NEBRASKA TECHNICAL NOTE

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THE NITROGEN CYCLE AND FERTILIZER MANAGEMENT

The topics covered in this Technical Note are intended to supplement the video entitled "The Nitrogen Cycle and Fertilizer Management" which was distributed to the District Conservationists.

USDA

THE NITROGEN CYCLE AND FERTILIZER MANAGEMENT (notes)

Nitrogen Terms

Nitrification bacteria converts ammonium to nitrate ($NH_4^+ \rightarrow NO_3^-$). As the soil warms, microorganisms convert ammonium to nitrate ($NH_4^+ \rightarrow NO_3^-$). Maximum conversion is at 80 to 90^0 F (soil temperature).

Mineralization Organic N is converted to inorganic nitrogen (Ammonium, NH_4^+) by soil microbes. Crop residue decomposed by soil microorganisms add to the organic N pool. Manure and sludge adds organic N to the soil.

Mineralization occurs if the organic material has a low carbon:nirtogen ratio, (C:N, <25-35), and undergoes decomposition. Soil inorganic nitrogen available to plant will increase.

When the soil starts to warm, soil organisms begin converting organic N to ammonium (mineral nitrogen) which is available to plants. Only 20-25% of the organic N (residues & etc.) will be mineralized each year, it may take 10-20 years for some organic N to be mineralized.

When bean stubble is tilled, 80-90% of the organic N will be mineralized for the growing season.

Mineralization is very hard to predict, mineralization will be high with warm, moist conditions and slow with cool, dry conditions.

Immobilization The conversion of inorganic nitrogen to organic nitrogen NO_3^- and NH_4^+ are converted by soil microbes to organic N (not available to plants)

N fertilizer that is applied to the soil with crop residues will be temporarily tied up in the bacteria that is decomposing the residue. This short term conversion to organic N immobilizes the mineral nitrogen in the soil.

The best way to minimize immobilization is to apply N fertilizers below the crop residue, (residues on and below the soil surface tie up the mineral nitrogen).

Nitrogen lost from the soil

Denitrification NO_3^- is reduced to gaseous nitrous oxide (N_2O) or elemental N (N_2). Denitrification occurs in waterlogged conditions. Some bacteria uses the oxygen from the soil nitrate and the nitrate is converted to nitrogen gases and lost to the atmosphere. This process can also occur in compacted soils.

Volatilization Loss ⇑ The conversion of ammonium (NH_4^+) to ammonia gas (NH_3)

N goes into the Atmosphere ($NH_4^+ \rightarrow NH_3\Uparrow + H^+$)

Leaching of nitrate is a major loss mechnaism which is most likely to occur when soil nitrate levels are high and/or water movement through the soil is rapid.

Other nitrogen losses can occur with erosion, runoff, and crop uptake.

Forms of Nitrogen

Organic N, this is the largest source of N, it is not available to plants (not mobile)

NH_4^+ Ammonium, NO_3^- Nitrate are forms of nitrogen that are available to plants.

Nitrogen applied enters the mineral N pool, (nitrate-N, NO_3^--N), (Ammonium-N, NH_4^+-N)

Soil microorganisms 6 billion / teaspoon of soil (need moist warm conditions for them to be active). Adding organic sources (Manure or sludge) after incorporation the nitrogen goes to the Organic N pool, (organic N is not available to plants until the N goes through the mineralization process.

Plant available Nitrogen

(mineral nitrogen = inorganic nitrogen)
(NH_4^+) Ammonium does not move in the soil
(NO_3^-) Nitrate highly mobile

Source	Analysis %N-%P_2O_5-%K_2O	Physical Form
anhydrous ammonia, NH_3	82-0-0	liquid under pressure gas at reduced pressure
urea, $(NH_2)_2CO$	46-0-0	solid
ammonium nitrate, NH_4NO_3	33.5-0-0 or 34.0-0-0	solid
UAN, urea plus ammonium nitrate)	28-0-0 to 32-0-0	liquid
ammonium sulfate, $(NH_4)_2SO_4$	21-0-0 24% Sulfur	solid
aqua ammonia, NH_3	16-0-0 to 25-0-0	liquid
ammonium phosphate-sulfate, NH4H2PO4(NH4)2SO4	16-20-0 15% Sulfur	solid
diamonomium phosphate, $(NH_4)_2HPO_4$	16-48-0 or 18-46-0	solid
monoammonium phospate, $NH_4H_2PO_4$	11-48-0	solid
potassium nitrate, KNO_3	13-0-44	solid

There are other ammonium phosphate fertilizers in liquid form.

