Enhanced Efficiency Fertilizers:

Will They Enhance My Fertilizer Efficiency?

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Introduction

Slow release fertilizers have been available for over 25 years but only a few are available for use with agronomic crops. Most are used in horticultural or turf applications where fertilizer cost is less of an issue. Enhanced efficiency fertilizers (EEF) is a newer term for new formulations that control fertilizer release or alter reactions that lead to nutrient losses. The mechanisms or products include fertilizer additives, physical barriers or different chemical formulations and are similar to earlier versions. Fertilizer additives claim to improve fertilizer availability by reducing N losses from volatilization, denitrification, leaching and immobilization. They may temporarily block bacterial or enzymatic processes in the conversion of urea to ammonium or ammonium to nitrate. Most of the product development has been for N compounds, although some are for phosphorus (Table1). The phosphorus products can either be polymer coatings or polymers that shield P from reactions that create less soluble phosphates.

Table 1. Enhanced efficiency fertilizers available in the United States.

Chemical or Compound	Common Product Names	Process Affected
Nitrogen Products*		
Dicyandiamide (DCD)	Guardian®	Nitrification
2-chloro-6 (trichloromethyl) pyridine (Nitrapyrin)	N-Serve®, Instinct®	Nitrification
N-butyl-thiophosphoric triamide (NBPT)	Agrotain®	N volatilization
Malic+ itaconic acid co-polymer with urea	Nutrisphere®,	Nitrification, N volatilization
Polymer-coated urea (PCU)	ESN®, Polyon®, Duration®	N release**
Sulfur-coated urea (SCU)	SCU	N release
Polymer + SCU	Tricote, Poly-S®	N release
Urea formaldehyde	Nitroform®	N release
Methylene urea	Nutralene®, CoRoN®, NFusion®	N release
Triazone	N-Sure®	N release
NBPT + DCD	Agrotain®Plus, SuperU®	Nitrification, N volatilization
Methylene urea + triazone	Nitamin®, Nfusion®	N release
Triazone + NBPT	N-Pact®	N release, volatilization
Phosphorus Products		
Malic+ itaconic acid co-polymer with MAP	Avail®,	Decrease mineral precipitation

*Mention or omission of a commercial company or trade name does not imply endorsement or censure by the author or the University of Nebraska-Lincoln.
**N release may include the process of the fertilizer granule taking in water for dissolution plus transformations including ammonification and nitrification.

Factors Influencing Fertilizer Use Efficiency

Nitrogen

Improved fertilizer use efficiency for nitrogen comes from the plant capturing more of the N applied as fertilizer as well as any residual nitrate in the soil. Loss of N from the system contributes to lower N use efficiency. An understanding of the conversion processes of N fertilizers when applied to soil plus an understanding of what can happen to them once they are applied helps explain where and how EEF's might work. Nitrogen can be lost during ammonification (ammonia volatilization) and after mineralization due to immobilization, leaching or denitrification. To work, enhanced efficiency fertilizer products must stop, slow down or decrease the effects of these losses. They can increase fertilizer availability by reducing the potential of volatilization, immobilization, leaching, denitrification and immobilization by temporarily blocking biological processes, either bacterial or enzymatic. The mechanisms of enhanced efficiency can include additives, physical barriers or different chemical formulations.

Phosphorus

Improvements in fertilizer use efficiency for phosphorus (P) also come from the plant capturing more of the P applied as fertilizer. Loss of P usually comes from decreased availability as soluble fertilizer P forms revert over time to much less soluble forms. All forms eventually revert to rock phosphate which was the original source for the fertilizer. P additives that would extend availability would have to slow down the reversion process. Phosphorus is lost primarily through erosion of P-enriched soil particles.

Mechanisms of Enhanced Efficiency

Nitrogen

One class of EEF's that has been around for years is **nitrification inhibitors** (Table 1). This includes products such as nitrapyrin and dicyandiamide. These products suppress *Nitrosomonus* bacteria in the soil (with different degrees of effectiveness) by slowing or stopping the conversion of ammonium to nitrite. The inhibitors break down over periods of days to months, depending on temperature and moisture conditions.

