four nitrate and pH value determinations the following conclusions are drawn:

1. The nitrate accumulation was found to be greater, but not significant, in the limed plots than in the unlimed.

2. The nitrate accumulation in the high potash plots was greater than that in the high phosphate plots.

3. Altho no lime has been added to the south half of the plots since 1907 its residual effects are still manifested by the high pH of these plots.

4. The pH value of the soils in the so-called limed and unlimed plots can not be considered as an important factor regarding the nitrate accumulation, as the pH value of both limed and unlimed portions of the plots was rather uniform.

NORTH CORN ACRE

Table V

A. Nitrates: p.p.m. NO_3

Plot and Treatment	Limed				Unlimed				Average	
	July		August		July		August			
	11	25	10	22	11	25	10	22	Limed	Unlimed
Plot 1,4-16-6	108.4	59.3	56.1	78.5	61.5	51.8	38.5	39.2	75.6	47.8
Plot 2,4-4-12	103.0	80.4	31.5	27.4	74.6	79.2	67.3	39.2	60.3	65.1
Plot 3,4-16-6	76.3	68.4	34.8	13.3	78.2	88.1	37.6	47.7	48.0	63.0
Plot 4,4-4-12	106.7	139.8	79.8	192.0	100.0	93.8	52.5	24.9	129.6	67.8

B. Acidity interms of pH

Plot of Treatment	Limed				Unlimed			
	July		August		July		August	
	11	25	10	22	11	25	10	22
Plot 1 4-16-6	5.93	6.05	6.03	6.10	6.00	5.89	6.16	6.14
Plot 2 4-4-14	5.97	6.02	6.16	6.34	5.85	5.80	5.65	5.93
Plot 3 4-16-6	5.88	6.00	5.90	6.03	5.76	5.59	5.63	5.69
Plot 4 4-4-12	6.45	6.36	6.50	6.41	6.22	6.14	6.39	6.24

Table V

NORTH CORN ACRE

C. Moisture Percentage, Dry Weight Basis

Plot and Treatment		Limed				Unlimed				Average	
		July		August		July		August			
		11	25	10	22	11	25	10	22	Limed	Unlimed
Plot 1	4-16-6	37.4	31.3	37.0	36.0	35.2	33.5	36.0	34.2	35.4	35.0
Plot 2	4-4-12	33.9	35.5	33.3	31.4	36.1	34.5	39.0	36.3	33.3	36.5
Plot 3	4-16-6	34.1	33.0	34.8	31.6	36.4	36.1	33.5	37.1	33.4	35.8
Plot 4	4-4-12	35.6	34.8	35.6	33.4	31.9	30.2	36.1	19.8	34.9	33.0

D. Soil Temperature in Degrees F

Plot and Treatment		July		August		July		August		Average	
		11	25	10	22	11	25	10	22	Limed	Unlimed
Plot 1	4-16-6	67	70	65	65	68	68	66	64	66.8	66.5
Plot 2	4-4-12	68	68	67	65	68	68	65	65	67.0	66.5
Plot 3	4-16-6	68	68	65	66	66	68	64	66	66.8	66.0
Plot 4	4-4-12	68	68	66	65	69	68	66	66	66.3	67.3

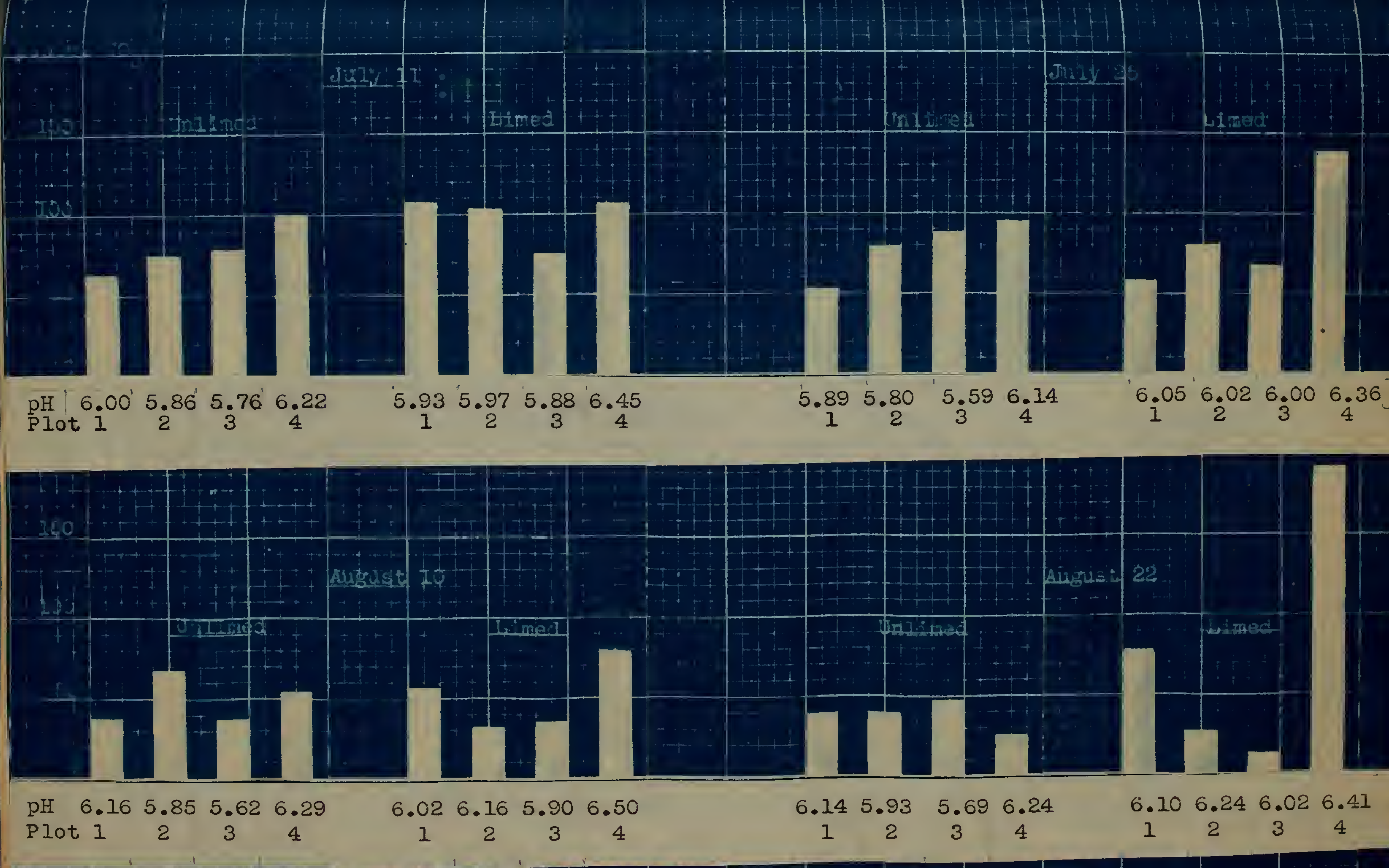

Figure 5, North Corn Acre

ALFALFA LONGEVITY TEST

The name given to this field signifies only its present utilization, because for several years it was used for various purposes and only within the past year was it set aside for a specific purpose which is to test the longevity of certain varieties of alfalfa under different lime and fertilizer treatments.

DESCRIPTION OF SOIL

The soil of this field is classified as Merrimac sandy loam. The drainage here is very good and the field is located in a rather level topography, but with an easterly slope.

LIME AND FERTILIZER TREATMENTS

Six hundred pounds of acid phosphate and three hundred pounds of muriate of potash per acre were applied to the block of plots studied. The lime applications were as given in the table below:

Plot No.	Lime Applications in Tons Per Acre
33 and 37	2 tons
34 and 28	4 "
35 and 39	6 "
36 and 40	8 "

Soil samples for nitrate and pH value determinations were taken from each plot when the alfalfa was about one inch high and again two weeks later. The results are given on pages 47 and 48.

Discussion of the results obtained from the two nitrate and pH value determinations.

A. Results of the first determinations.

(a) In the first set of plots, namely plots 33, 34, 35 and 36 there was a gradual increase of nitrate accumulation as the lime applications increased from 2 to 6 tons, plots 33, 34 and 35, but there was a marked decrease in nitrates in plot 36 which received 8 tons of lime. The nitrates of plot 36 being less than those of plot 33 which received only 2 tons of lime.

(b) In the second set of plots, namely 37 to 40, there was no marked difference in the nitrate accumulation of plots 37 and 38 although plot 38 had received 4 tons of lime and plot 37 received only 2. Moreover, there was a marked decrease in nitrates, the greater decrease following the greater lime application.

B. Results of the second analysis.

(a) The nitrates for both sets of plots were found to be much less, practically one-half as much as in the first analysis, suggesting that the young alfalfa plants had started to draw very heavily on the nitrates of the soil. In general, however, the trend of the

nitrate accumulation of the first set of plots (plots 33, 34, 35 and 36) was similar to that of the first determination, and hence what has been said for the first nitrate determination holds true for the second determination also.

(b) In the second set of plots (37, 38, 39 and 40) again there is a similarity of the results to those of the first determination with the exception that the 6 ton plot showed a greater decrease in nitrates than the 8 ton plot.

C. Results of the pH determinations.

In these alfalfa experiment plots two things stand out regarding the pH value of the soil:

1. That the greater nitrate accumulation in no case followed the increase of the pH value of the soil.

2. That the heavier applications of lime did not produce a corresponding increase of the pH value of the soil up to the time when the second soil samples were taken, except in the second set of plots (37, 38, 39 and 40) of the second determination where there was a gradual increase of the pH value of the soil from 6.03 - 6.14 - 6.93 - 7.06 for the 2, 4, 6 and 8 tons of lime respectively.

CONCLUSIONS

As a result of the two nitrate and pH determinations, as far as these alfalfa plots are concerned, the following conclusions are drawn.

1. Four to six tons of lime per acre were sufficient to bring about maximum nitrate accumulation in the plots under the conditions studied. Eight tons of lime had an inhibitory action on nitrate accumulation.

2. Within a brief period, at least, from the time of application the pH value of a soil may not bear a close correspondence to the amounts of lime applied.

