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Nitrogen in Missouri Soils

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Missouri soils commonly contain from 1,000 to 6,000 pounds of organic nitrogen. This nitrogen is made slowly available for plant use by the breakdown of stable organic matter (humus). Research in Missouri has shown that 1,000 pounds of organic nitrogen in the soil releases only about 20 pounds of nitrogen for crop use. As a result, additional nitrogen in the form of fertilizer or manure is needed on non-legume crops grown in Missouri.

Soil Nitrogen

Forms of soil nitrogen. There are two forms of soil nitrogen that plants can use: ammonium (NH_4^+) and nitrate (NO_3^-). The NH_4^+ form is held in the soil by negatively charged soil clays or colloids. Because soils have this natural negative charge, the NO_3^- form is not held by the soil. The NO_3^- form is subject to movement with water. (See figure 1.)

Nitrogen Reactions in the Soils

Symbiotic nitrogen fixation. Legumes, when inoculated with the proper strains of rhizobium bacteria, are able to convert atmospheric nitrogen (N_2) to the NH_4^+ form. Legumes are able to fix enough nitrogen for their needs so that additional nitrogen fertilizer is not necessary to grow these crops. Many legumes also fix enough nitrogen to supply some nitrogen for succeeding crops. (See table 1.)

Ammonification. Soil bacteria decompose organic nitrogen forms in soil to the NH_4^+ form. This process is referred to as ammonification. The amount of nitrogen released for plant uptake by this process is most directly related to the organic matter content. The initial breakdown of a urea fertilizer may also be termed as an ammonification process. (See figure 2.)

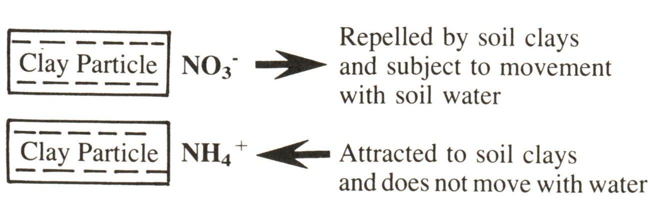

Figure 1. Forms of available soil nitrogen.

Table 1. Nitrogen supplied by legumes for a succeeding crop (Optimum).

Legume Crop	Nitrogen Added (lbs. N/Acre)
Alfalfa	
80-100% Stand	120-140
50-80%	40-60
Less than 50%	0-20
Sweet Clover (Green Manure)	100-120
Red Clover (Pure Stand)	40-60
Soybeans	15-60

The amounts of nitrogen released through ammonification and available to crops varies with the soil texture and temperature. In Missouri, contributions of nitrogen from the soil are based upon:

- soil organic matter content,
- soil texture and
- the time of year that the crop makes the greatest amount of growth. (See figure 2 and table 2.)

Nitrification. The nitrification process involves a bacterial reaction changing NH_4^+ to NO_3^-. (See figure 3.) There are several conditions that affect the speed of this reaction:

1. Soil oxygen. Oxygen is necesssary for the production of NO_3^- and for the nitrifying of bacteria. If excess water is present, the oxygen supply is low and the rate of nitrification will be slowed. Very compacted soils also will lower oxygen supplies and thus slow nitrification.

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Table 2. Contribution of nitrogen from organic matter in Missouri soils.

Soil Texture	Organic Matter	Cool Season Crops	Warm Season Crops
	(%)	(lbs. N/Acre)	
Sands - Sandy loams	0.5	10	20
	1.0	20	40
	1.5	30	60
Silt loams - loams	2.0	20	40
	3.0	30	60
	4.0	40	80
Clay loams - Clays	2.0	10	20
	3.0	15	30
	4.0	20	40
	5.0	25	50

$$\text{Soil Organic Nitrogen} \xrightarrow{\text{bacteria}} \text{amino acids} \xrightarrow{\text{bacteria}} NH_4^+$$

$$\text{Urea} \xrightarrow{\text{bacteria}} CO_2 + NH_4^+$$

Figure 2. Ammonification reactions in soils.

2. Soil pH. The nitrifying bacteria are sensitive to acid or alkaline soil conditions. Speed of nitrification will be highest at a soil pH_s of 6.0 to 7.0. The reaction will be slowed (due to a reduction in the activity of the bacteria) as the pH_s becomes higher or lower.

3. Soil temperature. The rate of nitrification will be highest when soil temperatures are between 65 and 90 degrees F. Nitrification may take place at soil temperatures down to 32 degrees F, but the rate is greatly reduced below a soil temperature of 50 degrees F.

4. Soil moisture. As pointed out in number 1, excess soil water will slow nitrification. Extreme dry conditions will also retard the nitrification reaction.

