EFFECT OF UREA AND WHEAT STRAW RESIDUE ON NITROGEN MINERALIZATION AND IMMOBILIZATION IN SOIL OVER TIME

By

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PREFACE

A 10 week incubation study was conducted to determine the effect of N fertilizer and wheat straw residue on N transformations in the soil. Exchangeable NH_4-N and NO_3-N were analyzed for at specified lengths of time to measure the rate of mineralization. Organic N was determined at the end of the experiment to measure the amount of N immobilized.

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CHAPTER I

INTRODUCTION

Over the last several years conservation tillage has gained in popularity as a means of reducing the loss of soil and water. Conservation practices include using a mulch consisting of plant residues that remain at the surface during the growing season which protects the soil from erosion and surface sealing caused by rain. Also, by slowing down lateral water movement, a mulch will increase water infiltration, thereby reducing the loss of nutrients caused by runoff (4). However, a complete understanding of the effects increased residue has on nutrient availability to higher plants is still in question.

Of the three major nutrients, N is the most likely to undergo microbial transformations resulting in mineralization, immobilization, or volatilization (Fig. 1). The availability of N is a relationship between microbial activity and its environment. Under typical conditions a cultivated soil maintains a narrow C/N ratio from 8:1 to 15:1, while supporting an abundant microbial population favorable for nitrification. As the amount of organic residue increases, as in conservation tillage methods, large amounts of C and relatively small amounts of organic N are released during decay.

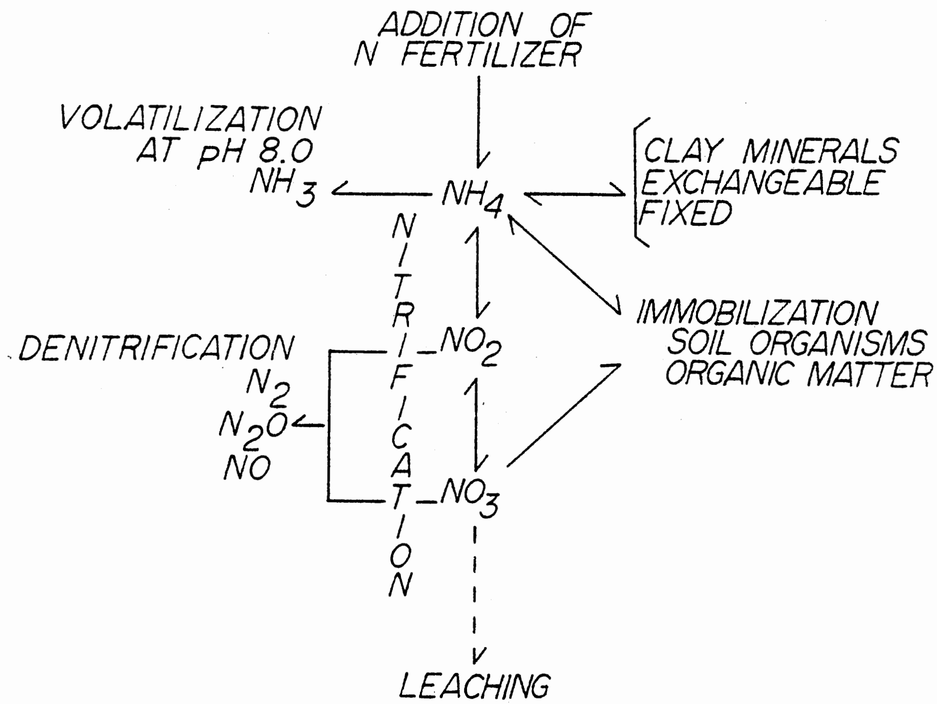

Figure 1. Nitrogen transformations in the soil under typical conditions

In turn, microbial activity increases because of the C providing a source of energy. The demand increases for NO_3 and NH_4 forms of N. Ammonium is transformed to NO_3 or incorporated into proteins, nucleic acids, and other organic complexes required for new cells. Consequently, N that would have been available for plant uptake is immobilized by soil microbes.

The rate of organic residue decay is a major concern in conservation tillage systems for it greatly influences the rate that N will become available for plant uptake. Residues with a wide C/N ratio (i.e. wheat straw is approximately 80:1) when mixed with the soil, as in conventional methods, immobilize N from both fertilizer and soil sources under favorable conditions (1, 8). In the case of conservation tillage, plant residue is not mixed readily with the soil which slows down the rate of decay (17). Evidence shows that as a result, NO_3 production is lower. Residues left on the surface decompose slower because soil nitrifiers and organic matter are not mixed together which slows down the rate of mineralization. A conservation of organic N occurs because plant uptake never fully utilizes this source (16).

The major difference in comparing conventional to conservation tillage is the distribution of organic matter. With no-till, the amount of residue in the 0-5 cm soil depth is doubled. The population of soil microbes immediately below the layer of mulch is greatly increased which significantly affects the fate of surface applied N. Under these conditions, fertilizer N is rapidly assimilated by soil microbes and immobilized by organic residue (5). Nitrogen immobilization has been shown to be twice as great on no-till soils compared to conventionally tilled soils (13). Another study reported that broadcast fertilizer N at a rate of 84 kg N/ha per year had 42 percent of the fertilizer N immobilized under no-till and 28 percent with conventional tillage systems. Other researchers agree, that not only N uptake is greater with conventional methods but there is a direct relationship in increased yields. (14).

There is some disagreement among researchers. In some instances more fertilizer N has been taken up under no-till than conventional tillage by spring wheat but showed no difference in dry matter production (9). Their conclusions were that any reduction in yield resulting from no-till would not likely be attributable to a lower fertilizer N use efficiency by the crop.

There seems to be a direct relationship between plant residue and its management in the field on the availability of N. Understanding the effect of conservation tillage on N mineralization and nutrient availability is vital to obtaining maximum fertilizer efficiency. To help achieve this goal a 10 week study was conducted under controlled conditions to compare the effect of N fertilizer as urea and wheat straw, including their interactions, on N mineralization and immobilization.

CHAPTER II

METHODS AND MATERIALS

The objectives of this study were to evaluate the effect of N and wheat straw on N mineralization and immobilization over time. Fourteen sampling dates were selected over a 10 week period. Treatment combinations of fertilizer N and straw were applied to 50 g of soil contained in petri dishes 9.0 cm in diameter and 1.0 cm in depth. A 4x4 factorial arrangement of treatments in a randomized complete block design with three replications was established for each sampling date.

The soil in this study was a Norge loam (Udic Paleustoll). After the removal of the large organic matter, the soil was dried and ground to pass through a 2mm screen. An initial soil pH of 6.2 was determined using a combination pH electrode and distilled water-to-soil ratio of 1:1 (vol/wt) (12).