Table VI

ALFALFA LONGEVITY TEST

A. Nitrates, NO_3 Dry Soil Basis — B. Acidity in Terms of pH

Plot No.	Lime	A. Date of sampling, August 3	A. August 17	A. Average	B. Date of sampling, August 3	B. August 17
33	2 Tons	127.8	61.7	96.8	6.50	6.57
34	4 "	159.0	70.0	114.5	6.36	6.62
35	6 "	178.0	91.9	135.0	6.05	6.19
36	8 "	112.0	72.7	93.4	6.24	6.34
37	2 "	137.2	56.5	96.9	5.81	6.03
38	4 "	141.0	65.3	103.2	5.76	6.14
39	6 "	92.2	36.6	64.4	6.14	6.93
40	8 "	85.2	52.5	78.9	6.57	7.06

C. Moisture Percentage Dry Weight Basis — D. Soil Temperature in Degrees Farenheit

Plot No.	Lime	C. Date of sampling, August 3	C. August 17	C. Average	D. Date of sampling, August 3	D. August 17	D. Average
33	2 Tons	30.6	23.7	27.2	61	59	60.0
34	4 "	28.5	26.2	27.[illegible]	60	59	59.5
35	6 "	30.2	25.9	28.1	61	59	60.0
36	8 "	28.8	24.1	26.5	62	59	61.5
37	2 "	28.3	26.5	27.4	62	59	61.5
38	4 "	28.5	25.6	27.1	61	60	60.5
39	6 "	25.7	24.8	25.2	62	60	61.0
40	8 "	30.0	23.8	26.9	62	60	61.0

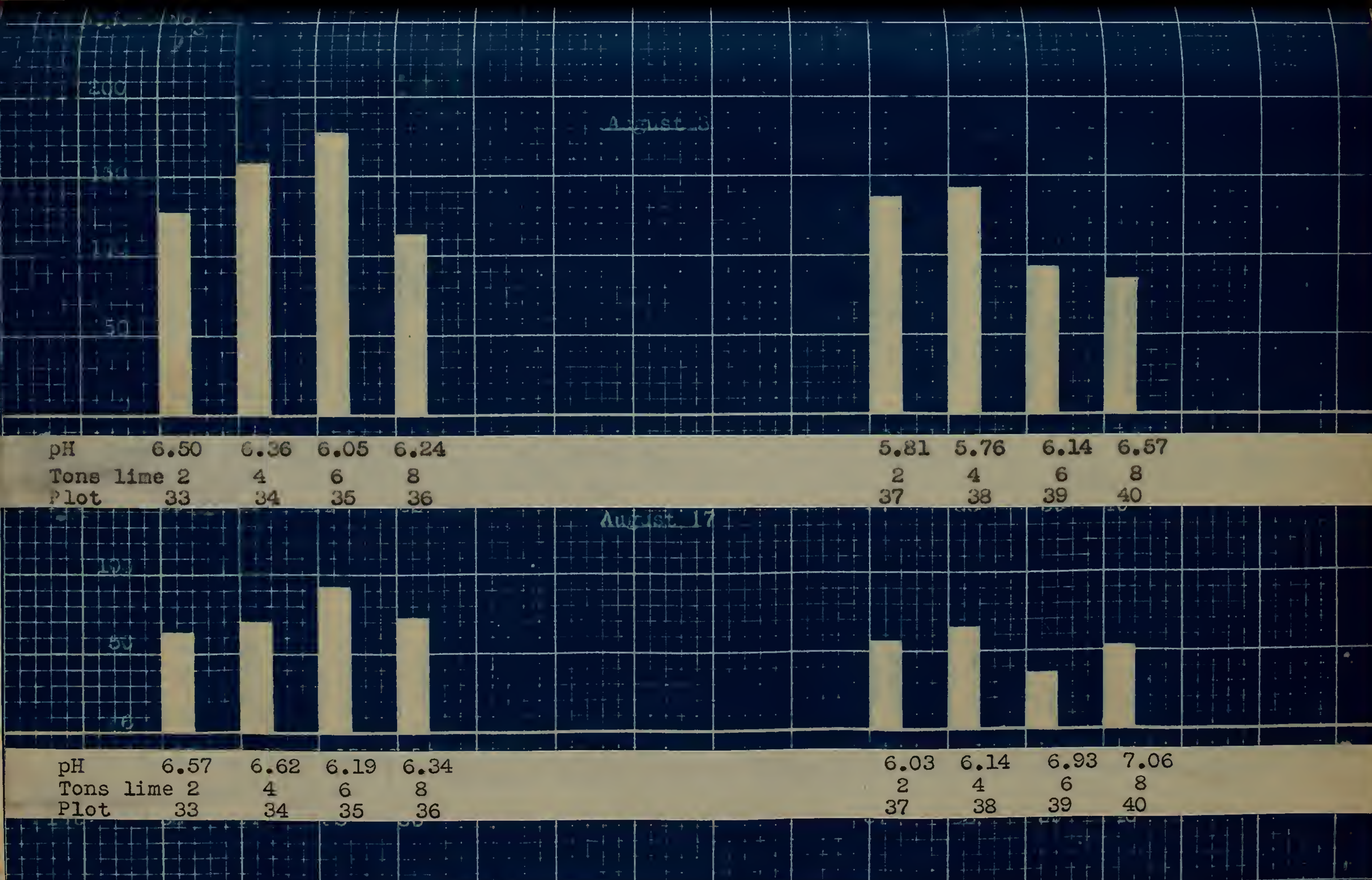

Figure 6, Alfalfa Longevity Test

WEST FIELD 3

On one of the fields of the College Farm previously known as Middle Flat but now known as West 3, it has been observed for several years that on certain areas of the field corn would make very poor growth, while corn nearby would make normal growth. The soil of this field belongs to the Hartford series. Its surface is a light brown sandy loam and is underlain by clay loam subsoil. Its natural drainage is fair, but by the use of tiles it has been improved. The topography in general is slightly irregular ranging from level to rolling. The area of poor corn growth is located on the side of the northern slope of the field.

In 1926 the Agronomy Department undertook to investigate the causes responsible for the poor corn growth in that area. The area under question was divided into eleven one-fortieth acre plots and treated as follows:

Plot 1 - Check

Plot 2 - 2 tons lime

Plot 3 - 2 tons lime and 1 ton acid phosphate

Plot 4 - 1 ton acid phosphate

Plot 5 - Check

Plot 6a - 4 tons lime

Plot 6b - 8 tons lime

Plot 7a - 4 tons lime and 2 tons acid phosphate

Plot 7b - 8 tons lime and 4 tons acid phosphate

Plot 8a - 2 tons acid phosphate

Plot 8b - 4 tons acid phosphate

The field is under a five year rotation of two years of hay followed by three years of corn. It is top dressed with manure every year and when in corn receives in addition to the manure 300 pounds of acid phosphate per acre. As the field was in corn during the last three years, all plots received, in addition to treatments made by the Agronomy Department, 300 pounds of acid phosphate per acre and top dressing of manure when the investigation begun. No lime was applied to the field from 1912 to 1916, but in 1916, 1920 and 1922 lime was applied on the entire field at the rate of two tons per acre.

In 1927 a study of the pH value and nitrate accumulation in the treated plots was made. Samples for nitrate and pH value determinations were taken every two weeks from July 12 to August 22. The results are given on pages 53 and 54.

From the data given on page 53, it will be seen that lime raised the pH value in all the lime

treated plots about pH 7.0. However, while the pH value of the soil was altered in such a way as to be ideal for nitrification, as is claimed by various workers on the subject, there was no essential increase in the nitrates in the plots at the time when the samples were taken.

Another interesting thing is the effect of fertilizer treatments upon soil reaction. The low pH value of plot 8 was brought about presumably by the acid phosphate applications.

In regard to the nitrate accumulation in these plots as affected by the various treatments all that can be said is that plots 2 and 6b, receiving 2 and 8 tons of lime respectively were influenced most by such applications, while in plot 7a, 4 tons of lime in addition to 2 tons of acid phosphate had a tendency to increase the nitrate accumulation somewhat. In check plot 2, on the other hand, even with normal corn growth, and the plants drawing heavily on the nitrate accumulation of the soil, the accumulation was greater than in the plots where the corn growth was poor and had received additional fertilizer treatments.

Two and eight tons of lime applications increased the nitrate accumulation in the soil considerably, while 2 tons of lime plus 2 tons of acid phosphate had a tendency to increase the nitrate accumulation to a

small degree. As for the other lime and acid phosphate applications they did not seem to have any influence upon the nitrate accumulation of the soil.

It is a question whether nitrate accumulation may be a factor regarding the poor corn growth in this area, for while in plot 2 there was a considerable nitrate accumulation at the time of sampling, the corn growth was no better than in the plots where the lowest nitrate accumulation was found.

Table VII

WEST FIELD - 3

(A) Nitrates: p.p.m. NO_3 Dry Soil Basis (B Acidity in Terms of pH.

Plot	July		August		Average	July		August	
	12	26	8	22		12	26	8	22
CK 1	9.3	6.2	5.9	3.2	6.2	6.89	7.03	7.22	7.06
CK 2	51.4	10.4	8.0	3.9	18.4	7.18	7.43	7.46	7.65
2	35.3	4.9	4.5	4.9	12.4	7.10	7.18	7.17	7.25
3	7.5	7.5	3.8	5.4	6.1	7.27	7.27	7.27	7.35
6a	7.0	5.3	3.3	4.2	5.0	7.34	7.31	7.41	7.44
6b	27.2	8.3	3.3	3.5	10.6	7.44	7.49	7.65	7.65
7a	13.3	9.5	7.9	3.7	8.6	6.98	7.03	7.22	7.35
$7b_1$	6.7	6.7	3.3	3.5	5.1	7.12	7.12	7.12	7.28
$7b_2$	-	9.2	-	-	9.2	-	7.25	-	-
$8a_1$	-	-	4.0	-	4.0	-	-	6.89	-
$8a_2$	-	-	5.5	-	5.5	-	-	6.45	-

Note: CK_1 = Poor Corn; 7b = Fair Corn; $8a_2$ = Corn Head high (West side)

CK_2 = Good Corn; $8a_1$ = Corn waist high (East side)

Table VIII

WEST FIELD 3

	Moisture Percentage, Dry Weight Basis					Soil Temperature in Degrees F				
	July		August		Average	July		August		Average
Plot	12	26	8	22		12	26	8	22	
CK_1	25.8	28.6	27.6	30.3	28.1	67	66	68	71	68.0
CK_2	20.6	18.8	28.0	21.4	22.2	69	66	68	66	67.3
2	33.4	32.4	34.1	35.3	33.8	67	65	68	70	67.5
3	36.0	36.8	34.9	36.3	36.0	68	66	68	72	68.5
6a	29.3	31.2	27.2	30.8	29.6	68	65	68	70	65.3
6c	30.4	28.9	27.5	26.4	28.3	67	68	68	70	68.3
7a	28.0	26.1	27.5	31.8	28.4	68	67	69	70	68.5
$7c_1$	28.4	28.9	28.1	31.2	29.2	67	66	68	71	68.0
$7c_2$	-	22.5	-	-	22.5	-	66	-	-	66.0
8a	-	-	31.6	-	31.6	-	-	68	-	68.0
8_2	-	-	30.1	-	30.1	-	-	67	-	67.0

CONCLUSIONS OF PART I

As a result of the study of the pH value and nitrate accumulation in soils under field conditions and under varying fertilizer treatments the following conclusions are drawn.

1. The general tendency of the lime applications was to bring about an increase in the pH value and nitrate accumulation in the soil.

2. The pH value in a soil does not bear a close relation to the lime added.

3. There is a general but not perfect agreement between the pH value and the nitrate accumulation in the soil.

4. The amount of nitrates as found while crops are growing is not a true index of the nitrification but an index of the net nitrate accumulation at the time of sampling.

PART II

LABORATORY STUDIES

As stated under the scope of this thesis, the purpose of Part II is to study in the laboratory the relation of soil reaction to nitrate accumulation, thus avoiding the loss of nitrates in drainage and absorption by plants. The soils that were studied are typical of this section of Massachusetts. Members of the Hartford, Gloucester, Merrimac and Suffield series were studied.