Presently, nitrification inhibitors are available that will retard this process and keep nitrogen in the NH_4^+ form. This form is less likely than the NO_3^- form to be lost due to leaching or denitrification. For more information on nitrification inhibitors, consult UMC Guide 9015.

Denitrification. Under waterlogged soil conditions, soil bacteria that thrive with low oxygen levels become important in nitrogen reactions. These bacteria get their oxygen from chemical forms such as NO_3^-. They change the NO_3^- form to nitrogen gases which are lost to the atmosphere. (See figure 4.)

$$2NH_4^+ + 3O_2 \rightarrow \underset{\text{nitrite}}{2NO_2^-} + 4H^+ + 2H_2O$$

$$2NO_2^- + O_2 \rightarrow \underset{\text{nitrate}}{2NO_3^-}$$

Figure 3. Ammonium conversion to nitrate through the nitrification process.

$$\underset{\text{nitrate}}{NO_3^-} \rightarrow \underset{\text{nitrite}}{NO_2^-} \rightarrow \underset{\text{nitrous oxide}}{N_2O} \rightarrow \underset{\text{elemental nitrogen}}{N_2}$$

Figure 4. Denitrification of nitrate to elemental nitrogen gas.

Soils have a small amount of denitrification going on all the time, but it only becomes important when waterlogged conditions exist for 36 or more hours. By this time, most oxygen is gone from soils, and the anerobic (non-oxygen loving) bacteria rapidly change NO_3^- to nitrogen gases. This nitrogen is permanently lost for crop growth. The effect of this process is commonly seen in wet spots of corn fields. The corn is stunted and yellow because of nitrogen deficiency even after the soil has dried out.

The NH_4^+ form of nitrogen is not affected by denitrification and will remain in the soil attached to clay particles. The NH_4^+ must first undergo nitrification before it can be denitrified. (See figures 3 and 4.)

Immobilization. When crop residues rich in carbon and low in nitrogen are returned to soil, the available nitrogen is temporarily tied up. This immobilization of nitrogen is caused by bacteria that are decomposing the crop residues. These bacteria need nitrogen for their protein. Once most of the crop residues are broken down, the nitrogen is released from the bacteria and again made available to the growing crops. Under ideal weather conditions, it takes about one month before nitrogen is released again.

Crop residues such as wheat straw and corn or milo stalks are rich in carbon. Sometimes nitrogen fertilizer can be used to speed up the decomposition of these residues. However, soils usually contain enough nitrogen to break down the crop residues.

Nitrogen Losses

Leaching. With sandy-textured soils, there is a serious problem with NO_3^- leaching. Since these soils are not capable of holding large amounts of water, heavy rains can move NO_3^- out of the crop rooting zone. Silty to clayey soils can hold considerable water and are therefore not subject to as much loss from NO_3^- leaching.