Wheat straw was dried, ground, and screened for a size range of 250-500 ug in diameter. Rates of 0, 1792, 3584, and 7168 kg/ha were applied uniformly, mixing each rate with a dish of soil.

Reagent grade urea was used as the source of N (46% N) and applied as a liquid at rates of 0, 84, 168, and 336 kg N/ha. Concentrations were made so that 1 ml of solution applied dropwise at the soil surface equaled the treatment rate needed. The urea solution was uniformly applied on the surface after the straw was mixed with the soil.

Soil moisture was maintained at 16-18% water by weight. Every two days a sufficient amount of water was added to each petri dish to compensate for evaporation. Air temperature was kept at 24 degrees centigrade $\pm 1^{o}C$.

At the designated time, incubation was stopped by placing the dishes in a freezer at a temperature below $0^{o}C$. Soil extracts were prepared according to Bremner (6) with slight modifications. The soil samples were placed into 500 ml plastic bottles, 250 ml of 1N Na_2SO_4-PMA extractant was added, and then shook for 45 minutes. The soil solution was then filtered into a 500 ml vacuum flask using Whatman #42 filter paper. A final volume of 500 ml was then made using distilled-deionized water.

Urea was analyzed, at sampling dates 1d and 2d, colorimetrically. Standards were also mixed with the color development reagents in the acid solutions, heated, and cooled. Absorbance was determined by a spectrophotometer and concentrations of urea were obtained from the standard curve (3).

At all sampling dates exchangeable NH_4 and NO_3 were determined by means of an automated procedure using the Technicon AutoAnalyzer II in accordance with the manufacturer (2, 11). For the determination of NH_4 in the extract a green color is formed, whose intensity is directly related to the concentration of NH_4.

The determination of NO_3 is also colorimetric, using a copper-cadmium reductor column that reduces nitrate to nitrite, forming a pinkish-red color. The intensity of the color is directly related to the concentration of NO_3, assuming that no NO_2 is present in the extract.

Finally, at the last sampling date, the organic N fraction present in the residue treatment was determined by the semi-microkjeldhal procedure (7). Differences in NH_4-N and NO_3-N concentrations between any two sampling dates could be found over the duration of the experiment, using the test criterion of least significant difference at the 0.05 level (15).

CHAPTER III

RESULTS AND DISCUSSION

Urea Hydrolysis

Urea hydrolysis occurs upon the addition of water and in the presence of the enzyme urease. Urea is converted to an intermediate form ammonium carbamate, then quickly to ammonia.

$$CO(NH_2)_2 + H_2O \xrightarrow{\text{urease}} H_2NCOONH_4 \longrightarrow 2NH_3 + CO_2$$

As this reaction takes place, the soil pH may go as high as pH 9.0. Under these conditions, the end product is in fact NH_3 and may escape as a gas.

Under prevailing conditions of 24 degrees centigrade $\pm 1^{o}C$ air temperature and a soil moisture range of 16-18% water by weight, analysis of the soil samples incubated 1 day detected unhydrolyzed urea at the rate 336 kg N/ha (Table 1). Complete hydrolysis occurred at fertilizer rates of 0, 84, and 168 kg N/ha for samples incubated the same period of time. At the highest rate (336 kg N/ha) urea hydrolysis was 69 percent complete and by the end of the second day of incubation 100 percent complete. Interpretation of the data shows that hydrolysis averaged 104 ug N/g in the first day. The rate of hydrolysis was more than enough to hydrolyze the lower rates of urea.

Urease activity (hydrolysis) in the soil is dependent on the amount of organic matter present. An increase provides a source of C, resulting in increased growth of soil microbes, including those which produce urease. This relationship is not in total agreement; increased organic matter may affect N availability by tying it up and inhibiting urea hydrolysis (10). Statistical analysis shows that only the fertilizer rate has a significant influence on the amount of urea hydrolyzed (Table II).

TABLE I

CONCENTRATION OF UREA REMAINING AFTER 1 DAY OF INCUBATION AS A FUNCTION OF N FERTILIZER AND CROP RESIDUE RATES

	Residue rate+			
Fertilizer rate+	0	1792	3584	7168
	ug/g#			
0	0	0	0	0
84	0	0	0	0
168	0	0	0	0
336	49	45	46	43

+ Rates expressed as kg/ha.
# Means of 3 replicates.

TABLE II

STATISTICAL ANALYSIS OF THE EFFECTS OF N FERTILIZER AND CROP RESIDUE RATES ON UREA CONCENTRATION AFTER 1 DAY

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Total	47	7734.09		
Trts.	15	2110.31	140.69	
Fertilizer, F	3	2104.74	701.58	3.99*
Residue, R	3	1.39	0.46	0.003
FXR	9	4.18	0.46	0.003
Exp. Error	32	5623.78	175.74	

* Indicates significance at the 0.05 level.

Effect of N Fertilizer and Crop Residue Rates on NH_4-N

The statistical analysis shows that the fertilizer rate, crop residue rate, hours of incubation, and their interactions had a significant effect on exchangeable NH_4 in the soil during the experiment (Table III). The most influential were the fertilizer rate, hours of incubation, and their interaction. By comparison, the residue rate was minimal in influencing NH_4 concentration. A table of means was averaged over all residue and fertilizer rates to show the effects of fertilizer and residue rates, respectively (Table VII). Graphs were then drawn from these values (Figures 2-9).

As urea hydrolyzes, NH_4 is produced as evident by the increase in NH_4 during days 1-3 (Table VII). Even though at fertilizer rates of 0, 84, and 168 kg N/ha urea hydrolysis was complete by the end of the first day of incubation, a time interval of two days between hydrolysis and reaching a maximum NH_4 concentration occurred (Figures 6-8). Measurements on the fourth day showed a significant decrease in NH_4. The exception was the 336 kg N/ha rate (Figure 9). Complete hydrolysis required two days coinciding with the maximum concentration of NH_4 occurring on the same day. On day three, a significant decrease in NH_4 was observed.

As nitrification proceeded oxidizing NH_4 to NO_3, the amount of NH_4 steadily declined at all fertilizer rates. At the rates 0 and 84 kg N/ha, NH_4 reached a low at 49 days of incubation (Figures 6 and 7). One week later at 56 days and then on day 63, a low was reached for the two higher rates (Figures 9 and 8, respectively). An indication that nitrification occurred at about the same rate during incubation.

Without the urea fertilizer as a source of N at the 0 kg N/ha rate an alternate source must have supplied the N needed for mineralization. The indigenous organic matter and the added residue along with the native NH_4 level of 9.09 ug/g undoubtedly supplied it. Soil microbes were fueled by the existing C and N in order for the ammonification of organic matter and subsequent nitrification. Thus, the nitrification process had two sources of NH_4, the ammonification of organic residue and indigenous NH_4.