The Hartford very fine sandy loam was taken from the Experiment Station onion plots. It is a glacial lake laid soil slightly reworked by water and wind. The field from which the soil was taken has a level topography, and was naturally poorly drained but is now well drained by land tiles. The mechanical analysis, organic matter content and water retentive capacity are given on page 60.

The Gloucester fine sandy loam was used. Its mechanical analysis, organic matter content and water retentive capacity are given on page 60. It is a glacial till derived from crystalline and sedimentary rocks. On it is located the apple orchard of the college. The ingredients that make up this soil vary

from very fine particles to large stones. Its drainage is in general fair to good with some poorly drained spots, especially where hard pan occurs near the surface. The soil under study was taken from an area where there is a considerable eastward slope.

The Merrimac very fine sandy loam used was taken from the North Corn Acre field which was studied in connection with Part I. The drainage here is good and the topography of this field is rather regular with a slight gravelly ridge running almost diagonally southwest - northeast. The soil was deposited by glacial action and later was reworked by water and wind. Its mechanical analysis, organic matter content and water retentive capacity are given on page 60.

The Suffield soil was taken from the South Field 4 of the College Farm. The topography of this field is level and was naturally very poorly drained. This soil belongs to the loam class, and also is of glacial lake origin. Having been deposited in some of the deepest water of the glacial lake, its texture is very fine. Its mechanical analysis, organic matter content and water retentive capacity are given on page 60.

The soils after being taken into the laboratory were air dried. Then the lumps were broken by a heavy roller and the larger stones only removed so that the physical condition would not be altered in any serious

way. Each soil was next divided into 32 250-gram lots and treated as follows in duplicate:

1. Check
2. 2 tons of lime+
3. 4 tons of lime
4. 6 tons of lime
5. 1/2 ton of 4-8-4 fertilizer
6. 1 ton of 4-8-4
7. 2 tons of 4-8-4
8. 2 tons of lime + 1/2 ton of 4-8-4 fertilizer
9. 2 tons of lime + 1 ton 4-8-4
10. 2 tons of lime + 2 tons 4-8-4
11. 4 tons of lime + 1/2 ton 4-8-4
12. 4 tons of lime + 1 ton 4-8-4
13. 4 tons of lime + 2 tons 4-8-4
14. 6 tons of lime + 1/2 ton 4-8-4
15. 6 tons of lime + 1 ton 4-8-4
16. 6 tons of lime + 2 tons 4-8-4

+Per acre.

The soils were then mixed well and placed in glass beakers, brought up to 60% of their water holding capacity, and incubated at room temperature for four and eight weeks. At the end of these periods nitrates and pH value determinations were made. The moisture content of the soils was kept at 60% of their water retentive

capacity by weighing the beakers every two or three days and adding the necessary amount of water. The results of the nitrate and pH value determinations are given in connection with the discussion of each soil.

The 4-8-4[+] fertilizer was especially prepared for this work by using:

1. Acid phosphate - 16% available P_2O_5
2. Muriate of potash - 50% available K_2O
3. One-half of the nitrogen from tankage - 13% NH_3
4. One-fourth of the nitrogen from $(NH_4)_2SO_4$ - 25% NH_3
5. One-fourth of the nitrogen from $NaNO_3$ - 18% NH_3

Agricultural lime of 60% CaO equivalent was used in connection with this work.

[+] Figures refer to NH_3, P_2O_5 and K_2O respectively.

PHYSICAL AND CHEMICAL PROPERTIES OF SOILS USED IN PART II.

Table IX

A. Mechanical Analysis

	Hartford	Merrimac	Gloucester	Suffield
Fine Gravel	0.15	1.62	2.13	1.00
Coarse Sand	0.33	3.68	4.56	1.54
Medium Sand	0.71	2.50	7.00	3.06
Fine Sand	8.71	6.47	11.67	14.81
Very Fine Sand	62.16	65.91	48.90	30.11
Silt	21.30	15.07	19.98	39.75
Clay	6.64	4.76	5.77	10.78

B. Loss on Ignition

Hartford	8.05%
Suffield	6.00%
Gloucester	5.66%
Merrimac	5.48%

C. Water Retentive Capacity.

Hartford	66.06%
Gloucester	54.54%
Suffield	53.18%
Merrimac	53.03%

The nitrates and pH values of the unincubated checks were as follows:

Nitrates:	p.p.m NO_3	pH value
Hartford	20.0	4.81
Gloucester	12.0	6.27
Merrimac	9.8	5.29
Suffield	10.0	6.40

Table X

Gain in Nitrates (p.p.m. NO_3) Above Unincubated check

and pH Values

4 Weeks Incubation

Treatment	Hartford Nitrates	pH	Gloucester Nitrates	pH	Merrimac Nitrates	pH	Suffield Nitrates	pH
Check	111.4	4.74	141.4	6.10	100.0	5.10	175.8	6.56
2 Tons Lime	133.5	5.81	116.4	7.40	98.5	6.37	210.5	7.35
4 " "	350.8	6.64	133.1	7.04	93.4	6.57	240.4	7.83
6 " "	266.9	7.09	131.0	7.79	156.0	7.12	234.6	7.72
1/2 " 4-8-4	166.7	4.97	321.3	6.55	176.5	5.50	99.4	6.52
1 " "	167.8	4.73	203.1	6.03	135.7	5.49	261.0	6.01
2 " "	253.2	4.58	287.4	5.72	171.0	5.09	434.0	5.59
2 " Lime + 1/2 Ton 4-8-4	309.9	6.12	338.8	7.36	168.1	6.36	383.7	7.30
2 " " + 1 " "	239.6	6.35	185.9	7.12	210.7	6.70	269.8	7.14
2 " " + 2 " "	110.7	6.34	243.2	7.02	431.2	6.65	415.7	7.08
4 " " + 1/2 " "	201.2	7.06	189.9	7.40	180.9	7.32	212.3	7.56
4 " " + 1 " "	317.5	7.00	351.1	7.43	164.1	7.31	357.2	7.51
4 " " + 2 " "	181.7	6.90	383.4	7.31	419.3	7.03	531.9	7.37
6 " " + 1/2 " "	213.8	7.17	174.4	7.65	333.3	7.55	313.3	7.61
6 " " + 1 " "	229.5	7.10	346.3	7.51	303.6	7.46	409.9	7.53
6 " " + 2 " "	236.5	6.98	319.3	7.40	293.6	7.36	646.8	7.47

