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Nitrogen Sources

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Nitrogen is an essential plant nutrient. It is a key component in plant proteins and chlorophyll. This fact sheet will discuss natural and man-made nitrogen sources and will describe the fate of nitrogen in the soil.

Natural Sources of Nitrogen

Some plants "make their own nitrogen". If a legume (i.e., soybeans, alfalfa, clovers) is colonized by certain strains of Rhizobium bacteria, nodules will form on the plant roots where the bacteria live and reproduce. Within these nodules, a symbiotic relationship develops between the bacteria and the host plant. The bacteria utilize plant sugars as a source of energy and in turn "fix" nitrogen, converting nitrogen gas into forms that can be used by the plant. Once nodules form, the plant usually receives all of the nitrogen necessary for growth from that "fixed" by the bacteria. Other crops, including all grass crops (e.g., corn, sorghum, wheat, forage grasses, etc.) and non-leguminous broadleaf crops (e.g., sunflowers, potatoes, sugar beets, cotton, etc.) are not colonized by nitrogen fixing bacteria and therefore must obtain the nitrogen they need from the soil.

In addition to nitrogen fixed by Rhizobium bacteria, other natural sources that contribute to the soil nitrogen include: mineralization of organic matter and nitrogen released as plant residues are broken down in the soil. Animal waste is a good source of natural nitrogen as well.

Barnyard or poultry manure and other animal waste products (e.g., bat guano) were used as a source of supplemental nitrogen long before inorganic nitrogen fertilizer came into popular use. Composted plant residues, legumes plowed under as green manure, and animal wastes continue to be used today, especially by organic crop producers, as a source of nitrogen.

A small amount of nitrogen is also contributed by rainfall in the form of nitric acid (HNO_3), which when dissolved in the soil water disassociates into hydrogen and nitrate ions. The nitric acid is formed when nitrogen and oxygen gases are combined with water by the intense heat of a lightening bolt during a thunderstorm.

While all these natural sources can make significant contributions to soil nitrogen levels, they usually do not supply enough nitrogen to meet all of the needs of high yielding non-leguminous crops in what are now considered "conventional" agricultural systems. Additional nitrogen in the form of added fertilizer is usually required for optimum yield. The remainder of this fact sheet will discuss inorganic (man-made) nitrogen fertilizer sources.

Inorganic nitrogen sources

The air we breathe is about 78% nitrogen in the form of N_2 gas and about 21% oxygen in the form of O_2 gas. The remaining one percent of the atmosphere is a combination of all the other gases, including carbon dioxide that is the source of carbon used by green plants. Even though there are 33,000 tons of nitrogen in the air over every acre, the nitrogen gas is so chemically stable, plants cannot directly use it as a nutrient.

Plants readily take up and use two forms of soil nitrogen, ammonium (NH_4^{+}) and nitrate (NO_3^-). Other forms of nitrogen must be converted to one of these compounds by natural or artificial means before plants can utilize them directly as a source of nitrogen for plant growth.

The ammonium molecule (NH_4^+**)** carries a positive electrical charge and is attracted to the clay and organic matter in the soil, which carry negative charges. Once attached to the soil matrix, ammonium becomes part of the cation (pronounced "kat-i-ən") exchange process whereby plants exchange a hydrogen ion (H^+) for one of the positively charged molecules in the soil. Besides ammonium, other essential nutrients obtained by cation exchange include: potassium, calcium, magnesium, iron, manganese, and zinc.

Nitrification

The conversion of ammonium to nitrite and then to nitrate is referred to as nitrification. Given aerobic soil conditions and soil temperatures above freezing, all forms of nitrogen in the soil, except nitrogen gas, are converted to the nitrate (NO_3^-) form by soil microorganisms. Nitrification occurs most rapidly between 60 and 85 degrees F. Nitrite (NO_2^-), the intermediate product in the conversion of ammonium to nitrate is toxic to plants and animals. Fortunately, under most soil conditions, the conversion of nitrite to nitrate occurs very rapidly.

