CROP INSIGHTS

Controlled-Release Nitrogen Fertilizers

by Steve Butzen, Agronomy Information Manager

Summary

- Controlled-release nitrogen fertilizers include coated ureas, non-coated "chemical-release" forms and other products.
- These fertilizers can reduce nitrogen (N) losses by delaying the initial supply of N and providing it gradually to the developing crop.
- Sulfur-coated urea releases N as it slowly degrades by microbial, chemical and physical processes. An additional polymer coating may be applied to better seal the granule.
- Nutrient release from polymer-coated urea is controlled by the properties of the coating material (i.e., its permeability characteristics as affected by temperature and moisture).
- Chemical controlled-release products are made by reacting urea with aldehydes to form fertilizers with low solubility or other properties for specific crop uses.
- Controlled-release products may be most useful in high-value crops, environmentally sensitive areas, fields highly susceptible to N losses or with limited opportunities for repeat applications, contest plots, and foliar applications.

Introduction

In North America, nitrogen (N) fertilizer is largely applied as anhydrous ammonia, UAN solutions or urea. However, these forms of nitrogen can be lost if adverse (primarily wet) weather conditions precede their uptake by crops. Controlled-release nitrogen fertilizers can reduce these losses by delaying the initial release of N and providing it gradually to better match its availability with crop uptake needs.

Controlled-release (also called slow-release or delayed-release) N fertilizers include coated ureas, non-coated "chemical-release" forms and other products. This article will discuss controlled-release nitrogen fertilizers and how they function to reduce nitrogen losses.

Coated Ureas

Coating urea prills (granules) with a water-insoluble, semi-permeable, or impermeable (with pores) material delays the release of nitrogen from the urea. Urea is highly soluble in water, but the solubility of coated urea is dependent on the coating material, its thickness, and the coverage and uniformity of the coating on the granule.

Materials used for urea coating or "encapsulation" include sulfur, polymers, or both. As the urea is gradually released from the coated granule, it is exposed to the same chemical and biological processes as non-coated urea (see previous Crop Insights on *Common Nitrogen Fertilizers and Stabilizers for Corn Production*, Butzen, 2013).

Figure 1. Nitrogen-sufficient corn field at V5. Most nitrogen is applied for corn well ahead of the period of peak crop uptake (V8 to tasseling).

Sulfur-Coated Urea

The additional labor and equipment required to produce coated fertilizers and the cost of the coating materials make them much more expensive than conventional nitrogen fertilizers. Due to the simplicity and relatively low cost of using sulfur as a coating material, sulfur-coated urea has become the most commonly used coated-urea product.

The Tennessee Valley Authority (TVA) developed the basic production process for sulfur-coated urea over 50 years ago, so the product is familiar to most farmers who use urea. This fact and the high nitrogen content of the product (30 to 40%, depending on the amount of sulfur applied) have added to its popularity among coated products. In addition, as a generic product, its cost has remained relatively low.

The sulfur coating is an impermeable layer that slowly degrades through microbial, chemical and physical processes (Figure 2). The completeness of the coating determines its effectiveness; incompletely coated or cracked prills are immediately amenable to dissolution in soil water and hydrolysis by urease. Because not all granules have complete integrity of their sulfur coating, some nitrogen is quickly made available to the soil solution. In fact, the "7-day

dissolution rate" is routinely as high as 30% and may be as high as 40 to 60% of the total N content of the product in some cases. With such high rates of dissolution, a rapid initial effect on the crop would be expected (Trenkel, 2010).

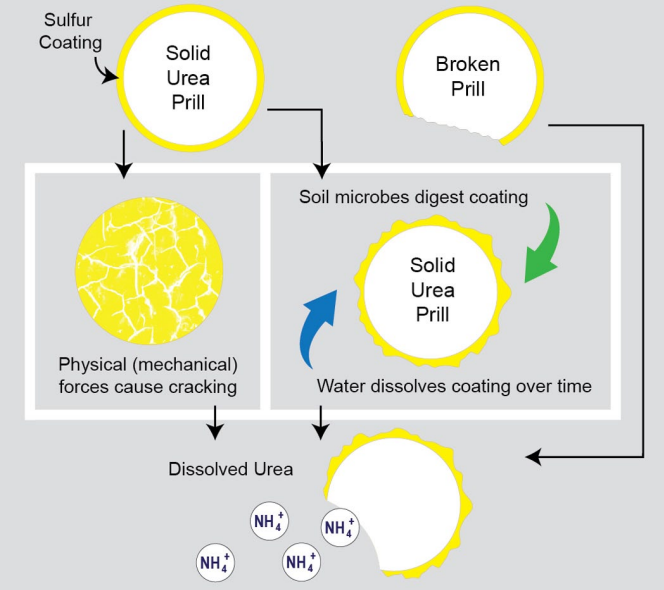
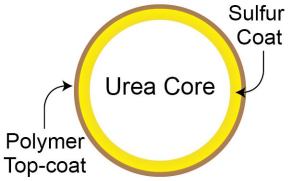


Figure 2. Breakdown of sulfur-coated urea. Adapted from Blaylock, 2010.

Sulfur + Polymer-Coated Urea



To help solve the problem of irregular nutrient release from sulfur-coated urea, a class of "hybrid" products has been developed. These products include a thin polymer coating on top of the low-cost sulfur coating. This has the benefits of reducing the overall cost vs. that of polymer-only products, while providing a better seal than the sulfur-only products.

