AN ABSTRACT OF THE THESIS OF

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Title: A Comparative Study of Nitrogen Forms in a Tallgrass Prairie and Agricultural Field

Abstract Approved: James M. Mayo

A study of nitrogen forms in a tallgrass prairie and an adjacent agricultural field was conducted. Both sites were located on the same Irwin silty clay loam soil series. Samples were taken from each site every 2-4 weeks and analyzed using the microdiffusion procedure of Keeney and Nelson (1982). A nitrification potential experiment was designed to minimize the disturbance to the system. When an abundance of ammonium (50 ppm) was added, nitrate production increased in both sites. One and one-half weeks after the beginning of this experiment, the Nitrosomonas population was examined and found to be 1000 times greater than the previous reading in both sites. With applied ammonium (and increased numbers of nitrifying bacteria), even the prairie produced a good deal of nitrate.

Results from the microdiffusion tests showed ammonium to be the dominant nitrogen form in the tallgrass prairie throughout the year, however, a substantial amount of nitrate (not less than 25 % of the total) was present at every sampling. The summer samples showed nitrate accounting for 47 % of the total mineral nitrogen present in the prairie. The agricultural field showed more fluctuation, with ammonium dominating winter and spring months and nitrate in summer and fall.

The data suggest a correlation between soil conditions and nitrogen form present. Saturated soil (with low oxygen levels) contained a high ammonium concentration in both sites, while drier, better oxygenated soils (as in summer) had a higher nitrate content. The microdiffusion tests and nitrification potential experiment suggest that in heavy clay soils, a dominance of ammonium may be due to increased soil water content and not to allelopathic effects.

A COMPARATIVE STUDY OF NITROGEN FORMS IN A TALLGRASS PRAIRIE AND AGRICULTURAL FIELD

A Research Thesis

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Nitrogen is a unique essential plant nutrient in that it occurs in two different inorganic forms in the soil, ammonium (a cation) or nitrate (an anion). Through microbial activity by Nitrosomonas and Nitrobacter, the ammonium ion is oxidized first to nitrite and then to nitrate in the following process called nitrification (Alexander 1961):

$$3NH_4^+ + 3O_2 \xrightarrow{\text{Nitrosomonas}} 2NO_2^- + 2H_2O + 4H^+ + \text{energy}$$

$$2NO_2 + O_2 \xrightarrow{\text{Nitrobacter}} 2NO_3^- + \text{energy}$$

The positively charged ammonium ion is adsorbed by the exchange complex, making it resistant to leaching, whereas the negatively charged nitrate ion is repelled, thus subject to loss due to leaching, runoff, and denitrification. Nitrite does not normally accumulate, but rather is quickly converted to nitrate (Brady 1974). Odum (1969) designated the use of ammonium by plants as a conservation step, which he demonstrated in two ways:

1. NH_4^+-N is not lost to leaching, thus remaining in the root zone for a longer period of time, making it available for absorption by plants.

2. NH_4^+-N can be incorporated directly into amino acids by plants whereas nitrate must first be reduced in a process requiring a great deal of energy.

Many researchers (Haines 1977; Rice and Pancholy 1972, 1973, 1974; Lamb 1980; Robertson and Vitousek 1981) have compared the form of nitrogen present between ecological successional stages. Rice and Pancholy (1972) determined the amount of NH_4^+-N increased from the first successional stage to the climax stand. In their work on successional plots in an Oklahoma oak-pine forest, a post-oak forest,

and a tall grass prairie, consistent results showed inhibition of nitrification increasing as succession advanced. They postulated that the vegetation in a climax stand is actually inhibiting the process of nitrification through the release of tannins or tannin derivatives. Haines (1977) studied five successional stages ranging from old-field to hardwood forest in South Carolina. He reported nitrate uptake decreasing from early to advanced successional stages. He suggested the use of nitrate by pioneer vegetation "makes evolutionary sense" since the disturbance causing secondary succession would remove those factors inhibiting nitrification. The use of ammonium by an ecosystem is actually an energy and nitrogen conserving step (Haines 1977).

Succeeding studies also have shown climax seres with higher concentrations of ammonium and lower concentrations of nitrate than early successional stages. Montes and Christensen (1979) looked at nitrate levels in soil from an old field, a pine stand, and an oak-hickory stand in South Carolina. As in previous studies, soil nitrate levels were higher in the old-field than either the pine or oak hickory stands. Lodhi (1979) studied mine spoil soils in various successional stages in North Dakota. He also found nitrification decreasing from pioneer to climax stands.

However, Robertson and Vitousek (1981) noted no decrease in nitrification from the first to the last successional stage. They concluded from their study on the Indiana dunes, that nitrification rates increased from early to later successional stages. As a result of nitrogen fixation, the early stage (nitrogen depleted) soils improved in fertility as succession progressed. However, numbers of nitrifying bacteria were not consistent with nitrate production, i.e.,

an old growth forest site had the highest rate of nitrate production of all four secondary seres studied, but the lowest numbers of Nitrosomonas.

Lamb (1980) reported an increase in nitrification as succession advanced (total-nitrogen also increased). He surmised that the rate of nitrification was more related to the size of the nitrogen pool and soil fertility (as fertility increased, so did nitrification) than to successional stages.

Montes and Christensen (1979) and Rice and Pancholy (1972) found Most Probable Number of Nitrosomonas higher in old field ecosystems than later successional stages. These nitrifying bacteria are autotrophic organisms, which through the oxidation of ammonium or nitrite, derive all the energy needed for growth (Belser 1979). These nitrifiers are aerobic, resistant to drying, adversely affected by light, and somewhat temperature tolerant. These bacteria are also very sensitive to metal ions, such as aluminum, zinc, copper, lead, and manganese (Meiklejohn 1954).