A second group includes the **urease inhibitors**. N-(n-butyl) thiophosphoric triamide (NBPT) and ammonium thiosulfate (ATS). NBPT blocks the function of the urease enzyme, preventing formation of NH4+ from urea. This reduces the potential for ammonia volatilization allowing time for rain or irrigation to move urea into the soil. NBPT breaks down over periods of days to weeks, depending on temperature and moisture conditions. ATS has shown short term effects on urease inhibition.

A third group is **slow release** N fertilizers. These products fall into two broad categories: coatings and chemical formulations. Coatings physically slow down dissolution and in some cases influence chemical properties near the fertilizer granule. The chemical formulation include different elements in the fertilizer product which decrease the solubility or conversion of the material to N forms that then are converted in the N cycle. In both cases, the intent is to match the supply of N from fertilizer to crop N demand.

For coated products, sulfur or polymer coatings can be applied to soluble fertilizer. Sulfur-coated urea (SCU) has been available for many years but is not widely used due to cost. The sulfur coating slowly breaks down allowing water into the granule which dissolves the urea. The release rate for polymer-coated urea (PCU) is determined by the polymer chemistry, coating thickness, coating process and temperature. This release can be highly controlled and can be designed to match plant uptake. Fertilizer is released by diffusion through the coating. One material that has been around since 1967 in the lawn and garden industry is Osmocote. It's a bit pricy for corn production, howeverDifferent chemical formulations include urea formaldehyde and methylene urea which are mixtures of urea and methyl-urea chains of various lengths. These can be formulated in either solid or liquid products. The N release characteristics are controlled by the chain length.

Phosphorus

Polymer coatings slow the release of P from the fertilizer and are designed to increase P use efficiency. The effectiveness depends on the thickness of the polymer coating and temperature, but can vary with soil type and moisture. Coated P may extend P availability into the second year after application. Young corn plants take up half of their P when they have only accumulated a quarter of their growth. Slow release P products would need to provide enough P during this critical time.

Another technology claimed to improve P availability is Avail®. It includes the addition of high capacity exchange resins or polymers which bind cations from the soil solution and hinder the formation of less soluble phosphates which is purported to maintain P locally in a more plant-available form. These polymers are organic molecules which can be influenced by soil micro-organisms, moisture and temperature. Avail® can be added to either dry or liquid fertilizers at the manufacturing plant or distribution location.

Product Performance

Nitrogen

Most of these products are considerably higher in cost per pound of nutrient than conventional fertilizers and although some are being actively marketed, many are still in their research phase. There are numerous testimonials on company web sites and in some cases, selected results of replicated research trials are presented. For some of the products, the soil chemical and biochemical pathways and reactions are known and predictions can be made whether the product has any potential to improve fertilizer efficiency. Some products and their soil chemical reactions have not been studied or they are proprietary and have not undergone unbiased third-party research testing.

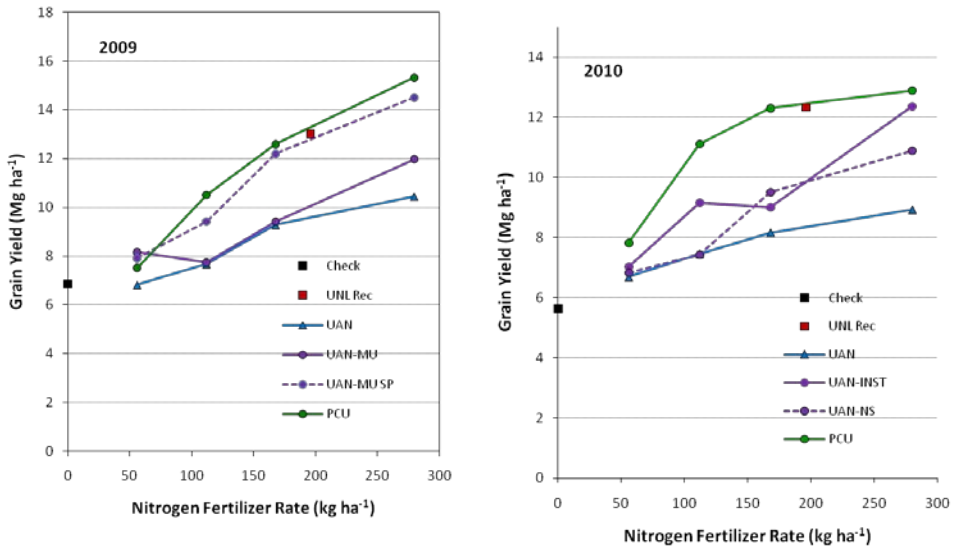
The N products are likely to be of value for fields with high risk for N loss. The slow release products and nitrification inhibitors are more likely to be beneficial if there is a high risk of N loss from leaching or denitrification. If fertilizer N is surface applied, especially with heavy crop residue cover and on high soil pH, the slow N release products and urease inhibitors are more likely to be beneficial. Table 2 below provides an overview of risk assessment and where you might consider using N products.

