AG-FO-3345
1988

MANAGEMENT OF SOILS
IN **SOUTH-CENTRAL** MINNESOTA

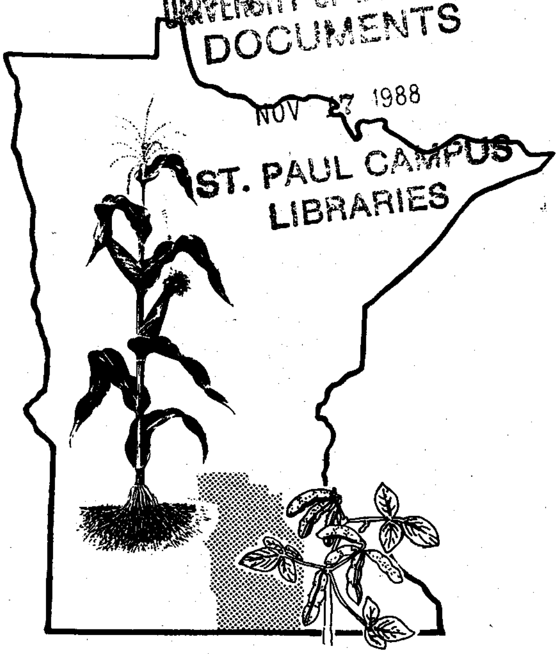
A Correspondence Course

Unit 5: Nitrogen Management

George Rehm

Objectives:

- Understand the many reactions of N in soils.
- Develop an appreciation for the amount of N supplied by legumes and manure.
- Become familiar with the factors that influence of movement of nitrate-nitrogen (NO_3-N) through the root zone and into the ground water.



Minnesota Extension Service • University of Minnesota

Nitrogen (N) is all around us. The air that we breathe contains about 78% N as an inert gas (N_2). Nitrogen is essential for crop growth. In south-central Minnesota, yield responds more to either soil or fertilizer N than to any other nutrient. Nitrogen is also noteworthy because, in the nitrate (NO_3) form, it can move through the root zone into the ground water.

Nitrogen is transient in soils and is involved in many biologically controlled reactions. In order to effectively manage N fertilizers and other inputs of N into the soil system, we must have a general understanding of these reactions.

THE NITROGEN CYCLE

The complexity of N in soils is illustrated by the many reactions involved in the nitrogen cycle (Figure 1).

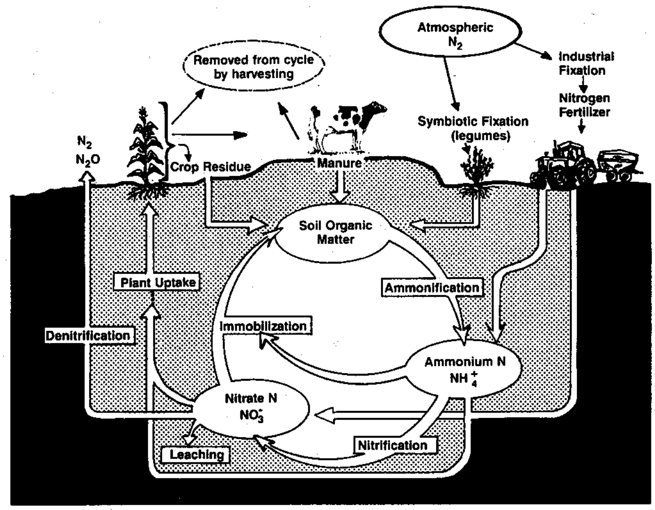


Figure 1. The nitrogen cycle in soils.

Gain and Loss of N in the Soil System

Nitrogen is supplied to the soil for plant use from:

- the atmosphere
- animal manures
- crop residues
- commercial fertilizers.

Legume crops are necessary to convert atmospheric N_2 into a form available to plants. The amount of N supplied by manure varies with type of livestock, handling, and method of application. The amount of N in crop residues varies with the crop, the yield, and the management system. Nitrogen exists in crop residues in several complex organic forms and the residue must decay before this N is converted into the NO_3-N used by plants.

Nitrogen is lost from the soil system as a result of:

- uptake by plants and subsequent removal in harvest
- denitrification
- leaching
- soil loss caused by erosion
- volatilization.

N TRANSFORMATIONS IN SOILS

As Figure 1 shows, soil N undergoes many reactions or transformations. The following paragraphs describe some of these.

