AGRONOMIC EVALUATIONS OF UREA-FORMALDEHYDE CONCENTRATE-85 (UFC-85) SOLUTION

by

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INTRODUCTION

Because of its high requirement by plants, nitrogen is considered the most important single element in the soil. Related processes of ammonification and nitrification occur when organic or inorganic fertilizers are applied to the soil. These phenomena will be discussed later in more detail.

An ideal source of nitrogen fertilizer is one which releases available nitrogen at a rate that approximates the plants' requirements during the growing season. This slow release of available nitrogen should reduce losses caused by leaching and denitrification. Organic and standard commercial nitrogen fertilizers fail to meet this requirement because of two reasons; first, conversions to ammoniacal and nitrate nitrogen are rapid resulting in leaching and denitrification losses; secondly, because the nitrogen requirement throughout the growing season is not satisfied by a single application, one or more side dressings are required to obtain maximum yields.

However, Urea-Formaldehyde Concentrate-85 releases nitrogen slowly throughout the entire growing season. Therefore, a single application may be adequate.

The product U. F. C.-85 (Urea-Formaldehyde Concentrate-85) is produced by the Nitrogen Division, Allied Chemical Corporation (39). Its principal uses thus far are industrial in nature and include the manufacturing of adhesives, textiles, paper, industrial finishes, etc. Chemically, its general composition is as follows:

Formaldehyde - - - - - - - - - - -	59%	85% Concentrate
Urea - - - - - - - - - - - - - - -	26%	
Water - - - - - - - - - - - - - -	15%	

Mole ratio of formaldehyde to urea 4.6:1

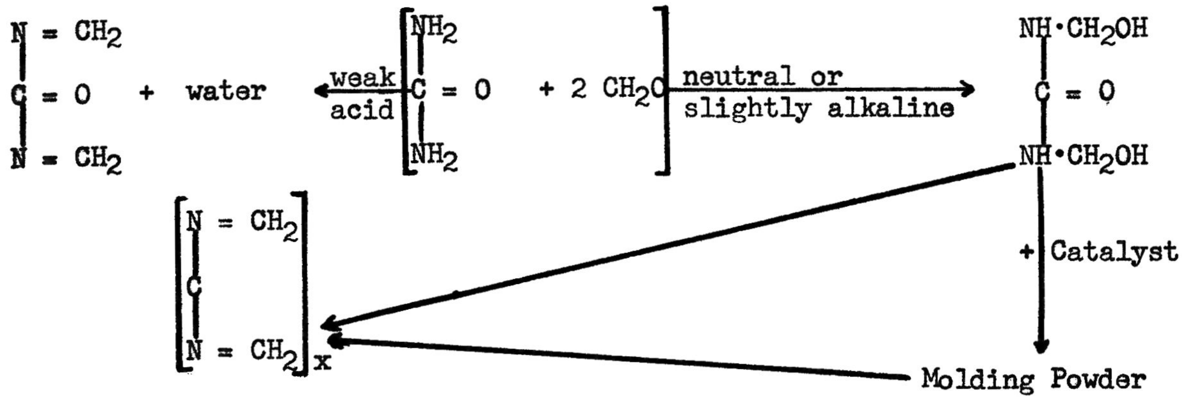
U. F. Concentrate-85 is a clear, colorless, viscous solution. It is relatively non-volatile, having a vapor pressure lower at corresponding temperatures than that of normally-used formaldehyde solutions. No permanent adverse effects are produced by storing the Concentrate at low temperatures. High storage temperatures may deteriorate the material quite rapidly. The pH of U. F. Concentrate-85 drops during storage at room temperature (39).

The purpose of the present experiment was to ascertain some agronomic adaptations of U. F. Concentrate-85. This study was further divided into three principal phases: (1) a detailed study determining the rate of conversion to ammoniacal and nitrate forms of nitrogen using various treatments on two soils, (2) emergence studies with oats and soybeans in the greenhouse using the same two soils as in (1), and (3) comparing equal rates of U. F. Concentrate-85 with ammonium nitrate and urea for oats under field conditions.

REVIEW OF LITERATURE

Urea-formaldehyde reaction products have been in general industrial use since the turn of the century (34, 37). Only in the past twenty years have investigators recognized the need for a slowly available nitrogen source and turned to this product (1, 38).

Urea-formaldehyde formulations can be made with a certain degree of controlled availability by varying the mole ratio of urea to formaldehyde (15,38). Early research work conducted by Fuller and Clark (15), and Yee and Love (38) in laboratory nitrogen availability studies, showed that urea-formaldehyde reaction products commonly called ureaform, when properly formulated are effective, slow releasing sources of nitrogen. Yee and Love (38) indicated that little is known of urea-formaldehyde materials produced with U/F ratios greater than 1 (18). They appear to contain methylene (=CH_2) and to have terminal $-NH_2$ groups. The following urea-formaldehyde reactions may occur:



Plastic

Yee and Love further suggested that such materials should offer some possibility of sources of slowly available nitrogen. They concluded that the availability of the nitrogen in the urea-formaldehyde products was found to be roughly proportional to their solubility in water.

Clark et al. (5) observed that a portion of the nitrogen as urea-formaldehyde improved both the quality and yield of tobacco.

Considerable interest has developed in recent years with regard to urea-formaldehyde fertilizer as a slow releasing source of nitrogen for use in turfgrass culture and pine seedlings (20, 23).

Early controlled plant growth studies were conducted by Arminger et al. (1), whereas the first field experiments on turfgrasses were reported by Musser et al. (24). Their results in general showed uniform release of nitrogen during the growing season.

Results of ureaform (or urea-formaldehyde) fertilizer experiments conducted on lawns and fairway turfs during the 1957 growing season at the Rhode Island Agricultural Experiment Station (36) showed that ureaform fertilizers were excellent sources of nitrogen over an extended period of time. Results indicated that a more uniform turf was obtained when an adequate amount of ureaform fertilizer was applied in one dormant application rather than split applications of the same rate.

In forest nurseries repeated nitrogen topdressings of pine seedlings (*Pinus taeda* L.) has been a standard practice. The topdressings are costly from the standpoint of labor and cost of materials. Results to date indicate that under conditions similar to those prevailing in 1955, the use of urea-formaldehyde fertilizer may eliminate the need for periodic nitrogen applications during the growing season. In 1955 a single application of 632 pounds per acre of urea-formaldehyde (248 pounds of N) prior to sowing resulted in seedling heights equal to those of seedlings receiving 1,141 pounds per acre of ammonium nitrate (376 pounds of N) in eight applications (20).

Scarsbrook (26) compared three formulations of experimental 12-12-12 grade fertilizers, each containing a portion of the nitrogen as urea-formaldehyde, with ammonium nitrate as sources of nitrogen for cotton and corn. Ammonium nitrate produced higher yields than equivalent rates of nitrogen from fertilizers containing urea-formaldehyde. However, the largest residual effect generally resulted from the urea-formaldehyde.

Recent experiments at Sandford, Florida, (10) indicate that U. F. Concentrate-85 may be substituted for formaldehyde for celery seedbed sterilization. This material seems to be less volatile than formaldehyde alone and more effective as a fungicide. In addition, it leaves the seedbeds rich in nitrogen, causing rapid plant growth.

When applied broadcast at a rate of 150 gallons per acre, U. F. Concentrate-85 at the Wisconsin station (2) was effective for controlling common potato scab on the Irish Cobbler variety in 1956 and the Chippewa variety in 1957. Stands were reduced by 42 per cent when potatoes were planted immediately after the U. F. Concentrate-85 had been applied broadcast at a rate of 250 gallons per acre, while rates of 50 and 150 gallons had no effect on the stand.

Pasteur (33) in 1860 was the first to recognize that the transformation of urea to ammonia is brought about by living organisms. It was later discovered that organisms capable of hydrolyzing urea are found in most families of bacteria, actinomycetes, and fungi (33). Heterotrophic nitrification due to actinomycetes and fungi has not been fully evaluated (29). It was considered by Sumner and Somers (30) that bacteria employ urease to convert urea to ammonia for their needs. Conrad (7) reported that urease activity in the soil may vary with the cropping system and that the higher the organic matter content, the greater the urease-like activities. Consequently, the surface soil is higher than the subsoil in these activities. This was further substantiated by Warington (35) who observed that the number of nitrifying bacteria apparently decreases with depth of soil. Also, Wilson (36) found that the number of nitrifiers varied with previous management of the soil. Further investigations by Wilson indicated that within similar treatments, the number of nitrifiers decreases with the decrease of pH in the range of 6.7 to 5.0.

Meyerhof (21) reported the optimum reaction for Nitrosomonas sp. to be 8.5 to 8.8, and for Nitrobacter, 8.3 to 9.3, although pH optima appeared to vary somewhat with bacterial strain and nature of the cultural medium.

Conrad and Adams (9), however, suggested that hydrolysis of urea should be considered catalytic in nature instead of completely microbial.

Laider and Hoard (19) contended that the maximum rate of urea hydrolysis was at a pH of 6.2 and a temperature of 30°C. Other investigators have reported other pH and temperature levels for maximum urea hydrolysis (8, 16).

The ammonia formed by urea hydrolysis becomes the raw material for the process of nitrate formation (7). The ammonium ion (NH_4^+) is a positively charged ion which exchanges with other ions on the surface of clay particles (27). Nitrification may be defined as the oxidation of ammonia to nitrate nitrogen (31). Therefore, the speed of nitrification may be dependent upon the quantity of ammonia available.

Nitrification is dependent upon bacteria. There are two groups of this bacteria. One group, Nitrosomonas or Nitrosoccus, transforms ammonia to nitrite nitrogen; and the other group, Nitrobacter, converts the nitrite to nitrate nitrogen (32). The equations for the reactions are generally written as follows:

1st step:

$$2\ NH_4^+ + 3\ O_2 \longrightarrow 2\ NO_2^- + 4\ H + \text{Energy}$$

2nd step:

$$2\ NO_2^- + O_2 \longrightarrow 2\ NO_3^- + \text{Energy}$$

The nitrate ion (NO_3^-) is a negatively charged ion that moves freely in the soil water and is readily available to plants (27).

Fisher and Parks (12) added nitrogen as urea to soil samples at rates equivalent to 100 and 200 pounds of N per acre. Results show that there was generally an increase in the rate of urea hydrolysis and subsequent nitrification with an increase in soil temperature. At a low temperature of 10°C., the rate of hydrolysis was relatively slow which may lead to leaching loss of urea nitrogen.

Eno and Blue (11) found that when anhydrous ammonia was applied to the soil the pH was raised to such a level for optimum nitrification. The high pH provides a base for the neutralization of the nitric acid. This process is effective only as long as high concentrations of ammonia are present in the soil.