Previous researchers (Montes and Christensen 1979; Robertson and Vitousek 1981; Rice and Pancholy 1972) have addressed the study of nitrification potential in various ways. Nitrification potential can be defined as the capacity of a soil to convert ammonium to nitrate (Mahendrappa et al. 1966). It can also be described as the effect of ammonium treatments on nitrate production (Montes and Christensen 1979). Generally, soil subsamples are removed to the laboratory where experiments are conducted. Rice and Pancholy used solution culture. Vitousek incubated samples in polyethylene cups using soil which had been sieved, then brought nearly to field capacity; the cups were then

sealed with a snap on lid. The technique of Montes and Christensen was similar to that of Vitousek, incubating soil samples in plastic cups in the dark for 30 days. All of these methods involve handling and manipulation (or disturbance) of the soil, which Vitousek et al. (1979) found to increase nitrification.

According to Alexander (1961), soil type, temperature, rainfall, pH, and vegetation all affect the process of nitrification. The previous studies cited have been performed on soil with a large amount of sand and a minimum clay content. The soil properties themselves contribute to the presence or absence of nitrification inhibition. Generally, sandy soil has a lower cation exchange capacity (the ability of a soil to hold cations to the soil colloid, Foth et al. 1982), thus providing fewer sites for ammonium to adsorb to the soil particle. Clay soils have a high cation exchange capacity, providing a temporary stockpile of a wide variety of nutrients, including ammonium (Foth et al. 1982). Clay particles are relatively small, allowing for pore space volume to be quite large. When a fine-textured soil is saturated, all available pore space is taken up by water, leaving few if any pores open for oxygen. Thus, when water accumulates above an impermeable layer, a poorly aerated or water-logged soil is created (Thompson and Troeh 1978). Since nitrification is an aerobic process, the low oxygen conditions produced by saturation reduces nitrification. Therefore, the soil type (in this case heavy clay) has a major effect on this process.

The question of nitrogen form preference has never been studied in the tallgrass region of eastern Kansas. The background studies cited here, do not succeed in answering the question of ammonium or

nitrate preference using a heavy clay soil. Previous methods of nitrification potential studies raise questions as to the techniques employed favoring nitrification. With these unknowns or questionable methods, a study of nitrogen forms in a clay soil of eastern Kansas was warranted. The study sites were located adjacent to one another in Chase County, Kansas, on an Irwin silty clay loam soil (Neill 1974).

The objectives of this work were as follows:

1. to extend the nitrogen studies to the heavy clay soils of eastern Kansas.
2. to determine the nitrogen forms in an active field and a native tallgrass prairie.
3. to conduct a study on nitrogen forms using adjacent sites (in order that weather conditions were consistent between the two) and the same soil series.
4. to monitor the numbers of Nitrosomonas as well as total microbial activity in both active field and native prairie.
5. to implement a nitrification potential experiment performed in situ.

MATERIALS AND METHODS

Two sites, a native tallgrass prairie (site A) and an adjacent agricultural field (site B) were selected for this study. Both were located in Diamond Township, N1/2, NE1/4, S 13, T 19, R 6, Chase County, Kansas, on an Irwin silty clay loam soil (Figures 1 and 2). The field was cultivated in milo, then wheat during the study period of August, 1984, through July, 1985. The native prairie was dominated by big bluestem, with all other major prairie grass species present. The prairie site has never been cultivated and has been routinely hayed, years permitting.

The pH was determined with a Beckman pH meter, using a glass probe in a 1:1 soil to water suspension. The hydrometer method of Bouyoucos (1936) was followed to determine soil texture. Data for the vegetation composition of the prairie was gathered by the plot frame method outlined by Wilk (1984). Ten transects of 100 meters were measured, a 1/4 square meter plot frame was placed every 10 meters along the transect and percent basal area covered by each species within the frame was estimated. An average percent composition for each species was then determined for the prairie.

Soil samples were taken from each site every 2-4 weeks and transported back to the lab where a ten gram sample was extracted with 100 milliliters of 2M KCl and stored in a refrigerator until tests could be run. The extract was analyzed for ammonium and nitrate following the microdiffusion procedure outlined by Keeney and Nelson (1982). This technique was chosen for it "requires little lab equipment or space and is capable of a high degree of accuracy." The

Figure 1. Photograph of site A.

Figure 2. Photograph of site B.

microdiffusion units were made up of three chambers, with the outer moat (when filled with potassium carbonate) serving as a seat for the cover. Two milliliters of extract was analyzed by adding potassium carbonate, causing NH4 in the sample to be reduced to NH3 which was then absorbed (during incubation) by the boric acid indicator solution contained in the central chamber. The indicator was then titrated with .05 N H2SO4 to the end point. The same sample was used to determine nitrate concentration. By adding Devarda's alloy to the sample chamber, NO3 was reduced to NH4, allowing for the liberation of NH3, which was then absorbed into fresh indicator solution. After incubation, the boric acid was titrated to determine nitrate content in the soil sample. Nitrite was found to be negligible in both sites. Further testing was done following the procedure in the absence of nitrite. A standard solution with known amounts of ammonium and nitrate was analyzed at each sampling.

Most Probable Number of Nitrosomonas and Total Plate Count experiments were conducted on each soil sample in order to determine the relationship between Nitrosomonas activity and nitrogen form dominance. The procedure of Schmidt and Belser (1982) was followed, using a dilution series to determine MPN and agar plates for Total Plate Counts. A ten gram sample of soil was analyzed by shaking with 95 milliliters of water, then following a dilution series, ten milliliters of the mixture was transferred to each succeeding flask (each of which contained 90 milliliters of water). One milliliter aliquots from each dilution were transferred to test tubes containing sterile ammonium calcium carbonate solution. The tubes were then incubated for 3 weeks. Another set of 1 milliliter aliquots from each

dilution was transferred to the center of sterile petri dishes. An all purpose medium was added and swirled, then incubated for one week. After incubation, Most Probable Number of Nitrosomonas was determined using modified Griess-Ilosvay Reagent, to test for the presence or absence of nitrite. Plates containing 30-300 organisms were counted after one week.

A nitrification potential experiment was designed with the objective of disturbing the natural system as little as possible. A grass clump was removed and soil ring embedded into the root zone (Figure 3). Fifty ppm of ammonium sulfate was added to the soil in the rings, then the clump was replaced on top and the system allowed to incubate for four weeks. After the incubation period, the rings were removed and the soil analyzed for ammonium and nitrate. Most Probable Number of Nitrosomonas was also determined.