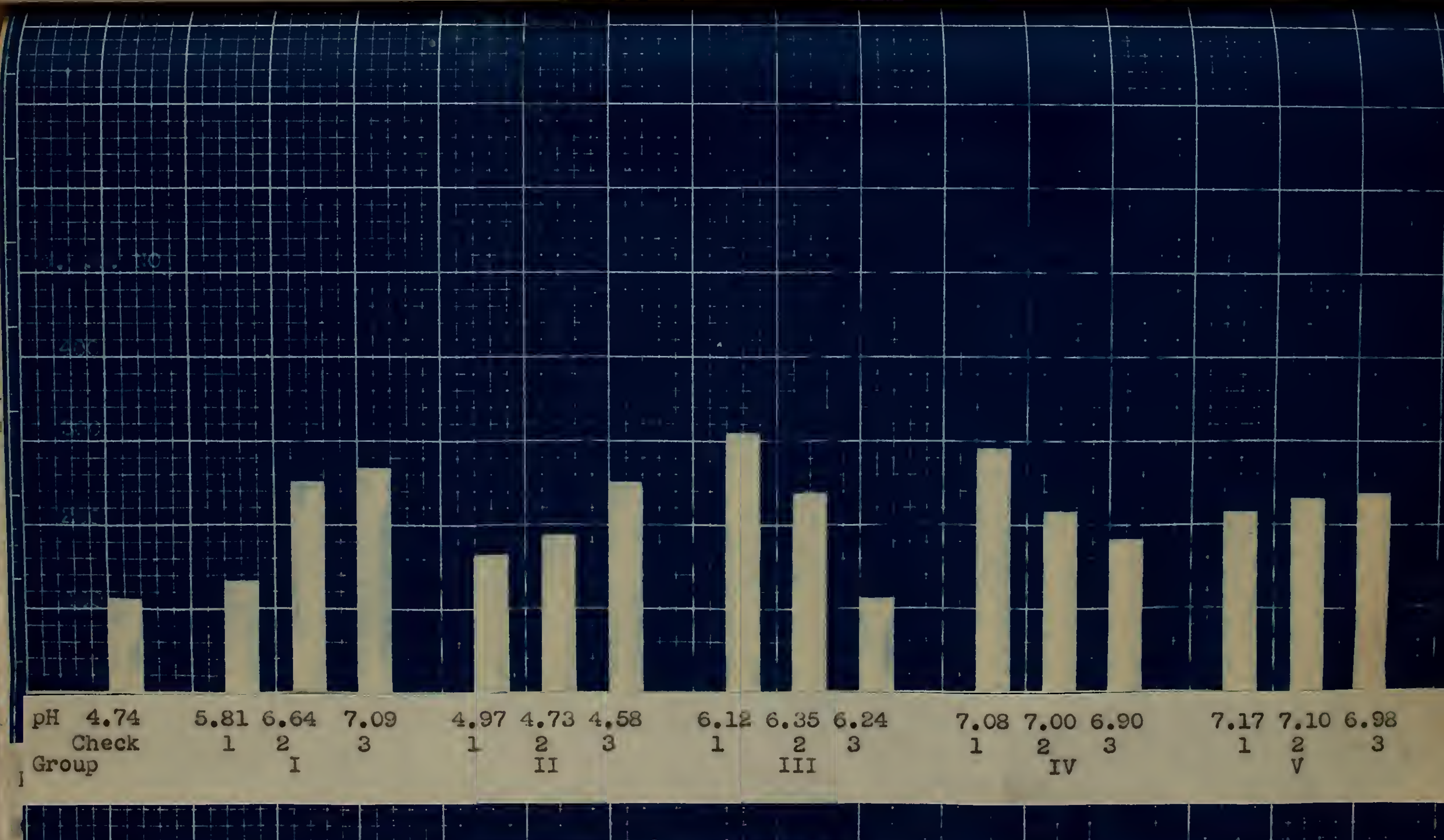

Figure 7, Hartford Soil, Incubated 4 Weeks

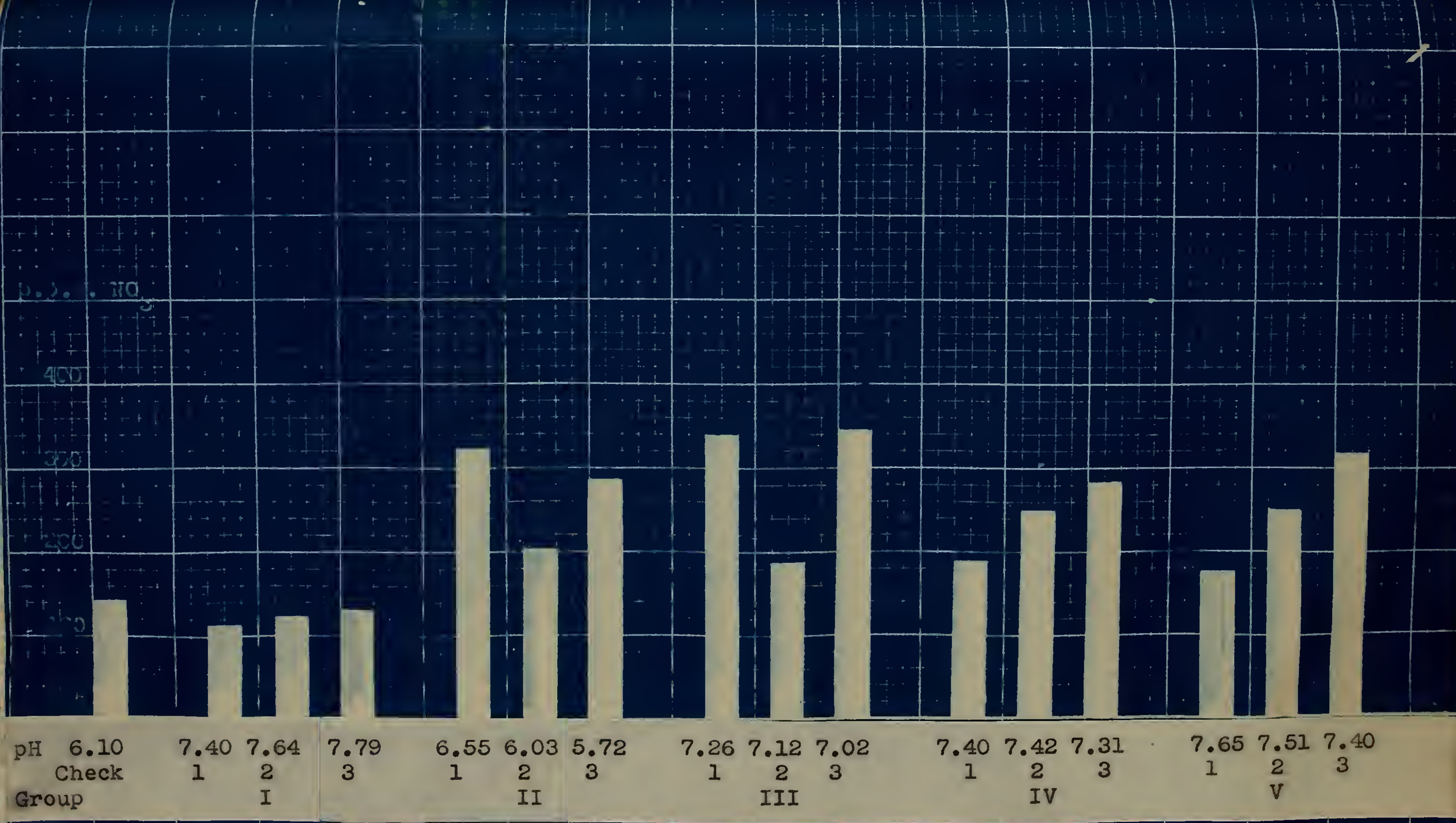

Figure 8, Gloucester Soil, Incubated 4 Weeks

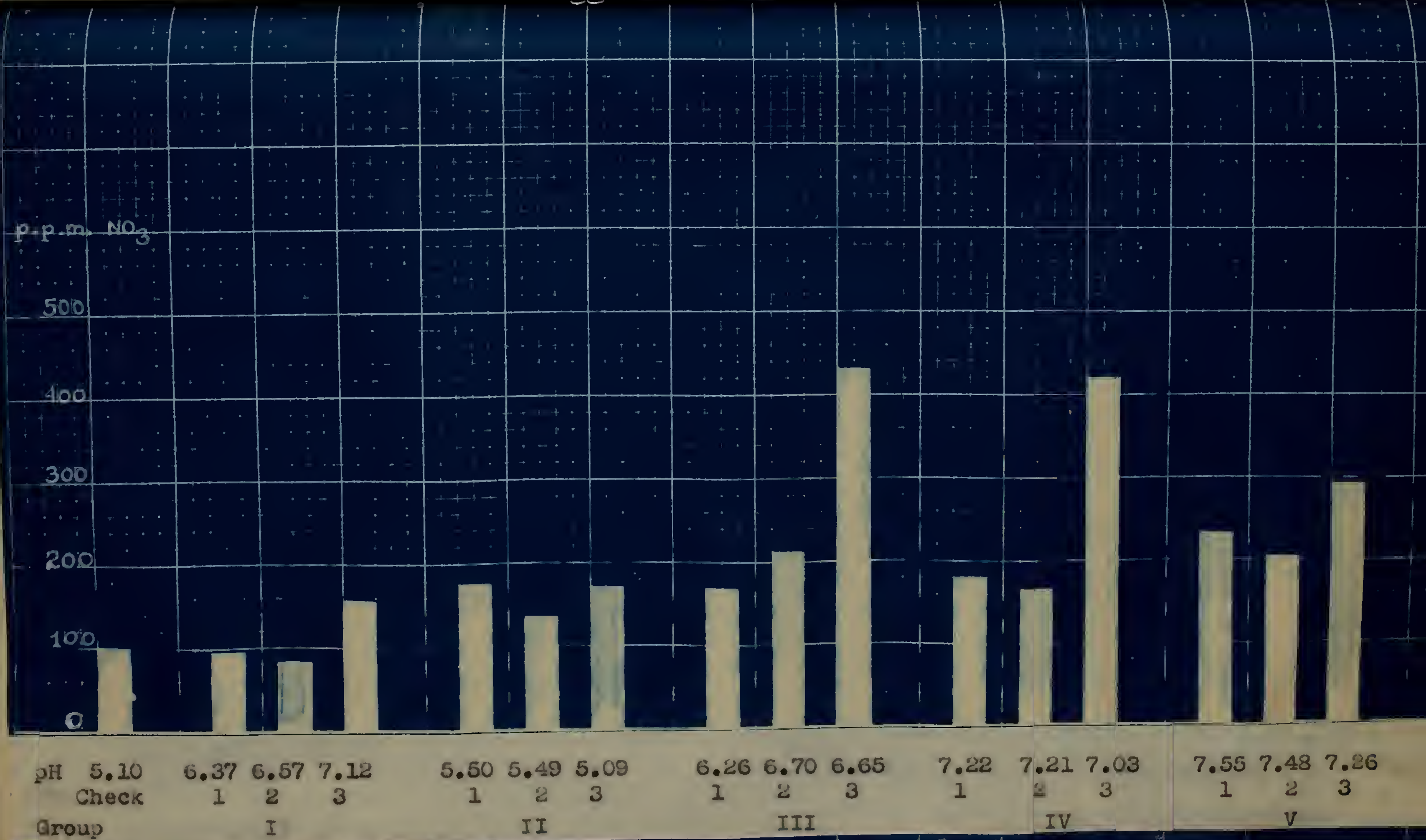

Figure 9, Merrimac Soil, Incubated 4 Weeks

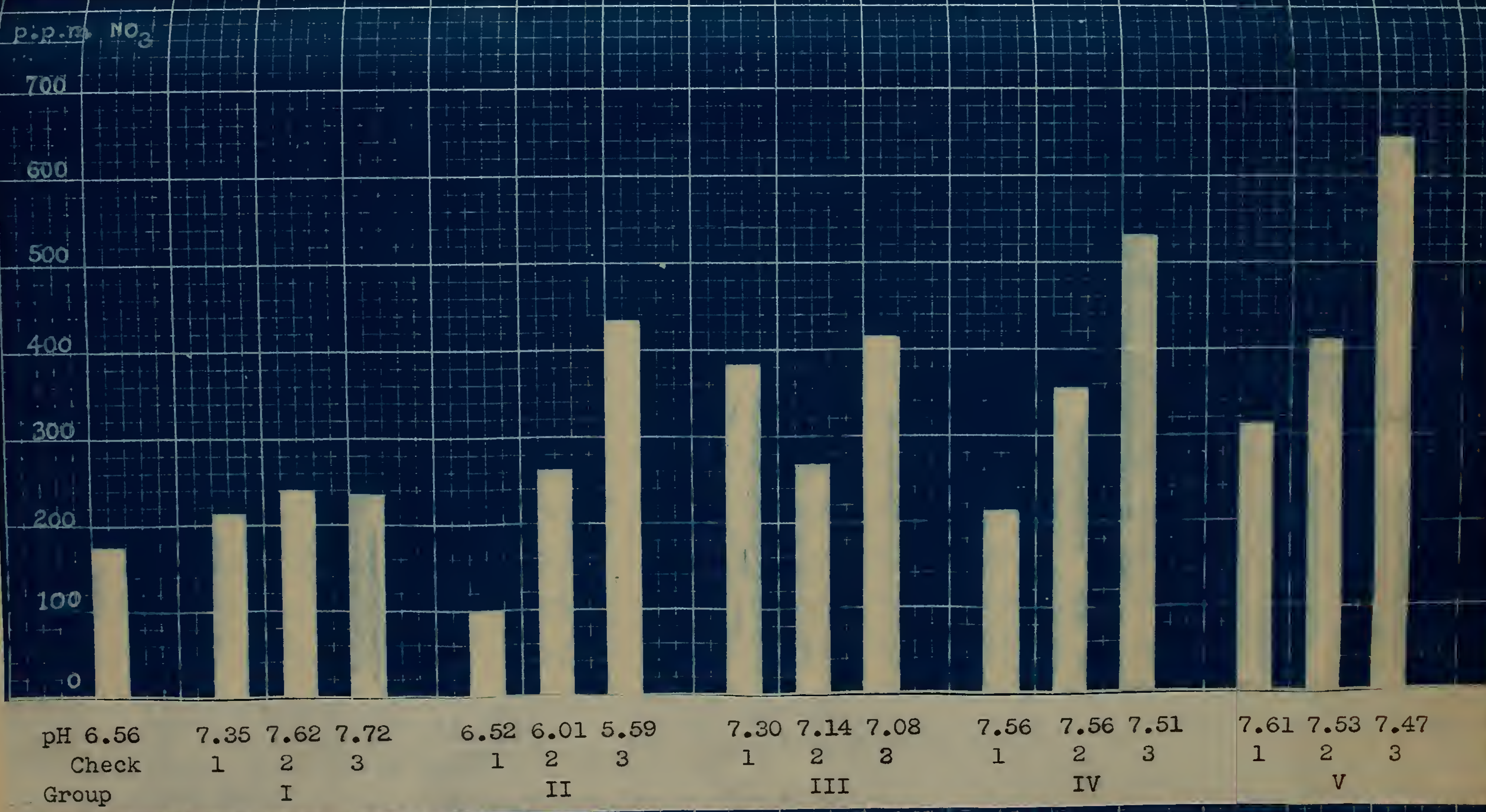

Figure 10, Suffield Soil, Incubated 4 Weeks

Table XI

Gain in Nitrates (p.p.m. NO_3) Above Unincubated Check.
And pH Values

8 Weeks Incubation

Treatment	Hartford Nitrates	Hartford pH	Gloucester Nitrates	Gloucester pH	Merrimac Nitrates	Merrimac pH	Suffield Nitrates	Suffield pH
Check	340.3	5.06	75.9	6.73	183.6	6.22	188.0	6.89
2 Tons Lime	314.8	5.76	140.3	7.39	311.9	7.16	220.0	7.68
4 " "	330.8	6.44	159.9	7.83	265.9	7.68	225.0	7.85
6 " "	439.7	7.10	175.8	7.87	289.8	7.83	239.0	7.86
1/2 Ton 4-8-4	339.4	5.15	188.5	6.67	745.4	6.01	67.8	6.77
1 " "	325.5	4.74	250.1	6.29	595.9	5.64	296.1	6.39
2 " "	683.4	4.50	380.7	5.86	679.8	5.49	288.5	6.12
2 Tons Lime + 1/2 ton 4-8-4	371.6	6.05	183.2	7.26	375.4	6.82	427.7	7.57
2 " " + 1 " "	310.0	5.99	33[illegible].6	7.10	544.6	6.98	165.8	7.40
2 " " + 2 " "	426.7	6.09	373.0	7.19	254.2	6.80	357.0	7.36
4 " " + 1/2 " "	460.2	6.74	302.9	7.66	375.4	7.46	326.5	7.80
4 " " + 1 " "	503.1	6.88	325.1	7.46	372.0	7.57	363.8	7.63
4 " " + 2 " "	463.2	6.88	311.0	7.47	709.2	7.24	703.0	7.50
6 " " + 1/2 " "	371.6	7.31	231.9	7.81	293.1	7.63	259.4	7.75
6 " " + 1 " "	445.2	7.20	325.1	7.69	447.8	7.54	343.3	7.69
6 " " + 2 " "	538.4	7.08	526.3	7.65	679.8	7.45	377.5	7.60