Table 2. Risk assessment for N fertilizer management.

Situation	Risk	Approaches
Fall application to silt loam or clay loam soil	Denitrification, leaching	NH_3 injection with nitrapyrin
Preplant application to silt loam or clay loam soil	Denitrification, leaching, runoff, volatilization	NH_3 with nitrapyrin; PCU; Urea with NBPT; Methylene urea
At-planting surface application with no-till	Volatilization, runoff, denitrification	Urea with NBPT; PCU; Methylene urea; UAN with NBPT
Sidedress application or fertigation	Wet weather preventing timely application	Preplant or at-planting application, using inhibitors or slow/controlled release formulation

Many of the products have been researched by land-grant universities, including the University of Nebraska (Fig 1.), but many have not. Often similar products will be marketed with different trade names, making comparison by the consumer difficult. Producers are encouraged to gather information from university research studies and Extension publications, or to contact their local Extension Educator or specialist if they have questions.

Figure 1. EFF N fertilizer impacts on irrigated corn yield on a coarse-textured soil in Merrick County, NE (R.Ferguson).



Phosphorus

The only product currently available is Avail and limited testing has been done in Nebraska. Results from other studies presented at national scientific meetings show no response to limited response. Information on company websites is generally favorable. The difficulty is that many products are marketed before there is full scientific testing. Once they are on the market, there is usually little incentive for a company to test the product.

Summary

We encourage producers to do their own research strip trials, e.g. with a split-planter design using several replications in a field or on more than one field to generate their own data. Well-calibrated yield monitors can be used to obtain the harvest data. Local agricultural experiment station personnel or Extension Educators can assist with design of the experiment and data analysis.

Our best advice is that producers do their own research strip trials using a split-planter with several replications in a field or on more than one field to generate their own numbers. Well-calibrated yield monitors can be used to obtain the harvest data. Local ag experiment station personnel or Extension Educators can assist with design of the experiment and data analysis.

Years ago a senior soil scientist suggested how producers should approach new or questionable products:

1. Have the salesman leave a sample which you to use on a field and pay him out of the increased profits of the treated versus non-treated area.
2. Only purchase enough the first year to run your test comparison strips.
3. Ask others who have had experience with the product.
4. Remember, it's your money.

It remains to be seen whether these products can match the N uptake demand for the different crops grown across the different agro-ecozones in Nebraska and be cost-effective. Enhanced efficiencies usually improve use by 10% to 30%, not 2X or 3X better (200% to 300%). Remember, a pound of nitrogen is a pound of nitrogen, regardless of the chemical form. For the phosphorus products, definitive lab work on phosphorus chemistry needs to be done to determine enhanced availability in addition to field testing.

In some instances, these products may not be an improvement over conventional sources, timing or placement combinations. That's why asking the question "Will they enhance my fertilizer efficiency?" is important. The enhanced efficiencies must be coupled with accurate rate recommendations to attain improvement. Again, if soil and climatic conditions are not conducive to N loss or phosphorus fixation, EEFs will be no better than standard fertilizers but will cost the producer more. They may simply be needed as insurance of yield potential by reducing N losses as opposed to a guarantee of increased yield. As the old Latin adage *Caveat emptor* states, "Let the buyer beware."