Nitrate (NO_3^-) carries a negative electrical charge, which is the same charge carried by clay particles. Unlike ammonium ions, nitrate ions are not attracted to clay particles, since like charges repel each other. Nitrate molecules are therefore free to move with the soil water. They are carried to the soil surface as moisture evaporates, and carried back down with

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rainfall or irrigation. Plants take up the nitrate form of nitrogen through the root system along with water as the plant transpires. If water leaches below the root zone, nitrate dissolved in the water will be leached as well. Therefore while the ammonium form of nitrogen is held in the soil, the nitrate form can be lost if water percolates below the active root zone of the crop.

Denitrification

Under anaerobic (saturated) soil conditions, denitrifying organisms in the soil will reduce nitrate to nitrogen gas through a series of intermediate steps, (NO_3^- to NO_2 to NO to N_2O and finally to N_2). The final two forms are not available to plants. The final product, nitrogen gas, will leave a saturated soil and return to the atmosphere. Some studies indicate that about four to five percent of the nitrate can be lost from a soil for each day it remains saturated.

Anhydrous Ammonia

Anhydrous ammonia (NH_3) is produced commercially by reacting nitrogen gas (N_2) from the atmosphere in the presence of a catalyst with steam and with methane (natural gas, CH_4). The tonnage of anhydrous ammonia used in agriculture is greater than any other form of nitrogen fertilizer due to its lower cost per pound of nitrogen and its relative nutrient density (82% nitrogen by weight) which keeps the transportation cost per ton of nitrogen as low as possible. Anhydrous ammonia is a gas at normal temperatures and atmospheric pressure but converts to the liquid state when sufficiently pressurized. The need for pressurized containers and additional personal safety precautions reduces some of the advantages for anhydrous ammonia over more easily handled forms of nitrogen.

All other forms of inorganic commercial nitrogen fertilizer are derived from anhydrous ammonia. They are more expensive per pound of nitrogen because of the additional processing steps involved in their manufacture and greater transportation costs because they have lower nutrient density than anhydrous ammonia. These other forms of nitrogen fertilizer have advantages in terms of personal safety and ease of storing, handling, and application which make them attractive to many farmers in spite of the higher cost per pound of nitrogen .

Urea and Urea - Ammonium Nitrate

Urea ($CO(NH_2)_2$) is produced by combining anhydrous ammonia (NH_3) with carbon dioxide (CO_2). (Carbon dioxide (CO_2) is a byproduct of the anhydrous ammonia production process. It is produced by combining oxygen from the air (O_2) with the carbon atom that remains after stripping the hydrogen from the methane molecule).

Fertilizers which contain urea and urea-ammonium nitrate (UAN) solution are the most widely used nitrogen fertilizers in Nebraska after anhydrous ammonia. Dry pelletized urea is popular as a nitrogen fertilizer compared to other forms because of its relatively high nitrogen content (46% of the total weight is nitrogen), good storage and handling properties, and widespread availability.

Urea-ammonium nitrate (UAN) is made by dissolving urea and ammonium nitrate in water. This results an aqueous solution usually containing 28% nitrogen by weight (a more concentrated product containing 32% is also available in some locations). Liquid UAN solution is popular because of the versatility of a liquid source, as well as widespread availability.

The urea form of nitrogen cannot be utilized directly by plants. It must first be converted to the ammonium form by chemical processes which, in turn, may be used by the plant or converted to the nitrate form by microbiological processes. The conversion of urea ($CO(NH_2)_2$) to ammonium $(NH_4)^+$ occurs in a two step process. When the urea combines with water (hydrolyzes) it forms ammonium carbonate $(NH_4)_2CO_3$. Ammonium carbonate is unstable and decomposes to form ammonia gas (NH_3) and carbon dioxide (CO_2). The ammonia gas produced is chemically identical to anhydrous ammonia. If the ammonia gas is in physical contact with water, it reacts

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The 16 Chemical Elements Essential for Plant Growth

Nitrogen is one of sixteen chemical elements essential for plant growth[1]. Green plants must be able to assimilate all sixteen nutrients to carry on cell growth and metabolic activities.