As far as denitrification is concerned factors such as low pH, very high temperature, high moisture level, and any other factor restricting oxygen from the soil are important (3).

Broadbent and Hill (4) found that when inhibition of nitrification occurs following ammonium fertilizer application, one or more of the following causes may be important:

1. Excessively high pH resulting from application of alkaline materials.
2. Excessively low pH resulting from formation of nitrous and nitric acids.
3. Presence of free ammonia, exerting selective inhibition on the nitrate forming bacteria.
4. Salt effect, resulting in osmotic concentrations too high for optimum activity of nitrifying bacteria.

METHODS AND MATERIALS

Soil Materials Used

The surface six inches of two soils were utilized in this experiment. A Sarpy sandy loam soil was obtained from the Ashland Agronomy Farm near Manhattan, Kansas. This alluvial soil is found adjacent to the Kansas River. A Geary silty clay loam was obtained from the Kansas State University Agronomy Farm near Manhattan, Kansas. This is a Reddish Prairie soil which has developed in reddish-brown loess or loess-like materials.

Fertilizer Used

The principal fertilizer employed throughout the duration of this experiment was Urea-Formaldehyde Concentrate-85. Aside from this, ammonium nitrate and urea were used for comparison purposes with U. F. Concentrate-85 on a field oats study.

U. F. Concentrate-85 is a clear, colorless viscous solution (specific gravity is 1.32) of HCHO (formaldehyde) and $(NH_2)_2CO$ (urea) reacted in a small amount of water. It is relatively non-volatile, having a vapor pressure lower at corresponding temperatures than that of normally used formaldehyde solutions. No permanent adverse effects are produced by storage at low temperatures; however, storage at high temperatures may deteriorate the material quite rapidly. The material contains about 85 per cent concentrates combined in a formaldehyde to urea mole ratio of 4.6:1. A typical solution contains 59 per cent formaldehyde and 26 per cent urea (39).

Ammonification and Nitrification Procedures

Each of the two soils, Geary silty clay loam and Sarpy sandy loam, were brought into the greenhouse, spread out on a table and thoroughly mixed. Two thousand five hundred grams of each soil were placed in 32 pots, thus making a total of 64 pots. Eight rates of U. F. Concentrate-85 were applied in a water mixture with four replications per rate.

Table 1. Rates of fertilizer application per soil for ammonification and nitrification studies.

Fertilizer	Number of pots at each application rate	Rate of application of nitrogen pounds per acre	Amount of fertilizer applied to each pot
U.F.Concentrate-85	4	no treatment	0.00 ml.
"	4	100	0.78 ml.
"	4	200	1.56 ml.
"	4	400	3.12 ml.
"	4	800	6.24 ml.
"	4	1200	9.36 ml.
"	4	1600	12.48 ml.
"	4	2000	15.60 ml.

On December 20, 1958, the Sarpy sandy loam was placed in a room in which the temperature was kept as close to 25°C. as was possible. On December 23, 1958, the Geary silty clay loam was placed in the same room. Since this was not a definite constant temperature room, a periodic check of the temperature was made. Variations of only 2 to 3°C. occurred during the experiment. The moisture content in each pot was maintained at field capacity.

Periodically, soil samples were removed from each of the 64 pots and placed in a cellophane bag. Toluene was added to each sample to prevent any further action of bacteria. The bags were sealed and placed in a refrigerated room until ammoniacal and nitrate nitrogen determinations could be made.

On June 20, 1959, the entire above procedure was repeated on the same two soils except fewer and lower treatments were employed. There were three treatments with four replications per treatment, thus making a total of 12 pots per soil or 24 pots for the two soils. A constant temperature room was available and the temperature was maintained at 80°F. Again moisture content was kept at field capacity. The soils used were obtained June 18, 1959.

Table 2. Rates of fertilizer application per soil for ammonification and nitrification studies.

Fertilizer	Number of pots at each application rate	Rate of application of nitrogen pounds per acre	Amount of fertilizer applied to each pot
U.F.Concentrate-85	4	no treatment	0.000 ml.
"	4	40	0.312 ml.
"	4	80	0.624 ml.

Greenhouse Procedure

On March 20, 1959, a portion of the remaining soil from the ammonification and nitrification studies was utilized for greenhouse studies. After the soil had been thoroughly mixed and placed in pots, four treatments of U.F.Concentrate-85 with four replications per treatment were applied to each soil.

Table 3. Rates of fertilizer application per soil for emergence studies in the greenhouse.

Fertilizer	Number of pots at each application rate	Rate of application of nitrogen pounds per acre	Amount of fertilizer applied to each pot
U.F.Concentrate-85	4	no treatment	0.00 ml.
"	4	200	1.56 ml.
"	4	800	6.24 ml.
"	4	1600	12.48 ml.

Clark soybeans and Andrew oats were the crops grown on each soil. Prior to fertilizer application, ten soybeans and fifteen oats were planted in each of 16 pots, thus making 32 pots per soil or a total of 64 pots. Moisture level was maintained at field capacity. Plant counts were taken daily as the seedlings emerged. After a twenty day waiting period, if no plants emerged, fresh seeds were planted in the culture where no emergence occurred.

On June 20, 1959, the entire procedure above was repeated on the same two soils except fewer and lower rates were employed. There were three treatments with four replications per treatment. The same two crops were grown. Moisture level was again maintained at field capacity. No replantings were necessary. The soils used were obtained June 18, 1959.

Table 4. Rates of fertilizer application per soil for emergence studies in the greenhouse.

Fertilizer	Number of pots at each application rate	Rate of application of nitrogen pounds per acre	Amount of fertilizer applied to each pot
U.F.Concentrate-85	4	no treatment	0.00 ml.
"	4	50	0.39 ml.
"	4	100	0.78 ml.

Field Procedure

The location of the field work was on heavy Geary soil located on the Kansas State University Agronomy Farm near Manhattan, Kansas. This was a comparison study of U. F. Concentrate-85 with ammonium nitrate and urea nitrogen fertilizers.

Table 5. Rates of fertilizer application on field oats study.

Fertilizer	Number of replications	Rate of application of nitrogen pounds per acre	Amount of fertilizer applied to each plot
No treatment	4	0	0.00 ml.
U.F.Concentrate-85	4	20	158.00 ml.
"	4	80	632.00 ml.
"	4	160	1264.00 ml.
Ammonium Nitrate	4	20	74.91 grams
"	4	80	299.64 grams
"	4	160	599.28 grams
Urea	4	20	56.75 grams
"	4	80	277.00 grams
"	4	160	454.00 grams

Each plot was 20' x 6'. There were ten plots per block and four blocks. Application of the fertilizer was on March 17, 1959, immediately before planting. The ammonium nitrate and urea were spread by hand while the U. F. Concentrate-85 was applied by use of a sprinkler can. Plant counts were taken from four places April 6, 1959, and April 21, 1959, on each of the ten plots on block number three. July 2, 1959, the five center rows of each plot were harvested by hand. Weights were recorded on the straw and grain samples. Upon threshing July 6, 1959, grain and straw yields were calculated.

Laboratory Analysis

Nitrate nitrogen was determined by the phenoldisulfonic method as outlined by Jackson (17). Ammoniacal nitrogen was determined by Richardson's Kjeldahl method (25).

Following threshing of the field oats, the grain yield was determined at 12 per cent moisture. The straw weight was determined on the oven dry basis.

RESULTS AND DISCUSSION

Ammonification and Nitrification Studies

Ammonification in Sarpy sandy loam starting December 20, 1958. The first sampling of Sarpy sandy loam reflected a definite increase in ammonification of all rates of U. F. Concentrate-85 as compared to the check. As the rate of N increases, the length of time required for optimum ammonification also increases. Fig. 1 and Table 6 show that while only 15-20 days were necessary for optimum ammonification to occur at the 100 ppm N rate, over twice this time was required for the highest rate (1000 ppm N) to reach maximum ammonification. Only the two lower rates (50 and 100 ppm N) declined to the same general position as the check. All other rates achieved maximum ammonification and then decreased somewhat more slowly.

Ammonification in Geary silty clay loam starting December 23, 1958. Ammonification in Geary silty clay loam generally resembled that in Sarpy sandy loam except the rate at which it occurred was much more rapid. The rates of ammonification for the lower rates (50 and 100 ppm N) were nearly the same as that for the check (Fig. 2 and Table 7). Other treatments produced increases in ammonification as compared to the check. The highest

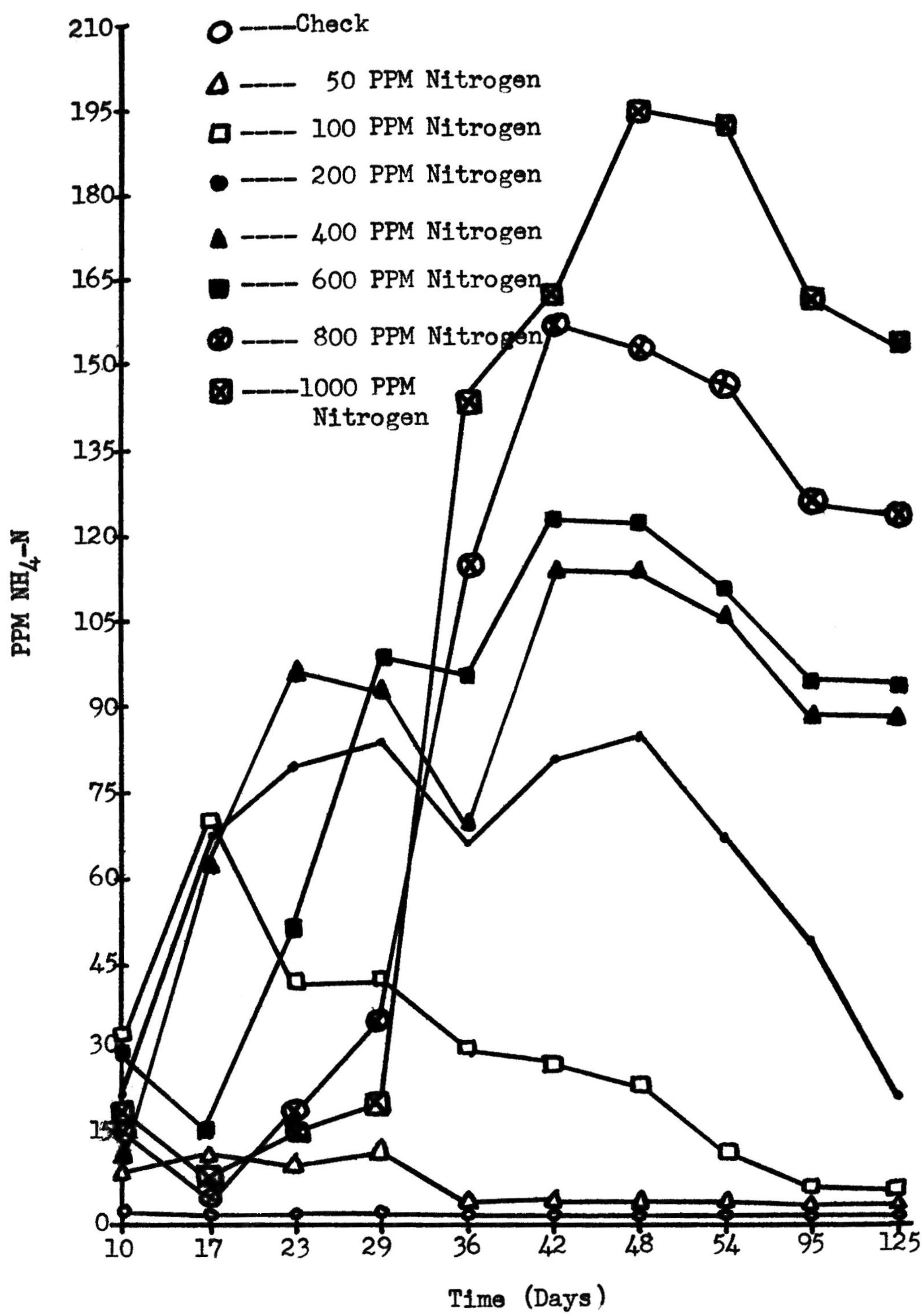


Fig. 1. Rate of ammonification in Sarpy sandy loam.

