Dr. Raun Lohry

Fine-tuning N For The Environment

Understanding the nature of N and how it can be managed are essential to making fertility practices environmentally friendly.

Summary: *Technological advances in the last fifty years such as genetic improvements, increased fertilizer use, expanded irrigation and improved management have raised average corn yield from 30 to over 135 bu/A. One mighty propellant of such proliferation has been nitrogen (N) fertilizer. However, while increasing N fertilizer use has improved plant performance, it has also raised environmental concerns. Attempts to define systems requiring lower N and pesticide inputs, often called "sustainable," nearly always increase time and management as substitutes. Discussion of such systems is shrouded by vague terms and less rigorous factual or scientific documentation. Truly sustainable systems should be 1) resource conserving, 2) environmentally compatible, 3) socially supportable, and 4) commercially competitive.*

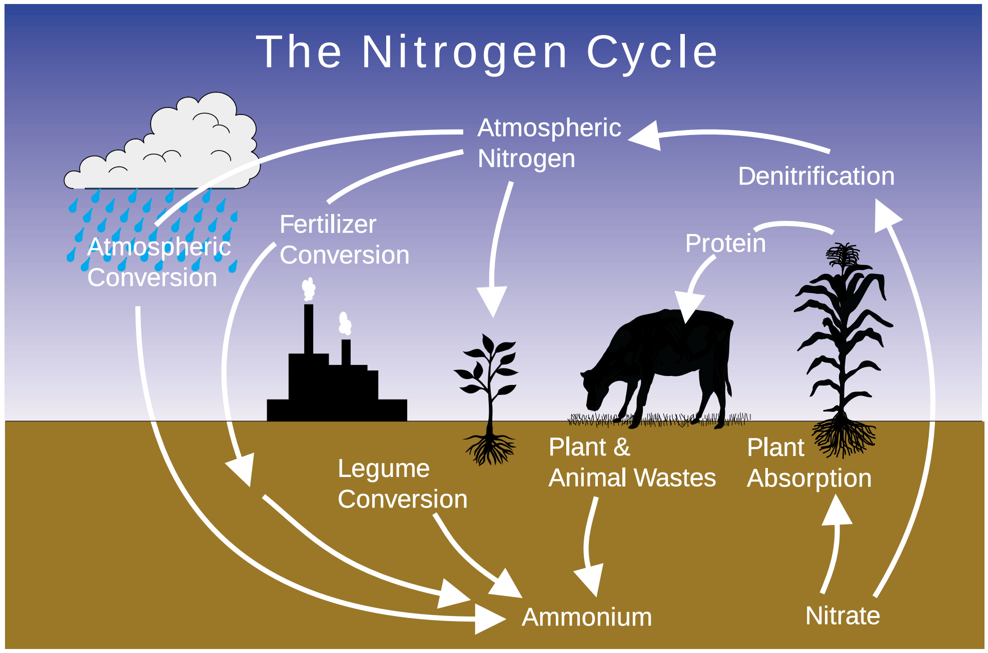

Figure 1. Nitrogen Cycle

The goal of sustainability is, in its final form, to manage inputs such that farm productivity is optimized and environmental stresses are minimized. The quest for higher farm productivity demands that the producer and fertilizer dealer be more knowledgeable and implement scientifically proven techniques that will increase farm profit while being environmentally friendly. The discussion that follows will explore nitrogen management and define techniques to manage nitrogen effectively to minimize environmental impact.

Before we get into nuts and bolts of how to better manage N, a quick refresher on its nature and sources is in order.

Nitrogen cycle

Nitrogen is required by plants in large quantities and, when water is not limiting, can be the most common limiting factor in crop production. One handful of soil that supports vegetable and field crops contains more living creatures than all the people whoever walked the earth. These subterranean citizens of the soil make up the biological factory that relentlessly manufactures different forms of N. Without them, the soil would be lifeless, yet they can make N unavailable to crops, causing economic and environmental losses. Plants obtain N from residual N in the soil and from applied sources such as fertilizer. All nitrogen moves through various phases as it is used by plants and soil organisms. This dynamic process of N movement through various pools is known as the nitrogen cycle (Figure l). Nitrogen cycling models depict plants removing inorganic N from soil N pools and returning energy and nutrient-rich residues.