Soil organic matter is a major source of N used by crops. The N from crop residues, manures, and legumes ends up here. With time, the N in the soil organic matter is converted by bacteria to ammonium nitrogen (NH_4-N). This conversion process, called **ammonification,** occurs when conditions favor growth and development of bacteria.

The NH_4-N can be absorbed and used by plants. It is held to soil particles and thus is not lost by leaching. Nitrogen in the NH_4 form is lost only if soil that it is attached to is lost by erosion.

Bacteria, being living organisms, also need N for growth and development. Some N in the NH_4 form is used by bacteria as they decompose soil organic matter. This process represents a tie-up of NH_4-N in the soil system and is called **immobilization.** From a practical standpoint, immobilization does not remove large amounts of NH_4-N from the root zone.

With favorable temperatures and an adequate supply of air, NH_4-N is rapidly converted to nitrate nitrogen (NO_3-N). This transformation, also carried out by bacteria, is called **nitrification.** Much of the NO_3-N produced by this reaction is absorbed by plants when conditions favor active plant growth. Generally, nitrification proceeds faster than immobilization and there is a net gain of NO_3-N in the root zone from the decomposition of organic materials.

Denitrification is the process by which NO_3-N is converted by bacteria to the nitrogen gases found in the atmosphere. Nitrogen in these gases is inert and cannot be used by plants. This process takes place when soils are saturated for two or three days at a time. Denitrification takes place in the topsoils where there is ample organic matter to provide energy for the bacteria that carry out this reaction. Very little denitrification takes place in the subsoil. Substantial amounts of N can be lost from soils in south-central Minnesota by denitrification if these soils are not well-drained.

Leaching is simply the loss of NO_3-N as it moves with soil water below the root zone. The NO_3-N lost by leaching usually ends up in the ground water. Loss of NO_3-N due to leaching is a major concern where soils are sandy. Most of the soils in south-central Minnesota have a clay loam or silty clay loam texture. Although it is possible to lose NO_3-N by leaching in these soils, this should not be a major concern unless excessive N has been added to the soil system. For these soils, NO_3-N will be lost through the tile lines before it is lost by leaching.

As we consider the many reactions in the nitrogen cycle, there are some major points that should be remembered. First, plants can absorb N in both the NO_3 and the NH_4 forms and one is not more important than the other. Since N in the NH_4 form is held on soil organic matter and clay particles, inhibiting the conversion to NO_3 can result in less N loss and more plant uptake. From a practical standpoint, it is not possible to prevent nitrification. So, both NH_4-N and NO_3-N are found in the root zone at any time during the growing season.

Nitrogen fertilizers are important additions to the nitrogen cycle. If anhydrous ammonia (82-0-0) is used, the ammonia (NH_3) is converted to NH_4-N in one or two days. After nitrification, this NH_4-N ends up as NO_3-N. When urea (46-0-0) is used, the N is converted first to NH_4-N, then to NO_3-N. Liquid N (28-0-0) contains both NH_4-N and NO_3-N; the NH_4-N in this product is rapidly converted to NO_3-N.

It's also important to remember that growing plants cannot identify the initial source of the NH_4-N and NO_3-N that they use. Both organic and inorganic sources are used in the same way. The NO_3-N from legumes, manure, or crop residue is used in the same way as NO_3-N from commercial fertilizers.

MANAGING N FOR CROP PRODUCTION

Since N is part of many reactions in the soil system and is mobile, farmers have several options for managing this nutrient. Decisions have to be made in the following areas:

- N application rate
- credit to be given for N from legumes and manure
- form of N to use
- timing
- whether to use split applications
- placement
- whether to use a nitrification inhibitor.

Rate

Of all the factors listed, selection of an appropriate N rate is probably the most important. In south-central Minnesota, the choice of an adequate but not excessive N rate depends on the realistic yield goal of the farmer and the previous crop in rotation.

University of Minnesota N recommendations for corn production are listed in Table 1. Suggested N rates are adjusted for the organic matter content of soils. The N recommendations are also adjusted downward if the corn crop is preceded by soybeans, alfalfa, or other forage legumes. The N credit for the forage legume depends on the quality of the stand, a judgment made by the farmer for individual fields.