Cations and Anions

NH_4^+ has a positive charge (cation), clay and organic matter have a negative charge (anion). They are attracted to each other, which make NH_4^+ not mobile because it is attached to clay and/or organic matter.

NO_3^- (nitrate)is negatively charged (-) this causes the NO_3^- molecule to be repelled by the negatively charged clay particles, so it stays dissolved in the water and goes where the water moves.

Crops can use NO_3^- and NH_4^+ equally. Most N is taken up in nitrate form NO_3^- because most of the nitrate is in the soil water. The root system will take up the water carrying the NO_3^-.

Common Fertilizers

Anhydrous gas (NH_3) is injected into the soil it quickly r reacts with water to form ammonium (NH_4^+). When ammonia (from anhydrous ammonia) is injected into the soil it kills the bacteria in the band, which delays the conversion of $NH_4^+ \rightarrow NO_3^-$. There are not enough bacteria present to complete the conversion.

With warm moist soil condition it may take 2-3 weeks for the bacteria to be repopulated to covert all of the $NH_4^+ \rightarrow NO_3^-$. If it is cold, it may take up to 6-9 weeks for NH_4^+ to be converted to NO_3^-.

Urea Ammonium Nitrate Solution (UAN)

28-32% Nitrogen
25% Ammonium (NH_4^+) available immediately to the plant
25% Nitrate (NO_3^-) available immediately to the plant
50% Urea$(NH_2)_2CO$
Urea needs converted to ammonium by the urease enzyme before it's available to the plant. The urease enzyme splits each urea molecule into 2 ammonium ions (2- NH_4^+), this will take 2-5 days depending on temperature. This chemical reaction can happen on the soil surface or in the soil.

If urea (dry) or nitrogen solution is applied on the soil surface or crop residues and not incorporated into the soil, their is a potential for ammonia volatilization. This will easily happen if a light shower falls on the fertilizer that has been spread on the surface (not enough moisture to get the fertilizer into the soil).

Some of the ammonia is lost to the atmosphere as a gas. With warm and humid conditions, 10-50% of the nitrogen applied as urea may be lost due to volatilization.(typical less than 20% loss). High losses are possible on high pH soils with high residue amounts. This loss can be reduced by mechanically incorporating the fertilizer or applying 1/2 inch or more of water.

Nitrification inhibitors / Slow release nitrogen

(N-serve, DCD)
These products block the conversion of NH_4^+ to NO_3^- by slowing down the nitrification process (kill or inhibit nitrifying bacteria). These products can be used with anhydrous and other nitrogen solutions.

Urease inhibitors (Agrotain)
The urease inhibitor blocks the conversion of urease to ammonium while the fertilizer is on the surface. It works good on high pH soils and in situations with high residues.

Inhibitor Use
The results of using inhibitors are variable. The best opportunities for using inhibitors is with fall or early spring applications of nitrogen, on sandy soils, on poorly drained soils, and where high rainfall is likely.