The concept of N cycling is important in plant nutrition because: 1) N from organic residues is a substantial portion of plant N uptake, and 2) it helps to explain where applied N goes. Although nitrogen in residues and other organic forms is the largest fraction of

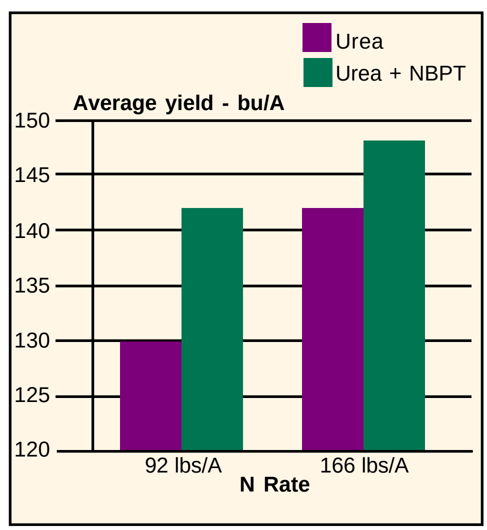

Figure 2. Average effect of NBPT on corn yields in 78 trials performed by university scientists.

Table 1. Effect of rainfall on volatilization

Rainfall	Time	Estimated loss
in.	days	%
0.4	less than 2	0
0.4	2 to 3	<10
0.1 to 0.2	less than 5	10 to 30
.25 to .35	less than 9	10 to 30
0	6	>30

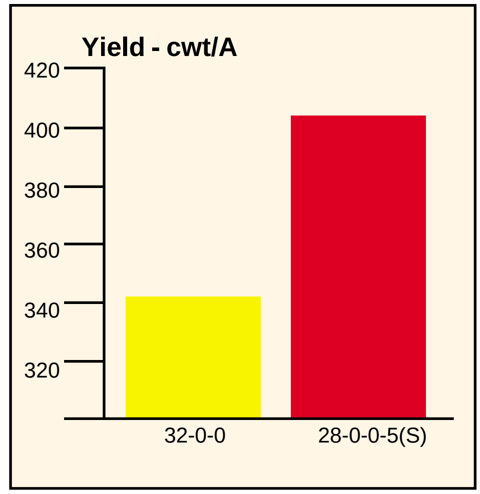

Figure 3. Effect of DCD on irrigated potato yields in Idaho,

soil N, most is not available to the crop. The active component of this organic fraction can contribute 30 percent of all mineralized N while comprising only 4 percent of the total N pool. The remaining inactive portion represents stored N that may not be available for a long time.

Plants cannot use organic N in significant quantities. Organic N must be converted to inorganic forms. The conversion of organic N forms to inorganic plant-available forms is called mineralization. Nitrogen bound in organic forms is released when soil organisms digest residues. The first product of mineralization is the ammonium ion (NH4+). Once NH4+ is released, it can be oxidized to nitrate (NO3-). The oxidation of NH4+ to NO_3- is called nitrification. So much for basics. A look now at a perennial problem and an answer.

Nitrogen loss

Agronomists know that a crop will take up 40 to 70 percent of applied N. Through research, they have identified several principal ways in which it can be lost.

Immobilization. When soil organisms use nitrogen, it is no longer available to the plant. Soil organisms, like plants, use fertilizer and soil nitrogen to grow. This process of nitrogen tie-up is called immobilization. Immobilization may be somewhat higher for ammonium-N than for nitrate. Soil bacteria require about one pound of N for every 11 lbs of carbon in the process of decomposing residues in the soil. The more carbon in the residue, the more likely is immobilization by soil bacteria. This loss of N is really only a temporary because as the soil organisms die, the N held in their cells is released for use by plants and other soil organisms.