Farmers always seem to be optimistic in setting yield goals. There's nothing wrong with being optimistic, but goals also must be realistic. Excessive fertilizer N will be used if the yield goal is unrealistically high.

N Source

Today's farmer can choose from anhydrous ammonia (82-0-0), urea (46-0-0) or urea-ammonium nitrate (UAN, 28-0-0). Ammonium nitrate (33-0-0) was popular once, but supplies are limited today. The choice of N source usually depends on factors such as price, ease of product handling, availability of equipment, and the quality of the service provided by the fertilizer dealer.

Nitrogen sources have been thoroughly evaluated in numerous studies at Waseca. In general, 82-0-0 has consistently produced the highest yield. The other sources may equal 82-0-0 in some years, but no source has proven superior.

Timing

Nitrogen fertilizers can be applied in south-central Minnesota in the fall, in the spring before planting, or as a side-

Table 1. N recommendations for corn in south-central Minnesota.

Yield Goal		N to Apply (lb/A) — Previous Crop and Organic Matter Level[a]								
Grain (bu/A)	Silage (ton/A)	Corn L,M	Small Grain H	Soybeans L,M	Soybeans H	Clover L,M	Poor Alfalfa H	Good Alfalfa L,M	Good Alfalfa H
175+	24+	220	190	180	150	160	130	120	90
156-175	22-24	220	170	160	130	140	110	100	70
136-155	19-21	180	150	150	120	120	90	80	50
116-135	16-18	150	120	120	90	90	60	50	30
96-115	13-15	120	100	100	70	60	30	30	30

[a]L = low; M = medium; H = high.

dress treatment. In general, fertilizer N is used most efficiently when the N is applied as a sidedress treatment, since this is the time when the corn has the greatest demand for N. Time of application, however, is a decision that must be made by each farmer. Sometimes slope and other factors limit the use of sidedress applications. In these situations, preplant application should be the first choice. Soil temperature is an important consideration for fall application of 82-0-0. Wait until soil temperatures reach 50° F to minimize nitrification. Application of 46-0-0 and 28-0-0 is not recommended in the fall in south-central Minnesota.

Split Applications

Recently we've heard a great deal about split applications of nitrogen fertilizers. Research trials throughout Minnesota have shown that split applications do not increase corn yields when soils are not sandy, although they have improved yields of corn grown on irrigated sandy soils. Split applications may be thought of as an insurance policy where there is potential for loss of N from the soil system; for example, on sandy soils where there is a potential for loss due to leaching and on very heavy soils that stay saturated for long periods and where denitrification is a problem.

Split applications of nitrogen fertilizers or manure will not prevent movement of NO_3-N to the ground water if excessive rates are used. The first consideration in managing fertilizer N must be the selection of an appropriate rate of N to match the realistic yield goal.

Placement

Placement has a major influence on the efficiency of use of immobile nutrients such as phosphorus (P) and potassium (K). Nitrogen in the nitrate form, however, is mobile in the soil. Should placement be a major consideration when managing N fertilizers?

Factors such as N source, tillage system, and weather affect decisions concerning the placement of fertilizer N. Anhydrous ammonia can only be placed at a depth of six to eight inches below the soil surface to eliminate loss. Liquid and urea N, however, can be broadcast on the soil surface, broadcast and incorporated, applied in a band on the soil surface, or applied in a band below the soil surface.

Nitrogen can be lost from urea and liquid N fertilizers by a process called **volatilization** if these fertilizers are applied on a dry soil surface where the pH is high (greater than 7.3), the temperature is high, and there is no incorporation. Since the pH of many soils in south-central Minnesota is higher than 7.3, this type of N loss should be a concern to farmers. It is a good policy to incorporate N fertilizers with some form of tillage when the conventional tillage systems are used. Nitrogen fertilizers can be broadcast without incorporation if there is a good probability of substantial rainfall in the immediate future.

Research has shown that both dry and liquid N fertilizer will lose some N if broadcast in high residue situations. Therefore, fertilizer N should be applied in a band below the soil surface for the ridge-till planting systems.

Nitrification Inhibitors

Earlier, the advantages of keeping most of the N in the soil in the NH_4 form were discussed. It is possible to delay nitrification with the use of products that inhibit the growth of the bacteria that carry out this process. These nitrification inhibitors are marketed throughout the Corn Belt.