References

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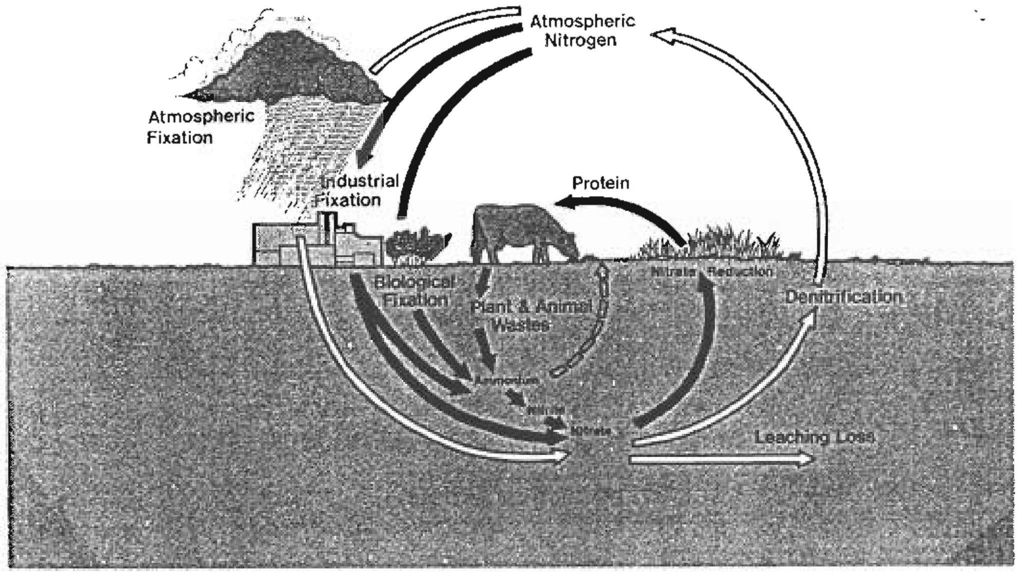
Soil Fertility Manual. 1995. Revised Printing. Norcross, Georgia, Potash & Phosphate Institute.

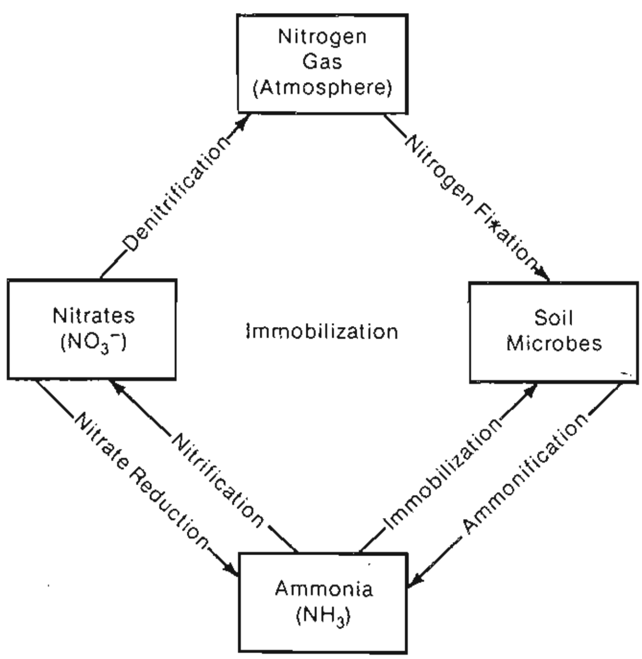
Tisdale, S.L., Nelson, W.L., Beaton, J.D., Havlin, J.L., 1993. *Soil Fertility and Fertilizers*. 5th ed. New York, Macmillan Publishing Company

Western Fertilizer Handbook. 1985. 7th ed., California Fertilizer Association, Danville, Illinois, TheInterstate Printers & Publishers, Inc.

