Enhanced Efficiency Fertilizers and Review of Stabilized Nitrogen Technology

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Introduction

High fertilizer prices coupled with low commodity prices are causing many grain producers to rethink fertilizer management decisions. The obvious goal is to improve fertilizer efficiency while maintaining crop productivity. Enhanced efficiency fertilizers are products designed to improve nutrient uptake while stabilized nitrogen products prevent fertilizer loss. Currently, many producers are trying to evaluate the usefulness of several of these products in their cropping systems. High fertilizer prices make these options more attractive because it takes fewer pounds of saved nutrient to offset the additional cost of the new technology. Currently, there are three types of products being marketed that claim to improve nitrogen use efficiency: nitrification inhibitors, urease inhibitors, and controlled release fertilizer products. These products work by slowing one of the processes within the nitrogen cycle, thereby reducing N loss. Prior to purchase, producers should have a good understanding of how these products work in order to make informed decisions regarding their use.

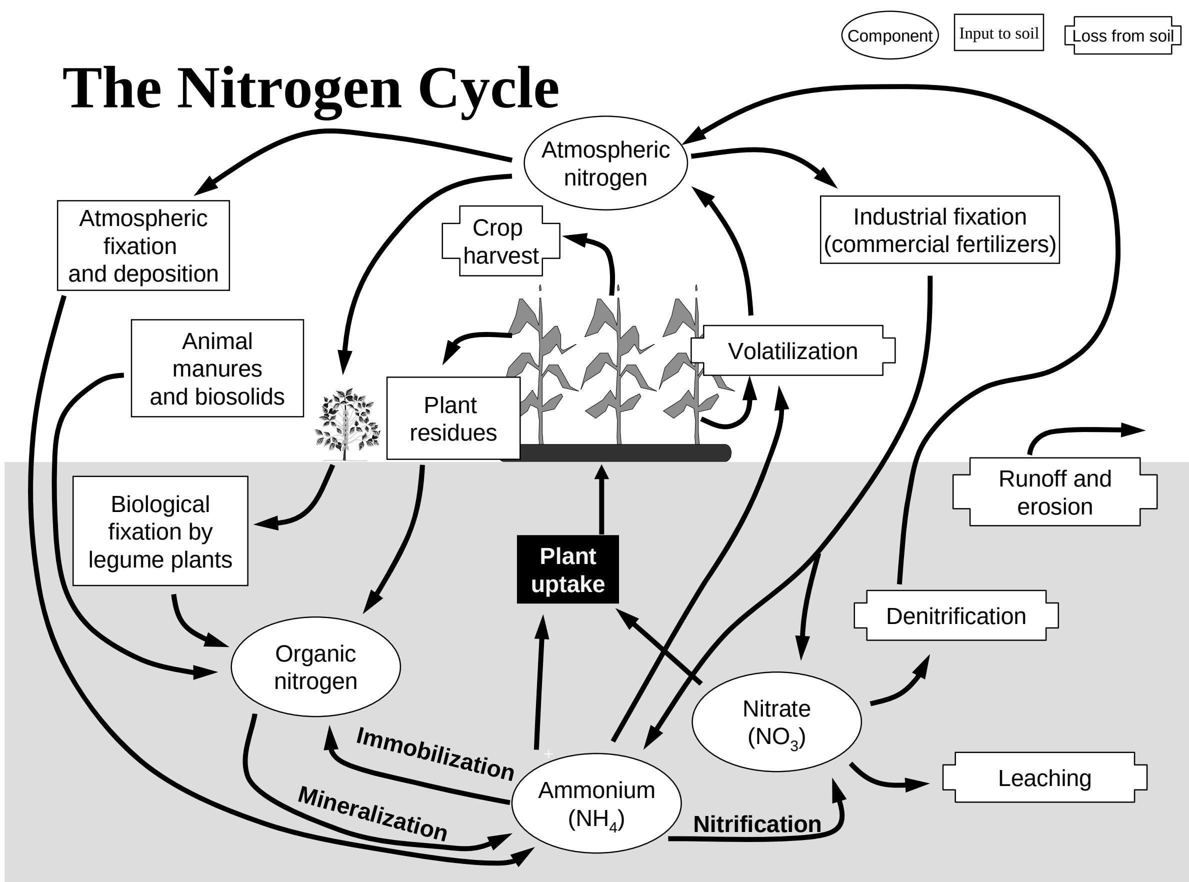

Figure 1. The nitrogen cycle showing components, inputs, losses, and transformations to soil nitrogen pools (from The Potash and Phosphate Institute).