Figure 3. Photograph of nitrification potential experiment.

Table 1. Chemical and physical characteristics of soil from each site.

Characteristic	Prairie	Field
Soil type	Irwin silty clay loam	Irwin silty clay loam
% Sand	20	16
% Silt	46	50
% Clay	34	34
CEC*	28 meq	28 meq
pH	6.0	5.5
Bulk density	1.03	1.28

* Cation Exchange Capacity, Thompson and Troeh (1978).

Table 2: Vegetational analysis of site A. Data for those species making up 5 % or more of the total composition.

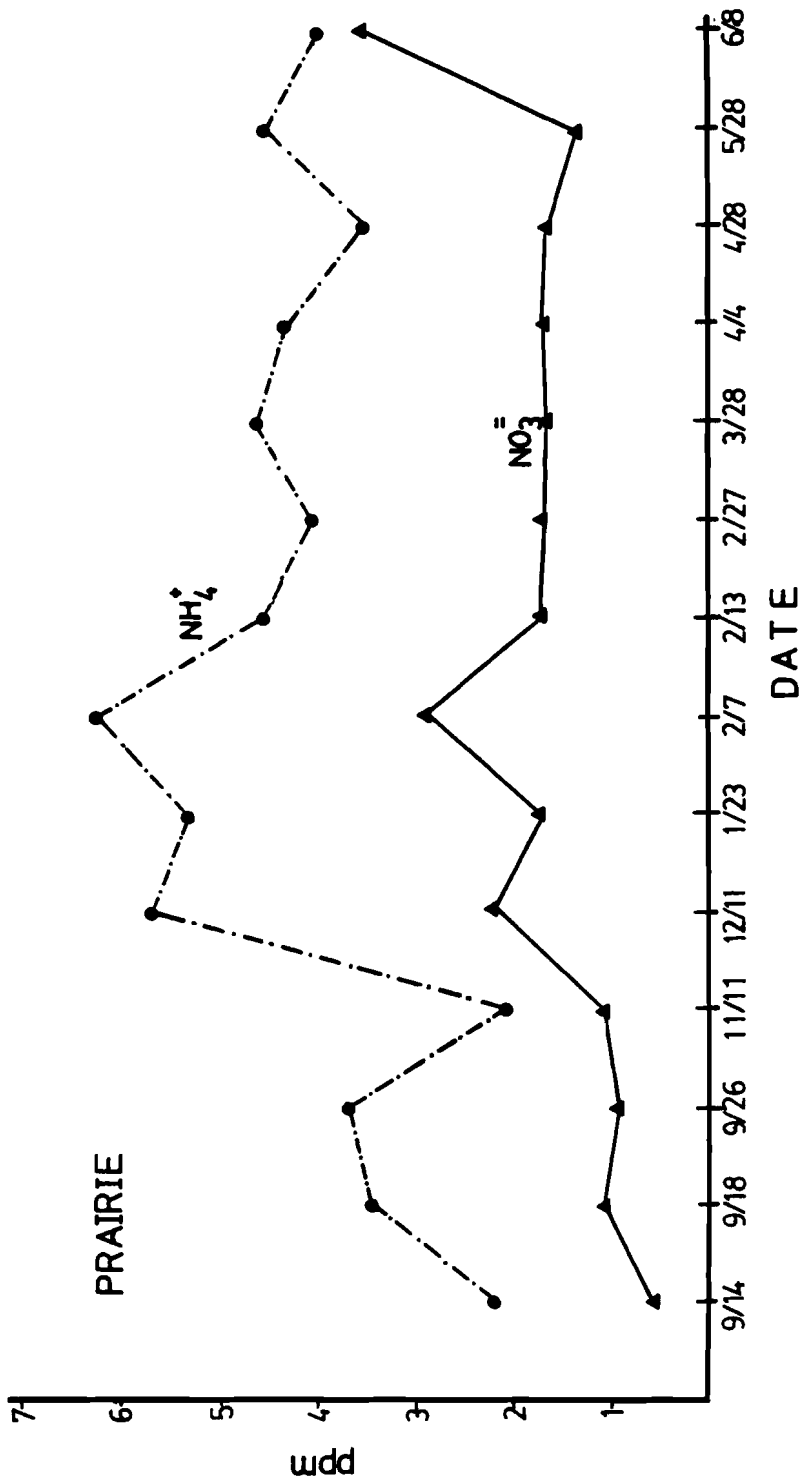
Species	Composition percent
Andropogon gerardi	39
Panicum virgatum	17
Sorghastrum nutans	14
Bouteloua curtipendula	10
Andropogon scoparius	9

Table 3. Concentrations of ammonium and nitrate in ppm of soil from tallgrass prairie (site A) and agricultural field (site B). Each value is the mean of four replicates. Ninety five percent confidence intervals are given for those samples analyzed following the modified procedure of Keeney and Nelson (1982). Those samples taken before February 7, 1985, were analyzed using the original procedure and could not be statistically compared.

Date	Prairie		Field	
	Ammonium	Nitrate	Ammonium	Nitrate
9/14/84	2.20	0.60	1.60	2.56
9/18/84	3.43	1.10	2.20	2.90
9/26/84	3.64	0.96	3.40	3.56
11/11/84	2.09	1.07	1.35	1.64
12/11/84	5.70	2.20	4.64	3.98
1/23/84	5.30	1.70	1.97	2.57
2/7/85	*6.22±0.21	*2.90±0.64	'6.33±0.38	'2.98±0.16
2/13/85	*4.58±0.30	*1.67±0.36	'4.05±1.11	'1.77±0.86
2/27/85	*4.00±0.22	*1.63±0.61	'4.05±0.33	'1.87±0.21
3/28/85	4.60±3.37	1.60±0.67	'3.60±0.66	'2.08±0.49
4/4/85	*4.29±1.47	*1.63±0.66	'3.33±0.60	'2.20±0.30
4/28/85	*3.48±0.85	*1.60±0.83	3.00±0.18	2.50±0.80
5/28/85	4.53±4.72	1.39±0.56	'3.05±0.27	'1.61±0.37
6/8/85	3.95±0.82	3.55±1.52	3.67±1.06	3.90±1.52

* Prairie readings significantly different from each other at the .05 confidence level.