Table XII RECLASSIFICATION OF TABLE XI

Treatment	Hartford		Gloucester		Merrimac		Suffield	
	Nitrates	pH	Nitrates	pH	Nitrates	pH	Nitrates	pH
Check	240.3	5.06	75.9	6.73	183.6	6.22	188.0	6.89
1/2 ton 4-8-4	339.4	5.15	186.5	6.67	745.4	6.01	67.8	6.77
1/2 ton " + 2 tons lime	371.6	6.05	183.3	7.25	375.4	6.83	427.7	7.57
1/2 " " + 4 " "	460.2	6.74	203.9	7.66	375.4	7.46	336.5	7.80
1/2 " " + 6 " "	371.6	7.21	231.9	7.81	293.1	7.63	259.4	7.75
Check	240.3	5.06	75.9	6.73	183.6	6.22	188.0	6.89
1 Ton 4-8-4	335.5	4.74	250.1	6.29	595.9	5.84	296.1	6.39
1 " " +2 tons lime	310.0	5.99	333.6	7.10	544.6	6.98	185.8	7.40
1 " " +4 " "	503.1	6.88	325.1	7.46	373.0	7.57	263.8	7.62
1 " " +6 " "	445.2	7.20	325.1	7.69	447.8	7.54	343.3	7.69
Check	240.3	5.06	75.9	6.73	183.6	6.22	188.0	6.89
2 tons 4-8-4	662.4	4.50	380.7	5.86	679.8	5.49	286.5	6.12
2 tons " +2 tons lime	436.7	6.09	373.0	7.19	254.2	6.60	357.0	7.36
2 " " +4 " "	463.2	6.88	311.0	7.47	709.2	7.24	703.0	7.50
2 " " +6 " "	538.4	7.08	526.3	7.65	679.8	7.45	377.5	7.60