Table 6. Ammonification (PPM NH_4-N) in Sarpy sandy loam using U.F.C.-85 as the source of nitrogen.

	Days after Initial Application									
Treatment*	10	17	23	29	36	42	48	54	95	125
1	0.86	1.59	0.14	1.84	0.84	0.86	1.00	0.14	2.20	0.97
2	11.00	11.60	10.30	13.00	3.87	1.58	1.28	0.85	2.56	1.29
3	32.80	70.60	42.80	43.50	31.00	28.00	25.10	12.10	4.13	1.18
4	21.40	69.00	80.00	84.30	67.70	81.30	86.30	66.60	46.90	21.80
5	12.80	63.20	97.90	94.50	69.40	114.00	114.00	106.00	89.60	89.70
6	29.80	16.80	52.30	99.60	95.60	123.00	123.00	111.00	95.00	94.90
7	16.90	2.60	19.70	36.10	115.00	158.00	153.00	147.00	126.00	124.00
8	17.70	9.54	18.30	23.40	144.00	163.00	195.00	193.00	162.00	155.00

*Treatments:

1. Check
2. 50 PPM N per acre
3. 100 " " " "
4. 200 " " " "
5. 400 " " " "
6. 600 " " " "
7. 800 " " " "
8. 1000 " " " "

Treatment L.S.D. $_{.01}$ = 48.90
.05 = 36.80

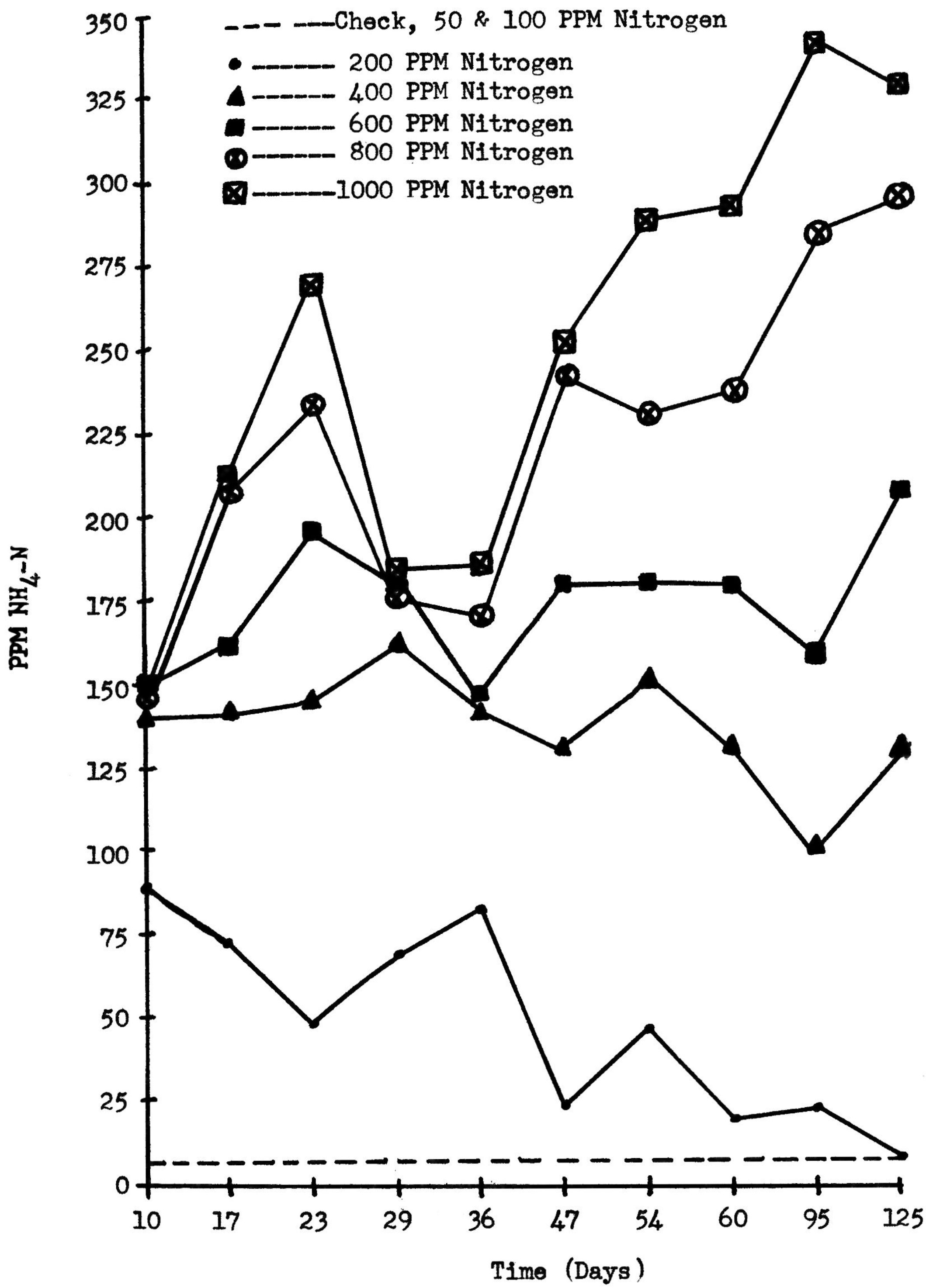


Fig. 2. Rate of ammonification in Geary silty clay loam.

Table 7. Ammonification (PPM NH-4) in Geary silty clay loam using U.F.C.-85 as the source of nitrogen.

	Days after Initial Application									
Treatment*	10	17	23	29	36	47	54	60	95	125
1	3.89	4.98	0.80	0.27	0.45	2.70	0.92	1.08	1.08	1.72
2	4.50	2.68	0.68	1.67	1.37	2.75	1.76	12.20	0.74	1.22
3	24.50	4.76	2.10	2.25	26.40	1.75	1.41	3.52	1.32	3.18
4	90.50	73.60	49.40	70.90	84.40	25.00	48.60	20.70	24.20	9.92
5	142.00	143.00	147.00	164.00	143.00	132.00	154.00	132.00	103.00	134.00
6	150.00	163.00	198.00	181.00	148.00	182.00	183.00	180.00	165.00	209.00
7	143.00	210.00	235.00	176.00	170.00	243.00	233.00	239.00	286.00	291.00
8	146.00	212.00	271.00	178.00	186.00	254.00	290.00	293.00	343.00	330.00

*Treatments:

Treatment L.S.D.$_{.01}$ = 43.57
$_{.05}$ = 32.76

1. Check
2. 50 PPM. N per acre as U.F.C.-85
3. 100 " " " " " "
4. 200 " " " " " "
5. 400 " " " " " "
6. 600 " " " " " "
7. 800 " " " " " "
8. 1000 " " " " " "

rates of U. F. Concentrate-85 (400, 600, 800 and 1000 ppm N) had not declined in ammonification at the time of the last sampling. This however, was not true with the Sarpy sandy loam. The two highest rates in the Geary silty clay loam also required longer to reach maximum ammonification than in the Sarpy sandy loam.

Nitrification in Sarpy sandy loam starting December 20, 1958. With every rate of U. F. Concentrate-85 there appeared to be a reduction in nitrification in the Sarpy sandy loam as compared with the check. However, the second sampling reflected a definite increase in nitrification for the lower rates of 50 and 100 ppm N. Nearly a month was required before nitrate accumulation at the 200 ppm N rate was greater than in the check. Over three months were required before the 400 ppm N rate exceeded the check, and nearly 100 days were required before nitrification at the 600 ppm N rate was above that of the check. Therefore, as the level of N was increased, the longer it took for nitrification to occur and proceed to a maximum. Once nitrification commenced a significant increase was noticed (Fig. 3 and Table 8). Only the two lower rates of U. F. Concentrate-85 showed any decline in nitrification once a maximum was obtained. The two lower rates appeared to be declining to the level of the check when the last sampling was analyzed.

