FACT SHEET

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ENHANCED EFFICIENCY NITROGEN FERTILIZERS

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Introduction

Most nitrogen (N) fertilizers are either ammonium (NH_4^+), nitrate (NO_3^-), or urea ($CO(NH_2)_2$). Fertilizer that is applied to fields but not used by crops can be lost. Lost nitrogen from fertilizer can impair water quality (fish kills from ammonia (NH_3) in surface water; nitrate (NO_3^-) contamination of groundwater) or air quality (smog from atmospheric ammonia; nitrous oxide (N_2O) as a greenhouse gas), as well as hurt the grower's bottom line. Some of these losses are unavoidable, but it makes sense and cents to keep them as low as possible.

This factsheet will describe the various methods used to improve the efficiency of nitrogen fertilizers, the impact they will have on the various loss pathways for nitrogen (Figure 1), and how they may fit into common nitrogen management systems in Atlantic Canada.

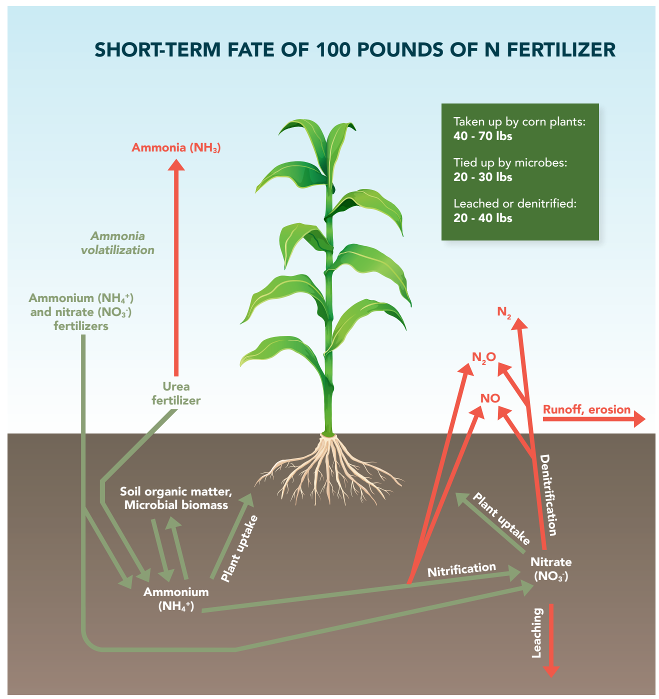

Figure 1. It is important to keep in mind the different pathways of the nitrogen cycle when thinking about nutrient use efficiency and nitrogen loss.

Controlled-Release Fertilizers

Controlled-release fertilizers have a coating (Figure 2) added around the granules to delay the release of the fertilizer into the soil in a controlled manner. This will protect nitrogen from loss if the fertilizer is applied before the crop is ready to absorb the nitrogen, or it can extend the timing of nitrogen release over a period of time. The thin polymer coatings do not add a lot of extra weight to the fertilizer, so there is no significant effect on transport or application costs.

Polymer Coated Urea

The most common polymer coated urea for agricultural use is Environmentally Smart Nitrogen (ESN®), although there are other products (e.g. PurYield™, Osmocote®, etc.). The polymer coating allows water to diffuse into the granule and dissolve the urea inside, then the dissolved urea slowly diffuses through the coating depending on the temperature and moisture in the soil. The delay in nitrogen release is from 2-6 weeks, depending on product and conditions. The polymer coating is biodegradable, so there is nothing left in the soil at the end of the season.

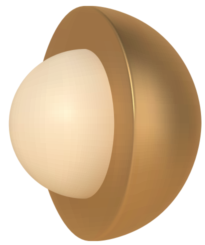

Figure 2. The polymer coating around a urea prill slows the release of the nitrogen fertilizer to better align with crop need.

Polymer coated urea may be eligible for funding to cover the difference between regular and enhanced fertilizers under the On-Farm Climate Action Fund. For more information, please visit: **ofcaf.perennia.ca**

Delaying the release of urea will reduce the concentration of free ammonia (NH_3) as the urea breaks down. This can theoretically reduce the loss of ammonia to the air from fertilizer applied to the surface, so more of the applied nitrogen is available to the crop, but at least one study showed greater NH_3 volatilization from ESN than urea (Jantalia et al., 2012). There have been studies showing improved crop safety if protected urea is banded with the seed at planting (Malhi & Lemke, 2013), although this is not a common practice outside the prairie provinces. The agronomic value of delayed release could be supplying nitrogen from a preplant application to crops that do not require most of their nitrogen until later in the season (e.g. corn, late-potatoes, storage cabbage). This could replace the need for a side-dress application, or increase the efficiency of spring applied N. When using polymer coated urea in a pre-plant application, differences are often only seen if there is excessive rainfall between planting and sidedress time to cause nitrogen losses, so not every trial has shown an advantage. For shorter season crops (e.g. small grains, canola, short-season vegetables), delaying the release of nitrogen may reduce nitrogen availability when the crop needs it most, so there would be little advantage to using a polymer coated urea.