Plants get oxygen (O), carbon (C), and hydrogen (H) from the air and water, the other nutrients are taken from the soil. Nitrogen (N), phosphorus (P), potassium (K), are sometimes referred to as the primary nutrients while calcium (Ca), magnesium (Mg), and sulfur (S) are referred to as secondary nutrients. Another seven essential nutrients are taken up in much smaller quantities and are collectively referred to as micro-nutrients. These are: boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Z). Table 1 lists the total crop removal of soil nutrients to produce a 150 bushel corn crop.

(1) Cobalt has not been proven essential for higher plant growth but nodulating bacteria need it for fixing atmospheric nitrogen in legumes. It therefore sometimes will appear in a listing of essential nutrients.

Table 1.
Total Crop Removal, lb/acre of Essential Soil Nutrients by a 150 bushel corn crop.

Nitrogen	200
Phosphorous (P_2O5)	85
Potassium (K_2O)	200
Calcium	42
Magnesium	44
Sulfur	25
Zinc	0.15
Iron	0.10
Manganese	0.08
Boron	0.06
Copper	0.05
Molybdenum	0.03
Chlorine	unknown

to form the ammonium ion $(NH_4)^+$. If the ammonium ion is in contact with the soil, it is attracted to the clay and organic matter particles and is held in the cation exchange complex.

Broadcasting urea-based fertilizers without incorporating them with tillage carries the risk of nitrogen loss to the atmosphere by ammonia volatilization. If just enough moisture is present to hydrolyze the urea but not enough to convert it to ammonium and carry it to the soil, the ammonia gas can escape into the atmosphere (volatilize). Volatilization is favored by high soil pH, warm temperatures, wet soils under drying conditions, and crop residues that insulate the urea from the soil. Under extremely unfavorable conditions, urea fertilizer that is broadcast to the soil surface with no mechanical incorporation can have volatilization losses exceeding 75%. On the other hand, surface applied urea that receives sufficient rainfall to hydrolyze the urea and to incorporate the resulting ammonium (e.g., one-half inch of rainfall or irrigation) will suffer very little volatilization loss.

Ammonium Nitrate

Another popular form of dry nitrogen fertilizer is ammonium-nitrate (NH_4-NO_3). Ammonium-nitrate is 34% nitrogen, by weight. It is produced by reacting anhydrous ammonia (NH_3) with nitric acid (HNO_3). When dissolved in water, the ammonium (NH_4^+) and nitrate (NO_3^-) fractions disassociate. The nitrate fraction remains dissolved in the soil water. The ammonium fraction becomes bound to negatively charged soil particles. Both the ammonium and nitrate fractions are available for direct plant uptake and neither form is subject to appreciable volatilization losses. The volatilization losses from surface applied ammonium nitrate are therefore usually quite small, especially compared to urea-based fertilizers.

A selling point for both urea and ammonium-nitrate fertilizers over anhydrous ammonia is that they can be broadcast as a dry product to the soil surface whereas ammonia must be injected into the soil to prevent vaporization. Broadcast application is faster and less expensive than injection and therefore would have advantages if volatilization losses from urea can be minimized.

Phosphorus / Nitrogen Sources

Some fertilizers that are applied primarily as sources of phosphorus also contain significant levels of nitrogen. Diammonium phosphate (DAP) contains 18% N and 46% P_2O_5 by weight (18-46-0). Monoammonium phospahte (MAP) is usually formulated as 11-52-0. Other common phosphorus sources that contain nitrogen include 10-34-0 and 11-37-0. If any of these compounds are applied as a source of phosphorus, one should credit the nitrogen contained in these compounds when computing total nitrogen fertilizer to apply.