' Field readings significantly different from each other at the .05 confidence level.


PRAIRIE
ppm
7
6
5
4
3
2
1
NH_4^+
$NO_3^=$
9/14
9/18
9/26
11/11
12/11
1/23
2/7
2/13
2/27
3/28
4/4
4/28
5/28
6/8
DATE

Nitrate levels somewhat paralleled those of ammonium decreasing to a minimum of 0.60 ppm on September 14 and a maximum of 3.55 on June 8, 1985.

The field showed a great deal of fluctuation in both ammonium and nitrate up to the January 23 sample; after which a pattern began to develop (Figure 5). Ammonium reached a high of 6.33 ppm on February 7 and continued to dominate (however decreasing) through the spring months. Nitrate dominated from June through September.

Factors influencing the nitrogen form seemed to be fairly consistent between the prairie and field (Figures 6 and 7) as seen by the parallel graphs of nitrate and ammonium. When the NH_4^+-N concentration in the prairie decreased, it did likewise in the field. The nitrate graphs (Figure 7) reflect each other very closely, with similar increases and decreases in concentration. This rise and fall of ammonium reflects the soil water potential. With soil drying in the summer and fall, nitrate levels rose at both sites. Winter and saturated spring samples from both sites showed increased ammonium. Thus, levels of ammonium and nitrate seem to reflect the degree of soil saturation (and thus oxygen content) in both sites.

The data collected support the results of other researchers (Rice and Pancholy 1972, 1973, 1974; Montes and Christenson 1979; Haines 1977; Lodhi 1982) who determined ammonium to be the dominant nitrogen form in a climax ecosystem. However, there are some interesting disparities between previous studies and this one. There has been no previous record of an increase in ammonium in an early successional stage during the months of January through May. The agricultural field (which can be thought of as the first stage of secondary

Figure 5. Ammonium and nitrate concentrations in ppm from site B taken September 14, 1984 through July 3, 1985.

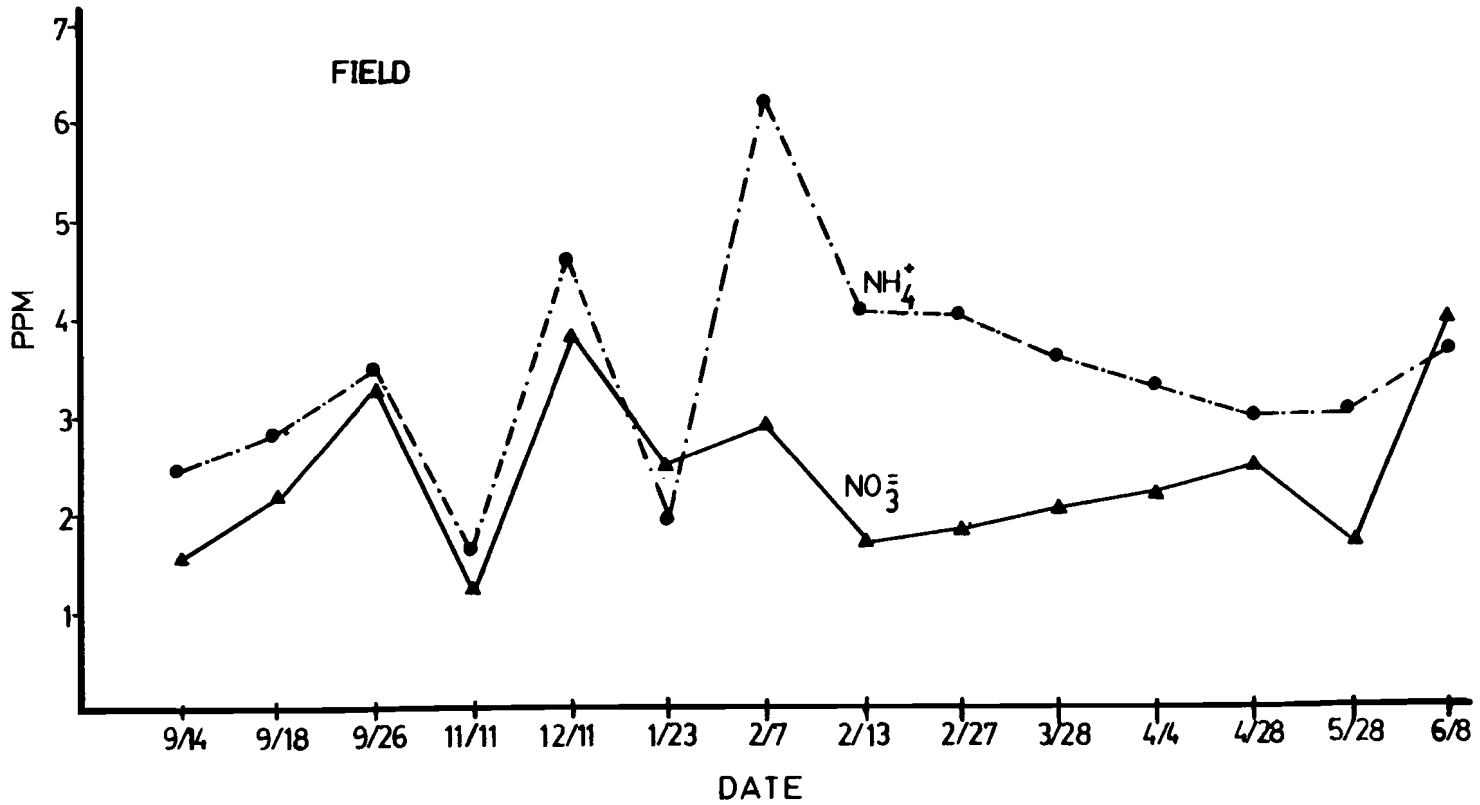

FIELD
PPM
7
6
5
4
3
2
1
NH_4^+
$NO_3^=$
9/14
9/18
9/26
11/11
12/11
1/23
2/7
2/13
2/27
3/28
4/4
4/28
5/28
6/8
DATE

Figure 6. Concentration of ammonium in ppm in sites A and B.