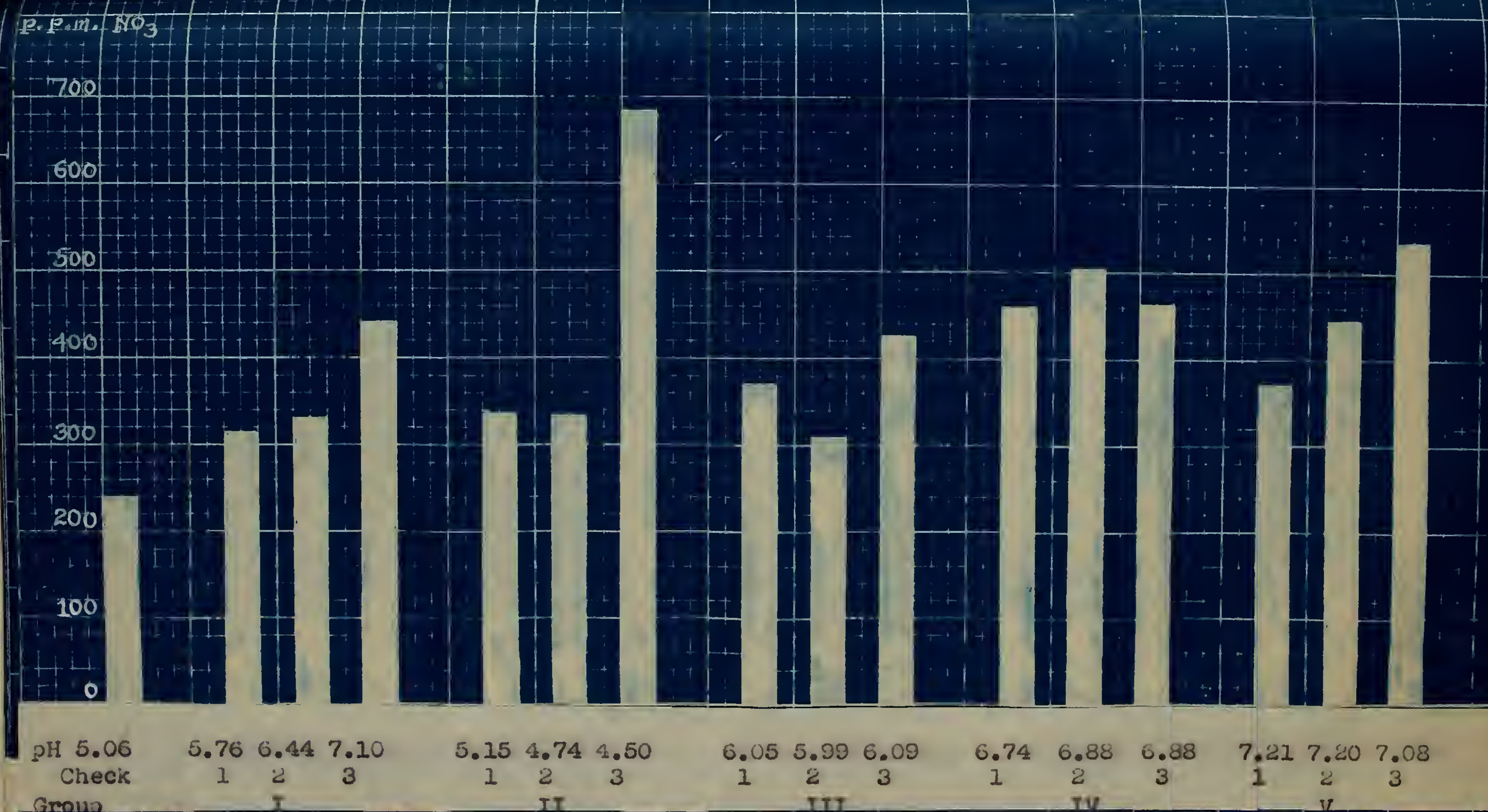

Figure 11, Hartford Soil, Incubated 8 Weeks

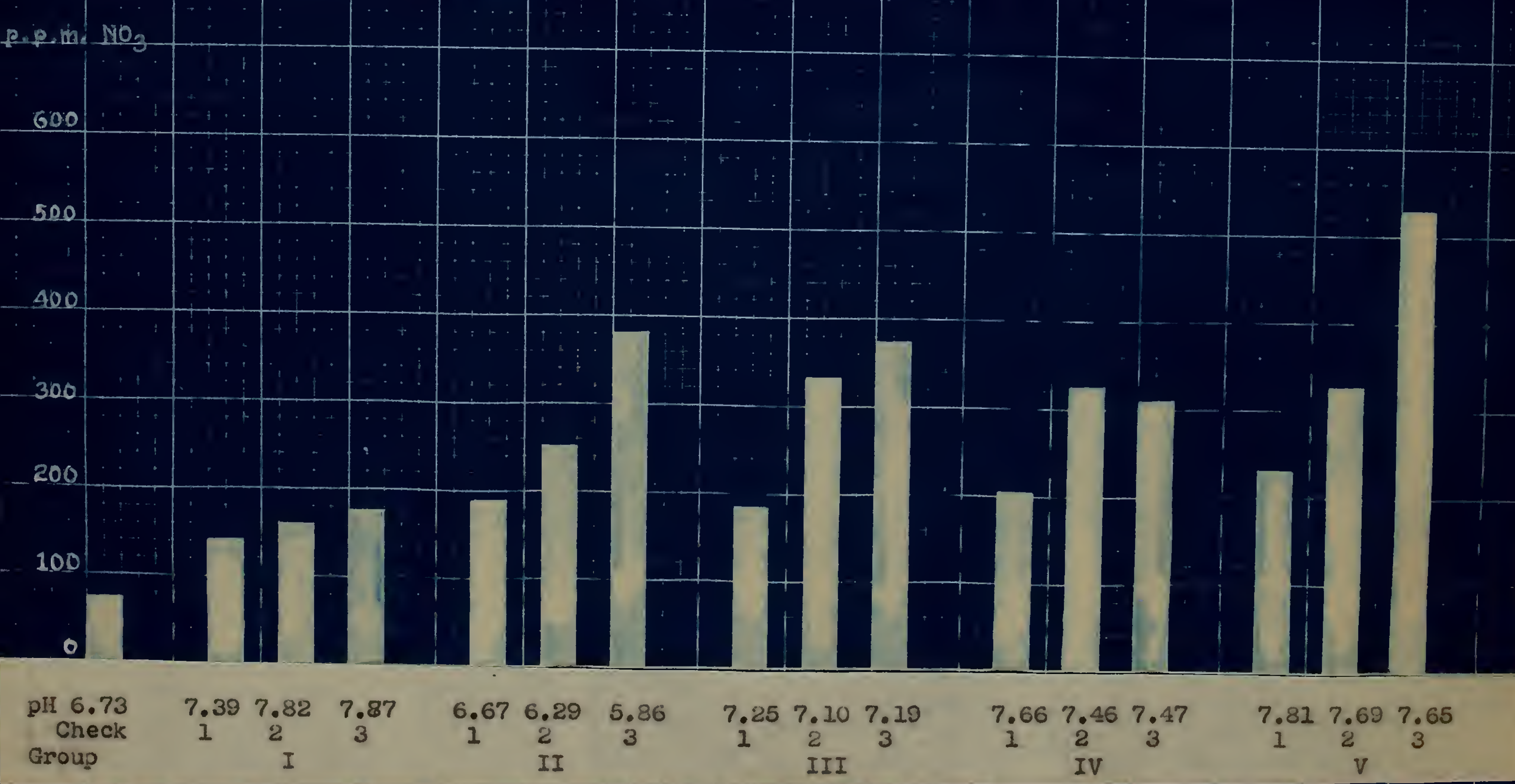

Figure 12, Gloucester Soil, Incubated 8 Weeks

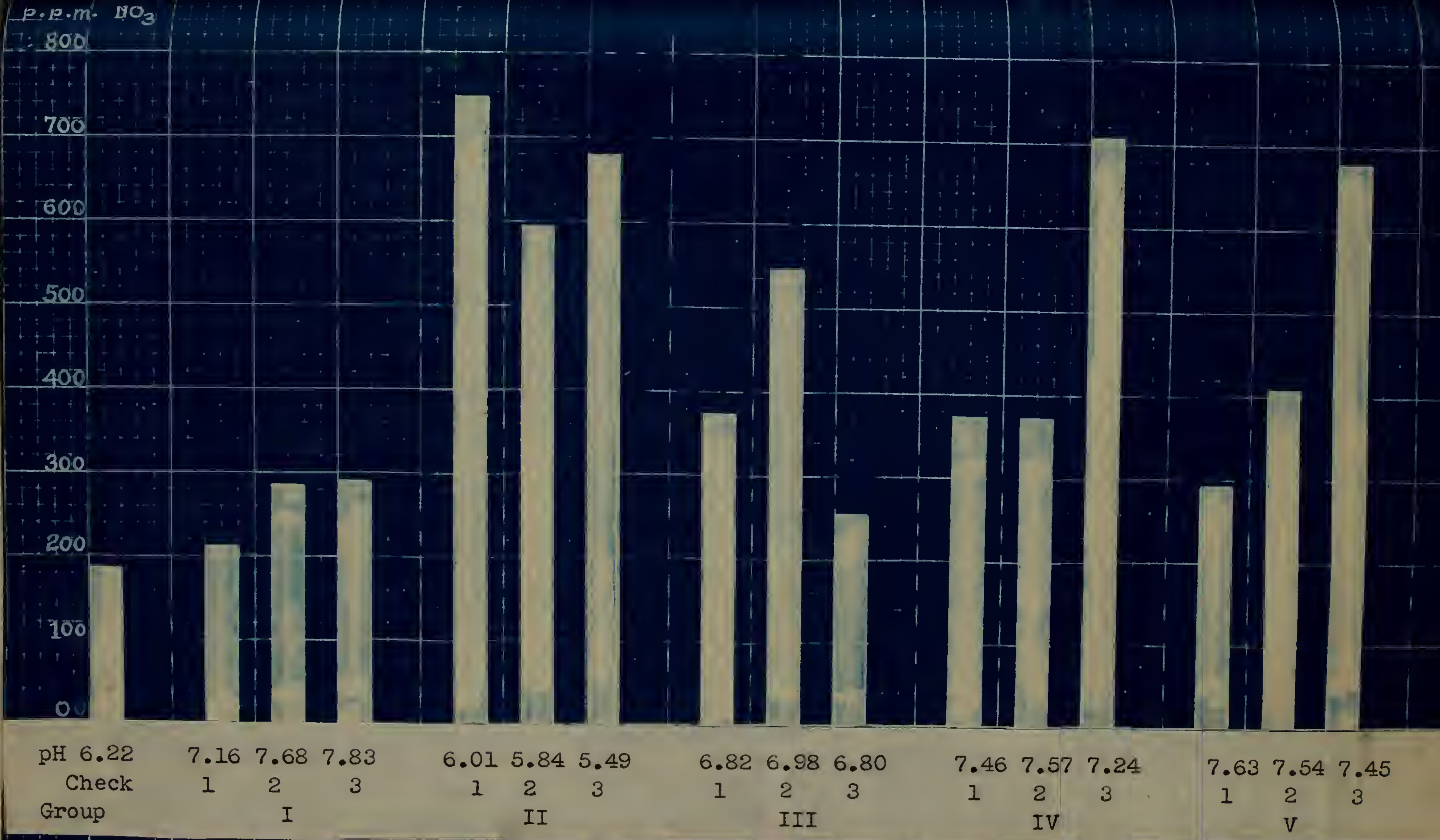

Figure 13, Merrimac Soil, Incubated 8 Weeks

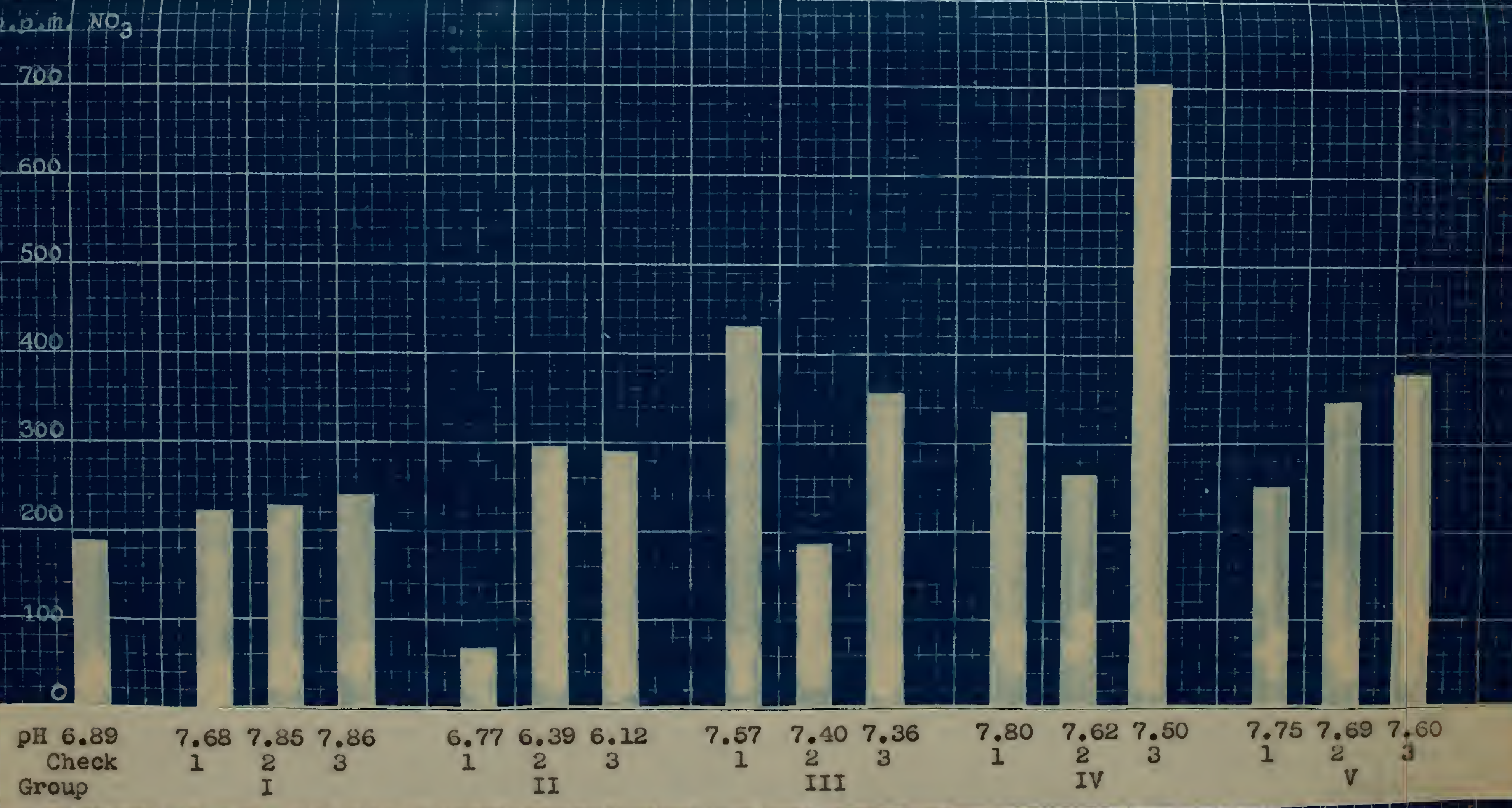

Figure 14, Suffield Soil, Incubated 8 Weeks

As stated in the introduction, the purpose of Part II is to study the nitrate accumulation and pH value in a soil as affected by varying amounts of lime, of fertilizer, and mixture of both lime and fertilizer applications in the absence of plant growth. The results of the nitrate and pH determinations for the four and eight weeks incubation period, together with their graphic representations, for each soil studied, are given on the following pages.

1. Hartford soil, pages 62, 63, 67, 68 and 69
2. Gloucester soil, pages 62, 64, 67, 68 and 70
3. Merrimac soil, pages 62, 65, 67, 68 and 71
4. Suffield soil, pages 62, 66, 67, 68 and 72

While the results of the four week incubation period may be of interest in some respects, the results of the eight week incubation period will be discussed in detail.

I. Discussion of the results of the Hartford soil.

A. Lime Treatments (Group I)

There was a considerable increase in nitrates above the check due to lime applications ranging from about 70 p.p.m. for the 2 tons of lime, to 100 p.p.m. for the 6 tons of lime. There was no marked difference in nitrates between the 2 and 4 tons of lime applications.

B. Fertilizer Treatments (Group II)

There was no essential difference in the increase of nitrates between the one-half and one ton of 4-8-4 applications. Moreover, the increase of nitrates produced by any one of the one-half, or one ton 4-8-4 treatments was no greater than that produced by the two or four tons of lime. The two tons of 4-8-4 treatment caused a very marked increase in nitrates.

C. Two tons of lime with varying amounts of 4-8-4 applications (Group III)

The two tons of lime plus one-half ton of 4-8-4 caused only a small increase of nitrate above that of two tons of lime, or one-half of 4-8-4 alone. There was no essential difference in nitrates between the 2 tons of lime, one ton of 4-8-4, or mixture of the two. The two tons of lime plus two tons of 4-8-4 treatment brought about a very marked increase in nitrates. The gain, however, was 256 p.p.m. less than that from the two ton application of 4-8-4.

D. Four tons of lime with varying amounts of 4-8-4, (Group IV)

There was a considerable increase in nitrates above that of four tons of lime or one-half of 4-8-4 brought about by the combined application of four tons of lime plus one-half ton of 4-8-4. The increase was

still greater with the four tons of lime plus one ton of 4-8-4. The 4 tons of lime plus two tons of 4-8-4 treatment caused an increase not greater than the four tons of lime plus one-half of 4-8-4 treatment.

E. Six tons of lime with varying amounts of 4-8-4 (Group V)

There was an increase in nitrates as the 4-8-4 applications increased. The one-half 4-8-4 plus six tons of lime treatment caused a slight increase in nitrates above that of one-half ton of 4-8-4, and a considerable decrease below that of six tons of lime.

F. One-half of 4-8-4 with varying amounts of lime (Group VI)

There was no significant increase in nitrates brought about by the addition of two or six tons of lime in the soil together with one-half ton of 4-8-4. The combined treatment of four tons of lime, plus one-half ton 4-8-4, however, caused an increase in nitrates of about 120 p.p.m. above that of the one-half of 4-8-4 treatment. While this combined treatment was the best, it was but slightly better than the six tons of lime alone.

G. One ton of 4-8-4 with varying amounts of lime (Group VII)

The one ton of 4-8-4 plus two tons of lime caused an increase in nitrates no greater than the two tons

of lime alone, and a slight decrease below that of one ton of 4-8-4 alone. One ton of 4-8-4 plus four tons of lime, and one ton of 4-8-4 plus six tons of lime caused an increase in nitrates, above that of one ton of 4-8-4 alone, of about 170 and 110 p.p.m. respectively. The one ton of 4-8-4 plus six tons of lime treatment did not cause any greater increase in nitrates than the six tons of lime alone.