Nitrification Inhibitors

Nitrification is the conversion of ammonium nitrogen (NH_4-N) to nitrate nitrogen (NO_3-N) in the soil (Figure 1). Depending on soil conditions, some inhibitors can slow this process by a few weeks. The most common, Nitrapyrin (N-Serve®), has been commercially available for 30 years. It can be used with any N fertilizer that contains or produces (when applied to the soil) NH_4-N. Examples are anhydrous ammonia, urea, and urea-ammonium nitrate (UAN) solutions. A new product, Nutrisphere-N® (Specialty Fertilizer Products, Belton, MO), also claims to prevent nitrification.

Inhibiting nitrification is important because nitrogen in the NH_4-N form is held tightly by the soil particles and is not subject to leaching or denitrification loss. **Leaching** is when NO_3-N is moved deeper into the soil profile by moving water. It is possible that soil NO_3-N can be leached below the rooting zone and then become an environmental concern. **Denitrification** occurs when NO_3-N is converted into a gas and escapes into the atmosphere. This reaction only happens when soil lacks oxygen or is largely water saturated. Depending on the amount of oxygen in the soil, the gas emitted is either in the nitrous oxide or nitrogen gas form. Nitrous oxide is considered a greenhouse gas and emissions may be regulated in the future. Denitrification losses are most common on poorly drained soils saturated for many days during the spring.

Urease Inhibitors

When urea fertilizers are applied to the soil, an enzyme called urease begins converting them to ammonia gas. If this conversion takes place below the soil surface, the ammonia is almost instantaneously converted to NH_4-N, which is bound to soil particles. If the conversion takes place on the soil surface or on surface residues, there is a potential for the ammonia gas to escape back into the atmosphere a process called **ammonia volatilization**.

Volatilization losses depend on the environmental conditions at the time of application. Soil temperature, soil moisture, amount of surface residue, soil pH, and length of time between application and the first rain event or irrigation are all factors that determine the total amount of N that could be lost via volatilization. Nitrogen losses from fertilizer applied prior to May 1 are generally very low. After May 1, N loss is greatest, especially when urea is surface applied to soils with high residue or vegetation (i.e., no-till corn or pastures), during warm, wet weather followed by a warm, breezy drying period.

Volatilization losses can be substantially reduced if a urease inhibitor is used with the fertilizer. The most common urease inhibitor is NBPT (N-(n-butyl) thiophosphoric triamide) sold under the trade name Agrotain®. Urease inhibitors reduce the activity of the urease enzyme for up to 14 days. As long as it rains during this 14-day period, the urea will be moved into the soil where it can be converted to NH_4-N without the risk of volatilization. Nutrisphere-N® (Specialty Fertilizer Products, Belton, MO), also claims to prevent volatilization loss.

Controlled Release Urea

Controlled release fertilizer products have also been available for more than 30 years. Probably the best known of these products is sulfur coated urea. A sulfur coating is applied to urea granules and urea dissolves/diffuses through imperfections in the coating. By altering the thickness and number of imperfections in the coating, release characteristics can be controlled. Sulfur coated urea was not a useful agronomic product in part because the cost of coating was high relative to the cost of the N fertilizer.

Recent advancements in polymer (plastic) technology have created a whole new type of controlled release fertilizer, the most common of which is **polymer coated urea** (PCU). Polymer coated urea has been used in the turf and horticultural industries for several years, but the cost of the materials prohibited their greater use in the agricultural market. Now Agrium, Inc., has introduced a PCU called ESN® that is priced competitively in the agricultural market.

Modern polymers allow chemists to create release curves that closely match the uptake characteristics of target crops (Figure 2). The amount and rate of release is controlled by the thickness and other characteristics of the polymer

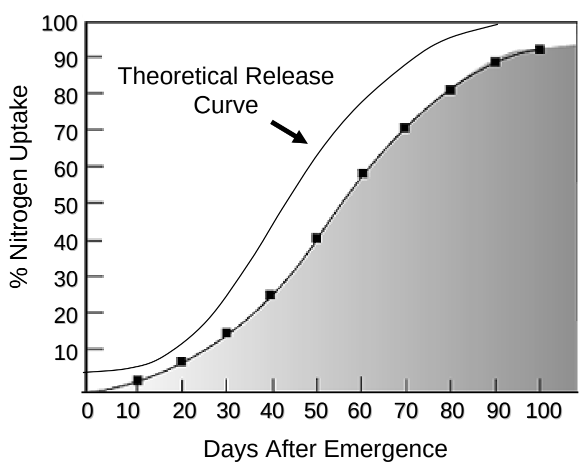

Figure 2. Typical nitrogen uptake curve for corn and a theoretical polymer coated urea release curve.

