NITRATE-NITROGEN ACCUMULATION AND MOVEMENT IN SOME NORTH DAKOTA SOILS UNDER DRYLAND CONDITIONS

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Several summer fallow fields were sampled periodically during the fallow period to monitor nitrate accumulation, and movement. Tillage appeared to cause a temporary immobilization of NO_3-N as newly incorporated organic matter was being mineralized. Nitrate leaching was not found to be a serious problem during this study except on very sandy soils which received excessive amounts of rainfall.

INTRODUCTION

A knowledge of the nitrate-nitrogen (NO_3-N) level, and its accumulation or loss in the soil is very important when making nitrogen fertilizer recommendations. Summer fallowing has long been used by farmers to store moisture, and accumulate NO_3-N in soils. In 1970 an estimated 9,380,000 acres were summer fallowed in North Dakota. In 1975 the estimated acres summer fallowed decreased to 6,948,000. The tendency toward less acres being fallowed, and the continued removal of nitrogen by crops, causes farmers to turn to commercial nitrogen fertilizers to supply the additional needed nitrogen. In North Dakota the two most common nitrogen fertilizers have been anhydrous ammonia (82-0-0) and ammonium nitrate (34-0-0). The sale of these fertilizers increased from 57,000 tons in 1968 to 160,000 tons in 1976.

Nitrate-nitrogen is water soluble and can move within and through the soil profile. Movement is dependent on a number of factors such as soil texture, soil structure, and especially precipitation. The NO_3-N formed from organic matter decomposition as well as that added as fertilizers and other sources, can contaminate ground waters if leached. Movement of NO_3-N below the rooting zone, however, is minimal under normal conditions of dryland farming in North Dakota.

In Wisconsin Peterson, et al. (1965) found that on a well drained silt loam soil which received 11.1 inches of water in 14 storms during the growing season, the loss of NO_3-N from the top 24 inches of soil by leaching was small. Under such conditions the nitrogen not removed by the crop normally remains within the root zone, and, therefore, should be taken into account when making nitrogen fertilizer recommendations. In contrast, Herron (1968) found that in a year of above normal late summer precipitation in Nebraska about 90% of the total NO_3-N moved out of the upper 12 inches of a 6-foot profile. Most of the NO_3-N, however, usually was found in the top 3 feet (90 cm) of soil. At a given site they found a high correlation between NO_3-N in the profile in the fall after harvest and corn yield the following year without applied N. Soper and Huang (1963) found that the NO_3-N content of the soil profile to a depth of 4 feet was a very good indicator of the response of barley to nitrogen, but that surface (0-6 inches) soil samples were unsatisfactory for predicting nitrogen requirements of prairie soils.

The objective of this study was to gain knowledge of the accumulation and movement of NO_3-N in several North Dakota soils during summer fallow.

FIELD PROCEDURES 1970

Experimental sites representing 13 soils with textures ranging from coarse to fine were selected at 16 locations within the state of North Dakota. The location and soil type of each site are given in Table 1. In June of 1970, 11 sites were established on fields which were summer fallowed during the 1970 growing season. An

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Table 1. Soil Series, Profile Textural Group, Cooperating Farmers and County Locations of Sites Used in This Study.

Site No.	Soil Name	Profile Textural Group	Cooperating Farmer	County
1	Towner	coarse/medium	Walter Stutrud	Pierce
2	Gardena	medium	W. E. Fairbrother	McHenry
3	Williams	medium	Minot Exp. Sta.	Ward
4	Nutley (like)	fine	Maurice Wheelock	Mountrail
5	Grail	fine	Tony Stroh	Dunn
6	Shambo	medium	Ed Michel	Stark
7	Hecla	coarse	Laurence Baarstad	Cass
8	Hamerly	medium	Wayne Richman	Barnes
9	Barnes	medium	Don Lawrence	Stutsman
10	Svea	medium	Ervin Frey	Stutsman
11	Fargo	fine	Bob Fredrickson	Cass
12	Svea	medium	Ervin Frey	Stutsman
13	Williams	medium	Minot Exp. Sta.	Ward
14	Arnegaard	medium	Ed Michel	Stark
15	Hecla	coarse	Frank Saunders	Cass
16	Glyndon	medium	Dick Cripe	Cass

additional five sites were established in the fall of 1970 on fields which were to be fallowed during the 1971 growing season.

