Nitrogen Status of North Dakota Soils

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The average acre of soil in North Dakota to plow depth (6 2/3") contains from 3,000 to 5,000 pounds of nitrogen. Nearly all of the nitrogen is present in the soil organic matter fraction. In addition to the N found in the organic matter there is elemental nitrogen in the atmosphere. Elemental nitrogen is an inert colorless gas present in the air we breathe at a concentration of 78 per cent by volume. It has been estimated that the weight of nitrogen over each acre is approximately 70 million pounds. With these amounts of nitrogen present it may seem strange that nitrogen is the element that most often limits crop growth in North Dakota.

Organic Matter and Nitrogen

The availability of nitrogen to plants growing in soil is influenced by the soil organic matter. Most soils in North Dakota contain 2-5% organic matter (Table 1). In the western part of North Dakota the average organic matter content is 2.5%, increasing to the east. In the Red River Valley the average organic matter content is 4% (56% of soils tested have 3-5% organic matter). In general, in the Great Plains of the United States, organic matter increases from west to east and from south to north (Buckman and Brady, 1974). The reason for this is that effective soil moisture increases from west to east and temperature decreases from south to north. The processes that break down organic matter are more rapid and continue for a longer period of time in the south, therefore, the southern soils have less organic matter (Jenny, 1941). Sandy soils tend to have less organic matter than fine textured soils in the same climatic zone because they have less available water and more air (oxygen). North Dakota, located in the north, has many fine textured soils, some having the highest organic matter content found in the United States.

Table 1. Per cent of North Dakota soils in several organic matter ranges in four areas of the state.*

Area	Soil organic matter content 0-2%	2-3%	3-4%	4-5%	5-6%	Over 6%
Red River Valley	4.5	12.5	26.0	30.0	15.5	11.5
East Central	5.5	12.5	32.5	28.5	13.5	7.5
West Central	9.5	23.0	34.5	20.5	7.0	5.5
Western	29.0	29.0	29.5	8.5	3.5	0

*Data based on results of NDSU Soil Testing Laboratory analyses of farmer submitted soil samples.

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Source of Soil Nitrogen and Organic Matter

Organic matter in soils comes from green plants. Green plants are produced from minerals in the soil plus carbon dioxide and water reacting in the presence of sunlight and chlorophyll. Fresh organic matter is decomposed by many soil organisms including insects, bacteria, molds, etc. These organisms use organic matter as a source of minerals and energy.

Soil organic matter acts as a reservoir for nitrogen that originally came from the nitrogen in the atmosphere. Some of the nitrogen in organic matter was made available by lightning during thundershowers, contributing only 3 to 5 lbs of nitrogen per acre (Russel, 1961). Most of the nitrogen present in soil organic matter was originally made available to plants by microorganisms such as the rhizobia bacteria. These bacteria live in the root nodules of leguminous plants, such as alfalfa. In recent years nitrogen in inorganic fertilizers, such as anhydrous ammonia, has become an important source.

Decomposition of Plant Residues

Plant residues are composed of three major compounds: 1. polysaccharides (starch, cellulose, sugars); 2. lignins (woody tissues); and 3. proteins (Allison, 1973). Besides these three groups there are many other substances in plant tissue.

Polysaccharides, which make up the bulk of mature plant tissue, are used by microorganisms mainly for energy and are converted to carbon dioxide and water. The lignins, which are much less susceptible to microbial breakdown, tend to accumulate as slightly altered compounds which play a role in holding nutrient elements in the soil (Bartholomew, 1965). Plant proteins are high in nitrogen. This nitrogen is used in the growth of microbial cells. Since microorganisms may contain as much as 90% protein, soil organic matter tends to be much higher in nitrogen than fresh plant residue.

Mature plant tissue generally contains 50 per cent carbon and less than 1 per cent nitrogen. As microorganisms decompose plant tissue, most of the carbon goes back to the atmosphere as carbon dioxide and the nitrogen remains in the soil to be used in building microbial protein. As a result of decomposition the carbon-nitrogen ratio may go from 50:1 in fresh plant residue to approximately 12:1 in soil organic matter (Allison, 1973). The carbon-nitrogen ratio and the amount of fresh organic material added to soil has an important influence on the availability of nitrogen to plants.

Significance of the Carbon-Nitrogen Ratio

The carbon-nitrogen ratio is of practical importance for two reasons: (1) the addition of plant residues with a wide carbon-nitrogen ratio results in strong competition between microorganisms and plants for available nitrogen; (2) since this ratio tends to be constant for a particular soil the amount of nitrogen in a soil will influence the organic matter level (Buckman and Brady, 1974).

