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Nitrogen sources and transformations

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Quick Facts

- Nitrogen in the air is the ultimate source of all soil nitrogen.
- Nitrogen may enter the soil through rainfall, plant residues, nitrogen fixation by soil organisms, animal manures and commercial fertilizers.
- There is no difference between the nitrogen that enters the plant from commercial fertilizers and that from organic products.
- Once in the soil, each source of nitrogen is subject to transformation.
- Nitrogen may be lost from the soil by plant removal, voltalization, leaching or erosion.
- Leaching of nitrate is a pollution hazard; losses of nitrogen can be controlled by proper management practices.

The maximum benefit from nitrogen fertilization with a minimum pollution hazard can be obtained only when nitrogen properties and transformations are understood.

Nitrogen Sources

The earth's atmosphere consists of 78 percent nitrogen and is the ultimate source of nitrogen. In most areas of the world, the nitrogen found in soil minerals is negligible. Nitrogen may be added to or lost from soil by a number of processes (see Figure 1). In the soil, nitrogen can undergo a number of transformations.

Rainfall adds about 10 pounds (4.5 kilograms) of nitrogen to the soil per acre (.4 hectare) per year. The nitrogen oxides and ammonium that are washed to earth are formed during electrical storms, by internal combustion engines and through oxidation by sunlight. Some scientists also believe that some of the gaseous products that result from the transformation of nitrogen fertilizers may cause a depletion of the ozone (O3) layer around the earth. The extent of this possible damage has not been substantiated at the present time.

Crop residues decompose in the soil to form the soil organic matter. This organic matter contains about 5 percent nitrogen. An acre-foot (.1 hectare-meter) of soil having 2 percent oganic matter would contain about 3,500 pounds (1575 kg) of nitrogen. Generally only about 1-3 percent of this organic nitrogen is converted per year by microorganisms to a form of nitrogen that plants can use.

Legumes fix atmospheric nitrogen through their symbiotic association with the *Rhizobium* bacteria. If plant roots are well nodulated, the legume plant will not benefit from the addition of fertilizer nitrogen. Perennial legumes, such as alfalfa, can fix several hundred pounds of nitrogen per acre (225+ kg/ha) per year.

Manure contains an appreciable amount of nitrogen. Most of this nitrogen is in organic forms—protein and related compounds. Cattle manure contains about 10 pounds (4.5 kg) of nitrogen per ton (907 kg). About half of this nitrogen will be converted to forms available to plants during the first growing season. Lesser amounts will be converted to usable forms during succeeding seasons. Each ton (907 kg) of applied manure is equal to about five pounds (2.2 kg) of commercial fertilizer nitrogen.

Commercial fertilizer nitrogen comes in three basic forms—gas, liquid and dry. All forms are equally effective when properly applied. Once applied on or into the soil, fertilizer nitrogen is subjected to the same transformations as other sources of nitrogen. There is no difference between the ammonium (NH_4^+) or nitrate (NO_3^-) that enters the plant from commercial fertilizer and that produced from natural products such as manure, crop residues or organic fertilizers.

Nitrogen Transformations

Nitrogen exists in a number of chemical forms and undergoes both chemical and biological reactions. The transformations summarized below are numbered to coincide with those in Figure 1.

1. *Organic nitrogen → ammonium nitrogen (mineralization).*

Organic nitrogen comprises about 95 percent of the nitrogen found in soil. This form of nitrogen cannot be utilized by plants but is gradually transformed by soil microorganisms to ammonium (NH_4^+). Ammonium is not leached to a great extent. Since NH_4^+ is a positively charged ion (cation), it is attracted to and held by the negatively charged soil clay. Ammonium is available to plants.

2. *Ammonium nitrogen → nitrate nitrogen (nitrification).*

In warm, well-drained soil, ammonium is transformed rapidly to nitrate (NO_3^-). Nitrate is the principle form of nitrogen utilized by plants. It is easily leached, since it is a negatively charged ion (anion) and not attracted to soil clay. It is the nitrate form of nitrogen that is a major concern in pollution.

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3. *Nitrate or ammonium nitrogen → organic nitrogen (immobilization).*

Soil microorganisms utilize nitrate and ammonium nitrogen when decomposing plant residues. These forms will be temporarily "tied-up" (incorporated into microbial tissue) in this process. This can be a major concern if crop residues are high in carbon relative to nitrogen. Residues typical of this class are wheat straw, corn stalks and sawdust. The addition of 20 to 70 pounds (9-31.5 kg) of nitrogen per ton (907 kg) of these residues is needed to prevent this transformation. After the residues are decomposed, the microbial population begins dying back and processes 1 and 2 outlined above take place.

4. *Nitrate nitrogen → gaseous nitrogen (dentification).*

When soil does not have sufficient air, microorganisms use the oxygen from NO3- in place of that in the air and rapidly convert NO3- to nitrogen oxide and nitrogen gases (N2). These gases escape to the atmosphere and are not available to plants. This transformation can occur within two or three days in poorly aerated soil and can result in large loses of nitrate-type fertilizers.

5. *Ammonium nitrogen → ammonia gas (ammonia voltalization).*

Soils that have a high pH (pH greater than 7.5) can lose large amounts of NH_4^+ by conversion to NH_3 gas. To minimize these losses, solid ammonium-type fertilizers, urea and anhydrous ammonia should be incorporated below the surface of a moist soil.

Nitrogen Loss

Nitrogen may be lost from the soil by plant removal, dentrification, leaching, voltalization and erosion.

The first alternative, absorption by crops, is the desired goal.

Erosion losses of N could be significant. The loss of 10 tons of soil/acre/year (9070 kg/.4 ha) with 2 percent organic matter could result in a loss of 20 pounds (9 kg) of N.

Leaching can contribute to ground and surface water pollution problems. Loss of nitrates by leaching is undesirable from all standpoints. The loss can be minimized and crop utilization maximized by proper management practices.

- Split the applications of nitrogen on sandy or shallow soils where leaching or erosion hazards are greatest and when heavy rates of nitrogen are required.
- Apply nitrogen during the growing season (not in the fall) on soil subject to leaching and erosion.
- Apply the proper amount of nitrogen and other plant nutrients for vigorous crop growth. This should be based on a soil test.
- Use good soil conservation techniques to minimize erosion losses of topsoil.

Figure 1: Nitrogen in the air is the source of all soil nitrogen.