Agronomics of N Products

As alluded to earlier, there are several factors that should be considered before deciding if these products are appropriate and economical in your specific production system.

Ideally, corn producers strive to apply just enough N to reach maximum yield: about 150 lbs N/acre (Figure 3). If a farmer applied the optimal amount of fertilizer and used an inhibitor or PCU, N would be saved, but yield would not be increased. This is because maximum yield has already been obtained. In order for these new products to be agronomically useful, the producer must reduce the rate of applied nitrogen by the amount expected to be saved as a result of using the additive. To be economical, the cost of the saved N must exceed the price of the additive.

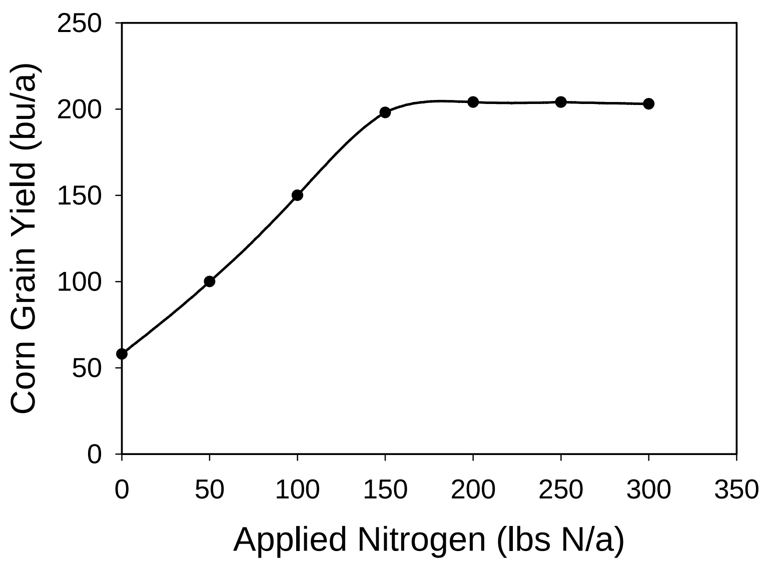

Figure 3. Typical nitrogen response curve for corn grown on well-drained soils in Kentucky.

The second consideration is the time of year fertilizer is being applied. Denitrification occurs primarily when the soil is water saturated. Therefore, losses are usually highest for N applied in the fall or early spring. Later side-dress applications usually result in very little denitrification loss since soil saturation is less likely. The total amount of nitrogen lost as a result of denitrification is a function of the number of days the soil remains saturated and the amount of nitrogen in the NO_3-N form (Table 1). Approximately 3-4% of the NO_3-N can be lost per day of soil saturation beyond two days.

Table 1. The percentage of fertilizer N in the NO_3-N form 0, 3, and 6 weeks after application.

N Source	Weeks After Application		
	0	3	6
	% of Fertilizer as NO_3-N		
Anhydrous Ammonia (AA)	0	20	65
AA with N-Serve	0	10	50
Urea	0	50	75
Urea with N-Serve	0	30	70
UAN solutions	25	60	80
Ammonium Nitrate	50	80	90

Volatilization losses are highest when the soil is warm (above 50^{o}F), experiencing high evaporation rates, and/or when soil pH is greater than 7. In most years, temperatures become high enough to cause concern in early May. After this time, urea N contained in surface applications is more volatile. If the fertilizer is surface applied and incorporated or a ¼ inch or more rain is received within two days, volatilization losses will be minimal. If, on the other hand, it is not incorporated and no rain is received, loss can exceed 25% with an average of about 10% of the total. High surface residue levels also increase volatilization; therefore, maximum losses will be observed when urea is broadcast on no-till or pasture fields after May 1.

Polymer coated urea, because of its slow release characteristics, offers farmers the option of early fertilizer application with a reduced risk of denitrification or leaching loss. There is still the potential for volatilization losses from this product because it's urea. However, research results demonstrate that the risks of significant volatilization loss from polymer coated urea is much smaller than unprotected urea.

Enhanced Efficiency Phosphorus Fertilizers

Unlike nitrogen, phosphorus loss from the soil is generally not a problem for well-managed agricultural systems. Phosphorus is tightly bound to clay particles and can be lost when soil particles are eroded into surface waters. Phosphorus can also be leached through the soil profile, but this only happens on very sandy soil and is almost never a problem in the Midwest. The major problem with phosphorus availability is phosphorus precipitation reactions (Figure 4). Depending on the soil pH, phosphorus reacts with calcium (high pH) and with iron, aluminum, and manganese (low pH). These secondary minerals effectively make P unavailable for plant uptake.