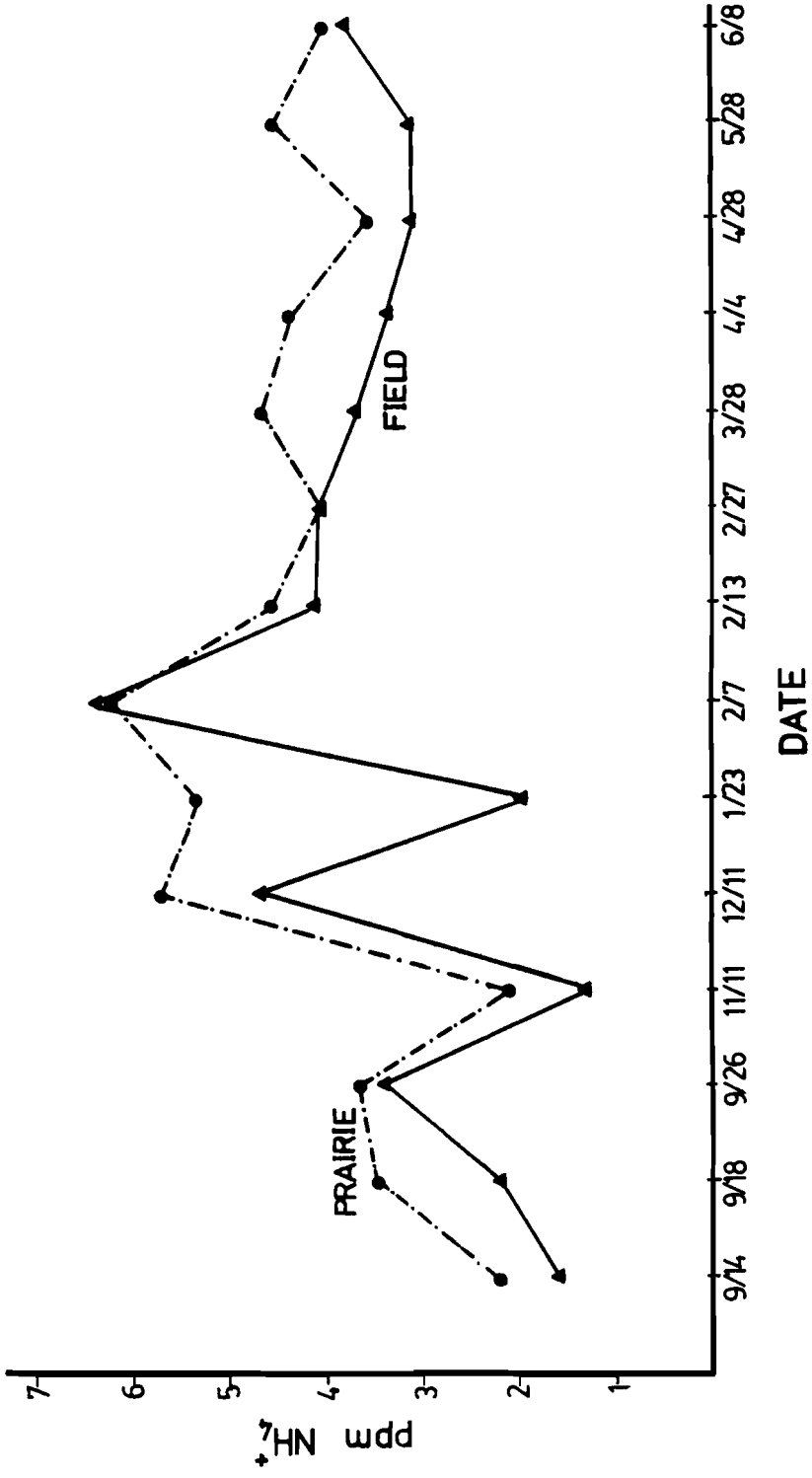
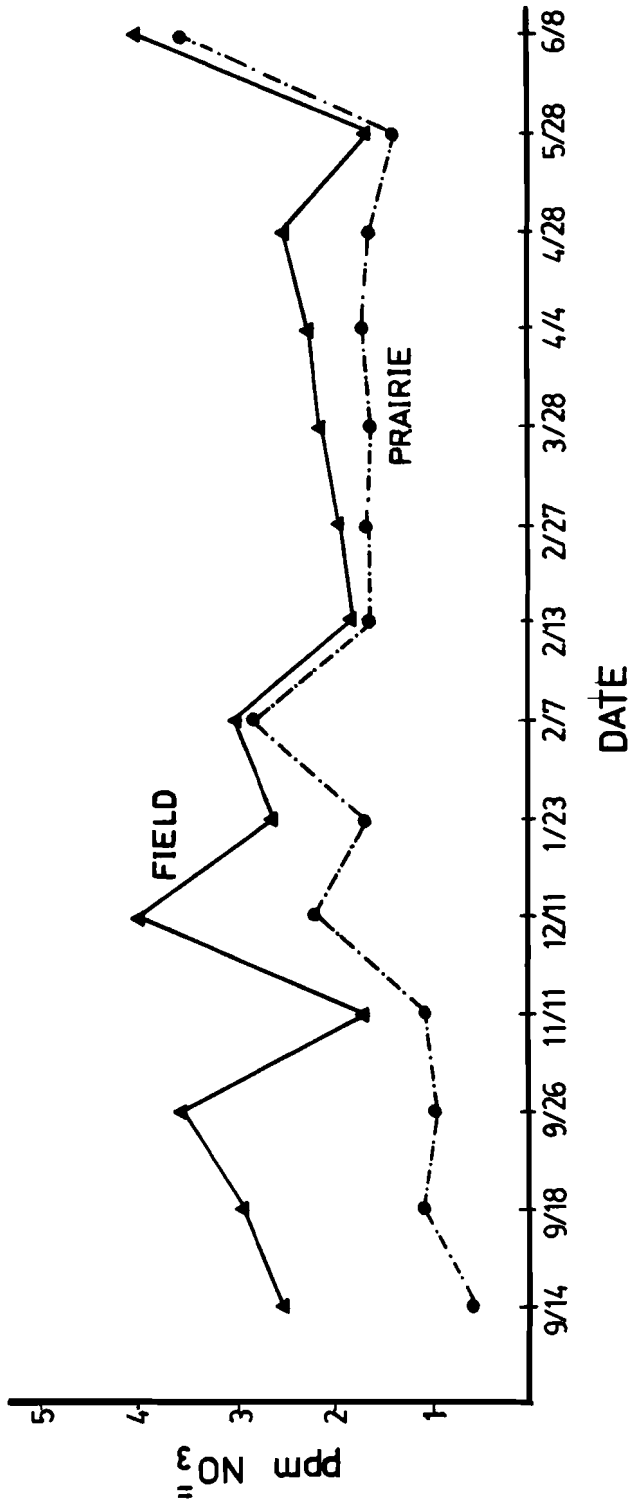

