# Common Nitrogen Fertilizers and Stabilizers for Corn Production

Nitrogen (N) fertilizer is a critical input in corn production, but it is subject to loss under wet field conditions. Losses may be moderate or severe, depending on the form of N fertilizer applied and the type of weather conditions that follow. Nitrogen stabilizers (also called "additives") are available to help reduce N losses from the soil. These products must be used with compatible N formulations to be effective. The most common forms of N fertilizer are shown in Table 1.

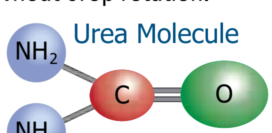
**Table 1.** Nitrogen fertilizers most commonly used for field crop production in North America.[1]

| Fertilizer | Form | % N |
|---|---|---|
| Anhydrous ammonia | Gas, applied as liquid from pressurized tank | 82% |
| Urea | Solid | 46% |
| Urea-ammonium nitrate solutions | Liquid | 28% - 32% |

[1] These forms account for over 80% of N applied for corn production.

**Anhydrous ammonia, $NH_3$,** is the most basic form of N fertilizer. Ammonia, a gas at atmospheric pressure, must be compressed into a liquid for transport, storage and application. Consequently, it is applied from a pressurized tank and must be injected into the soil to prevent its escape into the air. When applied, ammonia reacts with soil water and changes to the ammonium form, $NH_4^+$. Most other common N fertilizers are derivatives of ammonia transformed by additional processing, which increases their cost. Due to its lower production costs, high N content that minimizes transportation costs, and relative stability in soils, anhydrous ammonia is the most widely used source of N fertilizer for corn production in N. America.

Unfortunately in Canada escalating insurance costs over safety issues has drastically reduced retail outlet availability. Anhydrous still remains the most efficient form of N fertilization as its soil conversion to the Nitrate molecule occurs over a prolonged period reducing early season N losses from volatilization or denitrification. The need for deep banding Anhydrous also provides the positional advantage of N placement well below the carbon zone in a corn after corn or wheat crop rotation.




**Urea** is a solid fertilizer with relatively high N content (46%) that can be easily applied to many types of crops and turf. Its ease of handling, storage and transport; convenience of application by many types of equipment; and ability to blend with other solid fertilizers has made it the most widely used source of N fertilizer in the world.

**Urea-ammonium nitrate (UAN) solutions** are also popular nitrogen fertilizers. These solutions are made by dissolving urea and ammonium nitrate ($NH_4NO_3$) in water to create 28%, 30% or 32% N-containing solutions.

**Other N-fertilizer choices** include ammonium sulfate, calcium nitrate, ammonium nitrate and diammonium phosphate.

## Nitrogen Fertilizers and Soil Reactions

***Anhydrous ammonia*** is applied by injection six to eight inches below the soil surface to minimize escape of gaseous $NH_3$ into the air. $NH_3$ is a very hygroscopic compound and once in the soil, reacts quickly with water and changes to the ammonium ($NH_4^+$) form. As a positively charged ion, it reacts and binds with negatively charged soil constituents, including clay and organic matter. Thus, it is held on the soil exchange complex and is not subject to movement with water.

**Soil Reactions** - Over time, with soil temperatures that support biological activity, $NH_4^+$ ions are converted to the nitrate ($NO_3^-$) form by soil bacteria in the process of **nitrification**. Nitrification generally occurs at soil temperatures above 50° F and increases at higher temperatures. However, some limited activity occurs below 50° F as well. Ammonium is converted first to nitrite ($NO_2^-$) by the action of *Nitrosomonas* bacteria and then to nitrate by *Nitrobacter* and *Nitrosolobus* bacteria.

Only after the nitrification process has converted ammonium to negatively charged ions repelled by clay and organic matter in the soil complex, can ammonium N be lost from most soils by leaching or denitrification. Plants can take up N in both the ammonium and nitrate forms. Thus, if N can be held as ammonium until uptake by plants, it is at little risk of loss (except on sandy soils that cannot bind much ammonium.)