When the experiment was initiated, soil samples were taken to a depth of 10 feet, or to the water table if less than 10 feet, from 20 different areas within each experimental site. Each site consisted of an area 48 feet by 24 feet which was divided into two areas 24 feet by 24 feet. One area was not fertilized (treatment 1), the other area received ammonium nitrate (34-0-0) at the rate of 200 lb. of N per acre (treatment 2). Rain gauges were installed at each site and precipitation was recorded by cooperating farmers. Soil samples for moisture and NO_3-N content were taken from the 0-6, 6-12, 12-24, and 24-36 inch depths two weeks after installation and continuing subsequently every two weeks throughout the summer until September 3, 1970. Two subsamples were taken from each treatment, each subsample consisted of soil from five randomly chosen areas within each treatment. The final sampling of the first 11 sites was taken to a depth of 10 feet or to the water table if the water table was less than 10 feet below the soil surface.

1971

In 1971, sites 1 through 11 were planted with small grain and sites 12 through 16 were summer fallowed. Soil samples were again taken every two weeks, starting May 5 and continuing until October 30, in the same manner as in 1970.

Plant tissue samples were taken at sites 1 through 11, five times during the 1971 growing season. The first tissue samples were taken on June 8, at that time the plants were in the tillering stage. Entire plants were taken for the first tissue sampling and subsequent samples were taken from the flag leaf. Straw yields were obtained by weighing the straw from a small area of each treatment at maturity. Grain yields were obtained by harvesting an area approximately 18 feet by 18 feet from the center of each treatment with a plot combine.

1972

In 1972 sites 1, 2, 3, 8 and 9 were second cropped and sites 12 to 16 were seeded to small grains. The other sites were either summer fallowed or were discontinued as part of the study. Soil samples were taken periodically, beginning April 24 and continuing until September 20.

1973

Some of the experimental sites were cropped continuously and others were on an alternate crop fallow system. In November of 1973, all sites, except sites 4, 5, 11, and 16 which had been discontinued, were again sampled to a depth of 10 feet to determine how much, if any, of the applied NO_3-N still remained in the soil profile.

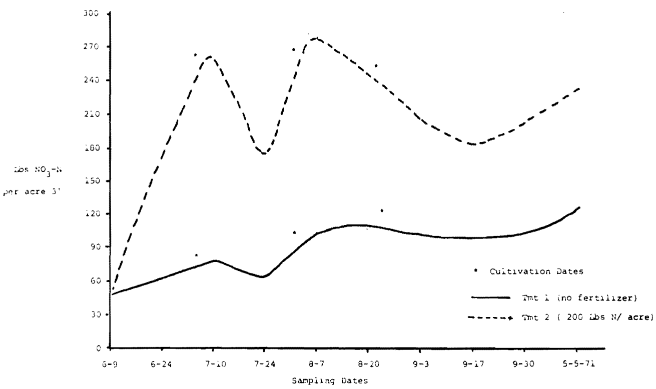
To inhibit mineralization of N, the soil samples obtained in this project were kept cool while in the field by packing them around sealed containers of ice in a small portable cooler. In the laboratory, the soil samples were weighed and dried to determine moisture content. Nitrate-nitrogen was determined on each sample using a nitrate electrode. After NO_3-N analyses were completed, the samples from each treatment and each site were composited and total nitrogen and ammonium nitrogen were determined. Tissue samples were analyzed for total nitrogen by the Kjeldahl procedure, and for NO_3-N using a nitrate electrode.

RESULTS AND DISCUSSION

On the average about 85% of the 200 lbs of applied N was in the nitrate form two weeks after application. At most sites fluctuations in NO_3-N levels were noted between sampling dates, especially on treatment 2, and to a lesser extent on treatment 1. The fluctuating NO_3-N levels tended to coincide with tillage operations (Figure 1). After tillage NO_3-N levels usually decreased. About four weeks after tillage NO_3-N levels had returned to previous or higher levels. Tillage incorporated more of the previous year's crop residue into the soil, which was decomposed by microorganisms. As microorganisms decomposed the crop residue, some of the NO_3-N probably was immobilized for a short period of time.

Large differences were found in the amount of NO_3-N which accumulated at different sites during the respective fallow seasons (Table 2, 3). Several factors known to affect nitrification were studied to determine the reason for the large differences. It was found that as soil moisure content increased above the permanent wilting point nitrate accumulation also increased. Total nitrogen was determined on the soil samples taken when the sites were established. It was found that the effect of total nitrogen on NO_3-N accumulation was more important in the years when soil moisture was not a limiting variable. Soil temperature was measured at the surface, and at one-foot intervals to a depth of five feet at each site when samples were taken. No correlation was found between soil temperature and NO_3-N accumulation in this study since the soil temperatures at each site were very similar. pH was not a factor in governing the difference in NO_3-N accumulation. The pH values of the soils in this study ranged from 6.0-7.8. Even though this is a fairly broad range these pH values were in a range in which the activity of microorganisms would not be inhibited.