Nitrification in Geary silty clay loam starting December 23, 1958. Nitrification in Geary silty clay loam was similar to that of the Sarpy sandy loam except it was at a higher level for every rate of addition and with the check as well. Initially, all rates of U. F. Concentrate-85 were retarded in degree of nitrification except the lowest rate. Fig. 4 and Table 9 show that the lower rates produced more nitrate nitrogen in a shorter period of time than did the heavier treatments. However, when nitrification did begin at the

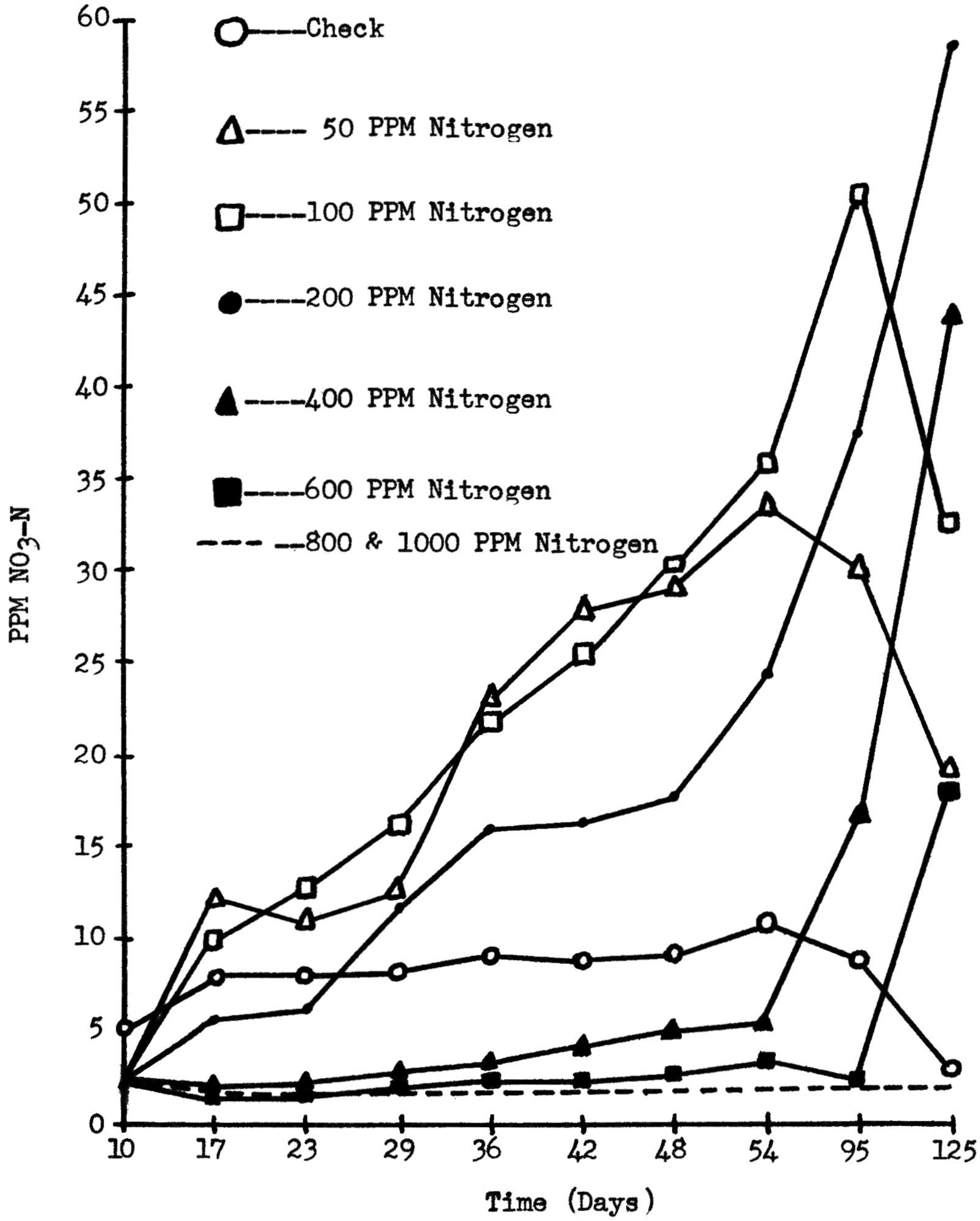


Fig. 3. Rate of nitrification in Sarpy sandy loam.

Table 8. Nitrification (PPM NO_3-N) in Sarpy sandy loam using U.F.C.-85 as the source of nitrogen.

	Days after Initial Application									
Treatment*	10	17	23	29	36	42	48	54	95	125
1	5.3	7.7	7.8	8.0	9.2	8.6	9.1	10.6	8.7	2.4
2	3.2	12.2	11.4	12.6	23.2	28.0	29.4	33.9	30.8	19.4
3	2.5	10.4	12.6	16.3	23.0	25.4	30.4	36.4	50.2	32.8
4	2.8	5.6	6.2	12.2	15.9	16.0	17.7	24.4	37.9	58.6
5	3.3	2.1	2.1	2.8	3.2	4.7	5.1	5.2	16.9	44.0
6	3.5	2.0	2.2	2.3	2.4	2.2	3.4	4.0	2.0	18.8
7	2.9	2.0	2.4	2.6	2.7	2.6	3.1	1.9	1.7	6.4
8	3.2	2.1	1.7	2.3	2.1	2.7	2.6	2.7	1.2	3.0

*Treatments:

Treatment L.S.D. $_{.01}$ = 11.10
.05 = 8.34

1. Check
2. 50 PPM. N per acre
3. 100 " " " "
4. 200 " " " "
5. 400 " " " "
6. 600 " " " "
7. 800 " " " "
8. 1000 " " " "

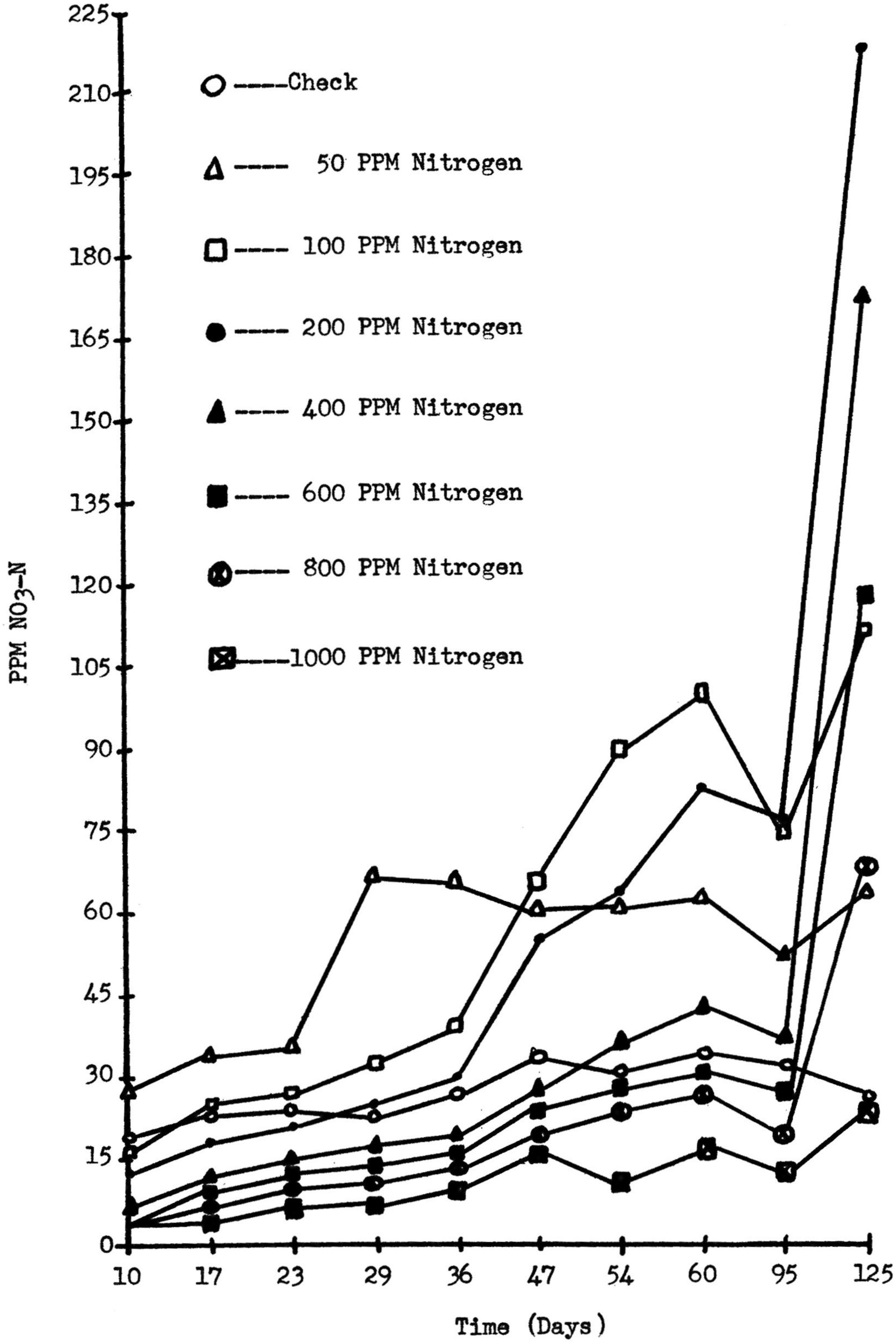


Fig. 4. Rate of nitrification in Geary silty clay loam.

Table 9. Nitrification (PPM NO_3-N) in Geary silty clay loam using U.F.C.-85 as the source of nitrogen.

	Days after Initial Application									
Treatment*	10	17	23	29	36	47	54	60	95	125
1	20.6	24.6	26.3	25.6	27.6	34.7	31.6	33.9	32.6	26.4
2	29.5	35.3	36.9	68.5	66.3	61.4	61.6	63.4	51.3	64.9
3	19.1	26.1	29.0	33.0	41.2	67.6	90.0	101.3	74.5	111.6
4	13.5	19.2	21.9	26.3	30.1	56.3	64.8	83.0	75.8	217.7
5	6.0	13.2	15.3	18.6	20.4	29.2	37.3	43.9	37.2	172.5
6	4.2	9.9	12.6	14.5	17.8	24.4	30.0	33.2	27.0	118.4
7	4.0	7.3	11.2	13.4	15.2	19.5	24.0	27.1	19.0	68.9
8	3.8	5.7	8.7	7.4	13.8	16.7	11.3	17.5	14.1	26.2

*Treatments:

1. Check
2. 50 PPM. N per acre
3. 100 " " " "
4. 200 " " " "
5. 400 " " " "
6. 600 " " " "
7. 800 " " " "
8. 1000 " " " "

Treatment L.S.D. $_{.01}$ = 30.6
.05 = 23.1

higher rate an abrupt increase in the rate occurred. There appeared to be a significant difference in nitrification once a particular rate had reached its particular level. When the last sampling was analyzed only the highest rate of N was still below the level of the check. The lower two rates showed a slight reduction in nitrification once a maximum was reached. This reduction, however, was not as low as that of the check.

Ammonification in Sarpy sandy loam starting June 20, 1959. This particular ammonification study differed from the previous one with Sarpy sandy loam only in so far as rates of U. F. Concentrate-85 were concerned. An immediate increase in ammonification occurred with the lower rate (20 ppm N) and then a rapid decline occurred, whereas the heavier rate (40 ppm N) was significantly higher than either the lower rate or the check and tended to remain at a constant level (Fig. 5 and Table 10).

Ammonification in Geary silty clay loam starting June 20, 1959. There was a significant difference between treatments and the check on Geary silty clay loam at each sampling. Ammonification again was similar to Sarpy sandy loam except much greater. A similar decrease was noted for the lower rate (20 ppm N) as was seen with Sarpy sandy loam. Again the higher rate (40 ppm N) seemed to decline more slowly than the lower rate (Fig. 6 and Table 10).