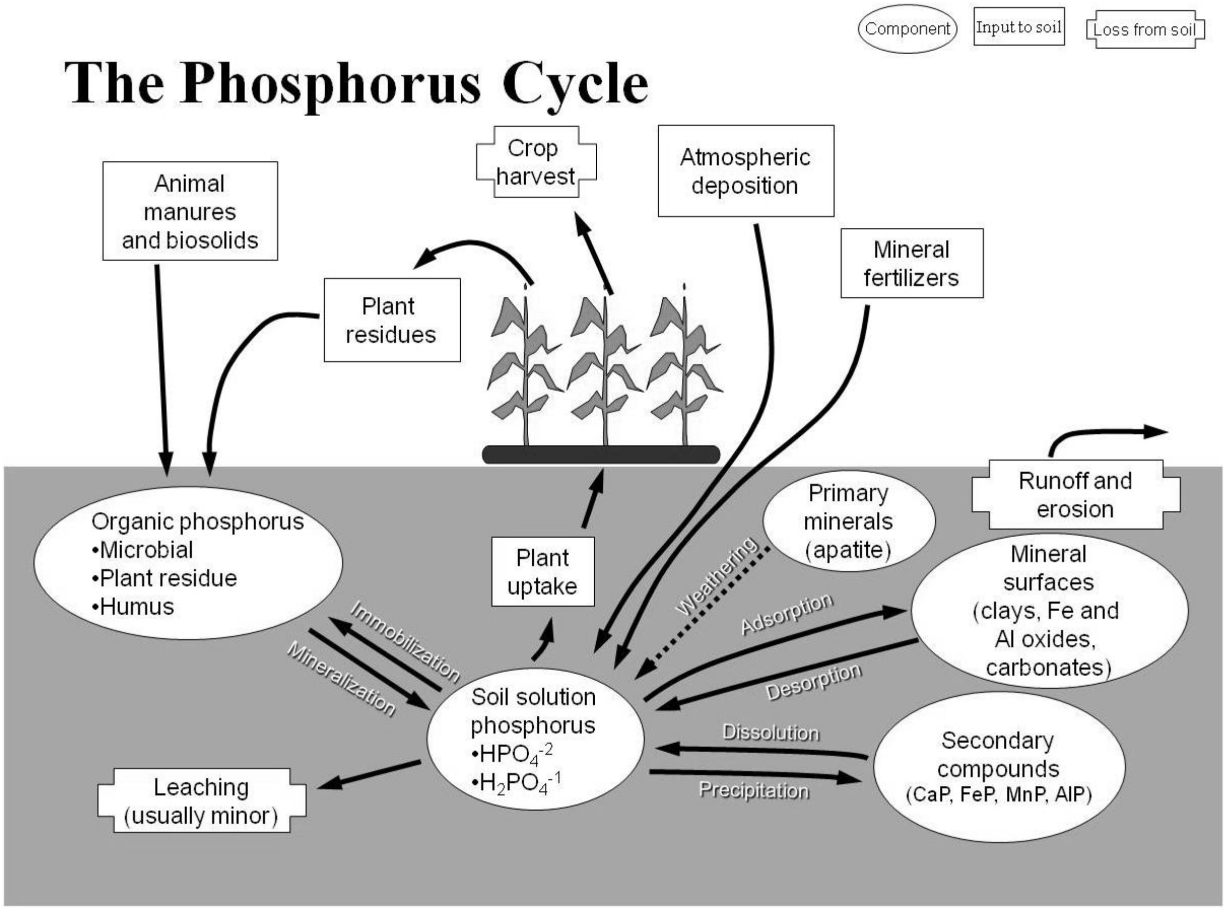

Figure 4. The phosphorus cycle showing components, inputs, losses, and transformations to soil phosphorus pools (from The Potash and Phosphate Institute).

A new product, AVAIL® (Specialty Fertilizer Products, Belton, MO), claims to prevent the precipitation of phosphorus compounds by binding with calcium, iron, manganese, and aluminum. However, a study conducted in Kentucky (Murdock et al., 2007) found no benefit to using AVAIL for fescue grown on very low testing soil.

Conclusions

There are several products that grain farmers could use to help improve fertilizer efficiency. These products are only useful in specific situations, so it is important to understand how they work and when they are most useful. It is also important to realize these products are designed to conserve fertilizer.

Benefits will only be realized if the total application rate is reduced by the amount of fertilizer estimated to be saved by using one of these products.