The term "plant-available nitrogen" is commonly used to refer to forms of nitrogen that plants most readily absorb, largely ammonium (NH_4^+) and nitrate (NO_3^-). These forms can come either through fertilizer or through mineralized nitrogen from organic sources and organic matter.

Slow-Release Fertilizers

These fertilizers have either inert coatings or are chemically composed to delay the release of urea. The release is less predictable than from polymer coated urea.

Sulfur Coated Urea

This material is used in some turf fertilizers to extend the release of nitrogen to the grass and keep it green. A coating of elemental sulfur is gradually consumed by bacteria in the soil, releasing the urea inside. The rate of release will depend on the thickness of the coating. The coating can make up 25% of the weight of the fertilizer, so transportation costs are increased. This, along with the cost of the coating itself, has typically made this material uneconomical for the agricultural market.

Urea-triazone or Methylene Urea Compounds

When urea is reacted with methylene under controlled conditions, it forms either long chain (methylene urea) or cyclic (urea-triazone, N-Sure®) compounds. These are broken down slowly by microbial action, releasing the urea into the soil solution over a period of up to 16 weeks. N-Sure® is marketed in liquid formulations with 26 to 28% nitrogen used in foliar applications or drip irrigation. Advantages to these materials is lower risk of leaf injury in foliar applications compared to urea solutions, compatibility with most other fertilizer materials, and reduced ammonia volatilization, but high cost has limited its use to specialty crop applications.

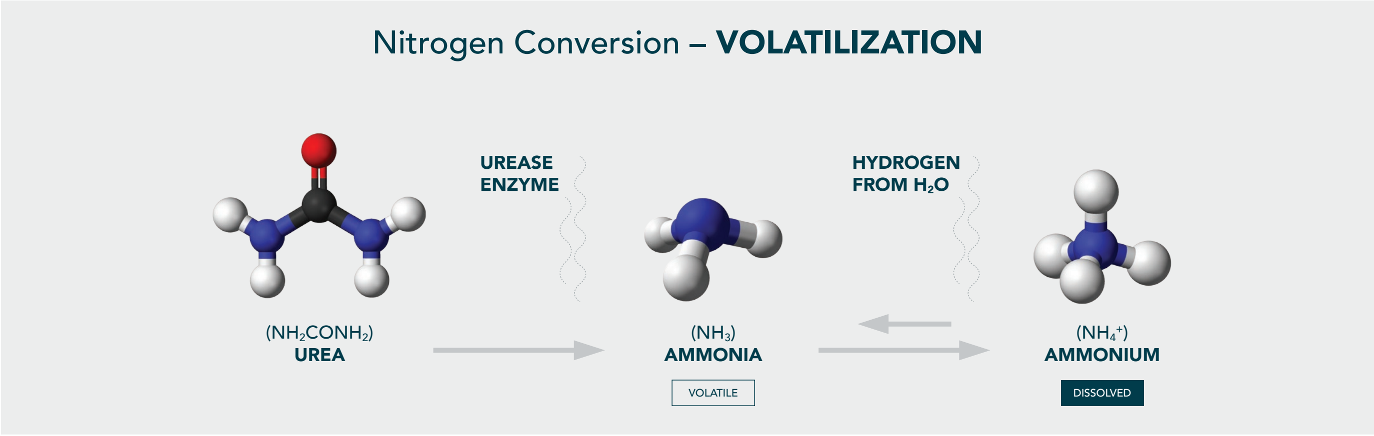

Figure 3. Urea is broken down in the soil to release ammonia (NH_3) and ammonium (NH_4^+).

Urease Inhibitors

Urea is broken down into carbon dioxide and ammonia with the help of the urease enzyme, a process than can be completed within a few days in warm, moist soils (Figure 3). Urease inhibitors block this enzyme, delaying this transformation. The most common products are marketed as Agrotain®, Limus® or ENpower® (See Table 1). This can be added as a coating on urea granules or mixed with Urea-Ammonium Nitrate (UAN) solutions. There is some suggestion that ammonium thiosulfate acts as a urease inhibitor but research has shown that it is only effective when used at very high rates which are toxic to crops (McCarty et al., 1990). Normal use rates of ammonium thiosulfate as a sulfur fertilizer have no inhibitory effect on urease.

Placing urea below the soil surface, either by injection or incorporation following broadcast, reduces ammonia losses (Woodley et al., 2020) so there is little additional nitrogen retention to be gained from adding inhibitors where the nitrogen fertilizer is going to be incorporated.