Nitrification in Sarpy sandy loam starting June 20, 1959. Differences in nitrification among treatments in Sarpy sandy loam was much less than with ammonification. However, according to Fig. 7 and Table 11, it appeared that nitrification for both the 20 and 40 ppm N rates of U. F. Concentrate-85 was increasing and might have become significantly greater in a few more days. Although there was a retarding effect initially from the higher rate as compared with the check; this soon disappeared and nitrification then surpassed

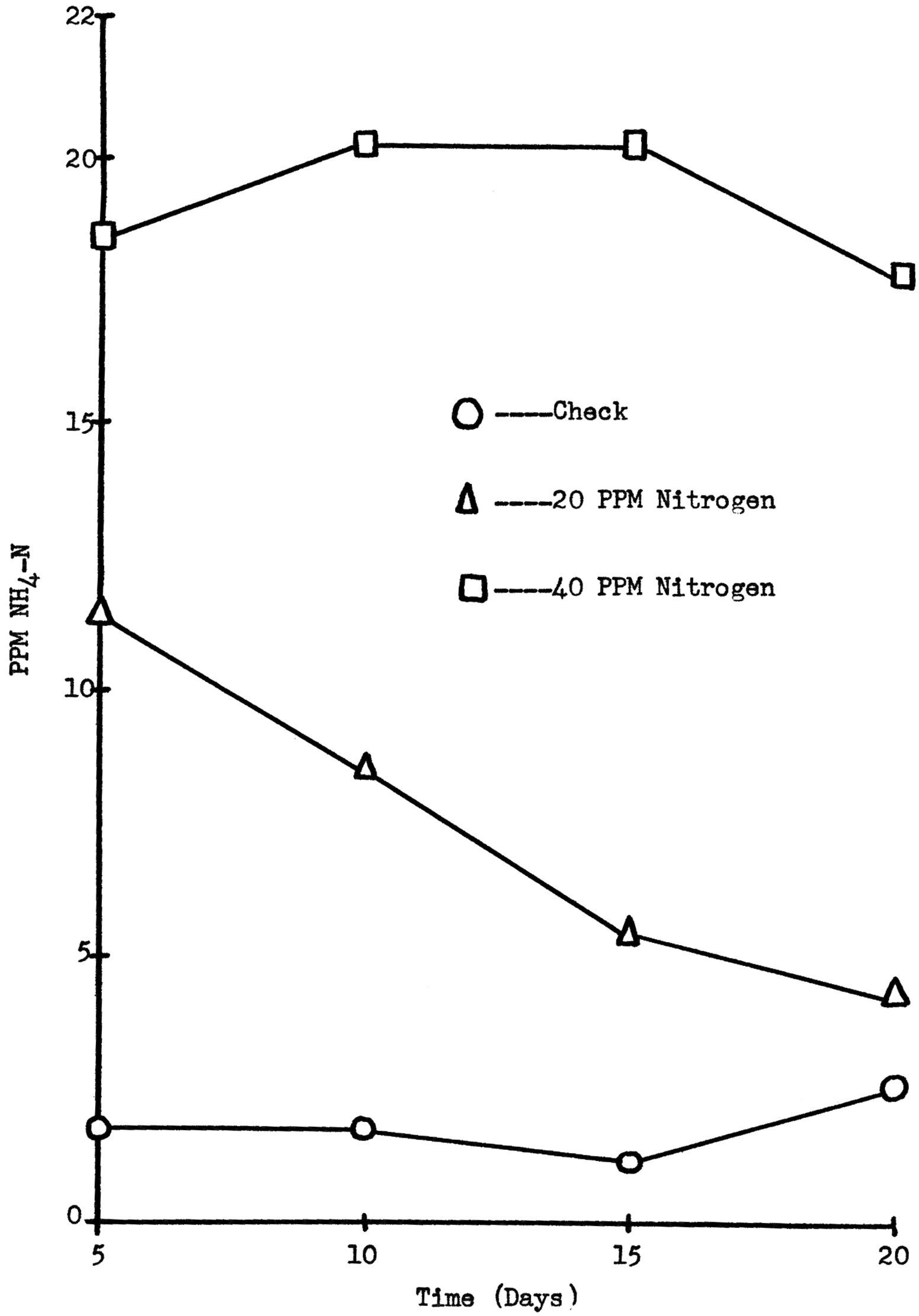


Fig. 5. Rate of ammonification in Sarpy sandy loam.

Table 10. Ammonification (PPM NH_4-N) in Geary silty clay loam and Sarpy sandy loam soils using U.F.C.-85 as the source of nitrogen.

	Days after Initial Application							
	Geary silty clay loam				Sarpy sandy loam			
Treatment*	5	10	15	20	5	10	15	20
1	3.4	3.7	2.7	2.2	1.8	1.8	1.2	2.6
2	27.4	24.2	21.1	16.3	11.4	8.6	5.5	4.2
3	43.5	42.5	38.3	29.5	18.6	20.3	20.3	17.9

Geary silty clay loam: Treatment L.S.D.$_{.01}$ = 6.82; .05 = 4.50

Sarpy sandy loam: Treatment L.S.D.$_{.01}$ = 6.30; .05 = 4.16

*Treatments:

1. Check
2. 20 PPM N per acre
3. 40 " " " "

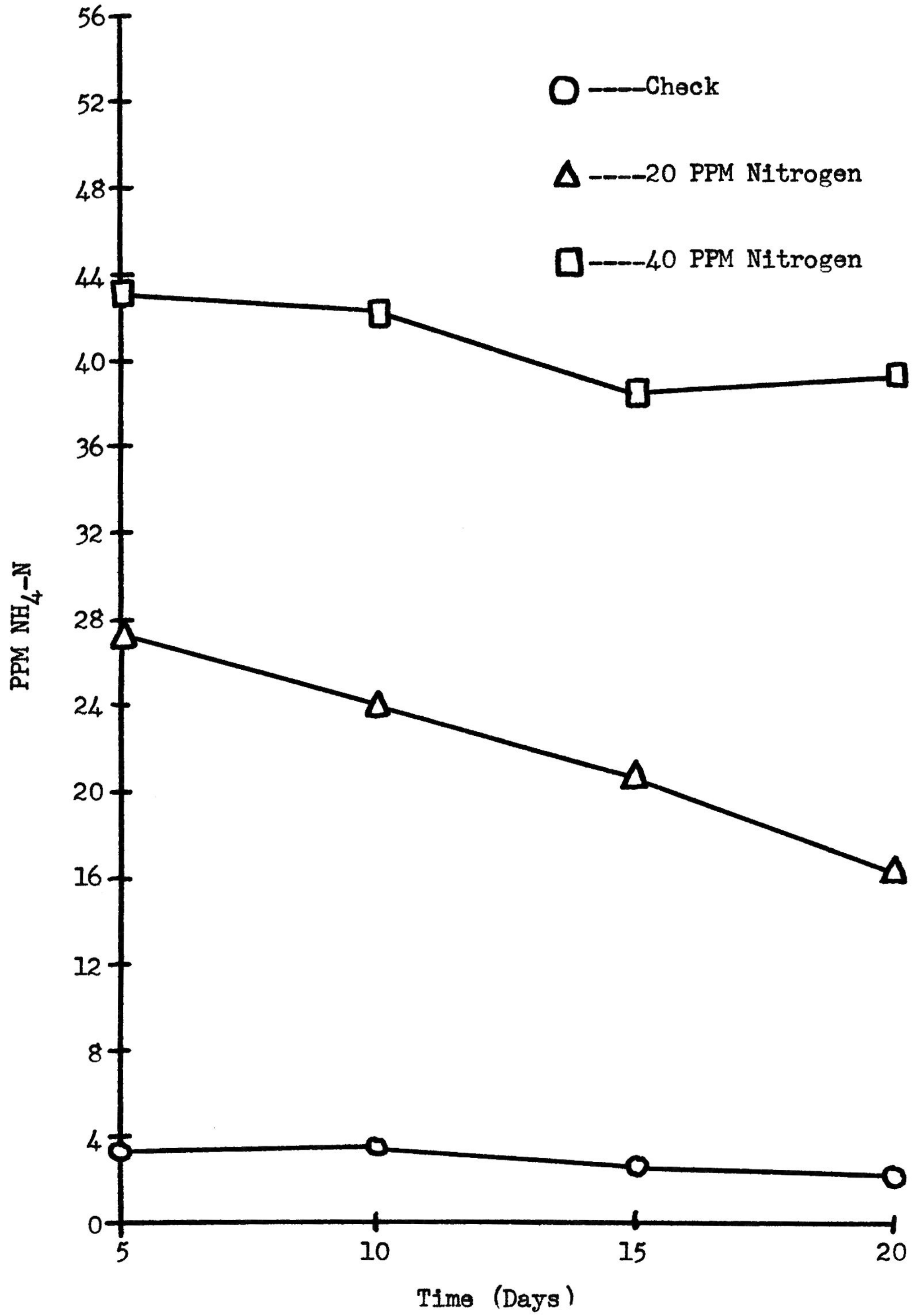


Fig. 6. Rate of ammonification in Geary silty clay loam.