ppm NH_4^+
7
6
5
4
3
2
1
9/14
9/18
9/26
11/11
12/11
1/23
2/7
2/13
2/27
3/28
4/4
4/28
5/28
6/8
DATE
PRAIRIE
FIELD

Figure 7. Concentration of nitrate in ppm in sites A and B.


ppm $NO_3^=$
5
4
3
2
1
FIELD
PRAIRIE
9/14
9/18
9/26
11/11
12/11
1/23
2/7
2/13
2/27
3/28
4/4
4/28
5/28
6/8
DATE

succession) has shown this increase in ammonium during the winter and spring months. This may be due to poor aeration, high clay content, low temperature, and compaction of the clay soil. The prairie also showed the highest ammonium concentrations during this period. Soil samples taken from both areas during January and February were frozen. Gasser (1958) and Sabey et al. (1959) have shown that nitrification is slowed and almost completely inhibited at temperatures below 0 C. Gasser (1958) showed no change in ammonium or nitrate content of soils kept frozen for 28 days at -10 C. However, Frederick (1956) and Allen and Grimshaw (1962) have shown nitrification to be appreciable when the temperature was near 0 C (this was when soil conditions favored nitrification). Mahendrappa et al. (1966) studied nine soils in the western United States. In northern soils, nitrification rates were fastest at 20 and 25 C, while soils from the southern region showed increased nitrification at higher temperatures (35-40 C). This suggests the nitrifying bacteria are able to adapt to regional conditions, so nitrification can occur as frequently as possible. A sharp rise in ammonium concentration was recorded by this researcher during the months where extracts were taken from frozen soil samples. The nitrifying bacteria were slowed, but not completely inactive, as nitrate was always present. Frederick (1956) and Myers (1975) have suggested an optimum temperature range for nitrification of 35-40 C.

Soil samples taken from March through May, 1985, were extremely wet, due to an abundance of precipitation that spring. The heavy clay soil assayed in this study tends to become water-logged with an excess of rainfall. In the summer, (a more xeric period in eastern Kansas), the soil became drier and Nitrosomonas were stimulated, converting the

ammonium into nitrite and nitrate. Nitrification increased in both prairie and field in the summer sampling, with NH4 and NO3 concentrations nearly equal. Since nitrification is an aerobic process, it would seem reasonable that anaerobic conditions would inhibit the nitrifying bacteria. Pilot and Patrick (1972) noted that some nitrification may occur in a water-logged soil due to the functioning of facultative anaerobes. However, Nakos (1977) and Alexander (1961) surmised that poor soil aeration may bring about the absence of nitrification. Moraghan and Pesek (1963) supported this assumption with their research, showing an accumulation of ammonium under water-logged conditions.

Most Probable Number of Nitrosomonas (MPN) and Total Plate Counts (TPC, a measure of all soil microbes) (Table 4) were taken for each sample date. Overall numbers of nitrifying bacteria and total plate counts were higher in the field. The samples were fairly consistent (except that of November 4, 1984) in terms of total microbial numbers. However, Most Probable Number of Nitrosomonas varied considerably from one sample to the next, particularly in the agricultural field. The sample of March 31, 1985, showed a dramatic increase in Nitrosomonas (from 1600 to 54,000), however the nitrate concentration did not increase substantially (from 1.9 ppm to 2.1 ppm). March is a month of rapid growth of wheat (which was planted in the field at the time). The uptake of nitrate by wheat could account for the nitrate levels remaining constant. Total Plate Counts showed numbers of microbes to be fairly consistent throughout the year in both the field and the prairie. Only the sample taken November 11, 1984, showed a sharp decline in total microbial activity. The number of prairie

Table 4. Most Probable Number of Nitrosomonas and Total Plate Counts for sites A and B.

Date	Most Probable Number		Total Plate Counts		Soil Notes
	Prairie	Field	Prairie	Field	
9/09/84	460	14,000	6.3×10^6	1.6×10^6	Very dry
10/09/84	17	200	8.2×10^6	1.2×10^7	Very wet
11/04/84	220	1300	1.5×10^3	4.6×10^4	Very wet
12/11/84	410	6400	7.2×10^6	8.3×10^6	Cold and wet
1/07/85	490	70	8.2×10^6	11.3×10^6	Cold and wet
2/03/85	8	11	1.5×10^6	1.1×10^6	Frozen soil
3/02/85	13	1600	7.7×10^6	6.4×10^6	Extremely wet
3/21/85	5	54,000	1.4×10^7	7.2×10^6	Extremely wet
4/28/85	-	-	5.9×10^6	3.5×10^6	Wet
6/09/85	23,000	1,700,000	2.7×10^{11}	4.2×10^5	Dry
7/07/85	79*	430*	1.3×10^6	9.9×10^6	Dry

* Most Probable Number estimate done 7/24/85

nitrifying bacteria was lower in the frozen and extremely wet soil samples. Belser (1979) stated that temperature and moisture are the two environmental factors most influencing the population of nitrifying bacteria. He said that under low temperature conditions nitrification rates are greatly reduced. Chen et al. (1972) discovered the poor aeration produced from saturated soil inhibited nitrification by decreasing the population of Nitrosomonas. The results of these previous researchers agree with the data presented in this study. A decrease in the population of the nitrifying bacteria in both prairie and field was noted in frozen as well as saturated soils (except in the noted case of field sample March 31, 1985).