For example, if a large amount of plant residue with a wide carbon-nitrogen ratio is added to a soil the microorganisms will quickly become very active. Under these conditions practically all available nitrate-nitrogen is used by microorganisms to build their tissues leaving little or none available for higher plants. As decay continues the carbon-nitrogen ratio in the soil organic matter decreases because carbon is being lost from the soil as carbon dioxide and nitrogen is being conserved. When decay nears completion the activity of the microorganisms decreases due to a lack of carbon compounds that can be easily digested. As the number of microorganisms decrease and their cells begin to decay the supply of available nitrogen in the soil increases. As a result of the addition of the plant residues, the soil is for a time somewhat richer both in nitrogen and humus.

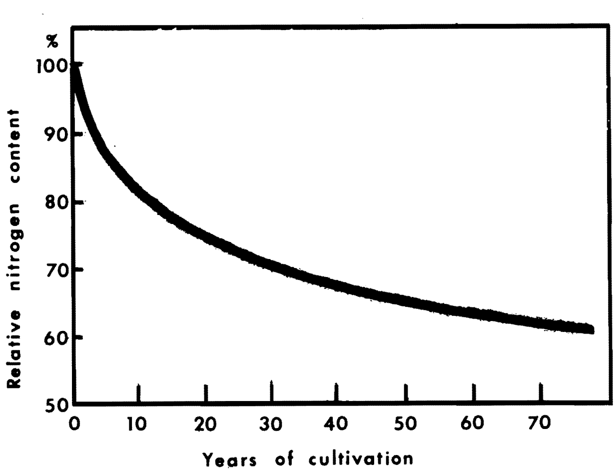

Figure 1. Decline in soil nitrogen levels due to cultivation of Midwest (USA) soils. (From Jenny, 1941).

Availability of Nitrogen from Organic Matter

Prairie soils, such as we have in North Dakota, contain large amounts of nitrogen and carbon that have accumulated over many years. When virgin soils are cultivated there is an initial rapid release of nitrogen in the soil (Haas, et al., 1957). During this period of rapid release, which lasts several years, a large amount of nitrogen is made available for plant growth.

Based on data from several Midwestern experiment stations, Jenny (1941) summarized the decline in soil nitrogen as follows:

- 25 per cent decline in soil nitrogen during the first 20 years of cultivation
- 10 per cent decline in soil nitrogen during the second 20 years of cultivation
- 7 per cent decline in soil nitrogen during the third 20 years of cultivation

This decline in soil nitrogen is illustrated in Figure 1.

After approximately 60 years of cultivation a new equilibrium level of soil organic matter and nitrogen is reached and the amount of available nitrogen removed by crops each year reaches a steady state, assuming there are no additions of nitrogen fertilizer (Stevenson, 1965).

Nitrogen Release from North Dakota Soils

Recently Swenson et al. (1979) studied the movement and accumulation of nitrate-nitrogen in 16 major North Dakota soils. Large differences were found in the amount of NO_3-N which accumulated during summer fallowing (Table 2). The amount varied from 18 to 80 lb NO_3-N per acre and averaged 56 lb NO_3-N per acre.

Table 2. Accumulation of NO_3-N on 10 sites during the summer of 1970.

Site No.	NO_3-N Accumulation lb/acre 3 feet
1	76
2	73
3	40
4	58
5	49
6	28
7	39
8	54
9	80
10	61
Average	56

Several factors were studied to determine the reason for these large differences. It was found that as soil moisture increased above the permanent wilting point nitrate accumulation increased. It was also found that in years when soil moisture was not limiting the amount of available nitrogen accumulation was related to total nitrogen. Soil temperature and pH were not found to be factors in governing the amount of NO_3-N formed. Although rainfall is important for maintaining soil moisture it was found to be negatively correlated with NO_3-N accumulation. This negative correlation was due to leaching of NO_3-N on sites receiving excessive precipitation.

The data of Swenson, et al. (1979) is in close agreement with the amount of available nitrogen found when comparing non-fallow and fallow fields tested for farmers in the NDSU Soil Testing Laboratory (Table 3).

Table 3. Average accumulation of nitrate-nitrogen on summer fallowed and cropped fields in North Dakota based on soil test summaries from the NDSU Soil Testing Laboratory.

	1975	1976	1977	1978	Average
	lb NO_3-N per acre - 2'				
Fallow fields*	97	110	108	116	108
Cropped fields*	51	63	60	58	58
Accumulation during fallow	46	47	48	58	50

*These fields were sampled and tested in September and October of each year.