Figure 1. Soil NO_3-N levels on site 10 (Svea loam) as influenced by fertilizer nitrogen and tillage during the 1971 fallow season.



Precipitation, although very important for maintaining soil moisture, was negatively correlated with NO_3-N in the surface 36 inches of soil sampled. This negative correlation was due to NO_3-N leaching on sites receiving excessive precipitation.

Table 2. Accumulation of NO_3-N/Acre 3 feet on 10, non-fertilized fallowed sites, June 1970 to May 1971.

Site No.	June-70	Sept-70	May-71	Summer Accumulation	Winter Accumulation	Total Accumulation
			Lbs N/Acre 3 feet			
1	31	107	134	76	27	103
2	24	97	127	73	30	103
3	17	57	89	40	32	72
4	47	105	112	58	7	65
5	55	104	152	49	48	97
6	14	42	66	28	24	52
7	26	65	103	39	38	77
8	36	90	88	54	−2	52
9	80	160	170	80	10	90
10	51	112	125	61	13	74
11*						
	AVERAGE			56	23	79

*Data from Site 11 are omitted due to contamination of samples.

Table 3. Accumulation of NO_3-N/Acre 3 feet on five, non-fertilized fallowed sites, May 1971 to April 1972.

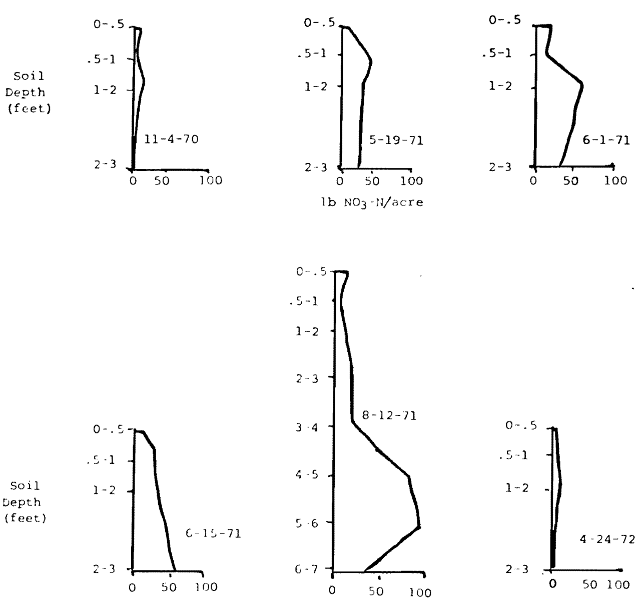
Site No.	May-71	Oct-71	Apr-72	Summer Accumulation	Winter Accumulation	Total Accumulation
			Lbs N/Acre 3 feet			
12*						
13	36	101	98	65	−3	62
14	32	54	59	22	5	27
15	15	16	15	1	−1	0
16	41	133	152	92	19	111
	AVERAGE			45	5	50

*Data from site 12 omitted due to contamination of samples.

During the 1970 fallow season precipitation ranged from 3.0 inches at site 10 to 12.7 inches at site 5, and no appreciable amounts of NO_3-N moved to depths greater than 12 inches at any of the 11 sites. During the 1971 fallow season the precipitation was greater ranging from 12.2 inches at site 14 to 25.6 inches at site 15. The additional precipitation caused more water to move within the soil profile and NO_3-N movement into the 24-36 inch depths occurred at all sites.