H. Two tons of 4-8-4 with varying amounts of lime (Group VIII)

There was a marked increase in nitrates as the lime applications increased. In no case was the combined treatment nearly as good as the fertilizer treatment alone. The two tons of 4-8-4 plus two tons of lime treatment was no better than six tons of lime alone.

In regard to the pH value of the soil, as the lime applications increased, a corresponding increase of the pH took place while with the fertilizer the reverse was true. Also there was a gradual decrease of the pH value of the soil as the fertilizer applications increased while the lime was kept constant. The effect of lime, fertilizer, and mixture of lime and fertilizer upon the pH value of the soil is given on the following page.

The pH Value of the Soil as Affected by the Various Treatments

Lime		4-8-4		2 T. lime + 4-8-4		4 T. lime + 4-8-4		6 T. lime + 4-8-4	
Amount tons	pH	Amount tons	pH	Amount 4-8-4 tons	pH	Amount 4-8-4 tons	pH	Amount 4-8-4 tons	pH
2	5.76	1/2	5.15	1/2	6.05	1/2	6.74	1/2	7.21
4	6.44	1	4.74	1	5.99	1	6.88	1	7.20
6	7.10	2	4.50	2	6.09	2	6.88	2	7.08

Check - pH = 5.06

CONCLUSIONS

From the discussion given above the following conclusions have been drawn.

1. As the lime applications increased the nitrate accumulation as well as the pH value of the soil increased.

2. As the fertilizer applications increased the nitrates in the soil increased and the pH value decreased.

3. The combined treatment of lime and fertilizer in this soil in no case was as good as the sum of the individual treatments of lime and fertilizer. The presence of lime seems to be responsible for the variation in results.

4. There was no close correlation between the pH value and the nitrate accumulation in the soil.

II. Discussion of the results of the Gloucester soil.

A. Lime Treatments (Group I)

All lime treatments gave a considerable increase in nitrates above the check. There was a slight but gradual increase in nitrates with the increase of lime from two to six tons.

B. Fertilizer Treatments (Group II)

There was a marked increase in nitrates over the check due to the addition of 4-8-4 fertilizer, and as the fertilizer application increased from one-half to two tons a corresponding increase in nitrates took place.

C. Two tons of lime with varying amounts of 4-8-4 (Group III)

There was a considerable increase in nitrates as the 4-8-4 in the combined treatment increased from one-half to two tons. The nitrate accumulation brought about by the combined treatments of one-half and two tons of 4-8-4 in addition to the two tons of lime was no greater than that brought about by the individual fertilizer treatments without the lime. As for the one ton of 4-8-4 plus two tons of lime treatment there was a significant increase in the nitrates of the soil. The net nitrate gain above the check of this last treatment mentioned, was even

greater than the sum of the nitrate gain of the two individual treatments.

D. Four tons of lime with varying amounts of 4-8-4 (Group IV)

The combined treatment of one-half ton 4-8-4 and four tons of lime gave almost as great an increase in the nitrate accumulation of the soil as the single treatment of one-half ton of 4-8-4 alone. The presence of lime in the one ton of 4-8-4 application brought about a considerable increase in the nitrate accumulation over that of the one ton of 4-8-4 application without the lime. The presence of four tons of lime with the two tons of 4-8-4 treatment caused a considerable decrease in the nitrate accumulation as compared with the two tons of 4-8-4 treatment without the lime.

E. Six tons of lime with varying amounts of 4-8-4 (Group V)

In this group of treatments as the applications of 4-8-4 increased from one-half to two tons, an increase in nitrates took place, and in all cases the nitrate accumulation brought about by the combined treatments of lime and fertilizer was greater than that of the fertilizer alone. The net nitrate gain above the check of the two tons of 4-8-4 plus six

tons of lime treatment was even greater than the sum of the nitrate gain of the two individual treatments.

F. One-half ton of 4-8-4 with varying amounts of lime (Group VI)

The nitrate accumulation in the one-half ton of 4-8-4 plus two tons of lime treatment was about the same as that of the one-half ton of 4-8-4 treatment without the lime. With the increase of lime in the treatments only a small increase in nitrates took place.

G. One ton of 4-8-4 with varying amounts of lime (Group VII)

While the one ton of 4-8-4 plus two tons of lime brought about a considerable increase in nitrates above that of the one ton of 4-8-4 treatment, the higher applications of lime had a tendency to decrease rather than to increase the nitrate accumulation in the soil.

H. Two tons of 4-8-4 with varying amounts of lime.

The presence of two tons of lime with the two tons of 4-8-4 treatment neither increased nor decrease the nitrate accumulation of the two tons of 4-8-4 treatment. The presence of four tons of lime brought about a decrease and the six tons of lime an increase in the nitrate accumulation of the soil as

compared with the nitrate accumulation brought about by the two tons of 4-8-4 treatment without the lime.

The effect of the different lime and fertilizer treatments upon the pH value of the soil was similar to that in the Hartford soil. The pH value of this soil as affected by the different amounts and kinds of treatments is given in the table on the following page.

The pH Value of the Soil as Affected by the Various Treatments

Lime		4-8-4		2 T. lime + 4-8-4		4 T. lime + 4-8-4		6 T. lime + 4-8-4	
Amount tons	pH	Amount tons	pH	Amount 4-8-4 tons	pH	Amount 4-8-4 tons	pH	Amount 4-8-4 tons	pH
2	7.39	1/2	6.67	1/2	7.25	1/2	7.66	1/2	7.81
4	7.82	1	6.29	1	7.10	1	7.47	1	7.69
6	7.87	2	5.86	2	7.19	2	7.47	2	7.65

Check pH = 6.73

CONCLUSIONS

From the discussion of the results from this soil the following conclusions have been drawn.

1. As the lime applications increased nitrate accumulation as well as the pH value of the soil increased.

2. As the fertilizer applications increased while the nitrate accumulation increased the pH value of the soil decreased.

3. In the combined treatments of lime and fertilizer, the general tendency of the lime was to depress nitrate accumulation in the soil as compared with the sum of the effects of the individual treatment except with the two tons of lime plus one ton of 4-8-4, and six tons of lime plus two tons of 4-8-4 treatments.

4. There was no close correlation between the nitrate accumulation and the pH value of this soil.

III. Discussion of the results of the Merrimac soil.

A. Lime Treatments (Group I)

There was a gradual increase in nitrates over the check, as the lime applications increased to four tons, but there was no essential increase in nitrates as the lime application was increased from four to six tons.

B. Fertilizer Treatments (Group II)

There was a very marked increase in nitrates over the check, brought about by the fertilizer applications. However, there was no corresponding increase in nitrates as the applications were increased from one-half to two tons of 4-8-4. In fact the one-half ton application gave the greater increase in nitrates. In terms of p.p.m. the increase in nitrates above the check, was about 561.8, 421.3 and 496.2 for the one-half, one, and two tons of 4-8-4 applications respectively.

C. Two tons of lime with varying amounts of 4-8-4 (Group III)

There was a marked increase in nitrates as the 4-8-4 in the combined treatment was increased from one-half to one ton, and it was followed by a marked decrease in nitrates as the 4-8-4 was increased to two tons. From the results of the combined treatment

compared with those of the fertilizer treatments alone it will be seen that the presence of lime brought about a very depressing effect upon the nitrate accumulation of the soil.

D. Four tons of lime with varying amounts of 4-8-4 (Group IV)

All the combined treatments of lime and fertilizer brought about a considerable increase in the nitrate accumulation of the soil above the check or above the four tons of lime alone. The nitrate accumulation brought about by one-half ton 4-8-4 plus four tons of lime, was equally as good where the 4-8-4 was increased to one ton. The combined treatment of four tons of lime plus two tons of 4-8-4 caused a nitrate accumulation a little greater than that of the two tons of 4-8-4 alone. Here again the presence of lime had a tendency to cause depressing effects upon the nitrate accumulation of the soil.

E. Six tons of lime with varying amounts of 4-8-4 (Group V)

There was an increase in nitrates as the 4-8-4 in the combined treatment was increased from one-half to two tons. The combined treatment of six tons of lime plus one-half ton of 4-8-4 brought about an increase in the nitrate accumulation of the soil no greater than that of six tons of lime alone. The six tons of lime

plus two tons of 4-8-4 caused a nitrate accumulation no greater than the two tons of 4-8-4 alone. While the presence of lime had depressing effects upon the nitrate accumulation of the soil, the depressing effect was less pronounced with the highest 4-8-4 application.

F. One-half ton of 4-8-4 with varying amounts of lime (Group VI)

There was a gradual decrease in nitrates as the lime applications increased.

G. One ton of 4-8-4 with varying amounts of lime (Group VII)

There was a gradual decrease in the nitrates of the soil as the lime applications increased. The four tons of lime plus one ton of 4-8-4 gave the greatest decrease.

H. Two tons of 4-8-4 with varying amounts of lime (Group VIII)

The combined treatment of two tons of 4-8-4 plus two tons of lime brought about a very marked decrease in the nitrate accumulation of the soil as compared with the nitrate accumulation of the two tons of 4-8-4 treatment. As for the four and six tons of lime; together with two tons of 4-8-4, there was no essential difference between the nitrate accumulation brought about by each treatment. The presence of

four and six tons of lime in the two tons of 4-8-4 treatment neither increased nor decreased the nitrate accumulation of the soil, as compared with the two tons of 4-8-4 treatment without the lime. The effect of the various treatments upon the pH value of the soil was similar to that of the Hartford soil.

The changes in the pH value of this soil brought about by the different treatments are given on the following page.

pH Value Changes Brought about by Treatments

Amount	pH	Amount	pH	Amount	pH	Amount	pH	Amount	pH
Tons		Tons		Tons		Tons		Tons	
2	7.16	1/2	6.01	1/2	6.82	1/2	7.46	1/2	7.63
4	7.68	1	5.84	1	6.98	1	7.57	1	7.54
6	7.83	2	5.49	2	6.80	2	7.24	2	7.45

Check pH = 6.22

SUMMARY OF RESULTS

1. There was an increase in nitrates as the lime applications increased.

2. There was a marked increase in nitrates brought about by the fertilizer treatments. The maximum of the nitrate accumulation in this soil was brought about thru the one-half ton treatment and the minimum by the one ton.

3. In the combined treatments of lime and fertilizer, the presence of lime seemed to have depressing effects upon the nitrate accumulation of the soil. Such depressing effect of the lime was less pronounced with the two tons of 4-8-4 applications.

4. The maximum nitrate accumulation in this soil was brought about by four tons of lime, one-half ton of 4-8-4, and two tons of 4-8-4 plus four tons of lime.

5. There was no perfect correlation between the pH value and nitrate accumulation of the soil.

IV. Discussion of the results of the Suffield soil.

A. Lime Treatments (Group I)

There was a considerable increase in nitrates, over the check, brought about by the addition of lime. However, as the lime applications increased from two to six tons only a very small increase in nitrates took place in this soil.

B. Fertilizer Treatments (Group II)

There was a marked increase in nitrates below that of the check for the one-half of 4-8-4 treatment and a marked increase in nitrates above the check for the one and two tons of 4-8-4 treatments. The nitrate increase brought about by the one ton of 4-8-4 treatment was a little greater than that of the two tons of 4-8-4 treatment.