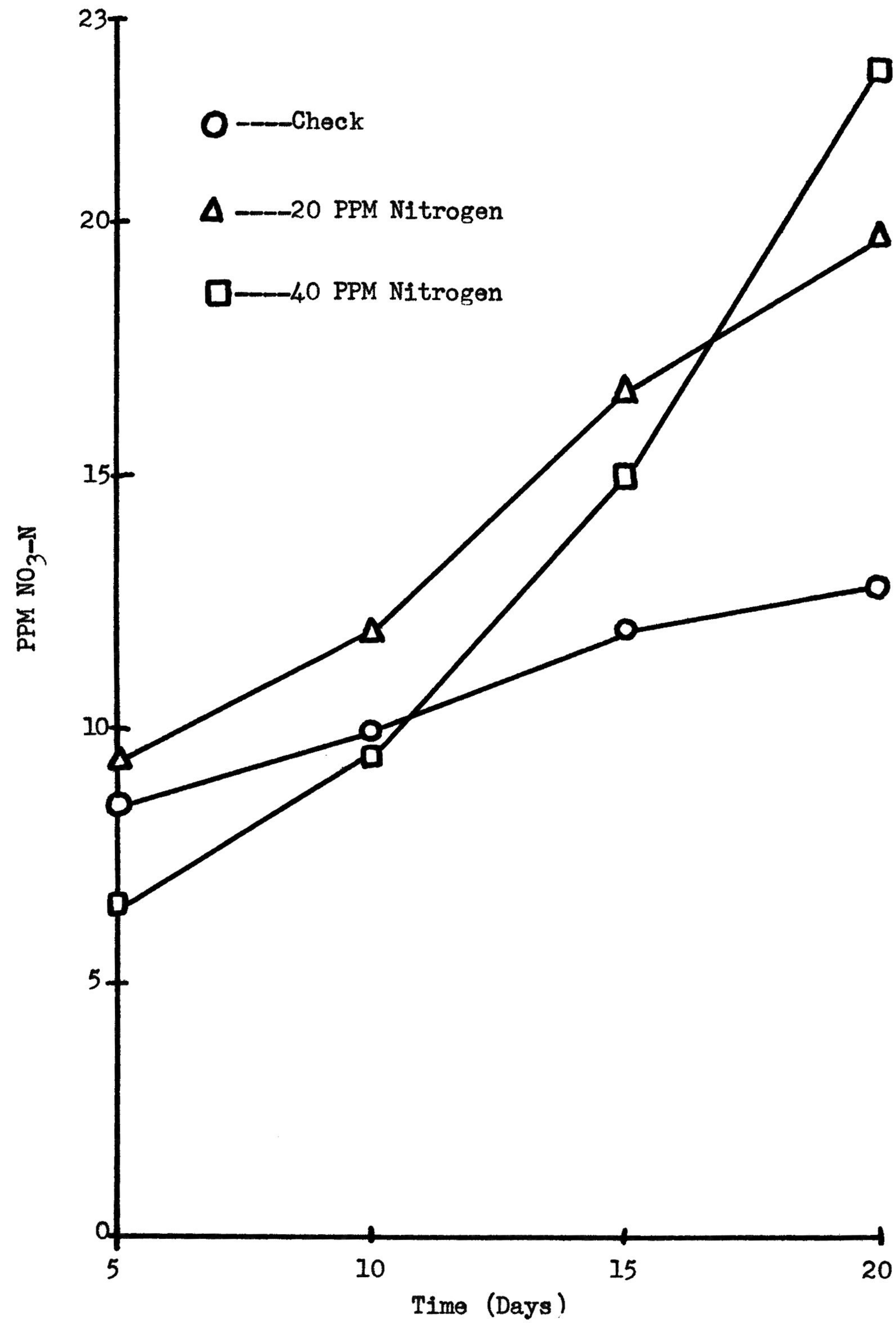


Fig. 7. Rate of nitrification in Sarpy sandy loam.

Table 11. **Nitrification** (PPM NH_4-N) in Geary silty clay loam and Sarpy sandy loam soils using U.F.C.-85 as the source of nitrogen.

	Days after Initial Application							
	Geary silty clay loam				Sarpy sandy loam			
Treatment**	5	10	15	20	5	10	15	20
1	24.5	25.4	25.3	23.2	7.7	9.9	11.8	12.1
2	24.2	29.0	32.9	36.5	8.6	11.8	16.5	19.5
3	20.7	24.5	30.5	32.0	6.3	9.4	14.9	22.4

*Not Significant

**Treatments:

1. Check
2. 20 PPM N per acre
3. 40 " " " "

the check and even the lower rate (20 ppm N) sometime after the third sampling.

Nitrification in Geary silty clay loam starting June 20, 1959. Similar nitrification trends were obtained with Geary silty clay loam as for Sarpy sandy loam, except the level of nitrification was higher. The lower rate (20 ppm N) showed an immediate increase in nitrification. The level was much higher than either the heavier rate of U. F. Concentrate-85 or with the check. The higher rate of U. F. Concentrate-85 in the Geary silty clay loam produced a slower rate of nitrification than with the Sarpy sandy loam, although it might have produced a peak in nitrification which was higher than for the 20 ppm N rate (Fig. 8 and Table 11).

Emergence Studies in the Greenhouse

Emergence of Oats on Sarpy sandy loam. In the earlier emergence study with oats on Sarpy sandy loam, every rate of U. F. Concentrate-85 showed some delay in emergence. Twenty days following the initial planting only the check and the 100 ppm N rate were growing. At the end of the first twenty days fresh seeds were planted in the pots containing the 400 and 800 ppm N rates. Plants thrived in pots containing 400 ppm N rate, but failed to grow in the pots containing the 800 ppm N rate. Following a lapse of twenty days after the second replanting (or a total of 40 days), fresh seeds were again placed in the pots containing 800 ppm N. After this second replanting (or additions of three groups of fresh seed), germination occurred and plants thrived. Plate I illustrates the plants growing after initial planting and after the first replanting. Table 12 presents data for emergence study and is listed under Trial I.

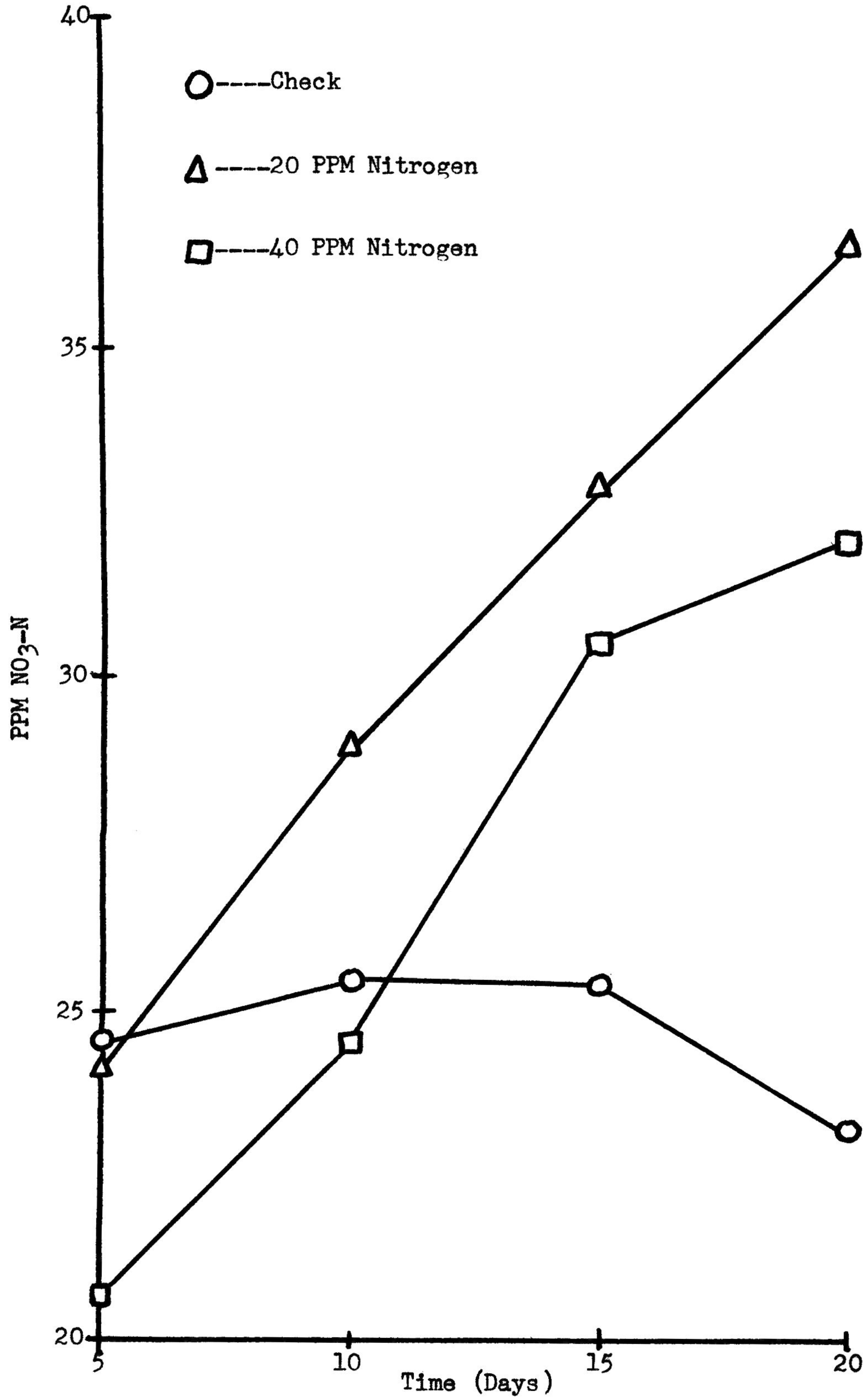


Fig. 8 Rate of nitrification in Geary silty clay loam.

EXPLANATION OF PLATE I

Fig. 8 Growth of oats twenty days after initial planting.

Fig. 9 Growth of oats forty days after initial planting (3 and 4 were replanted).

PLATE I

Fig. 8

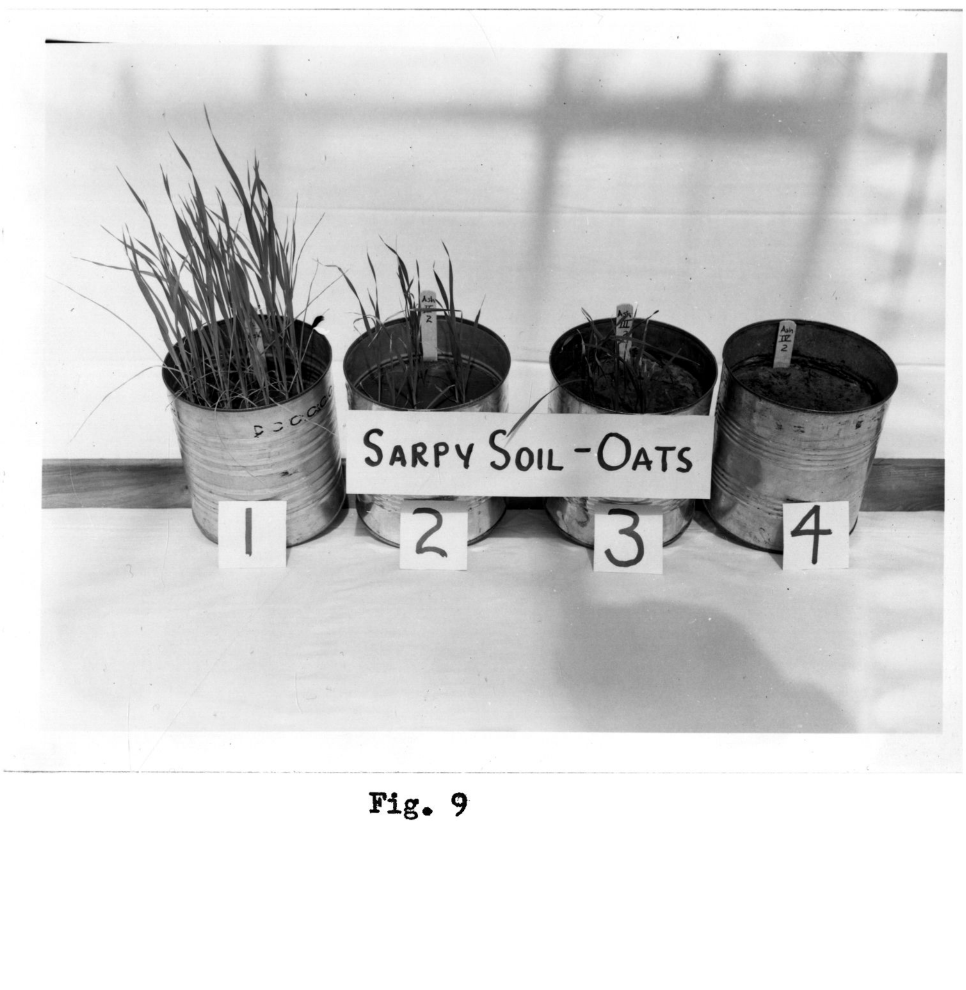


Fig. 9

In the most recent emergence study on oats a reduction in the number of plants was noted for both rates of U. F. Concentrate-85. No replantings were necessary for any of these rates. Slower emergence was noted with the 50 ppm N rate than with the 25 ppm N rate. Total emergence of the 25 ppm N rate was greater and proceeded at a faster rate than did either the check or the 50 ppm N rate. Although the 50 ppm N rate slowed emergence, the total emergence was the same as the check (Table 12, Trial II).