Treatments involving urea fertilizer had a third source of NH_4 that was available upon hydrolysis. However, there was no way to determine the source without atomic labeled nitrogen, which is beyond the scope of this study.

A more detailed comparison of the treatment combinations and how they affect NH_4 concentration during incubation is also tabulated (Table VIII). Most apparent is the significant increase of NH_4 in the soil samples as fertilizer rates increased. Not as obvious, though, is the influence of residue rates upon NH_4 concentration. Comparing the mean values of any one of the residue rates averaged over all fertilizer rates to another appears almost identical (Figures 2-5).

The influence exhibited by the crop residue during incubation on NH_4 concentration is primarily within a given rate. In comparison, the effect that fertilizer has on NH_4

is not only within a particular rate but transcends the four rates of N.

TABLE III

STATISTICAL ANALYSIS OF THE EFFECTS OF N FERTILIZER AND CROP RESIDUE RATES ON NH_4-N CONCENTRATION

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Total	672	2631540.45		
Blks.	2	1377.23	688.62	
Trts.	226	2614375.75	11568.03	
Fertilizer, F	3	835329.75	278443.25	7234.95*
Residue, R	3	867.64	289.21	7.52*
Hours, H	13	313944.53	24149.58	627.49*
FXR	9	1356.05	150.67	3.92*
FXH	39	111043.92	2847.28	73.98*
RXH	39	6553.73	168.04	4.37*
FXRXH	117	7743.93	66.19	1.72*
Exp. Error	446	17164.70	38.47	

* Indicates significance at the 0.05 level.

Effect of N Fertilizer and Crop Residue Rates on NO_3-N

The statistical analysis on NO_3 indicates that the fertilizer rate, crop residue rate, hours of incubation, and their interactions had a significant effect during the experiment (Table IV). The most influential were the fertilizer rate, hours of incubation, and their interaction. To a lesser degree was the influence of residue rate on NO_3 concentration. These conclusions are identical to those found for exchangeable NH_4. Again, a table of means was averaged over all residue and fertilizer rates to show the effects of fertilizer and residue rates, respectively (Table IX). Graphs were drawn from the table (Figures 2-9).

Nitrification is a microbiological transformation of NH_4 to NO_3 and is dependent on the environment. Existing levels of N and C in the soil play an integral part in the growth of the microbial population, which in turn, determine the amount of available N in the soil. Generally speaking, organic residue with a C/N ratio of less than 20:1 results in N mineralization, and ratios greater than 30:1 show immobilization of nitrogen, while C/N ratios between 20-30:1 may exhibit neither a loss nor gain of N in the soil.

Wheat straw with a C/N ratio of 80:1 was added to the samples at the rates of 0, 1792, 3584, and 7168 kg/ha. Initially immobilization was expected; however, a slight increase was found for days 1-3 at all N fertilizer and residue rates, though not significantly (Table IX).

Immobilization of N began to appear on day 4, decreasing NO_3 levels, though not statistically significant.

The C/N ratio of all treatment combinations ranged from 2-31:1, except for the ones involving zero application rates. Nitrogen mineralization was expected as the soil and treatments began to equilibrate. On day 21, NO_3 levels did begin to increase with all treatments, signalling mineralization.

The influence of fertilizer rates on NO_3 levels indicates that there is a direct increase in NO_3 in the soil as rates increase. As the experiment proceeded, a basic pattern of increasing levels of NO_3 developed, particularly at the 84, 168, and 336 kg N/ha rates amid sometimes fluctuating NO_3 levels (Figures 7-9).

Without added N, maximum NO_3 concentration occurred at 21 days, then declined (Figure 6). This decrease is a possible indication of a limited N supply not meeting the demands of the microbial population resulting in immobilization. As the lack of N continued, a decline in population occurred, and in time N levels began to increase, as evident at day 70.

The influence of organic residue on NO_3 levels is most pronounced toward the end of the experiment, at day 49. As the amount of residue increases, supplying carbohydrates for microbial growth, the amount of NO_3 in the soil decreases to meet their demands (Figures 2-5). As the experiment progressed, NO_3 levels continued to increase, indicating N mineralization. A more detailed comparison of the effect fertilizer and crop residue rates have on NO_3 levels is included (Table X). Perhaps the most significant is the combination of 1792 kg/ha of residue and 336 kg N/ha of fertilizer having the highest accumulation of NO_3 by the end of the experiment (a C/N ratio of 4:1).

TABLE IV

STATISTICAL ANALYSIS OF THE EFFECTS OF N FERTILIZER AND CROP RESIDUE RATES ON NO_3-N CONCENTRATION

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Total	672	156857.65		
Blks.	2	76.92	38.46	
Trts.	226	154423.35	683.29	
Fertilizer,F	3	24281.71	8093.90	1482.93*
Residue,R	3	374.42	124.80	22.87*
Hours,H	13	38092.95	2930.23	536.86*
FXR	9	373.56	41.51	7.60*
FXH	39	41747.37	1070.44	196.12*
RXH	39	722.90	18.54	3.40*
FXRXH	117	1048.99	8.97	1.64*
Exp. Error	446	2434.30	5.46	

* Indicates significance at the 0.05 level.