***Urea*** readily dissolves in water, including soil water. Thus, it can be "incorporated" into the soil by sufficient rainfall or irrigation (½ inch is typically suggested). Otherwise, it should be incorporated by tillage to reduce losses.

**Soil Reactions** - Urea applied to the soil and not incorporated by water or tillage is subject to volatilization losses of N as urea undergoes hydrolysis to carbon dioxide and ammonia:

$$(NH_2)_2CO + H_2O \longrightarrow CO_2 + 2(NH_3)$$

Urea hydrolysis is catalyzed by urease, an enzyme produced by many bacteria and some plants, and thus, is ubiquitous in soils. The biological degradation of urea by urease that releases the N for plant use also makes it subject to volatilization (as $NH_3$, a gas) depending on whether the reaction occurs in the soil or on the soil surface. If within the soil, the ammonia quickly reacts with soil water to form $NH_4^+$, which is then bound to the soil. If it occurs at the soil surface, the gaseous ammonia can easily be lost into the air. If plant residue is abundant on the soil surface, it increases bacterial populations, concentration of urease, and volatilization losses of urea.

***UAN solutions*** are mixtures of urea, ammonium nitrate and water in various proportions. All common UAN solutions (28%, 30% and 32%) are formulated to contain 50% of actual N as amide (from urea), 25% as ammonium (from ammonium nitrate) and 25% as nitrate (from ammonium nitrate).

**Soil Reactions** - The urea portion of UAN solutions reacts just as dry urea does (see previous section on urea). If applied on the surface, the amide-N in the solution may incur losses due to volatilization, but if UAN is incorporated by tillage or sufficient water, the $NH_3$ quickly reacts with soil water to form $NH_4^+$. This $NH_4^+$, as well as the $NH_4^+$ derived from ammonium nitrate in the solution, adheres to soil components at the application site and is not subject to immediate losses. Like N applied as anhydrous ammonia, this N will either be taken up by plants in the $NH_4^+$ form or converted to $NO_3^-$ by soil bacteria.

The remaining 25% of N in UAN solutions is in the nitrate ($NO_3^-$) form. Because it is negatively charged, it will not adhere to clay and organic matter particles (which are also negatively charged) but rather, will exist as an anion in the soil solution. Because it moves with water, it is easily taken up by plant roots but is also subject to losses by leaching and denitrification. Leaching is defined as moving below the root zone of plants; denitrification is loss of nitrate to the air as $N_2$ gas under anaerobic conditions (flooded or saturated soils).

## Nitrogen Stabilizers / Additives

***Nitrification inhibitors*** are compounds that slow the conversion of ammonium to nitrate, thus prolonging the period of time that nitrogen is in the "protected" form and reducing its loss from the soil. Several compounds have proven effective for this purpose, but only nitrapyrin and DCD (dicyandiamide) have current widespread use in North American agriculture.

**Nitrapyrin,** 2-chloro-6-(trichloromethyl) pyridine, works by inhibiting *Nitrosomonas* bacteria. Nitrapyrin has a bactericidal effect, actually killing part of the *Nitrosomonas* population in the soil. Thus, it is effective until the bacterial population recovers in the zone of application and diffusion. Its activity is very specific to *Nitrosomonas.* Nitrapyrin products for delaying nitrification of ammoniacal and urea fertilizers include N-Serve® 24 (launched in 1976) and Instinct® (launched in 2009).

**DCD (dicyandiamide)** - Products containing only DCD are generally used with N solutions and liquid manure. In the U.S., products that contain DCD include Guardian®-DF, Guardian®-DL 31-0-0, Guardian®-LP 15-0-0 and Agrotain® Plus.

**When to Consider Nitrification Inhibitors** - The highest value of nitrification inhibitors should be realized when $NO_3^-$ losses are expected to be high from leaching or denitrification, including these conditions: tile-drained soils when leaching potential is high, wet or poorly drained soils, and fields with preplant N application. On the other hand, nitrification inhibitors are usually least valuable when $NO_3^-$ losses are unlikely, for example, when N is applied sidedress, as crop demand is high at this time (Ruark, 2012).