C. Two tons of lime with varying amounts of 4-8-4.

There was a very marked increase in nitrates above that of the one-half ton of 4-8-4 treatment brought about by the combined treatment of one-half ton of 4-8-4 plus two tons of lime. The nitrate accumulation brought about by this combined treatment was much greater than the sum of the individual treatments of two tons of lime and one-half ton of 4-8-4. The two tons of lime plus one ton of 4-8-4 treatment caused a nitrate accumulation less than that brought

about by either lime or the fertilizer alone. As for the two tons of lime plus two tons of 4-8-4 there was a nitrate accumulation greater than that of the lime alone or fertilizer alone.

D. Four tons of lime with varying amounts of 4-8-4 (Group IV)

The presence of lime in all the fertilizer treatments brought about an increase in nitrates above the check, greater than that of the fertilizer treatments without the lime. The nitrate accumulation brought about by one-half ton of 4-8-4 plus four tons of lime was considerably greater than that of the fertilizer without the lime, but was not as great as that of the lime without the fertilizer.

E. Six tons of lime with varying amounts of 4-8-4 (Group V)

In this group of treatments there was a marked progressive increase in nitrates as the amount of 4-8-4 increased from one-half to two tons. In no case was the nitrate increase of the combined treatments of lime and fertilizer equal to the sum of the individual treatments of lime and fertilizer.

F. One-half ton of 4-8-4 with varying amounts of lime (Group VI)

There was a marked increase in nitrates with the

two tons of lime treatment followed by a marked decrease as the lime treatment increased to four tons and again a considerable increase as the lime was increased to six tons. The greatest nitrate accumulation was brought about by the one-half ton of 4-8-4 plus two tons of lime treatment.

G. One ton of 4-8-4 with varying amounts of lime (Group VII)

As the lime applications increased from two to six tons a gradual increase in nitrates took place. The one ton of 4-8-4 plus two tons of lime brought about a nitrate accumulation in the soil no greater than that of the one ton of 4-8-4 without the lime.

H. Two tons of 4-8-4 with varying amounts of lime (Group VIII)

In this group the two tons of 4-8-4 plus two tons of lime treatment brought about a small nitrate accumulation than the two tons of 4-8-4 treatment without the lime. As for the other treatments there was a considerable nitrate accumulation as the lime in the combined treatments increased from two to six tons.

The effect of lime, fertilizer and combined fertilizer and lime treatments upon the pH value of the soil was similar to that of the other soils. The changes brought about in the pH value of this soil by the different treatments are shown on the following page.

The pH Value of the Soil as Affected by the Various Treatments

Lime		4-8-4		2 T. lime + 4-8-4		4 T. lime + 4-8-4		6 T. lime + 4-8-4	
Amount tons	pH	Amount tons	pH	Amount 4-8-4 tons	pH	Amount 4-8-4 tons	pH	Amount 4-8-4 tons	pH
2	7.68	1/2	6.77	1/2	7.57	1/2	7.80	1/2	7.75
4	7.85	1	6.39	1	7.40	1	7.62	1	7.69
6	7.86	2	6.12	2	7.36	2	7.50	2	7.60

Check pH = 6.89

CONCLUSIONS

From the discussion of the results the following conclusions have been drawn.

1. The maximum nitrate accumulation due to lime was brought about by the four ton treatment.

2. The maximum nitrate accumulation due to various fertilizer treatments was brought about by the two tons of 4-8-4.

3. The general tendency of the lime, in the combined treatments of lime and fertilizer, was to depress the nitrate accumulation in this soil, except in the one-half ton of 4-8-4 plus two tons of lime and one ton of 4-8-4 plus two tons of lime, where the nitrate accumulation brought about by the combined treatments was about equal to the sum of the separate treatments of lime and of fertilizer.

CONCLUSIONS FOR PART II

As a result of the points brought out in the discussion of the results of Part II the following conclusions are drawn.

1. There was an increase in nitrates in all the soils, brought about by the addition of lime alone. As the lime applications increased from 2 to 6 tons an increase in nitrates took place. Moreover the lower the pH value of the soil the greater was the gain in nitrates derived from the lime applications, except for the Suffield soil which altho it had a higher pH value than the Gloucester, had a greater nitrate gain than the Gloucester soil. The greatest gain in nitrates due to lime alone occurred with the Hartford soil, which had the lowest pH value and the largest amount of organic matter, characteristics which would tend to make lime effective as an aid to nitrification.

2. There was a general, but not perfect correlation between the pH value and the nitrate accumulation in the soils.

3. There was an increase in nitrates brought about by the applications of 4-8-4 fertilizer. The general tendency of the 4-8-4 was to bring about an

increase in nitrates as the applications increased. Also the lower the pH value in the soil the greater was the gain in nitrates for such treatments. An exception to this was the Merrimac soil which altho it had a higher pH value than the Hartford soil, its gain in nitrates was greater than that in the Hartford soil.

4. Fertilizer alone was more effective than lime alone with all soils and much more effective with three of the soils studied, in causing nitrate accumulation.

5. The gains in nitrates due to the combined treatments, of lime plus fertilizer were not additive in any of the soils. The presence of lime in the 4-8-4 treatments seemed to have depressing effects upon the nitrate accumulation of the soil from the standpoint of the sum of the individual effects. The relation of the gain in nitrates to the pH value of the soils was more irregular in the combined treatments than the relation of the pH value and the gain in nitrates from the individual treatments of lime and fertilizer.

6. In the 4 weeks incubation there was no correlation between the pH value and the gain in nitrates brought about by any of the different treatments. This inconsistency may be due to the short

incubation period.

7. The average gain in nitrates for the different treatments are given on the following page.

Gain in NO_3 in p.p.m. for the Different Treatments

Sum of gains due to: Lime	4-8-4	Lime + 4-8-4	Sum of gain in nitrates for all treatments	Average gain for all treatments
1. Hartford (pH 5.06) 361.4	Merrimac 673.7	Merrimac 1350.5	Merrimac 6858.2	Merrimac 457.2
2. Merrimac (pH 6.22) 261.9	Hartford 452.4	Hartford 1296.6	Hartford 6331.6	Hartford 422.1
3. Suffield (pH 6.84) 228.0	Gloucester 273.1	Suffield 1084.7	Suffield 4590.4	Suffield 306.0
4. Gloucester (pH 6.73) 158.7	Suffield 217.5	Gloucester 937.0	Gloucester 4106.4	Gloucester 273.6

GENERAL SUMMARY AND CONCLUSIONS

In this thesis have been reported the results of field and laboratory studies of the relation of soil reaction and associated factors to the accumulation of nitrates in soils. A wide range of soils and soil conditions has been considered, including soils of four series, several distinct cropping systems, a diversity of soil management and fertilizer practices, and soil reactions varying from 4.41 to 7.87 pH value.

As a result of the investigations, the following general conclusions are made:

1. In general, nitrates accumulate to a greater degree in soils of high (6.0 - 8.0) pH value than in those having low (4.0 - 6.0) pH values. To this general rule there are many exceptions, particularly in field soils supporting growing vegetation.

2. Apparently nitrate accumulation shows closer relationship to lime application than to soil reaction. This leads to the conclusion that lime is of more value in the nitrification process from the physiological standpoint than has been commonly supposed. Very high (7.0 - 8.0 tons per acre) applications of lime apparently do not increase nitrate accumulation.

3. In connection with soil reaction, the ordinary

range of arable soil types is not as important factor in the accumulation of nitrates, providing drainage and nutrient conditions are reasonably good.

4. Of the other factors considered in connection with soil reaction, the amount of fertilizer applied to the soil is the most important. Fertilizer alone appears to be more important than lime or soil reaction alone, in the accumulation of nitrates. Given a large amount of applied fertilizer, nitrates accumulate in large amounts in soils of comparatively low pH value.

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BIBLIOGRAPHY

1. Barthel, C. E.
Formation of nitrates in soil Svensk Kem. Tid 32, 173-183; Chem. Abs. Vol. 15:No. 7; p. 1053, 1921.

2. Bear, F. E.
A correlation between bacterial activity and lime requirements of soils. Soil Science 4: 433-463, 1917.

3. Brown, P. E. and Hitchcock, E. B.
Effect of alkali salts on nitrification. Soil Science 4: 207-229, 1917.

4. Brown, P. E. and Lipman, J. G.
Influence of previous treatment on the fixation of nitrogen. In New Jersey Agr. Station Report 1908-1909, p. 140.

5. Christie, A. W. and Martin, J. C.
Chemical effects of CaO and $CaCO_3$ on the soil, Soil Science 5: 383-391, 1918.

6. Copson, G. V. and Halversen, W. V.
Soil Biological studies at the Oregon Station, Biennial. Oregon Station Report, p. 59-61, 1920-1922.

7. Fred, E. B. and Graul, E. J.
Some factors that influence nitrate formation in soils. Soil Science 1: 317-338, 1916.

8. Gowda, R. N.
Nitrates and nitrification in acid soils. Soil Science 17: 333-342, 1924.

9. Kellerman, K. E. and Robinson, T. R.
Lime and legume inoculations. Science New Series 32(1910):p. 159,

10. Kruger, W.
A study of the nitrogen transformation in soils (Translated title) 1908, p. 58. Abstract in Experiment Station Record Vol. 12, p. 222.

11. Lyon, T. L. and Bizzell, J. A.
Availability of soil nitrogen in relation to basicity of soils and growth of legumes. Jour. Indus. and Engin. Chem., 2(1910), No. 7, p. 313-315.

12. Meek, C. S. and Lipman, C. B.
The relation of the reaction and of salt content of the medium on nitrifying bacteria. Journal of Gen. Physiology 5: 195, 1923.

13. Potter, R. S. and Snyder, R. S.
Determination of amino acids and nitrates in soils. Iowa Research Bul. 24, 1925.

14. Prince, A. L. and Blair, A. W.
Variation of nitrate nitrogen and pH value of soils from the nitrogen availability plots. Soil Science Vol. 14, p.p. 9-20, 1922.

15. Scales, F. M.
Relation of lime to production of nitrates. Science New Series 42(1915), No. 1079, p. 317,

16. Shorey, E. C.
The principles of the liming of soils. Farmers Bulletin 921, 1918.

17. Stephenson, R. E.
Nitrification in acid soils. Iowa Agr. Exp. Res. Bul. 58, 1920.

18. Temple, J. E.
Nitrification in acid or non-basic soils. Ga. Exp. Sta. Bul. 103, 1924.

19. Vogel, J.
The action of lime on the bacterial life in soils. Chem. Abs., 2(1908), No. 15 pp. 2119-2120.

20. Waksman, S. A.
In principles of soil microbiology, Williams and Wilkins, Baltimore, 1927 pp. 66 and 529.

21. Whiting, A. L. and Schoonover, W. R.
Nitrate production in field soils in Illinois. Illinois Sta. Bul. 225 pp. 21-63, 1920.

22. Withers, W. A. and Fraps, G. S.
Nitrification in different soils. Jour. Amer. Chem. Soc. 24: 528-534, 1902.

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NITRATE NITROGEN ACCUMULATION IN SOILS AS AFFECTED BY SOIL

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