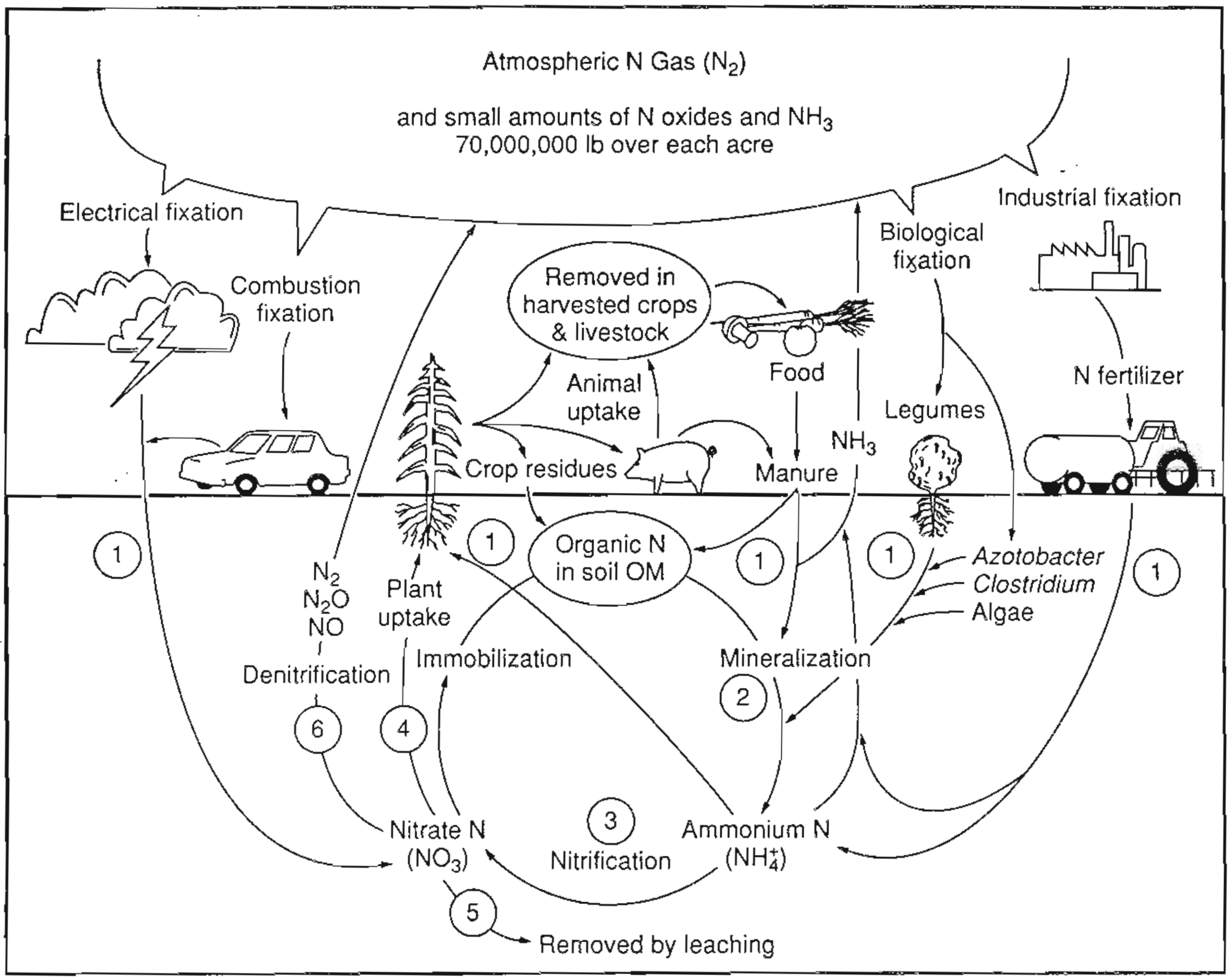
Nitrogen Cycles (various sources)

The Nitrogen Cycle





Nitrogen Cycles (various sources)



The N cycle. In step 1, N in plant and animal residues and N derived from the atmosphere through electrical, combustion, and industrial processes (processes by which molecular nitrogen, N_2, is combined with H_2 or O_2) is added to the soil. In step 2, N in the residues is mobilized as NH_4^+ by soil organisms as an end product of residue decomposition. Plant roots absorb a portion of the NH_4^+. In step 3, much of the NH_4^+ is converted to NO_3^- by nitrifying bacteria in a process called *nitrification*. In step 4, NO_3^- is taken up by plant roots and (along with the NH_4^+ absorbed) is used to produce the protein in crops that are eaten by humans or fed to livestock. In step 5, some NO_3^- is lost to groundwater or drainage systems as a result of downward movement through the soil in percolating water. In step 6, some NO_3^- is converted by denitrifying bacteria into N_2 and nitrogen oxides (N_2O and NO) that escape into the atmosphere, completing the cycle. *Council for Agricultural Science and Technology*. Agriculture and Groundwater Quality, *Report No. 103, p. 23, 1985.*