Emergence of Soybeans on Sarpy sandy loam. In the earlier emergence study, soybeans on Sarpy sandy loam were definitely retarded by the three rates of U. F. Concentrate-85. Twenty days following the initial plantings, pots containing rates of 400 and 800 ppmN were planted with fresh seed. Pots containing the 400 ppm N rate grew vigorously, while those containing 800 ppm N rate failed to germinate. Twenty days after the first replanting (or 40 days after initial planting) fresh seed was again placed in the pots containing the 100 and 800 ppm N rates. Plants emerged and grew quite vigorously. Plant counts are presented in Table 13 under Trial I. Plate II illustrates the plants growing after the initial planting and after the first replanting.

In the most recent emergence study on soybeans, no replantings were necessary. The 25 ppm N rate of U. F. Concentrate-85 tended to be faster in rate of emergence and had more total plants than either the check or the 50 ppm N rate. Rate of emergence and total plant counts were about the same for the 50 ppm N rate when compared with the check. These data are presented under Trial II of Table 13.

Emergence of Oats on Geary silty clay loam. In the earlier emergence study, oats on the Geary silty clay loam soil were definitely retarded by the

Table 12. Emergence (av.) of oats on Sarpy sandy loam in the greenhouse as effected by treatments of U.F.C.-85.

	Day*														
Treatment PPM N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Trial I															
Check	4	13	13	14	15	15	15	15	15	15	15	15	15	15	15
100	0	0	0	0	0	0	0	2	6	7	7	7	8	9	10
400**	0	0	1	5	8	11	12	14	14	14	14	14	14	14	14
800***	0	3	6	10	10	10	11	11	12	12	12	12	12	12	12
Trial II															
Check	2	8	9	11	11	11	11	11	11	11	11	11	11	11	11
25	2	8	10	12	12	12	13	13	13	13	13	13	13	13	13
50	0	0	3	4	6	8	9	9	10	10	10	11	11	11	11

* Starting counts from the day the first plant appeared in each trial.
** Plant counts following replanting (20 days after initial planting).
***Plant counts following replanting (40 days after initial planting).

Table 13. Emergence (av.) of soybeans on Sarpy sandy loam in the greenhouse as effected by treatments of U.F.C.-85.

	Day*									
Treatment PPM N	1	2	3	4	5	6	7	8	9	10
Trial I										
Check	3	9	9	9	9	9	9	9	9	9
100***	2	2	4	5	6	8	9	9	9	9
400**	0	4	6	8	9	9	9	9	9	9
800***	4	7	8	8	9	9	9	9	9	9
Trial II										
Check	2	3	4	5	6	6	6	6	6	6
25	2	6	7	8	8	8	8	8	9	9
50	1	2	4	5	6	6	6	6	6	6

* Starting counts from the day the first plant appeared in each trial.
** Plant counts following replanting (20 days after initial planting).
***Plant counts following replanting (40 days after initial planting).

EXPLANATION OF PLATE II

Fig. 10 Growth of soybeans twenty days after initial planting.

Fig. 11 Growth of soybeans forty days after initial planting (3 and 4 were replanted).

PLATE II

Fig. 10

Fig. 11

highest two rates of U. F. Concentrate-85 (400 and 800 ppm N) since a replanting was necessary in pots containing both of these rates. After replanting, total emergence was slightly higher at the 800 ppm N rate than any of the other rates. Although the 100 ppm N rate was not replanted, it was slower in rate of emergence and in total emergence than the check. Plate III shows growth of plants after the initial planting and first replanting. Trial I in Table 14 presents data on emergence.

In the most recent emergence study on oats, no replantings were necessary. Both rates of U. F. Concentrate-85 (25 and 50 ppm N) were slower in rate of emergence and in total emergence than the check. These data are presented in Table 14 under Trial II.

Emergence of Soybeans on Geary silty clay loam. In the earlier emergence study, soybeans on Geary silty clay loam soil again were definitely retarded by the higher rates of U. F. Concentrate-85 (400 and 800 ppm N), since pots containing these rates required replanting. After replanting, vigorous growth resulted at both rates. Rate and total emergence at both N levels were about the same or slightly above that of the check. Pots containing the 100 ppm N rate were not replanted. Rate and total emergence were about the same as the check. Plate IV illustrates plants growing following the initial planting and first replanting. Trial I under Table 15 presents the emergence data.

In the most recent emergence study on soybeans, no replantings were necessary. Both rates of U. F. Concentrate-85 (25 and 50 ppm N) were about equal with the check in rate and total emergence. These data are presented in Table 15 under Trial II.

For both soils, seeds (oats or soybeans) that failed to germinate or those that germinated only partially were placed in fresh soil free of U. F. Concentrate-85. No further germination occurred in any case. Before removing

EXPLANATION OF PLATE III

Fig. 12 Growth of oats twenty days after initial planting.

Fig. 13 Growth of oats forty days after initial planting (3 and 4 were replanted).

PLATE III

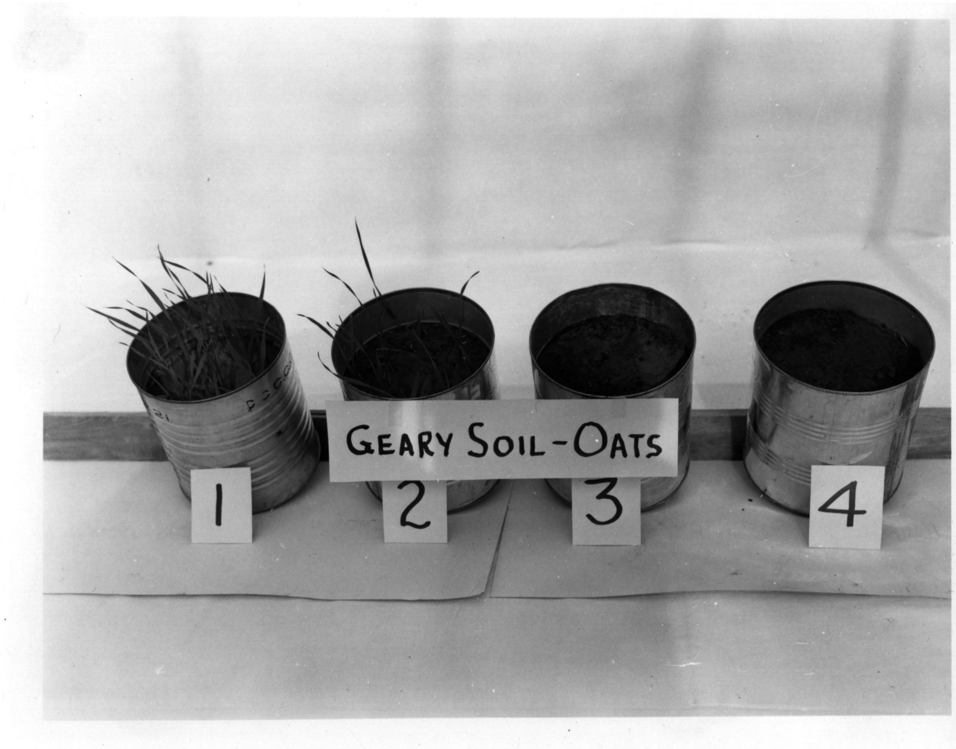


Fig. 12

Fig. 13

Table 14. Emergence (av.) of oats on Geary silty clay loam in the greenhouse as effected by treatments of U.F.C.-85.

	Day*									
Treatment PPM N	1	2	3	4	5	6	7	8	9	10
Trial I										
Check	4	13	14	14	14	14	14	14	14	14
100	0	0	0	0	3	4	8	10	12	12
400**	0	0	5	10	14	14	14	14	14	14
800**	0	0	6	14	16	16	16	16	17	17
Trial II										
Check	2	11	12	14	14	14	15	15	15	15
25	0	4	6	8	10	10	10	10	10	10
50	0	1	4	7	8	9	9	9	9	9

* Starting counts from the day the first plant appeared in each trial.
**Plant counts following replanting (20 days after initial planting).

Table 15. Emergence (av.) of soybeans on Geary silty clay loam in the greenhouse as effected by treatments of U.F.C.-85.

	Day*											
Treatment PPM N	1	2	3	4	5	6	7	8	9	10	11	12
Trial I												
Check	4	7	8	8	8	8	8	8	8	8	8	8
100	0	0	2	3	6	7	7	8	8	8	8	8
400**	0	3	8	8	8	8	8	8	8	8	8	8
800**	0	4	8	9	9	9	9	9	9	9	9	9
Trial II												
Check	2	4	4	7	7	7	7	7	7	7	7	7
25	2	4	4	5	5	6	6	6	6	6	6	6
50	2	4	4	6	6	7	7	8	8	8	8	8

* Starting counts from the day the first plant appeared in each trial.
**Plant counts following replanting (20 days after initial planting).

EXPLANATION OF PLATE IV

Fig. 14 Growth of soybeans twenty days after initial planting.

Fig. 15 Growth of soybeans forty days after initial planting (3 and 4 were replanted).

PLATE IV

Fig. 14

Fig. 15

ungerminated seeds from soil containing U. F. Concentrate-85, a lush growth of penicillin was noted, thus indicating the preserved nature of the seeds. This fact is illustrated in Plate V.

Field Oats Study

In the field study with oats, the 20 pound rate of the three fertilizers gave slightly greater yields than did the check. As the increment of N was increased, yield was reduced. The highest rates of N from all the fertilizers (U. F. Concentrate-85, ammonium nitrate, and urea) produced yields lower than the check. There appeared to be little difference in yield where the rates of N were the same for ammonium nitrate and urea. However, yields were much lower at the 80 and 160 pound N levels where U. F. Concentrate-85 was used as compared to equal rates of ammonium nitrate and urea. These data are presented on Tables 17 and 18, and by means of a bar graph in Fig. 17. The following plant counts were taken:

Table 16. Plant (av.) counts on block III.