Previous researchers (Robertson and Vitousek 1981 and Lamb 1980) have conducted nitrification potential experiments by removing soil samples to the laboratory. Lamb (1980) placed soil samples on vermiculite in a plastic box that was incubated for 20 days. Robertson and Vitousek (1981) placed sieved samples in polyethylene cups that were then incubated. Vitousek et al. (1982) stated "relatively fertile sites have the potential for very high nitrate losses following disturbance." His procedure for determining nitrification potential was just that, a disturbance. Sieving, placing soil in cups, etc., aerated the soil, thus changing the potentials. Removing the soil from the inhibiting effects would in itself change nitrification. A nitrification potential experiment was conducted using a technique performed completely in situ. Fifty ppm (NH4)2 SO4 was added to soil rings to determine nitrate formation in soil from each study area. The data (Table 5) showed that the added ammonium was quickly converted to nitrate. The population of Nitrosomonas

increased dramatically, going from 7.8 to 23,000 per gram of soil in the prairie and from 33 to 1,700,000 per gram of soil in the field (samples taken April 28, 1985 and June 9, 1985, Table 4). This increase in bacterial population resulted in a higher nitrate level in both sites. Montes and Christensen (1979) reported a rise in nitrate levels after added ammonium had incubated for 30 days. When calcium carbonate was added in order to increase pH, nitrification increased considerably.

Table 5. Net nitrate production in ppm from both sites when treated with 50 ppm (NH4)2 SO4 and incubated for 30 days.

	SUMMER		WINTER	
SITE	PRAIRIE	FIELD	PRAIRIE	FIELD
1	40.1	44.6	20.1	30.1
2	--	41.6	16.7	35.4
3	32.4	41.5	--	--
4	32.6	42.6	--	--

According to Dibb and Welch (1976) and Alexander (1961), the presence of NH4+-N and NO3-N is greatly affected by pH. Prairie and field pH were both relatively low, with readings of 6.0 and 5.5, respectively. Sarathchandra (1978) showed a dramatic rise in nitrate production as well as nitrification activity of Nitrosomonas, when the pH of the soil was raised from 5.5 to 7.5. He detected the existence of acid resistant strains of Nitrosomonas, allowing nitrification to proceed even at a lowered pH. Brar and Giddens (1968) reported a dramatic increase in nitrification when lime was added to raise pH

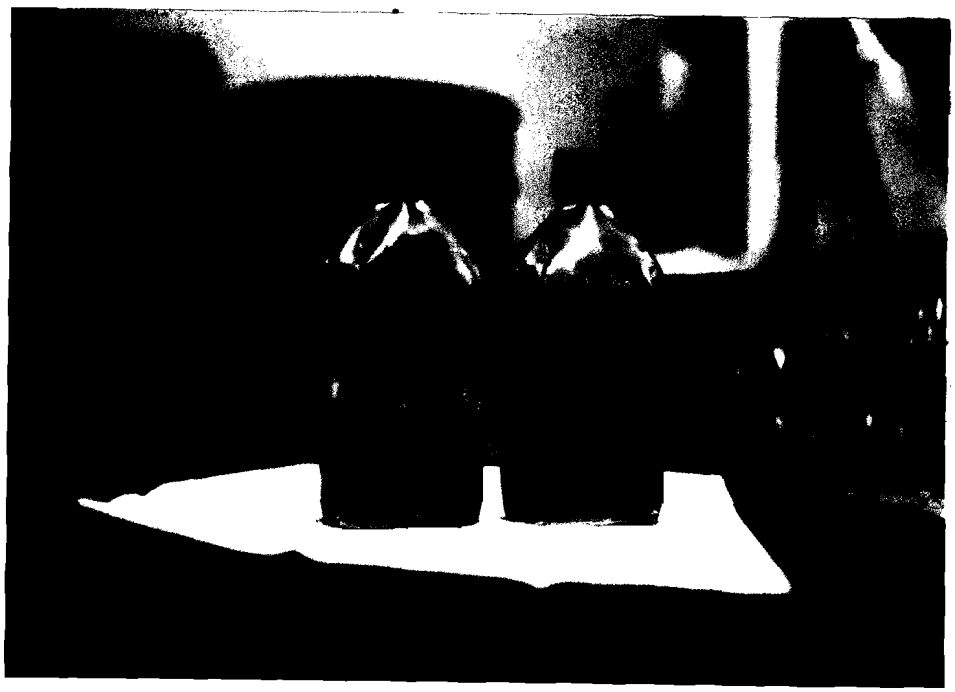
from 4.7 to 6.7. Meiklejohn (1954) noted cultures of Nitrosomonas grew better at pH 7.0 than at pH 5.4.

Organic matter in the soil increases the pH and contributes more sites for cation adsorption (Hausenbuiller 1985). Sarathchandra (1978) has speculated that the presence of organic material may influence the nitrification rate. Figure 8 shows the color difference between the two study soils when in solution. Soil high in organic matter is characterized by a rich brown color and humus "when present in sufficient quantity, may alone determine the color of the soil" (Hausenbuiller 1985). The amount of organic matter present may be another factor influencing the nitrification rate of each site.

The process of nitrification itself acidifies the soil by releasing hydrogen ions as ammonium is reduced to nitrite. Parr et al. (1971) showed the injection of anhydrous ammonia to temporarily increase pH. The subsequent protonation of NH3 to NH4+ decreased the pH, and with the onset of nitrification, pH level declined even further. By the addition of fertilizers (almost 1 million tons used in one year in Kansas alone, Kansas Crop and Livestock Reporting Service, 1984), nitrifying bacteria were stimulated, thus, increasing the nitrification rate (Table 4). The continuous addition of ammonium fertilizers (or the constant influx of hydrogen ions) may eventually cause soil acidity. The lowered pH would effect nitrification by decreasing the Nitrosomonas population.