In Minnesota, there is a potential for using nitrification inhibitors where soil conditions are conducive to N loss (sandy soils or heavy soils that remain saturated for long periods). Loss of N by denitrification is a concern for many soils in south-central Minnesota. This is especially true when 82-0-0 is applied in the fall or in the spring before planting. Except for years when there is no moisture in the subsoil, use of a nitrification inhibitor should be considered as an insurance policy against yield loss.

N MANAGEMENT AND GROUND WATER QUALITY

The NO_3-N found in ground water and the overall quality of the ground water in south-central Minnesota have been the focus of considerable activity recently. There are some who would have us believe that fertilizer N is the sole culprit. This is not true; another look at the nitrogen cycle will tell you why. Recall that NO_3-N is produced as a result of the decomposition of organic matter. This NO_3-N also can be leached to the ground water. There is no way to totally prevent the movement of some NO_3-N to the ground water.

We can, however, minimize losses of NO_3-N by giving special attention to the rate of N applied. It would be nice to

Table 2. N credit for various legume crops that precede corn in a rotation.

Crop	N Credit (lb/A)
Soybeans	40
Clovers	60
Alfalfa (poor stand)	60
Alfalfa (good stand)	100

Table 3. Approximate dry matter (DM) content and total N in various manures.

Livestock Source	Dry Manures: With Bedding DM (%)	With Bedding N (lb/ton)	Without Bedding[a] DM (%)	Without Bedding[a] N (lb/ton)	Liquid Manures: Liquid Pit DM (%)	Liquid Pit N (lb/1000 gal)	Lagoon DM (%)	Lagoon N (lb/1000 gal)
Swine	18	8	18	10	4	36	1	4
Beef	50	21	52	21	11	40	1	4
Dairy	21	9	18	9	8	24	1	4
Chickens	75	56	45	33	13	80	—	—
Turkeys	29	20	22	27	—	—	—	—

[a]With chicken and turkey manure, bedding is also called litter.

have a soil test that could aid in making N recommendations. At the present time, however, there is no satisfactory test for south-central Minnesota. We must still rely on selecting a realistic yield goal and giving appropriate credit for previous legume crops and/or N supplied in manure applications.

Amounts of N supplied for first-year corn by various legume crops are listed in Table 2. Some N from these legumes will be supplied to the second year of corn, but these amounts are not well-defined at this time.

We all recognize that manure can be an important source of N, yet the N contributed to corn following manure application is often forgotten. If we don't account for N applied in manure, we cannot expect to cause substantial decreases in the amount of NO_3-N that reaches the ground water in south-central Minnesota.

The total N content of various manures is listed in Table 3. It's important to remember that approximately 35 percent of the N from manure is available to the corn crop following application.

The amount of N supplied by manure is affected by the method of application (Table 4). One major piece is always missing in the manure puzzle. It is very difficult, if not impossible, to know the amount applied per acre. However, some estimate of application rate is crucial if farmers are to give appropriate N credits to manure.

More detailed information on N in manures can be found in extension publication AG-FO-2163, *Utilization of Animal Manure as Fertilizer,* available from the county extension office.

We can be optimistic about solving the problem of NO_3-N in the ground water. We already know that use of the management practices just described will help. Research will identify new and improved practices that can be used in the future.

Table 4. Effect of application method on N loss to the air from animal manure.

Application Method	Type of Manure	N Loss[a] (%)
Broadcast *without* incorporation	Solid	15-30
	Liquid	10-25
Broadcast *with* incorporation	Solid	1-5
	Liquid	1-5
Injection (knifing)	Liquid	0-2
Irrigation	Liquid	30-40

[a]Percent of total N in applied manure which was lost within three days after application.

RELATED READING

AG-FO-2613, *Utilization of Animal Manure as Fertilizer*

AG-FO-3073, *Using Anhydrous Ammonia in Minnesota*

AG-FO-0636, *Fertilizer Urea*

AG-FO-2734, *Nitrogen Fertilization and Possible Relationship to Ground Water*

AG-BU-3166: *Understanding Nitrogen and Agricultural Chemicals in the Environment*

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Patrick J. Borich, Dean and Director of Minnesota Extension Service, University of Minnesota, St. Paul, Minnesota 55108. The University of Minnesota, including the Minnesota Extension Service, is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, religion, color, sex, national origin, handicap, age, veteran status, or sexual orientation.