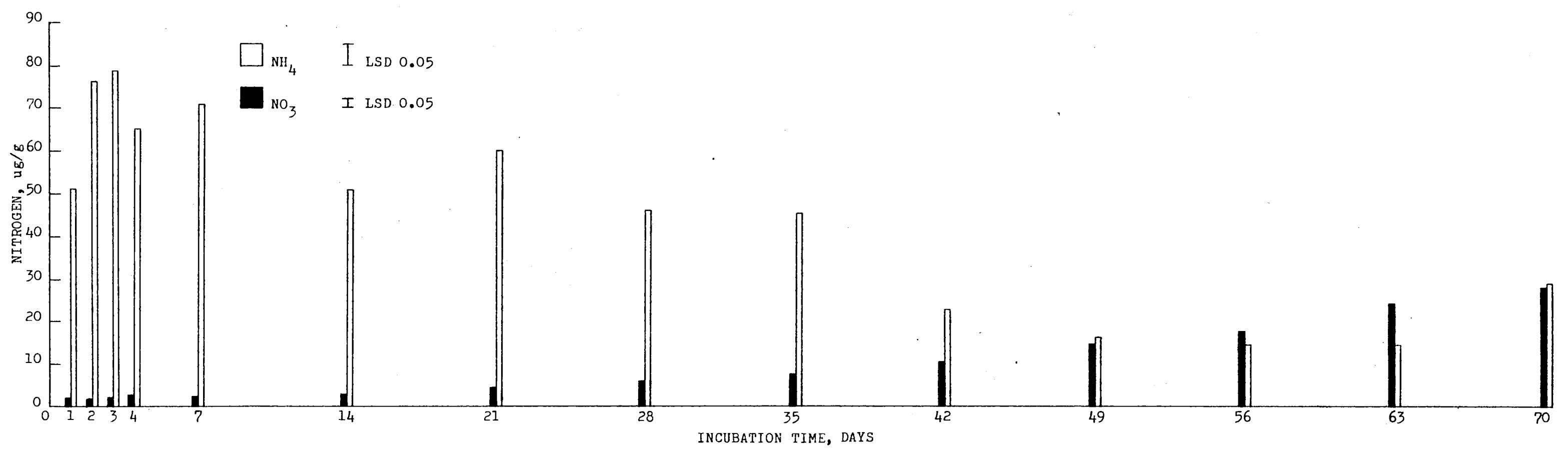

Figure 2. Ammonium-N and NO_3-N in soil during incubation without added residue averaged over all fertilizer rates

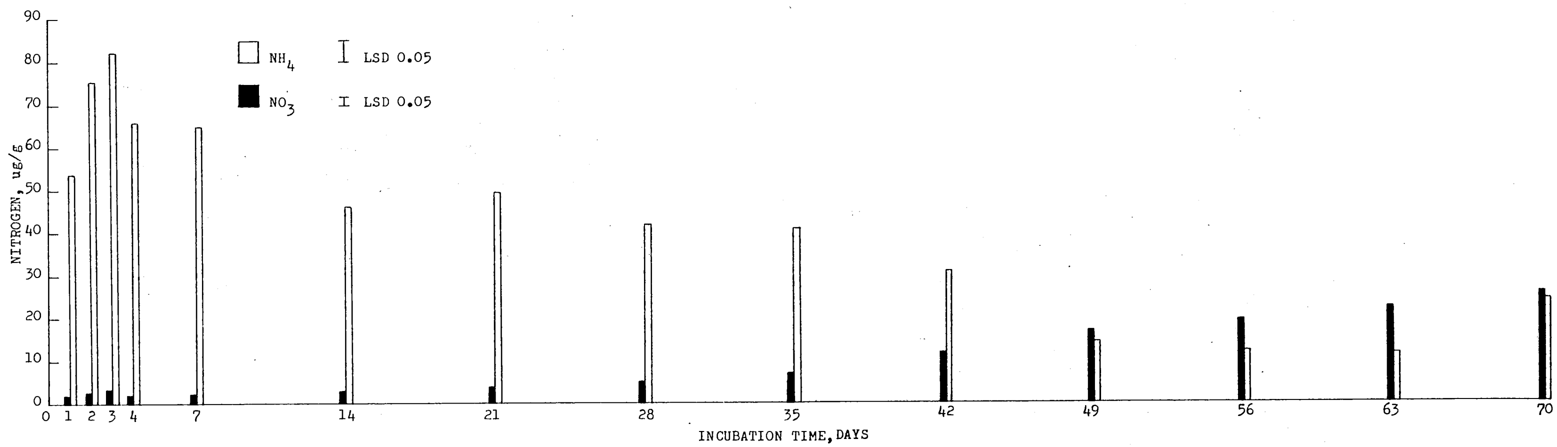

Figure 3. Ammonium-N and NO_3-N in soil during incubation with 1792 kg/ha of residue averaged over all fertilizer rates

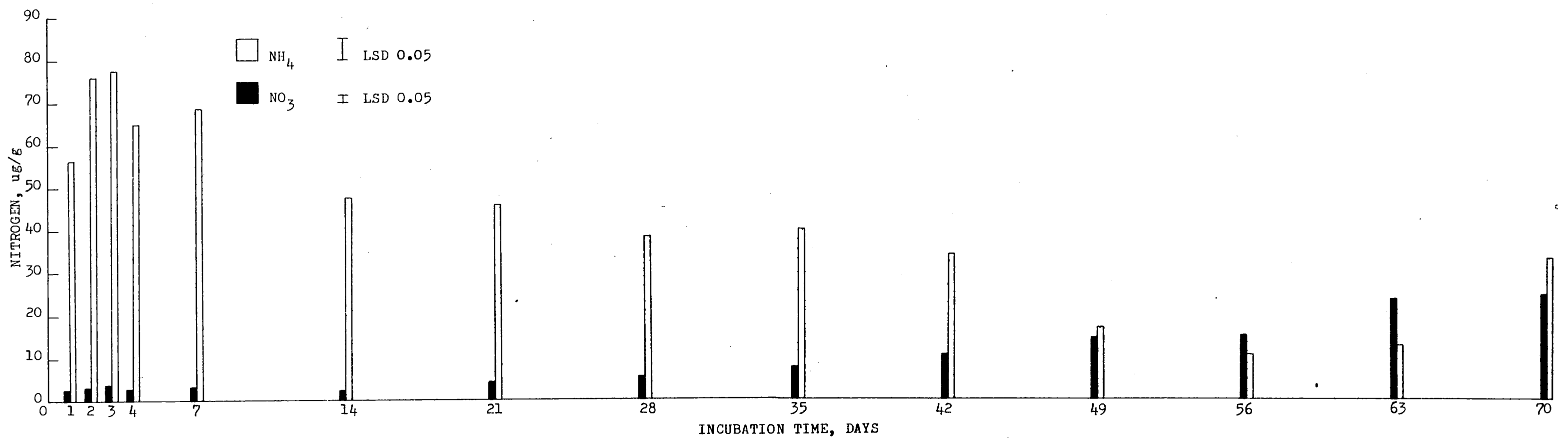

Figure 4. Ammonium-N and NO_3-N in soil during incubation with 3584 kg/ha of residue averaged over all fertilizer rates