Leaching. Nitrate is subject to leaching if precipitation or irrigation is heavy enough to move water downward. One inch of water on silt loam or clay loam can move NO_3 down four to six inches. Because infiltration and percolation are very rapid on sandy soils, an inch of water can move nitrates up to one foot. Less movement of NH_4+ will be observed, but on low CEC soils even the ammonium ion can be washed downward.

Volatilization. Nitrogen can be lost by ammonia volatilization. Ammonia volatilization is the loss of nitrogen as ammonia (NH_3) gas into the atmosphere. Under certain conditions, urea or ammonium nitrogen can be converted to NH_3 nitrogen. If this occurs at or near the surface, N will be lost to the atmosphere.

Surface applications of amino-based fertilizers such as UAN or urea are subject to losses from volatilization. In most neutral to acid pH solutions, nitrogen exists as NH_4+ or NO_3- ions. Urea is soluble and exists as a urea molecule $[CO(NH_2)_2]$. When a urea-containing solution is sprayed on the soil

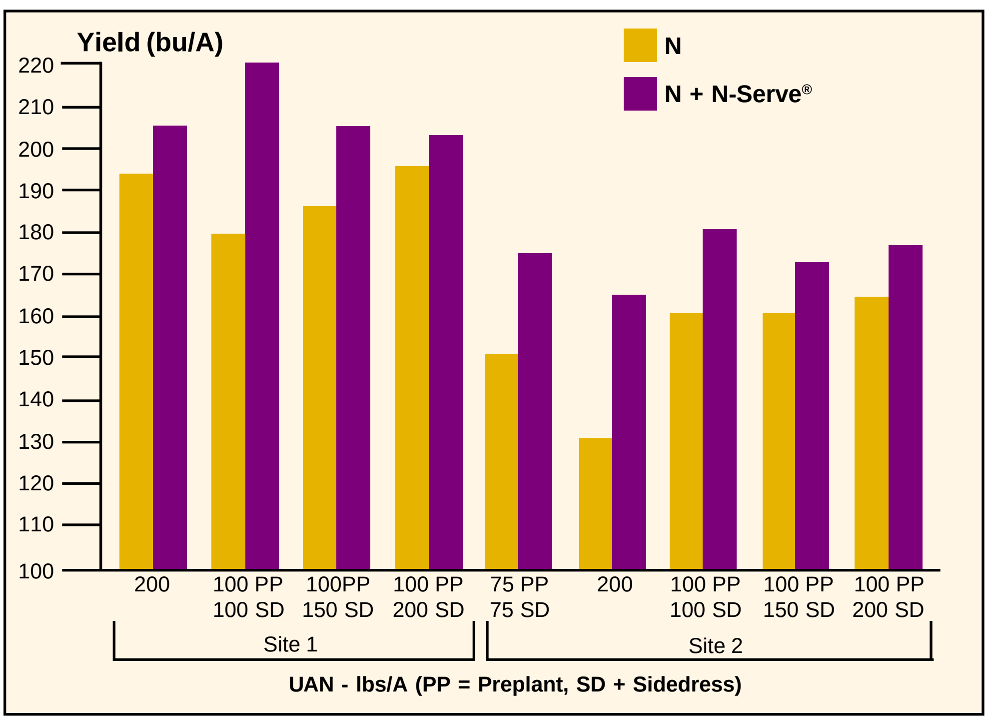

Figure 4. Response of center pivot irrigated corn to N-Serve; N source UAN, N-Serve used at rate of 1 qt/A.