The biggest impact of urease inhibitors is reducing the loss of ammonia to the atmosphere, particularly with surface applications. This ammonia loss is a direct cost to the grower, since it is no longer available to the crop in the field where it was applied, and can also indirectly lead to greenhouse gas emissions as nitrous oxide when it is re-deposited.

Stabilized Nitrogen Fertilizers

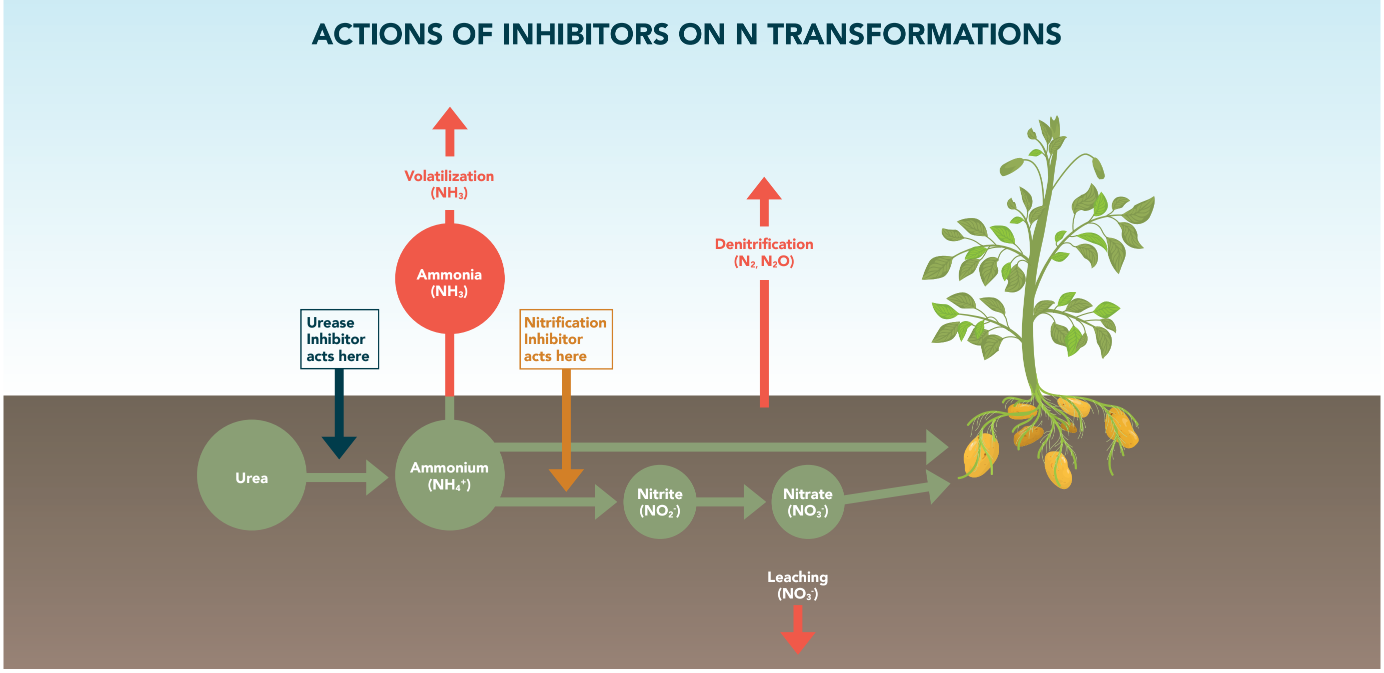

Figure 4. The mode of action of urease and nitrification inhibitors for reducing nitrogen losses.

Nitrification Inhibitors

Ammonium (NH_4^+) is held in the soil by the cation exchange capacity similar to other cations (positively charged ions) such as potassium (K^+), calcium (Ca^{2+}) or magnesium (Mg^{2+}). Most of the NH_4^+, however, is quickly converted to nitrate (NO_3^-) in the soil, which is mobile in soil water. Nitrification inhibitors block this process, either by inhibiting the growth of nitrifying bacteria or blocking the enzyme which aids the process, thus keeping the nitrogen in the ammonium form (Figure 4). Nitrification inhibitors sold in Canada include N-Serve®, Instinct®, Didin® and Centuro® (See Table 1).