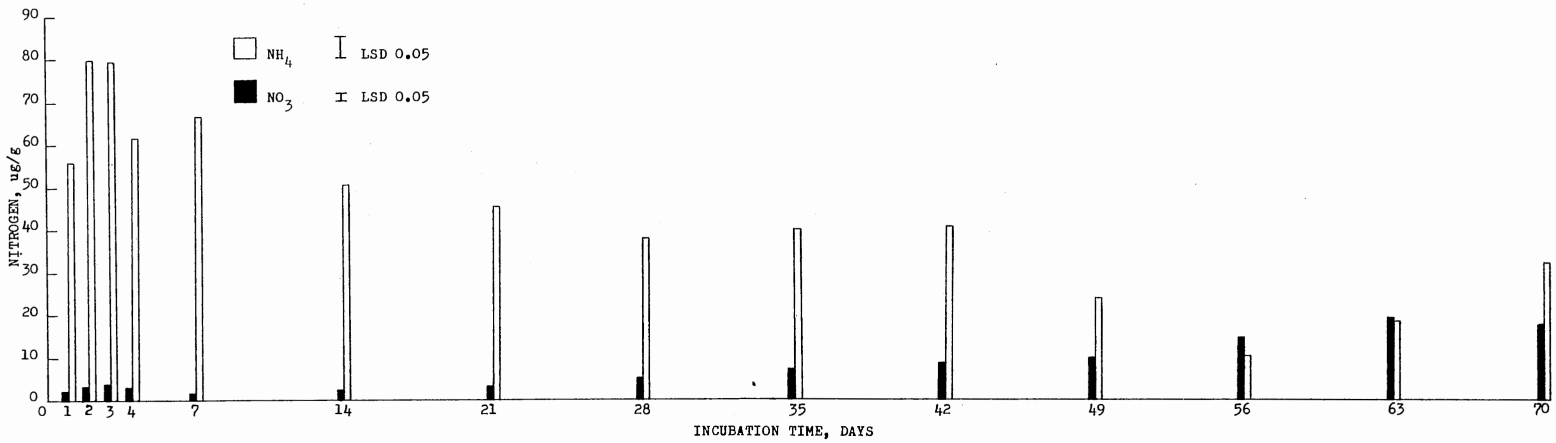

Figure 5. Ammonium-N and NO_3-N in soil during incubation with 7168 kg/ha of residue averaged over all fertilizer rates

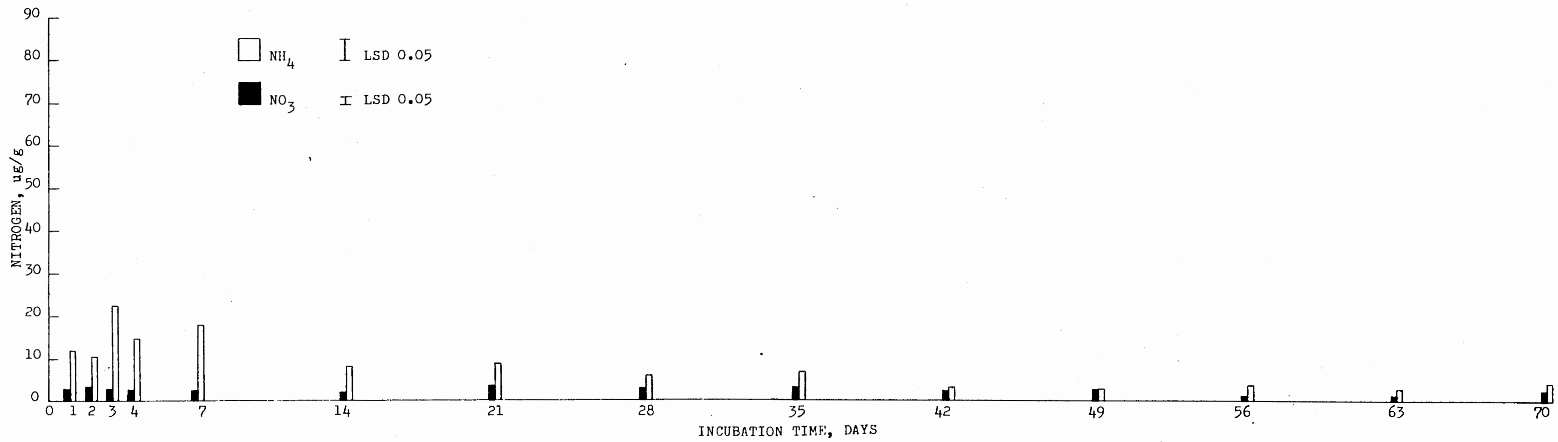

Figure 6. Ammonium-N and NO_3-N in soil during incubation without added fertilizer averaged over all residue rates

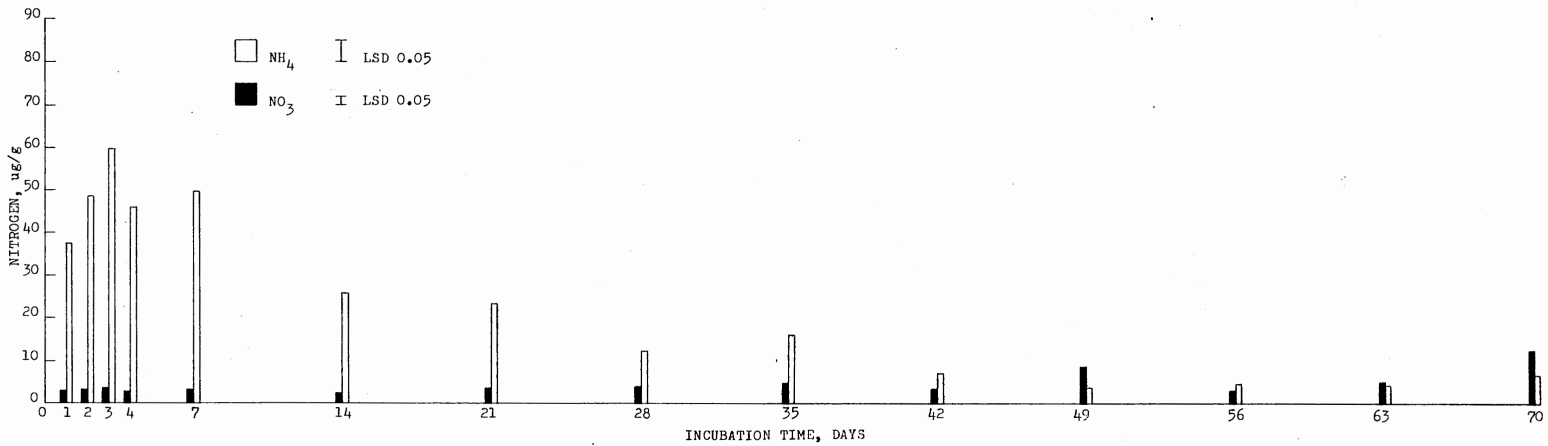

Figure 7. Ammonium-N and NO_3-N in soil during incubation with 84 kg N/ha of fertilizer averaged over all residue rates

