Nitrogen Management in Simple Terms

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Nitrogen (N) is an essential mineral element for plant growth and also the nutrient needed in the greatest amount by crops. When N is deficient, plants are stunted, older leaves turn yellow and the crop is low in protein. Excess N can delay maturity and cause excessive vegetative growth at the expense of grain yield. Nitrogen fertilizer is expensive and losses can be detrimental to the environment.

The air around us is approximately 78% N in the chemical form of N_2; however plants do not use this form of N directly. Plants generally take up ammonium and nitrate forms of nitrogen. Soils contain about 1,000 pounds of N/acre (6-inch depth) for each 1 % of organic matter content. Since N_2 is chemically quite stable, considerable energy must be expended to transform it to chemical forms that plants and animals can use.

How is N_2 transformed?

Biological N fixation: The term “fixation” is used to identify the transformation of N_2 to plant available-N, and lightning is believed to account for the addition to soils of about 5-10 lb/ac/year. A second, natural transformation of N_2 to plant-N results when free-living and rhizobium microorganisms reduce N_2 to amino-N and incorporate it into living cell components. Rhizobium associated with N assimilation by legumes are believed to account for transfer of about 90,000,000 tons of N from N_2 to biological-N annually. By comparison, worldwide manufacture of N fertilizers by industrial fixation of N_2 is estimated to be about 80,000,000 tons N annually.

N mineralization: As these plants and organisms die and decay, there is a release of N from organically bound forms called mineralization. Either through direct conversion or via microbial degradation, most of this N is converted to plant-available ammonium (NH_4^+). Mineralization is favored by conditons that support higher plant growth (e.g., moist, warm, aerobic environment containing adequate levels of essential mineral nutrients), organic material that is easy to decay, and material that is rich enough in N that it exceeds microorganism N requirements. Just as plant growth and development takes time, significant mineralization usually requires 2 to 4 weeks under moist, warm conditions.

Industrial N fixation: This is the process of manufacturing fertilizer. At high temperature and pressure, N_2 is converted to ammonia which is then made into various N fertilizer products.

What happens to available N forms in soil?

Immobilization: Decay of plant residue does not always result in mineralization of N. When residue does not contain enough N to meet the needs of microbes decaying it, the microbes will utilize N in the residue and any additional mineral-N (NH_4^+ and NO_3^-) present in the soil. This process of transforming mineral-N to organic-N is called immobilization, and is the opposite of mineralization.

Cation exchange: As the concentration of NH_4^+ in the soil increases, NH_4^+ will successfully compete for exchange sites on clay and humus occupied by other cations. This adsorption is responsible for NH_4^+-N being immobile in the soil.

Volatilization: Volatilization is loss of N from the soil system as ammonia gas. Volatilization is most likely to happen in high pH soils, but may also occur in acid soils when NH_4^+ accumulates from decay of N rich crop residue or animal manures on the soil surface. This condition is present in range and pasture situations as well as crop land where residue is not incorportated (no-till or minimum till). Volatilization is also promoted by surface drying.

Plant uptake: When plants are actively growing they will absorb NH_4^+. When plant absorption proceeds at about the same rate as mineralization there will be little or no accumulation of NH_4^+ in the soil.

Nitrification: Ammonium-N may be biologically transformed to NO_3^- in a two-step process called nitrification. Nitrification proceeds at about the same rate and under similar conditions as mineralization and immobilization. Perhaps the most important aspect of nitrification is that it transforms plant available-N from a soil-immobile form (NH_4^+) to a soil-mobile form (NO_3^-). Only small concentrations (10-20 ppm) of NO_3^--N are necessary in a large volume of soil to meet the N needs of plants.

Leaching: Nitrate-N is subject to loss from the root environment with water percolating through the soil. This is a significant problem when soils are porous (sandy) in high rainfall or irrigated condition.

Denitrification: When soils become anaerobic (e.g., there is little or no O_2 present) and conditions favor microbial activity, some microorganisms will satisfy their need for oxygen by stripping it from NO_3^-. As a result, gaseous forms of N (nitrous oxide, N_2O, and N_2) are produced that are lost to the atmosphere.

<u>What are the sources of N fertilizers and how are they managed?</u>

Manures: Early civilizations observed increased yields resulting from application of animal waste to fields where they had domesticated plants for food production. Animal waste, including sewage sludge (biosolids) from cities, continues to be an important source of N and other nutrients for improving nutrient availability in soils.

Synthetic N fertilizers: There are multiple forms of commercial N fertilizer products available, each with various properties and considerations.

<u>Anhydrous ammonia (82-0-0).</u> The leading N fertilizer in terms of tons sold nationwide is anhydrous ammonia (82-0-0). Anhydrous ammonia is a gas and because it has such a strong attraction for water and is transported and applied to soil as a liquid under high pressure, anhydrous ammonia is a hazardous material and special safty precauions must be taken in its use. When anhydrous ammonia is injected into the soil it reacts immediately with soil-water. Losses are minimized by injecting the NH_3 at least 4" deep in loam soils and 6" deep in sandy soils. In all application situations it is important to obtain a good "seal" as soil flows together behind the shank or injection knife moving through the soil. Packing wheels are sometimes used to improve the seal and minimize losses.