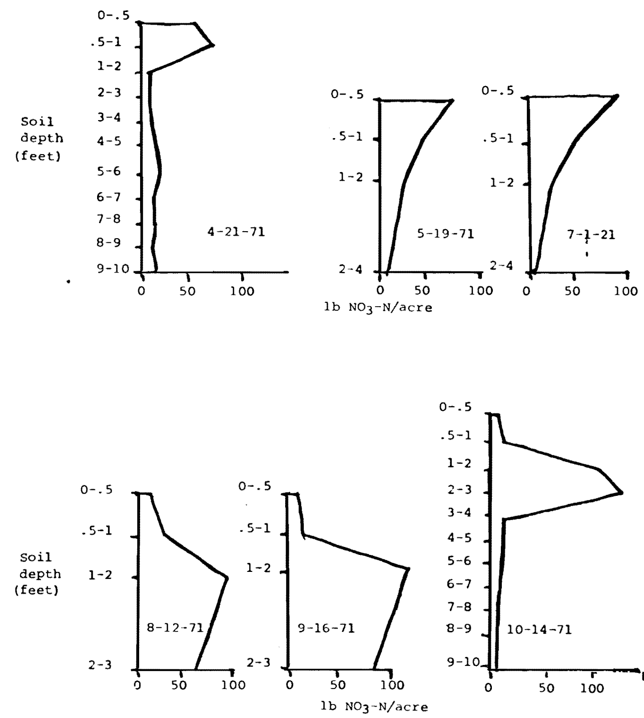
On a Hecla loamy fine sand a coarse textured soil (site 15) appreciable amounts of NO_3-N moved downward (Figure 2). This site received the greatest amount of precipitation (25.6 inches) during the 1971 growing season, with much of the precipitation occurring in a few very heavy storms. Between May 22-30, 2.7 inches of precipitation leached most of the NO_3-N into the 24-36-inch depths of the soil profile. Additional precipitation of 6.1 inches between June 15-30 essentially leached all of the NO_3-N out of the surface 36 inches of soil. Soil samples were taken to the water table at this site in August of 1971, and at that time most of the NO_3-N was concentrated in the four- to seven-foot depth of the soil profile.

Figure 2. Original profile NO_3-N distribution, and the NO_3-N distribution on several dates following the application of 200 pounds of N per acre on a Hecla loamy fine sand (site 15).



On a Williams loam, a medium textured soil (site 13) little downward movement of NO_3-N occurred below 3 feet (Figure 3). Precipitation at this location amounted to 18.1 inches during the 1971 growing season. Less NO_3-N movement occurred at this site mainly because the soil contained more clay, and was able to hold more of the water which it received. At all sites, with the exception of site 15, the NO_3-N was still well within the rooting zone for most crops. Thus there was little or no loss of NO_3-N due to leaching during this study.

Figure 3. Profile NO_3-N distribution on several dates in 1971 on Williams loam following the application of 200 pounds of N per acre in the fall of 1970.

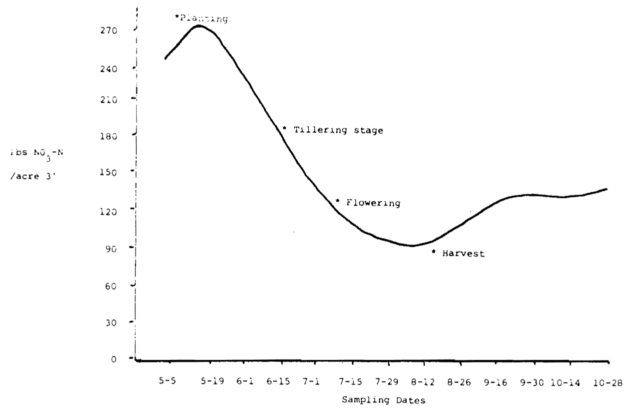


In 1971 sites 1 through 11 were planted to small grains. The NO_3-N levels of these plots decreased rapidly during May and June (Figure 4). The decreasing levels may have resulted, in part, from denitrification or nitrate movement but most of the N probably was used by plants. If we assume that the lower NO_3-N levels were due mainly to plant use, 45% of the NO_3-N was taken up by the time the plants were in the tillering stage and 85% by the time they were flowering. Since, small grains take up nitrogen over a relatively short period of time, it is important for farmers to know the NO_3-N levels of their fields and to adequately fertilize them prior to planting. Once grain is growing, the rate of mineralization is usually too slow to supply adequate nitrogen. Therefore, if residual NO_3-N is low late in the fall or in the spring prior to planting, it is necessary to add supplemental nitrogen as fertilizer.

Grain yields at all sites were similar on treatments 1 and 2 in 1971 (Table 4). This was expected as the NO_3-N accumulated during the fallow period was sufficient, in most cases, for the crops. The sites which were second cropped in 1972 had an average of 87 lbs of NO_3-N in the surface three feet on treatment 2. Nitrate-N levels in treatment 1 were lower and yields were less due to a deficiency of nitrogen. Yields were considerably better on treatment 2 indicating that there was residual nitrogen in the soil from the application of nitrogen that was made in June 1970.

In the fall of 1973, the sites were again sampled to a depth of 10 feet to determine if part of the nitrogen applied still remained as residual nitrogen in the soil.

Figure 4. Average NO_3-N levels on plots which received 200 pounds N per acre at various stages of crop growth during the 1971 growing season.



Most sites had the same amount of residual nitrogen on the check plot as on the plot that received 200 lbs of nitrogen (treatment 2). Four of the sites had between 20-30 lb NO_3-N/Acre, most of which was concentrated in the 24-48 inch depths of the soil profile.