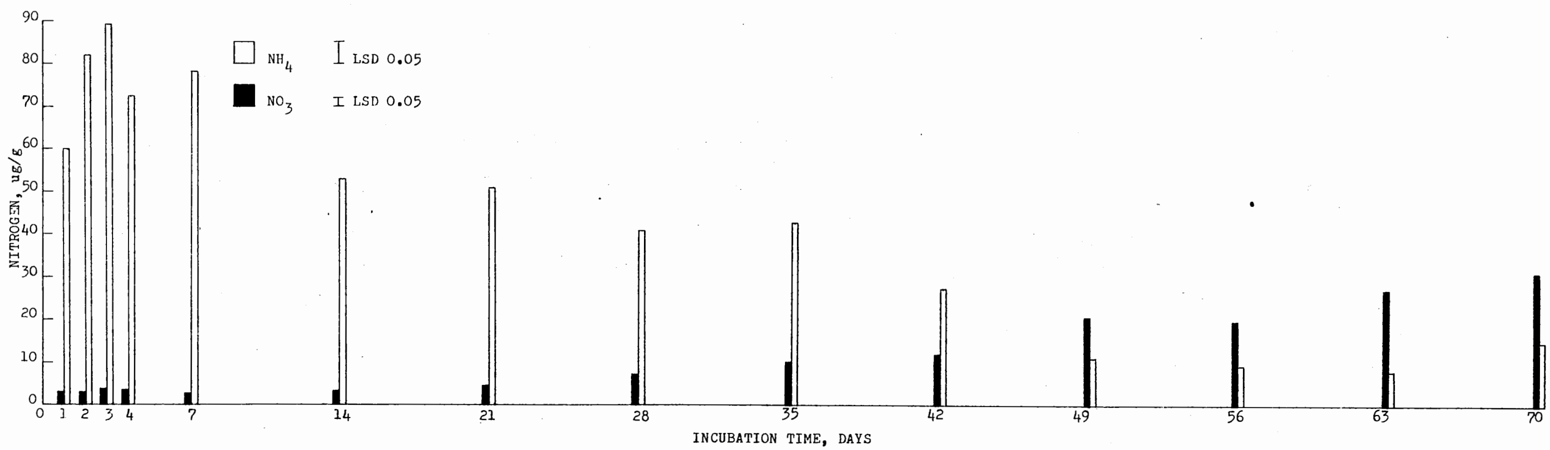

Figure 8. Ammonium-N and NO_3-N in soil during incubation with 168 kg N/ha of fertilizer averaged over all residue rates

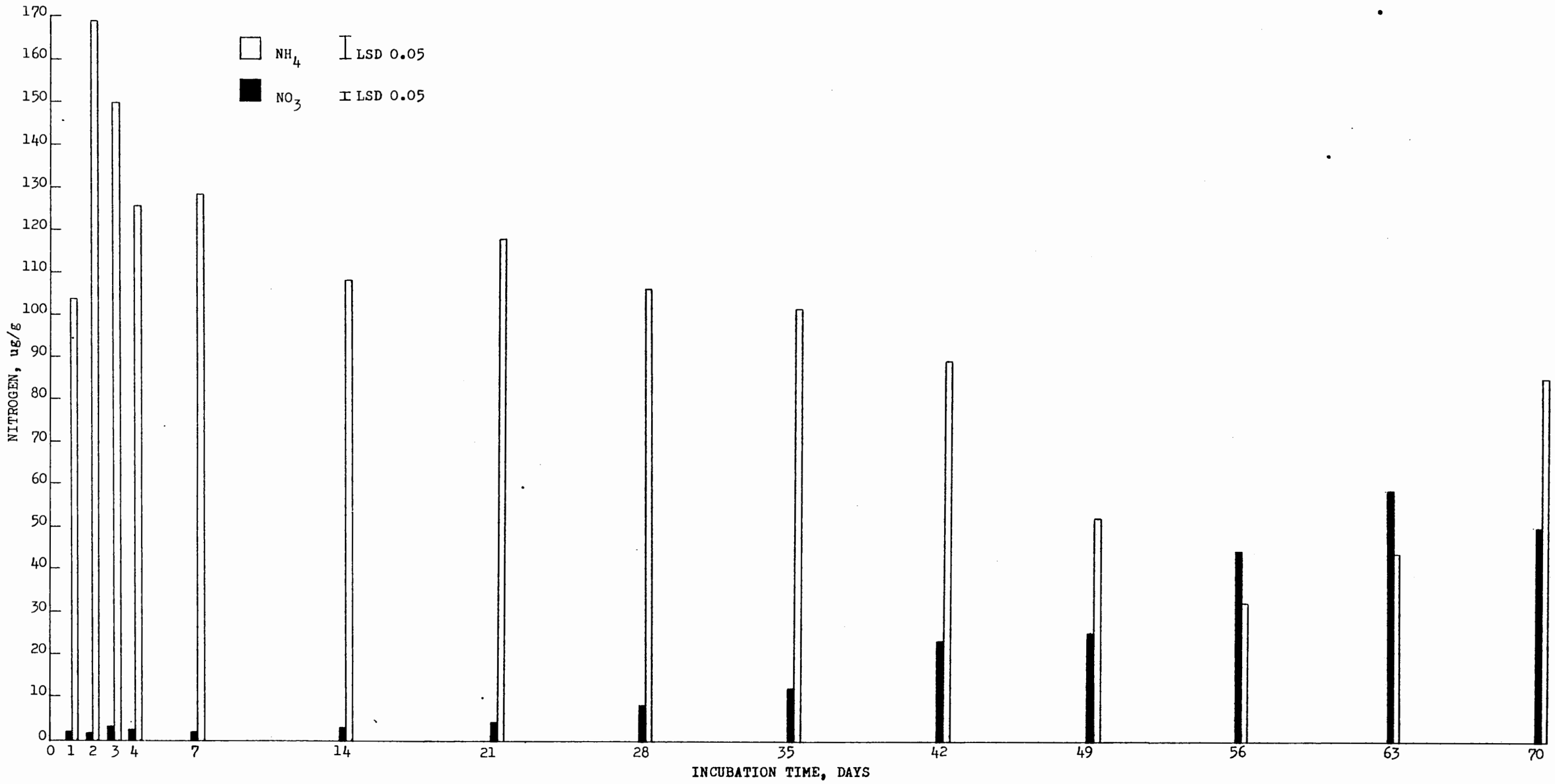

Figure 9. Ammonium-N and NO_3-N in soil during incubation with 336 kg N/ha of fertilizer averaged over all residue rates

Effect of N Fertilizer and Crop Residue Rates on Organic N

The amount of total N at the beginning of the experiment increased as treatment rates increased and is directly related to the concentration of mineral N (as NH_4 and NO_3) found at 10 weeks. However, no correlation could be found with increased levels of total N to the amount of organic N recovered at 10 weeks (Table V).

All treatments showed an increase of mineral N at 10 weeks compared to the initial amount of inorganic and organic N added. This net increase in N indicates that nitrification had occurred. Immobilization was also taking place evidenced by the substantial increase in organic N at 10 weeks compared to the initial fraction supplied by the crop residue.