While nitrate (NO_3^-) is the form of nitrogen absorbed by plant roots in the largest amounts, it is also the most subject to loss. Nitrous oxide (N_2O), which is a powerful greenhouse gas, can be released (lost as a gas) both during the conversion from ammonium to nitrate and when denitrification occurs in saturated soils. During denitrification, bacteria that cannot get adequate oxygen

from soil air will instead scavenge oxygen from nitrate, releasing some as nitrogen gas and some as N_2O (a greenhouse gas). Reducing the concentration of nitrate in the soil, particularly during times when the soil is more likely to be saturated, will reduce the risk of N_2O emissions. Nitrate that is in the soil when there is deep drainage occurring, mostly in the late fall through early spring periods, can also be carried downwards into aquifers, or out into estuaries and bays. Elevated nitrate in groundwater impairs its quality for drinking water, while high nitrate in brackish or marine environments can lead to harmful algae blooms.

The measured impact of nitrification inhibitors on crop yields is inconsistent, particularly for spring applied nitrogen. A meta-analysis of nitrification inhibitors showed a mean yield increase of 7.5%, but there were many trials within this with no yield increase at all (Abalos et al., 2014). This may arise from experiments where the application rate of nitrogen to the trial was high enough that even where nitrogen losses occurred there was sufficient nitrogen for the crop. A few studies showed increased NH_3 losses where nitrification inhibitors were used, presumably because delaying nitrification allowed higher concentrations of ammonium-nitrogen near the soil surface where it could volatilize. Alternatively, there may not have been conditions that led to nitrate loss during the experiment (i.e. wet soils), so even though the inhibitor delayed nitrification there was no effect on nitrogen availability to the crop.

While *yield* responses from the use of nitrification inhibitors is inconsistent, a much larger and more consistent reduction in *nitrous oxide emissions* have been documented when nitrification inhibitors are used.

Dual Inhibitor Products

As the name suggests, these products contain both urease inhibitors and nitrification inhibitors. The two products currently marketed in Canada are SuperU®, which is a pre-formulated granular material, and Agrotain Plus® which is a liquid formulation that can be mixed with liquid fertilizers or manure (See Table 1). By combining the actions of both inhibitors, the magnitude of the effects on reducing nitrogen losses is increased, as well as the chance that fertilizer response will be improved.

As with the individual inhibitors, if the conditions for nitrogen losses are not present, the impact of the inhibitors will be minimal.

These combination products (Urease + Nitrification Inhibitors) may be eligible for funding to cover the difference between regular and enhanced fertilizers under the On-Farm Climate Action Fund. For more information, please visit: **ofcaf.perennia.ca**

Table 1. Summary of Stabilized Nitrogen Fertilizers

Mode of Action	Trade Names	Active Ingredient	Compatible Products
Urease inhibitor	Agrotain Limus ENpower	N-(n-butyl) thiophosphoric triamide (NBPT)	Urea UAN solutions
Nitrification inhibitor	N-Serve Instinct	Nitrapyrin	Anhydrous ammonia Urea Manure
	Didin	Dicyandiamide (DCD)	Urea UAN solutions
	Centuro	Pronitradine	Anhydrous ammonia Urea solutions UAN solutions
Dual inhibitor (Urease + Nitrification)	SuperU	NBPT + DCD	Formulated into granules with urea
	Agrotain Plus	NBPT + DCD	UAN Manure

Where do enhanced efficiency nitrogen fertilizers fit in farming systems?

The key to benefiting from enhanced efficiency fertilizers is to understand where the greatest risk of nitrogen losses occurs in your operation (Figure 1) and to use a fertilizer with a mode of action that will address that risk. Inhibitors will have the greatest impact on nitrogen losses in scenarios where risks of losses are already high (i.e. surface application, wet conditions).

Inconsistent increases in yield may stem from nitrogen applications that are greater than optimum, so even with losses there is adequate nitrogen to meet the needs of the crop. With surface applied urea or UAN, where NH_3 losses can be significant, a moderate rainfall that washes the nitrogen into the soil does the same as a tillage pass so the nitrogen is protected from loss. Enhanced efficiency nitrogen fertilizer is better thought of as insurance against nitrogen losses under unfavourable conditions rather than a guaranteed improvement in nitrogen use efficiency.

In Atlantic Canada, producers are more likely to see yield gains and reduced losses to volatilization and leaching when nitrogen best management practices are used: split applications, incorporating fertilizer (i.e. tillage, injection, timing application before rainfall), and targeted applications (i.e. banding).

Consistent reductions in nitrous oxide emissions from using stabilized nitrogen fertilizers seem to arise from limiting the amount of nitrate produced at any one time, so there is less opportunity for nitrous oxide to be produced from either the nitrification or denitrification process. This appears to be independent of any impacts on other nitrogen losses. Using the dual inhibitors on fertilizer has a much larger effect than reducing nitrogen rates, so nitrous oxide emission reduction does not mean sacrificing crop yield (Burton, 2018).

Changing nitrogen management by reducing rates, switching from surface to subsurface application, or applying closer to when maximum crop uptake occurs, may have as much or greater impact on nutrient use efficiency from nitrogen applications as using an enhanced efficiency fertilizer.

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