SUMMARY

During dry years the amount of NO_3-N accumulation from mineralization will be less during fallow because conditions are not optimum for bacteria to mineralize organic materials in the soil. Tillage incorporates organic materials into the soil which is decomposed by microorganisms. As the microorganisms are decomposing the organic materials some of the NO_3-N in the soil is temporarily immobilized.

Nitrate accumulation between September 30 and April 5 was not great. Therefore, soil samples taken in the fall are a good indicator of the NO_3-N level in early

Table 4. Grain Yields of Study Sites Seeded to Small Grain in 1971 and 1972.

Site No.	1971 Crop	Treatment	1971 NO_3-N Level Lb/A-3'	1971 Grain Yield Bu/A	1972 Crop	1972 NO_3-N Level Lb/A-3'	1972 Grain Yield Bu/A
1	Barley	1	134	53	Barley	17	12
		2	237	50		47	49
2	Durum	1	127	42	Oats	21	72
		2	246	41		136	101
3	Durum	1	89	37	Wheat	10	26
		2	223	30		111	30
4	Wheat	1	112	30	**		
		2	241	34			
5	Wheat	1	152	26	**		
		2	299	22			
6	Wheat	1	66	20	**		
		2	186	24			
7	Wheat	1	103	30	**		
		2	215	29			
8	Wheat	1	88	28	Barley	16	52
		2	267	36		103	57
9	Wheat	1	170	35	Barley	66	22
		2	279	36		179	40
10	Wheat	1	125	35	**		
		2	233	38			
11	Wheat	1	177	21	**		
		2	335	36			
12*		1			Wheat	212	38
		2				311	38
13*		1			Barley	98	70
		2				263	76
14*		1			Wheat	59	30
		2				206	27
15*					**		
16*					**		

*Sites 12, 13, 14, 15, 16 were fallowed in 1971.
**Sites 4, 5, 6, 7, 10, 11, 15, 16 were not cropped or were discontinued in 1972.

spring. In April the soil is usually warm enough for nitrification to take place at a more rapid rate. Fields sampled between April 1 and planting generally have a higher NO_3-N level than the same field sampled on an earlier date. This must be taken into consideration when making a nitrogen recommendation.

Based on these data leaching of NO_3-N is not a serious problem on North Dakota soils in years of normal precipitation. Some leaching may occur, but it is doubtful that NO_3-N will be moved to depths below the rooting zone except on coarse textured soils with a deep water table.

In order to monitor nitrate movement, an excessive amount of fertilizer nitrogen was applied to treatment 2. If nitrogen requirements had been determined and applied according to soil test, nitrate movement would likely have been considerably less.

The amount of moisture stored on very sandy soil is minimal because of the large soil pores. Therefore, summer fallowing of very sandy soils is not a recommended practice. Also large amounts of NO_3-N may be leached from fallowed sandy soils after heavy amounts of precipitation.

Grain yields were not increased by added nitrogen fertilization the year after fallowing, as NO_3-N levels in these soils were generally sufficient for the crops which were planted. This, however, is not always the case and the only way a farmer can be sure he has sufficient nitrogen is to have his fields tested for NO_3-N each year.

Residual nitrogen from an application of 200 lbs N/Acre of nitrogen increased grain yields two years after application. Three years after application the residual nitrogen was gone except for a few sites which had 20-30 lbs of NO_3-N remaining in the 24-48-inch depths of the soil profile.

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1978 FARMLAND VALUES

Jerome E. Johnson

The 1978 North Dakota farmland market study estimates that average farmland values rose 11 per cent to $365 from $330 per acre. The study is based on farm real estate broker-reporter estimates of land values in their service areas and actual farm sales data. The sales data were analyzed to develop characteristics of the sales tracts, buyers, and sellers.

The average value of farmland in North Dakota rose an estimated 10.6 per cent during 1978, to an average value of $365 per acre from $330 in 1977. Farmland values continued to trend higher in 1978 after only rising a reported 1.5 per cent during 1977. The annual survey of farm real estate brokers by the Department of Agricultural Economics provides much useful information on characteristics of the buyers and sellers, and of the tracts being sold in the rural real estate marketplace.

Averages calculated from estimates provided by the reporters are presented for the last five years in Figure 1 for the seven state economic areas (SEAs). SEAs tend to represent similar agricultural land use patterns. The figures represent the average estimated value for average quality farmland and buildings in the reporter's service areas. Table 1 presents a comparison of the estimated average values for the last two years for each SEA, including both dollar and percentage changes per acre.

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