The statistical analysis of organic N at 10 weeks showed no significant effect with the fertilizer rate, crop residue rate, or their interaction (Table VI). The inability to detect the influence of the treatments on organic N were possibly due to N volatilization and trying to detect very small N concentrations.

TABLE V

CONCENTRATION OF NITROGEN AT 10 WEEKS AS A FUNCTION OF N FERTILIZER AND CROP RESIDUE RATES

Fertilizer rate+	Residue rate+ 0	1792	3584	7168
	%N*			
0				
Initial#	0.0011	0.0015	0.0019	0.0027
Organic@	0.09&	0.10	0.09	0.10
Mineral$	0.0061	0.0056	0.0053	0.0056
84				
Initial	0.0049	0.0053	0.0057	0.0065
Organic	0.10	0.10	0.10	0.10
Mineral	0.0073	0.0068	0.0065	0.0068
168				
Initial	0.0086	0.0090	0.0094	0.0102
Organic	0.10	0.10	0.09	0.10
Mineral	0.0101	0.0096	0.0093	0.0096
336				
Initial	0.0161	0.0165	0.0169	0.0177
Organic	0.10	0.09	0.10	0.10
Mineral	0.0191	0.0186	0.0183	0.0186

+ Rates expressed as kg/ha.
* Means of 3 replicates.
# %N calculated in fertilizer, wheat straw, and native NO_3 and NH_4 levels at beginning of incubation, does not include indigenous organic N found in soil.
@ %N found in crop residue at 10 weeks.
$ %N found as NO_3 and NH_4 at 10 weeks.
& Assumed to be % organic N indigenous to the soil for all treatments at beginning of incubation.

TABLE VI

STATISTICAL ANALYSIS OF THE EFFECTS OF N FERTILIZER AND CROP RESIDUE RATES ON ORGANIC N CONCENTRATION

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Total	47	0.0046		
Blks.	2	0.0006	0.0003	3.0^{ns}
Trts.	15	0.0006	0.00004	0.4^{ns}
Fertilizer, F	3	0.0002	0.0001	1.0^{ns}
Residue, R	3	0.0002	0.0001	1.0^{ns}
FXR	9	0.0002	0.00002	0.2^{ns}
Exp. Error	30	0.0034	0.0001	

ns Not significant at the 0.05 level.

CHAPTER IV

CONCLUSIONS

Urea hydrolysis occurred rapidly at all fertilizer rates and was complete by the end of the second day. Organic residue present in the soil had no significant effect on hydrolysis, though it appeared that higher rates of residue stimulated microbial growth, increasing the amount of urease in the soil. Surface applied urea in a conservation tillage system presents a potential source for NH_3 volatilization as the pH approaches 9.0. Deep placement of fertilizer has been suggested as a possible means of increasing N use efficiency.

After urea hydrolysis, NH_4 increased then declined as nitrification converted NH_4 to NO_3. Not until day 63 did NH_4 levels begin to increase in most treatments. This increase late in the experiment is attributable to meeting the demands for N by the soil microbes.

The comparatively high rates of crop residue supplied initially caused an immobilization of N as evidenced by the suppressed levels of NO_3. At day 21, NO_3 levels began to increase as the demand for N had lessened, and continued to increase for the remainder of the experiment. The most significant conclusion was that the amount of crop residue increased, supplying carbohydrates for microbial growth, the need for N increased, decreasing the amount of NO_3 in the soil. The treatment combination of 1792 kg/ha of residue and 336 kg N/ha of fertilizer appeared to have the most favorable environment with the highest accumulation of NO_3. Therefore, the increased amount of residue at the surface as in conservation tillage, must be taken into account when making fertilizer recommendations.

All 16 treatments showed an increase in mineral N at 10 weeks, compared to the initial amount added, indicating nitrification had occurred. Immobilization also occurred, evidenced by the increase in organic N compared to the initial fraction supplied by the crop residue. No correlation between treatments and organic N recovered at 10 weeks was found.

The processes of N mineralization and immobilization are never eliminated in arable soil, but the rates are easily influenced by the environment. It is apparent that the relationship between N fertilizer and crop residue rates is closely related to N transformations in the soil. Further study is needed to determine if the management practices of conservation and conventional tillage systems affect N mineralization and immobilization and to what degree. Understanding these interactions between N mineralization and plant nutrient availability is vital to obtaining maximum fertilizer efficiency.

LITERATURE CITED

1. Alexander, Martin. 1977. Introduction to soil microbiology, Second ed. John Wiley & Sons, New York.

2. Ammonia in water and wastewater. 1973. Industrial Method 98-70W, Technicon Industrial Systems, Tarrytown, New York.

3. Archibald, Reginald M. 1945. Colorimetric determination of urea. J. Biol. Chem. 157:507-518.

4. Blevins, R. L., R. E. Phillips, and G. W. Thomas (ed.) No-tillage research: research reports and reviews. Univ. Kentucky, Kentucky.

5. Blevins, R. L., M. S. Smith, G. W. Thomas, and W.W. Frye. 1983. Influence of conservation tillage on soil properties. J. Soil and Water Cons. 38:301-305.

6. Bremner, J. M. 1965. Inorganic forms of nitrogen. In C. A. Black et.al (ed.) Methods of soil analysis, part 2. Chemical and microbiological properties. Agronomy 9:1179-1237. Am. Soc. of Agron., Madison, Wis.

7. Bremner, J. M. 1965. Total nitrogen. In C. A. Black et. al (ed.) Methods of soil analysis, part 2. Chemical and microbiological properties. Agronomy 9:1149-1178. Am. Soc. of Agron., Madison, Wis.

8. Broadbent, F. E., and K. B. Tyler. 1962. Laboratory and greenhouse investigations of nitrogen immobilization. Soil Sci. Soc. Am. Proc. 26:459-462.

9. Fredrickson, J. K., F. E. Koehler, and H. H. Cheng. 1982. Availability of ^{15}N-labled nitrogen in fertilizer and wheat straw to wheat in tilled and no-till soil. Soil Soc. Am. J. 46: 1218-1222.

10. Murphy, Larry. 1983. Fertilizer placement: a primer. J. Soil and Water Cons. 38:246-249.

11. Nitrate and nitrite in soil extracts. 1977. Industrial Method 486-77A, Technicon Industrial Systems, Tarrytown, New York.

12. Peech, M. 1965. Hydrogen-ion activity. In C. A. Black et. al (ed.) Methods of soil analysis, part 2. Chemical and microbiological properties. Agronomy 9:914-926. Am. Soc. of Agron., Madison, Wis.

13. Rice, C. W., and M. S. Smith. 1982. Microbiological N transformations in no-tilled soils. Agronomy Abstracts. Am. Soc. of Agron., Madison, p. 196.