<u>Urea (46-0-0).</u> Urea is the most popular (based on sales) solid N fertilizer. It is very soluble in water and is the highest analysis solid material sold commercially. It is not hazardous and has low corrosive properties, although it is hygroscopic (attracts water) and requires storage free of humid air. It is mobile

in soil because it remains an uncharged molecule after it dissolves. Urea application can result in significant losses of gaseous ammonia (volatilization) if the fertilizer is not incorporated by cultivation, or if it does not receive irrigation or rain within a 2-3 days of application. Volatilization losses are greater when the soil or residue surface is moist and temperatures are warm (>60 F). There apparently is little or no loss of ammonia when urea is surface applied during cool weather.

Ammonium Nitrate (33-0-0). Ammonium nitrate is a dry product and is hygroscopic, like urea, and will form a crust or cake when allowed to take on moisture from the atmosphere. Unlike urea, loss of N as NH_3 volatilization is not a problem with ammonium nitrate. This fertilizer is corrosive to metal and it is important to clean handling equipment after use. A major advantage of ammonium nitrate fertilizer is that it provides one-half of the N in a soil-mobile form. This is often justification for use in short-season, cool weather, vegetable crops and greens like spinach.

UAN (urea-ammonium nitrate) solutions. When urea and ammonium nitrate are combined with water in a 1:1:1 ratio by weight, the result is a solution containing 28 % N. Because UAN has properties of both urea and ammonium nitrate, the ammonium portion is subject to ammonia volatilization when conditions for loss exist. It is a popular fertilizer, in part, because it can serve as a carrier for pesticides. UAN solutions that contain 30 or 32% N are simply more concentrated (contains less water) than the 28% solution. They are typically used in warmer areas or in the summer because they 'salt out', or precipitate when temperatures are below about 28 degrees F. Twenty-eight % UAN does not salt out until temperatures reach about 0 degrees F.

Ammonium sulfate (21-0-0-20S). This N fertilizer is a dry granular material that also supplies sulfur. Compared to some of the more common sources, ammonium sulfate has relative lower concentration of N. It's use is common in areas where S is often needed, such as very sandy fields, and in specialty crops, lawns and gardens, and in blended formulations that need S.

Ammonium thiosulfate (12-0-0-26S). Ammonium thiosulfate is a liquid fertilizer containing both N and S. The relative high sulfur percentage in this product makes it popular when sulfur in a liquid form is desirable. It will also reduce urease activity and thus potentially ammonia volatilization. It is not as effective at this as comparable commercial urease inhibitors sold specifically for that purpose.

Slow-release N fertilizers. Most of these materials are two to three (or more) times more expensive than urea or ammonium nitrate, calculated on a cost/lb of N basis. They are not often used in conventional agriculture, but rather in production systems that are less sensitive to fertilizer costs and which desire a somewhat uniform supply of N to the plants over a long period of time. Turfgrass systems are an example where this is a requirement and where these materials find most of their use. The advantage of these materials is that one application may provide a uniform supply of N to the plants for several weeks.

Urea-formaldehyde (38 % N) is a synthetic organic material of low solubility, whose N release depends upon microbial breakdown and thus is temperature dependent.
IBDU (isobutylidene diurea, 31 % N) is another synthetic organic material. N release from this fertilizer depends upon particle size, soil moisture content and pH.

Sulfur-coated urea (32-36 % N) is urea that has been encapsulated with elemental S in the prilling process. Release of N depends upon breakdown of the S coat (physical barrier).
Polymer-coated products utilize a polymer which acts as a physical barrier around the fertilizer particle that causes urea to dissolve and release N more slowly.

N fertilizer additives; ammonification inhibitors, denitrification inhibitors and others.

Urease inhibitors (such as Agrotain®): Urease is the enzyme responsible for breaking down urea into its basic chemical components, making the N plant available. This enzyme is very common and exists in most soils and plant tissues. Urease will act on urea and begin the breakdown process shortly after application of urea forms of fertilizer. Urease inhibitors function by disrupting these enzymes in the immediate vicinity of the fertilizer, which keeps the fertilizer in the urea form longer. Keeping the fertilizer in the urea form allows more time for rain to dissolve the urea and move it into soil so that ammonia losses are no longer a concern. Most sources indicate that it takes approximately ½ inch of rainfall to dissolve the fertilizer and move it into soil.

Nitrification inhibitors (such as Instinct®): These products dramatically slow the conversion of ammonium to nitrate in the soil system. This conversion is normally controlled by soil microbes and these additives inhibit that process. The advantage is that ammonium is not easily lost; it's bound to soil, but nitrate *is* easily lost via leaching or denitrification when conditions favor these losses.

In addition, there are also combination products that combine the activities of both the above groups. Some examples would include NutriSphere-N® and Agrotain Plus®.

The duration and degree of their effectiveness of any of these products will be determined by many factors including: soil temperature; soil characteristics, including organic matter, biological activity, microbial populations; precipitation and soil moisture; and the interaction of these factors.