***Urease inhibitors*** are compounds that inhibit the action of the urease enzyme on urea and thus, delay urea hydrolysis. This allows some time for urea to be incorporated into the soil (e.g., by rainfall) where volatilization losses are unlikely when hydrolysis occurs. Only one product has been widely used in agriculture as a urease inhibitor. That product, N-butyl-thiophosphoric triamide or NBPT, is a structural analog of urea and as such, inhibits urease by blocking the active site of the enzyme. NBPT is the active ingredient in the Agrotain family of urease-inhibiting products.

**Agrotain®**, with the active ingredient NBPT, is an additive for use primarily with urea (applied to urea by the retailer) and secondarily with urea-ammonium nitrate solutions. **Agrotain® Ultra** is a more concentrated formulation of Agrotain. (Most Ontario outlets are handling Agrotain Plus )

Eventually, these products degrade, allowing urea hydrolysis to naturally occur. Once in the $NH_4^+$ form, N from urea is subject to denitrification to $NO_3^-$, a form that may be lost from the soil. Agrotain and Agrotain Ultra provide no activity against nitrifying bacteria.

**Agrotain® Plus** is an additive specifically for UAN solutions, according to the product label. Agrotain Plus contains both the urease inhibitor NBPT and the nitrification inhibitor DCD. Thus, it acts against both the volatilization and nitrification processes that lead to N losses from UAN solutions. However, it does not protect the portion of the solution originally in the nitrate form (i.e., the 25% of the N content of the solution derived from nitrate in ammonium nitrate).

**When to Consider Urease Inhibitors** - Urease inhibitors may be considered when the incorporation of broadcast urea-containing fertilizers cannot be accomplished within 2-3 days of application or a quarter inch of rainfall is not anticipated. Research shows that N loss from surface-applied urea can be significant; loss is greatest with warm, windy weather and a moist soil surface. Urease activity increases as temperature increases; thus, hydrolysis is normally completed within 10 days at a temperature of 40° F and within 2 days at a temperature of 85° F. Hydrolysis is also highly correlated with the organic matter, total N and cation exchange capacity (CEC) of the soil and increases as any of these factors increase. Urease inhibitors help prevent volatilization, potentially for two weeks or more, thus increasing the chances that rainfall will incorporate urea before losses occur.

## Performance of N Stabilizers

N stabilizers/additives have been widely tested over many years. Research results vary widely, from no advantage to yield increases of more than 20%. This is not surprising; when conditions favor N losses for a period and an N stabilizer has been applied (and is not yet degraded), a large benefit is predictable. On the other hand, in conditions not conducive to N losses, little advantage would be expected. Therefore, N stabilizers can be considered as "insurance" to help protect against N losses should conditions develop that favor losses.

Regional performance differences for N stabilizers are expected, as soil and climate factors vary greatly across regions of North America. Soils differ by texture, drainage, organic matter, pH, slope and other variables. Climate differs by temperature extremes and durations, rainfall amounts and patterns and other variables. Because of these geographical differences, making decisions about the value of N stabilizers in each farming operation is complex. In order to make the best decisions, research results that represent your field and climate should be examined, and local prices for N fertilizers and stabilizers should be used.

This decision should take into account all factors that influence the risk of N loss for a particular field. These include geographic location; topography; soil type; residue level; form of N fertilizer applied; timing of application relative to crop growth; expected rainfall, temperature and soil moisture levels; and other factors. Even so, N stabilizers will not be cost effective every year, especially when conditions are not conducive for N losses. However, N stabilizers can provide some insurance against the risk of N losses in many susceptible fields. What may be of greater importance is your awareness that far more substantial N losses can be associated with liquid or dry preplant Urea N sources and that sidedressing offers far less risk of N losses in either a very dry or very wet year.