14. Smith, K. A., and R. S. Howard. 1980. Field studies of nitrogen uptake using ^{15}N-tracer methods. J. Sci. Food Agric. 31:839-840.

15. Steel, Robert G. D., and James H. Torrie. 1980. Principles and procedures of statistics a biometrical approach, Second ed. McGraw-Hill, New York.

16. Thomas, G.W., K. L. Wells, and L. Murdock. Fertilization and liming. p. 43-45. In R. E. Phillips, G. W. Thomas, and R. L. Blevins (ed.) No-tillage research: research reports and reviews. Univ. Kentucky, Kentucky.

17. Van Doren, D. M., Jr., G. B. Triplett, Jr., and J. E. Henry. 1976. Influence of long-term tillage, crop rotation, and soil type combinations on corn yield. Soil Sci. Soc. Am. J. 40:100-105.

APPENDIX

TABLE VII

CONCENTRATION OF NH_4-N DURING INCUBATION AVERAGED OVER FERTILIZER AND RESIDUE RATES

Incubation time, Days	Fertilizer rate, kg N/ha				Residue rate, kg/ha			
	0	84	168	336	0	1792	3584	7168
	ug/g							
1	11	37	59	110	52	54	56	55
2	10	48	82	168	76	76	76	80
3	21	59	88	149	79	82	77	79
4	14	45	71	126	66	65	64	61
7	17	49	78	127	71	65	68	67
14	7	25	52	108	51	45	47	50
21	8	23	51	118	60	49	46	45
28	5	12	40	106	46	42	38	37
35	6	15	41	102	45	40	39	39
42	3	7	26	89	23	30	33	40
49	2	3	10	52	15	13	16	23
56	3	3	9	32	14	12	10	11
63	3	4	7	44	14	12	13	19
70	3	6	15	85	28	25	23	33

LSD= 4.96 at the 0.05 level.

TABLE VIII

EFFECT OF N FERTILIZER AND RESIDUE RATES ON NH_4-N CONCENTRATION DURING INCUBATION

Incubation time, Days	0 kg/ha of residue				1792 kg/ha of residue			
	0	84	168	336	0	84	168	336
	kg N/ha				kg N/ha			
	ug/g*							
1	9	34	55	108	8	38	62	108
2	10	50	83	163	9	47	81	165
3	24	58	85	148	21	61	95	152
4	13	46	75	128	14	46	72	130
7	17	50	75	141	12	44	80	123
14	8	28	56	110	4	24	47	105
21	11	32	67	131	8	22	54	114
28	7	16	46	113	5	13	39	109
35	7	21	53	100	7	16	39	100
42	2	5	16	68	2	5	24	87
49	2	4	15	39	2	3	6	42
56	3	4	10	40	2	3	10	32
63	3	4	7	44	3	4	7	33
70	4	6	15	88	3	7	12	76

TABLE VIII (Continued)

Incubation time, Days	3584 kg/ha of residue				7168 kg/ha of residue			
	0	84	168	336	0	84	168	336
	kg N/ha				kg N/ha			
	ug/g*							
1	16	36	64	108	10	39	55	118
2	10	45	80	168	9	49	83	177
3	18	57	86	146	21	59	86	150
4	15	46	70	125	13	43	68	120
7	22	49	74	127	17	53	80	117
14	8	20	50	110	8	28	56	107
21	8	18	45	111	6	19	39	116
28	4	9	40	101	3	9	34	102
35	6	12	36	103	4	10	36	105
42	3	8	26	95	4	11	40	106
49	2	3	7	51	2	2	12	77
56	3	3	7	28	3	3	8	29
63	3	3	6	39	3	4	9	61
70	3	5	11	74	4	6	20	101

* Means of 3 replicates.
LSD= 4.96 at the 0.05 level.

TABLE IX

CONCENTRATION OF NO_3-N DURING INCUBATION AVERAGED OVER FERTILIZER AND RESIDUE RATES

Incubation time, Days	Fertilizer rate, kg N/ha				Residue rate, kg N/ha			
	0	84	168	336	0	1792	3584	7168
	ug/g							
1	2	2	2	2	2	2	2	2
2	2	2	3	2	2	2	2	2
3	2	3	3	3	2	3	3	3
4	2	2	3	3	3	2	2	2
7	2	2	2	2	3	2	2	2
14	1	2	2	3	2	2	2	2
21	3	3	4	4	4	4	3	3
28	2	4	7	8	6	6	5	4
35	2	5	10	12	7	8	8	7
42	2	3	12	24	10	11	11	8
49	2	8	20	25	15	17	14	10
56	1	3	20	45	18	18	16	16
63	1	4	27	58	24	23	23	20
70	2	12	31	50	27	26	24	18

LSD= 1.87 at the 0.05 level.

TABLE X

EFFECT OF N FERTILIZER AND RESIDUE RATES ON NO_3-N CONCENTRATION DURING INCUBATION

Incubation time, Days	0 kg/ha of residue				1792 kg/ha of residue			
	0 kg N/ha	84 kg N/ha	168 kg N/ha	336 kg N/ha	0 kg N/ha	84 kg N/ha	168 kg N/ha	336 kg N/ha
	ug/g*							
1	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	3	2
3	2	2	2	3	2	3	4	3
4	3	3	3	3	2	2	3	3
7	2	3	3	2	2	2	2	2
14	2	2	3	3	1	2	3	3
21	3	4	4	5	3	3	4	4
28	3	5	7	9	3	4	8	9
35	3	5	9	12	3	5	10	12
42	2	5	13	22	2	2	12	29
49	1	8	22	28	4	10	23	30
56	1	4	19	46	1	2	19	53
63	1	4	30	61	1	2	24	64
70	3	13	37	55	2	13	32	56

TABLE X (Continued)

Incubation time, Days	3584 kg/ha of residue: 0 kg N/ha	84	168	336	7168 kg/ha of residue: 0 kg N/ha	84	168	336
	ug/g*							
1	2	2	2	2	2	2	2	2
2	2	2	3	2	2	2	2	2
3	3	3	3	3	3	3	3	3
4	2	2	2	2	2	2	2	2
7	2	2	2	2	1	2	2	2
14	1	2	2	3	1	2	2	3
21	2	3	4	4	2	3	3	4
28	2	3	7	9	2	3	6	7
35	2	5	9	13	2	5	9	12
42	2	2	12	26	2	3	11	18
49	2	9	21	26	2	7	15	17
56	1	3	19	42	1	2	21	39
63	1	4	29	60	1	4	26	49
70	1	12	29	53	2	10	25	36

* Means of 3 replicates.
LSD= 1.87 at the 0.05 level.

VITA

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