The lowering of the pH has an effect on the solubility of nutrients and minerals present in the soil. As a result of low pH, aluminum comes into solution (or dissolves) (Thompson and Troeh 1978). Brar and Giddens (1968) suggested the high aluminum concentration in

Figure 8. Photograph of soil in solution from site A (right) and site B (left).



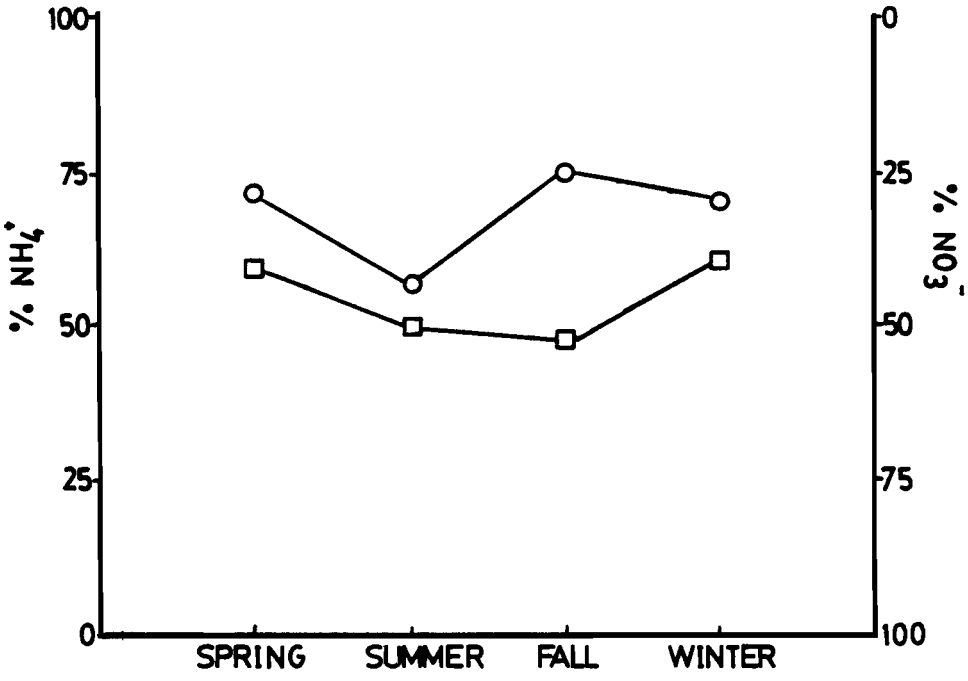
Bladen grassland soil was responsible for the low numbers of nitrifying bacteria. A balance between ammonium and nitrate (Figure 9) seems to be necessary to maintain a natural system. Although ammonium is the preferred nitrogen form in the prairie, nitrate is still present. In fact, nitrate made up at least 25 % of the total mineral nitrogen concentration in the fall, winter, and spring. The summer readings from the prairie showed nearly half of the nitrogen present was in the form of nitrate. Likewise, nitrate in the agricultural field accounted for nearly 50 % of the mineral nitrogen, however, ammonium was never less than 45 % of the total (Table 6).

Table 6. Percentage of ammonium and nitrate in sites A and B by season.

	Prairie		Field	
	% NH4	% NO3	% NH4	% NO3
Summer	53	47	48	52
Fall	75	25	45	55
Winter	72	28	62	38
Spring	73	27	60	40

Rice and Pancholy (1972) found that ammonium accounted for 93 % of the total mineral nitrogen (ammonium plus nitrate) in a climax prairie during the winter months. Their results showed ammonium and nitrate concentrations nearly equal during summer months (ammonium - 55 % and nitrate - 45 %). Ammonium was again dominant in spring and fall, representing 75 % of the total nitrogen content. Rice and Pancholy (1972) also found ammonium making up at least 20 % (and an average of 40 % year-round) of the nitrogen present in the earliest

Figure 9. Concentration of ammonium and nitrate in each site expressed as percent. o = site A □ = site B.


100
75
50
25
0
% NH_4^+
0
25
50
75
100
% NO_3^-
SPRING
SUMMER
FALL
WINTER

successional stage they studied. The results presented here, and those of Rice and Pancholy (1972), suggest that nitrate as well as ammonium is important in a prairie system. However, this research revealed a relationship between soil water potential and dominant nitrogen form that has not been reported previously. With increased soil water (lower oxygen levels), ammonium was found to be dominant. When the soil dried and oxygen levels rose, nitrifying bacteria increased their activity and nitrate became the dominant nitrogen form.

SUMMARY

A study of nitrogen forms in a tallgrass prairie and an agricultural field was conducted. The sites were located on the same Irwin silty clay loam soil series and adjacent to one another to insure that weather conditions were consistent between the two areas. Soil samples were analyzed following the microdiffusion procedure of Keeney and Nelson (1982). Most Probable Number of Nitrosomonas and Total Plate Counts were determined with each sample. A nitrification potential experiment was designed with the intent to minimize the disturbance to the system. A soil ring was embedded into the root zone and ammonium sulfate was added to the soil in the ring. The vegetation was replaced on top of the system. The rings were incubated for 3-4 weeks. Soil was then removed from the rings and tested for ammonium and nitrate content.

Results show ammonium dominating in both sites during the months of January through May. This phase of the study represents a cold and very wet period in eastern Kansas. The nitrifying bacteria population reached its lowest number in both sites during the winter and spring. Nitrate content increased as the soil dried (oxygen content increased) and reached the highest concentration in both sites in the summer months.

These data show a definite relationship between oxygen content and dominant nitrogen form. Saturated (low oxygen) soils in both prairie and field had higher ammonium levels, while drier (higher oxygen level) soils had much higher nitrate concentrations. Nitrification potential experiments revealed that when ammonium was added, the population of Nitrosomonas increased in both sites. Net nitrate

production was high in both prairie and field. Thus, when the soil in either site was given an abundance of ammonium, Nitrosomonas were stimulated and nitrate production increased. With the application of 50 ppm of ammonium, even the prairie produced a good deal of nitrate. This suggests that in heavy clay soils, a dominance of ammonium may be due to elevated soil water content, rather than allelopathic effects.

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