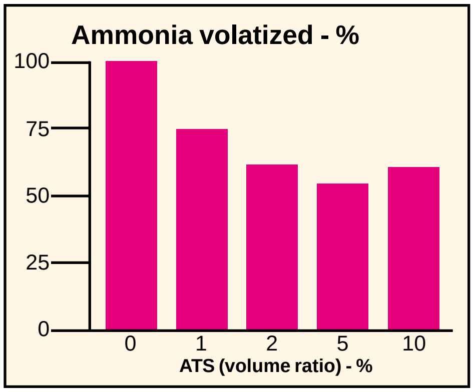

Figure 5. Effect of ATS in reducing ammonia volatilization.

surface, it dries and a series of chemical and biochemical reactions begins. These reactions are varied and complex and are dependent on environmental factors such as temperature, moisture conditions, level of organic matter, buffering capacity, and pH. It generally has been observed that greater N losses occur on calcareous soils. Liming may also increase the level of ammonia volatilization by shifting the NH_4+ concentration to higher levels of NO_3, which can be subsequently lost as a gas.

Investigators have noticed that if all other conditions are similar, volatilization is greater in coarser-textured soils. This is attributed to the higher CEC capacity of finer-textured soils. With a high CEC, more NH_4+ is held on the exchange complex and less NO_3- is present is the soil solution.

There seems to be varying effects of organic matter on volatilization but the results appear to be linked with CEC reactions. Usually volatilization is greater where sod or residues are present. This is probably caused by conversion of urea to NH_3 by hydrolysis on the surfaces of growing leaves or residue particles. Since CEC of the residues is limited, much less NH_4+ can be retained than on soil surfaces.

Proper placement. Surface banding, subsurface injection or soil incorporation of manures or urea-based fertilizers essentially eliminates ammonia volatilization.

Precipitation. Where mechanical incorporation is not available or practiced (conservation tillage), precipitation acts as a natural incorporator. Table 1 provides a guideline for the amount of loss under different moisture conditions. A light rain is sufficient to incorporate UAN and minimize N loss, but the longer the dry spell after application, the greater the chance for volatilization losses.

NBPT. The most active compound identified as a urease inhibitor is N-(n-butyl) thiophosphoric triamide, generally known as NBPT (Agrotain®). Urease is an enzyme that catalyzes the conversion of urea into its basic components. It is commonly thought to be present under almost all soil conditions and in large amounts. Without active urease, most soil microbes would be unable to break down urea because of the high amount of energy required to begin the conversion process.

A comprehensive study of 78 trials performed by university scientists showed NBPT to be effective at rates ranging 0.55 to 1.1 pounds active ingredient/A. Note in the summation of trials (Figure 2) how an average of 74 lbs/A of additional unamended urea-N was required to equal the yield advantage the NBPT additive gave by inhibiting losses of N applied at 92 lbs/A. Such N losses did not occur at all locations every year. Conditions giving rise to large yield losses are as unpredictable as the weather. When favorable, where N losses are minimized, use of NBPT would be a financial waste, as would an extra 74 lbs/A not be taken up by the crop. Losses from the root zone could find their way to groundwater.

It is also important to understand that, individually, additional N required would be greater than the 74-lb/A average difference in the model used above, since the average includes sites where N losses were low or negligible. On 6 of 21 sites, for example, the yield differential between high and intermediate N levels was 5 bu/A or less.

DCD. Recent research conducted on potatoes by the USDA-ARS, Kimberly, Idaho, showed impressive yield gains from the use of the inhibitor dicyandiamide (DCD), an agent believed to inactivate an enzyme necessary for nitrification. An application of 28-0-0-5S + DCD outyielded an application of 32-0-0 by 61 cwt/A (Figure 3).

N-Serve® is most commonly used to inactivate the enzyme necessary for nitrification and should be applied preplant. Research on N-Serve® is extensive. Some beneficial effects are shown in Figure 4.

Ammonium thiosulfate (12-0-0-26) may also act as a urease inhibitor. Research conducted with different rates of ATS showed a 38 percent reduction in volatilization when ATS was mixed in UAN at a 10 percent rate (volume basis) and nearly a 25 percent reduction at the 2 percent rate (Figure 5).

Dr. Lohry is agronomist for Nutra-Flo Company in Sioux City, Iowa. ❑