The average cropped field tested in September and October from 1975-1978 had 58 lb of NO_3-N in the top 2 feet of soil while the average fallow had 108 lb, or 50 lb more than the cropped fields. The amount of accumulation for a particular field can vary from practically nothing to much more than 50 lb depending on previous crop, fertilization, weather, etc.

As shown in Table 4 the accumulation of NO_3-N is less in western North Dakota than in eastern North Dakota. The 54 lb of NO_3-N that accumulates on the average in eastern North Dakota would be adequate to grow 25 bu per acre of wheat while the 38 lb that accumulate on the average in western North Dakota would be adequate for 20 bu per acre yield in a year with ideal weather. Under a system of continuous cropping the amount of NO_3-N released would be less because of less soil aeration and frequent periods when soil moisture would be near the permanent wilting point.

Table 4. Average accumulation of NO_3-N on summer fallowed fields from 1975-78 in four areas of North Dakota.*

Area	1975	1976	1977	1978	Average
	lb NO_3-N per acre - 2′				
Red River Valley	45	57	48	64	54
East Central	49	48	53	53	51
West Central	50	47	24	41	40
Western	38	43	25	44	38

*Data based on results of NDSU Soil Testing Laboratory analyses of farmer's submitted soil samples.

In general it can be concluded that most soils in North Dakota do not release adequate amounts of available nitrogen for optimum crop production. The NO_3-N soil test can be used to determine the amount of available nitrogen in your fields and thus is a good method to determine the amount of nitrogen you may need to add for optimum crop production.

REFERENCES

1. Allison, F. E. 1973. **Soil Organic Matter and Its Role in Crop Production.** Elsevier Scientific Publishing Co., Amsterdam.
2. Buckman, Harry O. and Nyle C. Brady. 1974. **The Nature and Properties of Soils 8th Edition.** The MacMillan Co., New York.
3. Bartholomew, W. V. 1965. **Mineralization and Immobilization of Nitrogen in the Decomposition of Plant and Animal Residues.** pp. 285-306. *In* W. V. Bartholomew and Francis E. Clark (ed.) Soil Nitrogen American Society of Agronomy, Madison.
4. Haas, H. J., C. E. Evans and E. F. Miles. 1957. **Nitrogen and Carbon Changes in Great Plains Soils as Influenced by Cropping and Soil Treatments.** USDA Tech. Bull. No. 1164.
5. Jenny, Hans. 1941. **Factors of Soil Formation.** McGraw-Hill, New York.
6. Russell, E. Walter. 1961. **Soil Conditions and Plant Growth 9th Edition.** Longmans, Green and Co. Ltd., London.
7. Stevenson, F. J. 1965. **Origin and Distribution of Nitrogen in Soil.** pp. 1-42. *In* W. V. Bartholomew and Francis E. Clark (ed.) Soil Nitrogen. American Society of Agronomy, Madison.
8. Swenson, L. J., W. C. Dahnke and D. D. Patterson. 1979. **Nitrate-Nitrogen Accumulation and Movement in Some North Dakota Soils Under Dryland Conditions.** North Dakota Farm Research Vol. 36, No. 5:3-8.

The Use of Anhydrous Ammonia in North Dakota

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Use of anhydrous ammonia as a fertilizer in the United States was somewhat of a novelty until 1948. Consumption was limited from 1948 to 1954, partly because of shortages of the fertilizer and of steel for tank manufacture. However, the growth of the ammonia industry during the past 25 years has been phenomenal. Anhydrous ammonia use in North Dakota compared to that nationally, and especially that in a major corn-growing state such as Iowa, lagged noticeably until about 1970. As shown in Table 1, however, the relative importance of anhydrous NH_3 to the nitrogen-fertilizer industry in North Dakota during 1978 greatly exceeded the national figure and was on par with that for Iowa.

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The reason for the increased consumption of ammonia in North Dakota is primarily one of economics. Anhydrous ammonia (82-0-0), which is the most highly concentrated nitrogen fertilizer available, is now a much cheaper form of N than the competitive solids, urea (45-0-0) and ammonium nitrate (34-0-0). Anhydrous ammonia normally must be added 5 or 6 inches below the surface to prevent gaseous losses of ammonia. North Dakota farmers are increasingly saving time and money by combining application of ammonia with another tillage operation. Consequently, various pieces of tillage equipment have been modified to include attachments for ammonia application. Nurse tanks rather than special applicator tanks traverse North Dakota fields.