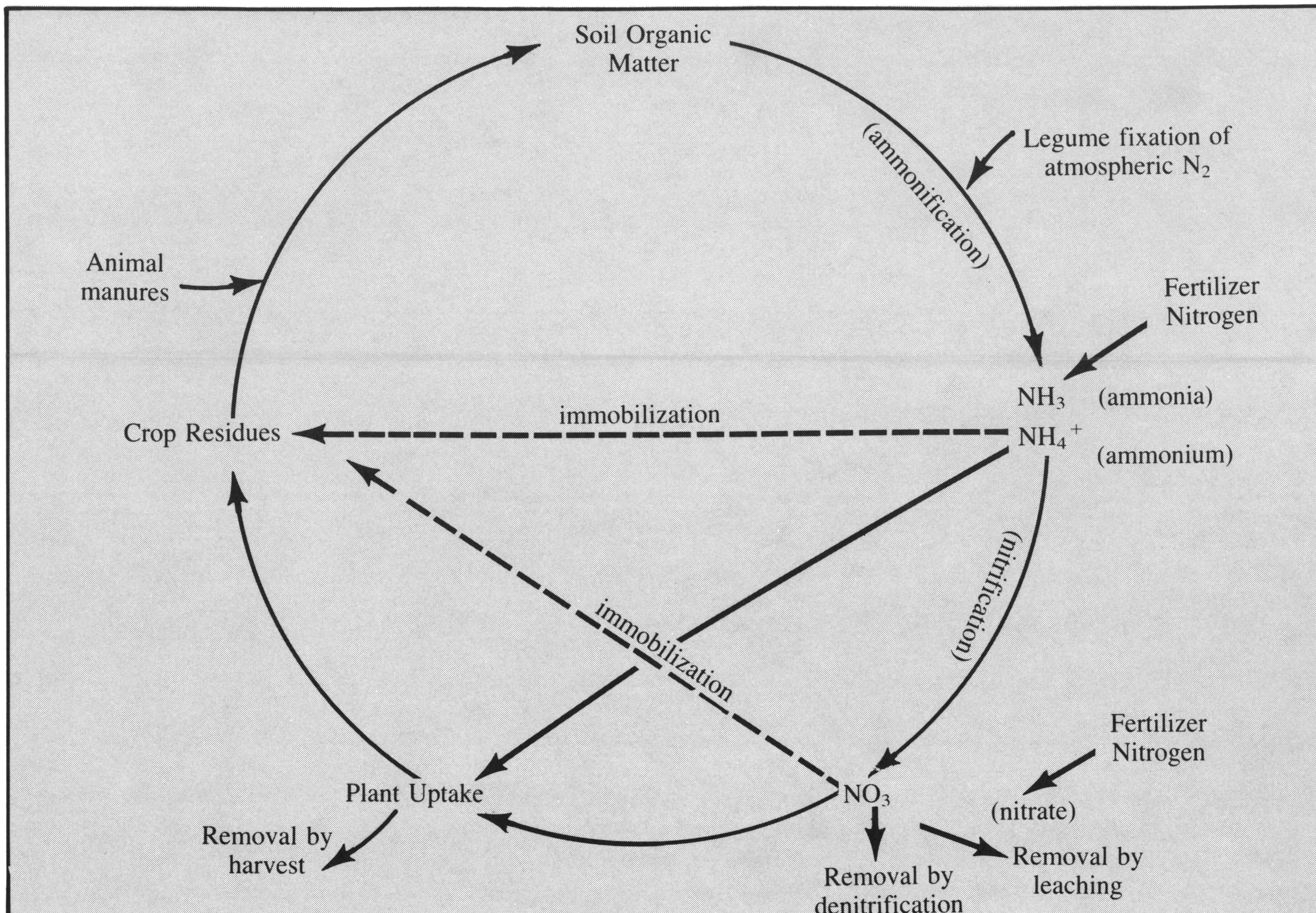

Figure 5. Nitrogen cycle.

The NH_4^+ form of nitrogen is not subject to leaching because of its attachment to clay particles. As already pointed out, NH_4^+ is rapidly changed to NO_3^- in warm soils. Thus, NH_4^+ fertilizers are also capable of leaching. Nitrification inhibitors may provide some limited protection by slowing nitrification and keeping more of the NH_4^+ present in the soil for a longer period of time.

Denitrification. See explanation under *Nitrogen Reactions in the Soils*. Adequate surface or subsoil drainage may help on soils that are poorly drained.

Volatilization. Volatilization is the process of nitrogen loss as ammonia gas from urea forms. Urea is broken down in soils by an enzyme to form ammonium carbonate. The carbonate creates an alkaline condition for a short time. This alkaline (or high pH) condition converts NH_4^+ to NH_3 gas (ammonia). The NH_3 gas is then lost to the air. In cooler conditions the enzyme breaks down urea much slower and the carbonate does not create as high a pH. Thus, little ammonia gas is lost when urea is applied to cool soils.

When manure, urea fertilizer or a nitrogen solution containing urea are surface applied to soils, nitrogen may be lost as ammonia (NH_3) gas. Applying these fertilizers when soil and air temperatures are cool or when rain occurs soon after application will greatly reduce the potential for volatilization of ammonia. Also, incorporation of these materials into the soil shortly after application will stop the potential losses by volatilization.

Volatilization **will not** take place when ammonium nitrate, ammonium sulfate or ammonium phosphate fertilizers are surface applied. (See figure 5.)

Glossary of Terms

Symbiosis is the association of one organism with another creating a favorable situation for both. For example, with rhizobium bacteria and soybeans, bacteria supply nitrogen, and soybeans supply energy.

Ammonium (NH_4^+) is the positive charged ion of plant available nitrogen, which is stable in soils. It will not leach or convert to nitrogen gas and be lost.

Nitrate (NO_3^-) is the less stable, but more common form of plant available nitrogen in soils. It is capable of leaching or converting to nitrogen gas and lost.

Colloid refers to both inorganic and organic matter. Colloids are usually considered to be very small particles of clay size.

Atmospheric nitrogen is the N_2 gas in the air we breathe. This form of nitrogen is not available for direct use by plants.

Nitrification is the formation of NO_3^- from NH_4^+ in soils by soil organisms.

Denitrification is the reduction of NO_3^- to N_2 gas. It is nitrogen gas freed by soil organisms in the absence of oxygen.

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