	Treatments									
	1	2	3	4	5	6	7	8	9	10
April 6, 1959	100	88	42	35	89	80	83	98	90	86
April 21, 1959	102	95	80	65	92	86	88	99	92	88

SUMMARY AND CONCLUSIONS

Ammonification and nitrification studies, involving twelve treatments, were conducted with Geary silty clay loam and Sarpy sandy loam soils.

Determination of rates of nitrification and ammonification following U. F. Concentrate-85 addition showed that when nitrate production was rapid,

EXPLANATION OF PLATE V

Fig. 16 Seed that failed to emerge twenty days after planting.

PLATE V

Fig. 16

Table 17. Comparing oats yield (bu./acre) using U.F.C.-85 and other standard nitrogen sources.

Treatment*	Block I	Block II	Block III	Block IV	Treatment Means
1	80.0	67.0	69.1	60.7	69.2
2	75.1	77.2	70.0	70.7	73.7
3	82.4	62.1	64.2	56.5	66.3
4	53.9	25.9	42.7	46.7	42.3
5	80.7	84.2	73.3	85.8	81.0
6	75.1	73.7	78.9	70.2	74.5
7	65.1	67.4	67.4	65.8	66.4
8	75.8	85.8	97.3	68.4	81.8
9	99.4	67.4	77.5	77.5	80.4
10	60.7	69.5	65.8	60.9	64.2

*Treatments:

Treatment L.S.D. $_{.01}$ = 10.19
$_{.05}$ = 7.55

1. Check
2. 20 lbs. nitrogen per acre as U.F.C.-85
3. 80 " " " " " "
4. 160 " " " " " "
5. 20 " " " " " Ammonium nitrate
6. 80 " " " " " " "
7. 160 " " " " " " "
8. 20 " " " " " Urea
9. 80 " " " " " "
10. 160 " " " " " "

Table 18. Comparison of straw and grain yield per plot on field oats.

Treatment*	Grain (lbs./plot)	Straw (lbs./plot)	Straw and Grain (lbs./plot)
1	3.0	3.5	6.5
2	3.1	3.9	7.0
3	2.8	3.3	6.4
4	1.8	2.8	4.6
5	3.5	3.9	7.4
6	3.2	4.2	7.4
7	2.8	3.9	6.7
8	3.5	4.0	7.5
9	3.4	4.5	7.9
10	2.8	4.2	7.0

*Treatments:

1. Check
2. 20 lbs. nitrogen per acre as U.F.C.-85
3. 80 " " " " " "
4. 160 " " " " " "
5. 20 " " " " " Ammonium nitrate
6. 80 " " " " " " "
7. 160 " " " " " " "
8. 20 " " " " " Urea
9. 80 " " " " " "
10. 160 " " " " " "

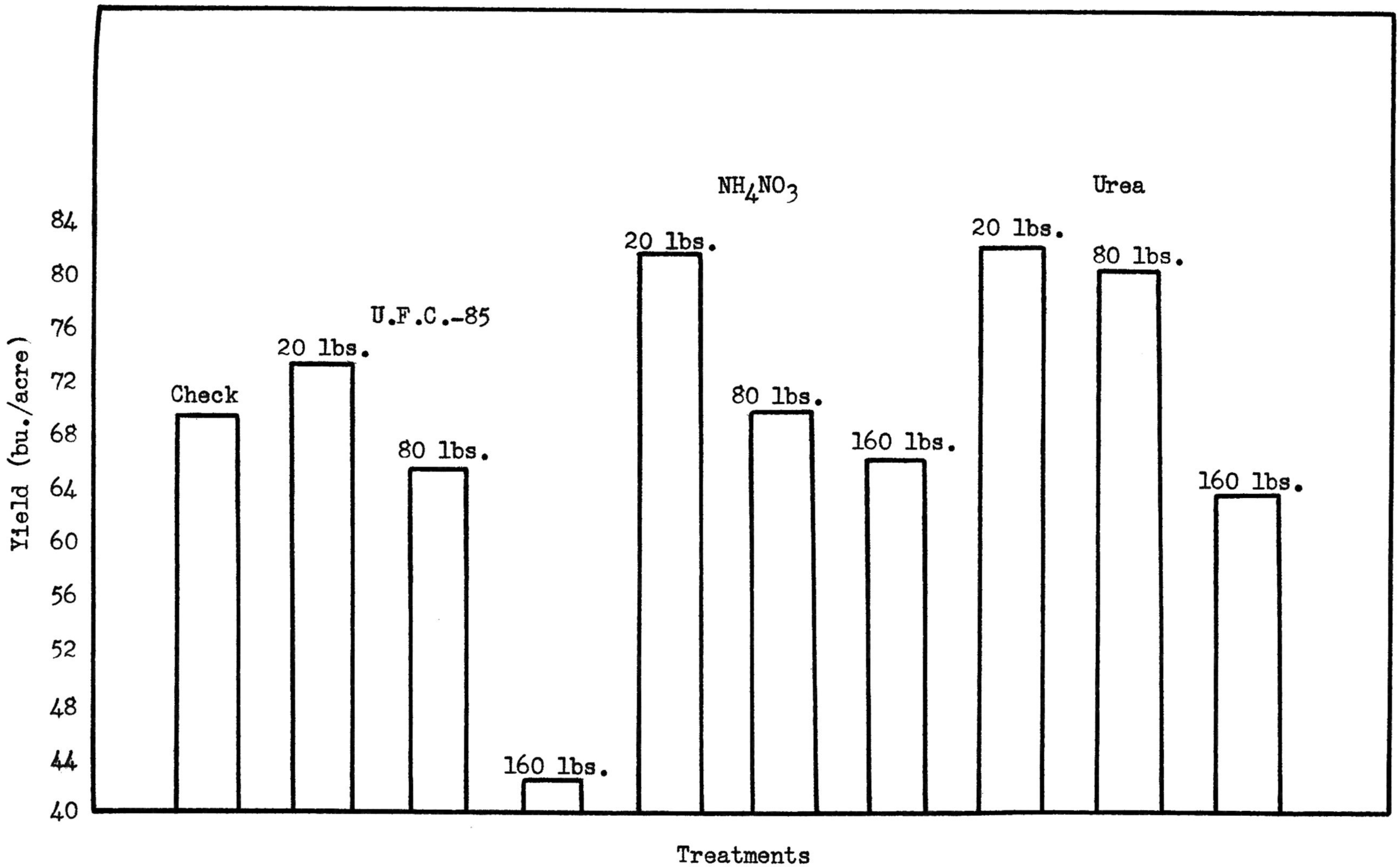


Fig. 17. Bar graph representation of oats yield in the field.

ammoniacal nitrogen did not accumulate. However, marked accumulations of ammoniacal nitrogen were noted where large additions of the Concentrate interfered with nitrifications.

Since the main nitrogen source was U. F. Concentrate-85 containing 26 per cent urea, it was assumed that the immediate conversion to ammoniacal nitrogen in the experiment was actually a process of hydrolysis.

Seemingly nitrification was curtailed more than ammonification after addition of U. F. Concentrate-85. The presence of free ammonia and free formaldehyde apparently inhibited the nitrate forming bacteria, thus requiring more time for the bacteria to become restored in sufficient numbers to initiate nitrification.

Six treatments of U. F. Concentrate-85 were applied to Geary silty clay loam and Sarpy sandy loam soils in the greenhouse. Emergence of oats and soybeans were checked daily. High rates of U. F. Concentrate-85 had a definite toxic effect on oats and soybeans with both soils in the greenhouse. This effect was attributed to two factors:

1. The presence of free formaldehyde tended to sterilize the soil, thus eliminating all possibilities for plant growth. However, once the formaldehyde had been volatized quick response to nitrogen was noted.
2. Since there was an immediate conversion to ammoniacal nitrogen, the presence of free ammonia probably resulted in nitrite accumulation in amounts toxic to plants.

It may be safely assumed that if a waiting period had occurred between the time of application of U. F. Concentrate-85 and the time of planting, better germination would have resulted. Also, the length of this waiting period tends to vary directly with the rate of the solution applied.

U. F. Concentrate-85 was compared with ammonium nitrate and urea in a field oats study. The reduction of the stand at higher rates of U. F. Concentrate-85 was due to the same factors that were discussed in the greenhouse study. Again, it may be safely assumed that if there had been an elapse of time between application and planting, better stands and yields would have resulted. In the field there was probably more aeration than in the greenhouse, thus reducing the amount of time required between application and safe planting.

Although U. F. Concentrate-85 was more costly than conventional sources of N, a single application lasted through the growing season.

Need for additional study with respect to difference in dates of application and planting was suggested by these results.

ACKNOWLEDGMENT

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AGRONOMIC EVALUATIONS OF UREA-FORMALDEHYDE CONCENTRATE-85 (UFC-85) SOLUTION

by

CARLYLE ARON THOMPSON

B. S., Kansas State University, 1958

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1959

Because of its high requirement by plants, nitrogen is considered the most important single element in the soil. Due to this fact new products are being evaluated from time to time. Since most standard inorganic and organic fertilizers convert rapidly to ammoniacal and nitrate forms of nitrogen, the plants' requirement for nitrogen is not met throughout the entire growing season. Therefore, repeated applications are necessary.

The solution, Urea Formaldehyde Concentrate-85, used in this study is somewhat different from ordinary nitrogen fertilizers. In the ammonification and nitrification studies conducted, there was immediate response to ammoniacal nitrogen. However, oxidation to nitrate nitrogen proceeded at a much slower rate due to the presence of free ammonia and free formaldehyde. An excess of free ammonia was believed to inhibit transformation of ammonia to nitrate nitrogen while the presence of free formaldehyde reduced the populations of the nitrifying bacteria. Therefore, release to nitrate nitrogen was very slow, depending on the rate of U. F. Concentrate-85 applied.

Further evidence was shown by greenhouse work that very high rates of U. F. Concentrate-85 had a definite toxic effect on plants. Nitrite accumulation and free formaldehyde induced such toxic effects that replantings were necessary where rates over 200 pounds of N per acre were applied. In some of the lower rates a reduction in emergence was noticed. Once the free formaldehyde was volatilezed, there was a quick response to nitrogen.

Where a high rate of U. F. Concentrate-85 was applied on oats in the field, a definite reduction in stand was noticed when compared with the no treatment or equal rates of ammonium nitrate and urea. However, a lower rate of 20 pounds per acre of the solution showed increases over the check.

From the results observed, it was believed that a waiting period between application of U. F. Concentrate-85 and planting would be necessary. The length of this waiting period would depend on the rate of N applied.