Polymer-Coated Urea

Polymer-coated urea fertilizers use a hydrophobic (water insoluble) coating that temporarily isolates the urea prill from the soil environment. These polymer coatings may be resins or mineral-based products that act as semi-permeable membranes or impermeable membranes with tiny pores. Nutrient release through these membranes is controlled by the properties of the coating material, i.e., its permeability characteristics as affected by temperature and moisture (Figure 3). Thus, they are not significantly affected by soil properties such as pH, salinity, soil texture, microbial activity, re-dox potential or cation exchange capacity. Therefore, it is possible to predict and control the nutrient release rate from these products more accurately than for sulfur-coated ureas (Trenkel, 2010).

Chemical Controlled-Release Products

The first chemical controlled-release products became available as fertilizers in the US over 50 years ago. From the beginning,

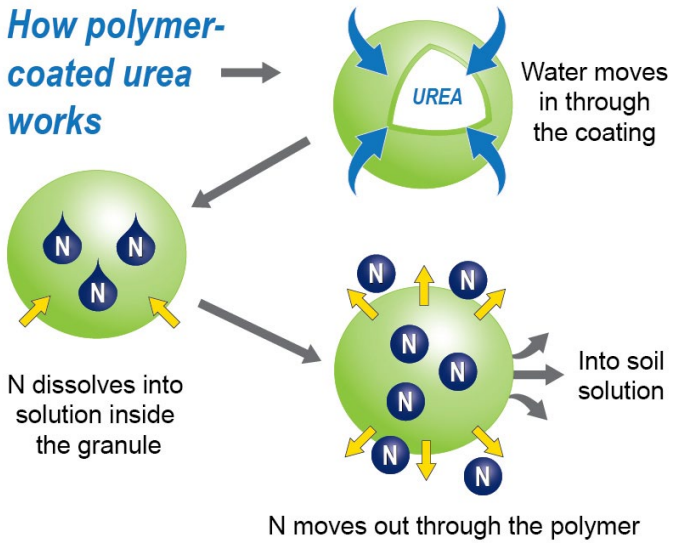


Figure 3. Release of nitrogen from polymer-coated urea. Adapted from Blaylock, 2010.

their high cost relative to other nitrogen fertilizers has limited their use in large-scale production of commodity crops such as corn, sorghum, wheat and canola. Rather, they have been more commonly used in specialty, high-value crops such as vegetables, orchards, nurseries, seed production, etc. Today, their use is limited but increasing in row crops, primarily due to higher grain prices, environmental concerns and regulations, and niche uses such as foliar fertilization. Common classes of chemical controlled-release products are described below.

Urea-Formaldehyde / Methylene Urea: By reacting urea with aldehydes, compounds with high molecular weights and complex chemical structures with low water solubility can be created. These products release their nitrogen slowly by gradually dissolving in soil water, decomposing by microbial activity, or both.

Reacting formaldehyde with excess urea under controlled conditions results in a mixture of methylene ureas with different polymer chain lengths. By changing the manufacturing conditions, the chain lengths, solubilities and nitrogen release rates can be varied. The release pattern is also influenced by soil temperature and moisture and by soil microorganisms and their activity (Trenkel, 2010).

Urea-Triazones: These compounds are produced by reacting an aldehyde and ammonia (or primary amine) with excess urea in an aqueous medium under controlled conditions. The resulting liquid fertilizer is a stable solution containing nitrogen from both triazone and unreacted urea. Products containing triazone-N remain in a liquid phase on plant tissue surfaces longer than some other urea-based products. These products have also proven safer to plant foliage than urea and UAN solutions in research studies (Clapp, 2001). Consequently, they are often used as foliar fertilizers.

Available Controlled-Release Products

A number of controlled-release nitrogen products are now available to row-crop producers in the US or Canada (Table 1).

Table 1. Controlled-release nitrogen products available in North America (adapted from Hergert et al., 2011)

Product Class	Product Name
Sulfur-Coated Urea	Generic
Polymer-Coated Urea	CoteN® Duration® ESN® Polyon®
Sulfur and Polymer-Coated Urea	Poly-S® Tricote®
Urea-Formaldehyde / Methylene Urea	Nitroform® Nutralene® CoRoN® NFusion®
Triazone	N-Sure®
Methylene Urea + Triazone	Nitamin® NFusion®
Triazone + NBPT[1]	N-Pact®
Urea + NBPT + DCD[2]	SuperU®

[1] A urease inhibitor (active ingredient in Agrotain® products).

[2] A nitrification inhibitor (active ingredient in Guardian® products).

Possible Uses of Controlled-Release Products

The higher cost of controlled-release products generally excludes their use in cases where conventional N fertilizers can perform the same function adequately. Most growers of commodity row crops who use controlled-release products likely apply most of their crops' N needs with conventional products and only use controlled-release products to supplement their primary N fertilization program. Controlled-release products may be most useful when:

- Growing a high-value crop (e.g., a seed crop)
- Applying on fields subject to high losses of nitrogen, for example:
  - light-textured, leachable soils
  - low-lying, heavy soils at risk of ponding and denitrification losses
- Applying in a regulated watershed
- Applying in a field that borders a stream, river, lake, etc.
- Applying in fields with limited opportunities for repeat applications due to expected weather patterns, field / crop conditions, distance, or labor / equipment issues
- Applying urea to the soil surface but not incorporating
- Foliar/remedial applications
- Application to contest plots to ensure constant N supply

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Credits

Illustrations by April Battani, DuPont Pioneer.