

# **Comparative Analysis of Enhanced Nitrogen Fertilizers on Canola**

Janelle MacDonald

A thesis submitted to the Department of Plant Sciences

In partial Fulfillment of the Requirements for an Undergraduate Research Thesis

April, 2010

Table of Contents

Abstract.....	5
1. Introduction.....	6
2. Enhanced Nitrogen Fertilizers .....	8
2.1 Nitrification Inhibitors .....	11
2.2 Urease Inhibitors .....	15
2.3 Controlled Release Nitrogen.....	19
3. Materials and Methods.....	23
3.1 Experimental Design.....	23
4. Results and Discussion .....	25
5. Conclusion .....	30
6. References.....	32

List of Figures

Figure 1 The Nitrogen Cycle .....	7
Figure 2 How ESN works .....	21
Figure 3-The arrangement of treatments in the trial. ....	24
Figure 4 Plant nitrogen uptake .....	26
Figure 5 Plant phosphorus uptake .....	27
Figure 6 Seed Yield .....	27

List of Tables

Table 1 Common enhanced efficiency fertilizers (EEF`s) .....	11
Table 2 Pre-seed Soil Sample. ....	25
Table 3 0-30 cm post-harvest soil sample residual NO <sub>3</sub> and NH <sub>4</sub> .....	28
Table 4 30-60 cm post harvest soil sample residual NO <sub>3</sub> and NH <sub>4</sub> .....	30

Acknowledgement

Advising by Dr. Jeff Schoenau and financial support of International Plant Nutrition Institute is gratefully acknowledged.

## **Abstract**

There are many different types of enhanced nitrogen fertilizers available. This study was conducted with three different enhanced nitrogen products: 1) Super U, a urea product treated with a urease (NBPT) and nitrification (DCD) inhibitor; 2) Nutrisphere N, which uses a stabilizer/ inhibitor of Malic+ itaconic acid co-polymer with urea; and 3) ESN, which is a polymer-coated urea that affects the rate of release. These products were compared to conventional Urea (46-0-0) and to a control treatment that contained no nitrogen addition. The experiment took place near Plenty, Sk., in the 2009 growing season as a replicated field scale trial. There were four replicates of the five treatments. The product was applied at the time of seeding using a side banding application of 45 kg/ha of actual N for each fertilizer. Sulphur and phosphate were applied as a blanket application at the same rate across all treatments. The crop was Nexera 845 CL canola (*Brassica napus*). Due to extreme drought conditions in this area in the early part of the cropping season, the crop was very slow to germinate and emerge. The Super U product produced the highest yield, with ESN, Nutrisphere and Urea producing similar yields that were about 400 kg/ha greater than the control. The Super U treatment had the highest nitrogen uptake followed, in order, by ESN, Nutrisphere N, Urea, and finally the unfertilized control. Due to the drought conditions, the Super U treatment may have had the highest yield, nitrogen uptake and recovery due to decreased ammonia volatilization attributable to the urease inhibitor contained in the product.

## 1. Introduction

In 1950, fertilizers comprised only a small percentage of the nutrients needed for grain production, with most of the supply being provided by the “natural fertility” of the soil, and added manure. By 2020, more than 70% of the grain yield will have to depend on fertilizers; the demand for plant nutrients is expected to increase with population growth, particularly in developing countries (Shaviv, 2001). Producers on the Canadian Prairies have traditionally attempted to optimise nutrient use efficiency by choosing specific combinations of the nutrient source, timing, placement and rate of application to minimize nutrient losses from the system and optimise the amount of applied fertilizer that is taken up and used by the plant, therefore increasing crop yield and quality (Grant and Dowbenko, 2008). Even with these methods to increase the efficiency of nutrient use, nitrogen use efficiency (NUE) has been estimated to range from 30% to 50% in the year of application (Grant and Dowbenko, 2008; Baylock et al, 2005; Grant, 2005). Although more than 75% of fertilizer applied in the prairies is applied using some form of in-soil banding to reduce the risk of nutrient loss or conversion to unavailable forms prior to crop uptake (Grant and Dowbenko, 2008), an extra application separate from seeding is often necessary to attain required levels of nitrogen, however these extra applications increase time, labour, fuel, and equipment. If the required amount of nitrogen was applied at the time of seeding, it would improve the NUE and eliminate the need for a separate application, however the amount of N that can be safely applied with the seed without causing seedling damage is often lower than the required amount to optimise crop yield and quality (Grant and Dowbenko, 2008). As shown in Figure 1, N can be lost from the crop through denitrification, runoff, volatilization, immobilization, or leaching (Baylock et al, 2005; Malhi et al, 2001). Not only does this cost the farmer to apply more fertilizer to account for these losses, but it also raises

concerns about water contamination, and greenhouse gas emissions. By increasing the NUE, we can reduce the N losses.

Enhanced efficiency nitrogen fertilizers (EEFs) reduce nutrient losses by reducing the exposure of the fertilizer to the pathways of loss for nitrogen, and increase nutrient availability by either slowing release or altering reactions that lead to losses (Olson-Rutz et al, 2009; Grant and Dowbenko, 2008). EEF's can spread out the release of nitrogen over the growing season, attempting to match the N supply to the plant nutrient demand over time (Olson-Rutz et al, 2009), which provides adequate and consistent nutrient availability, reducing plant stress which may result in increased yields.

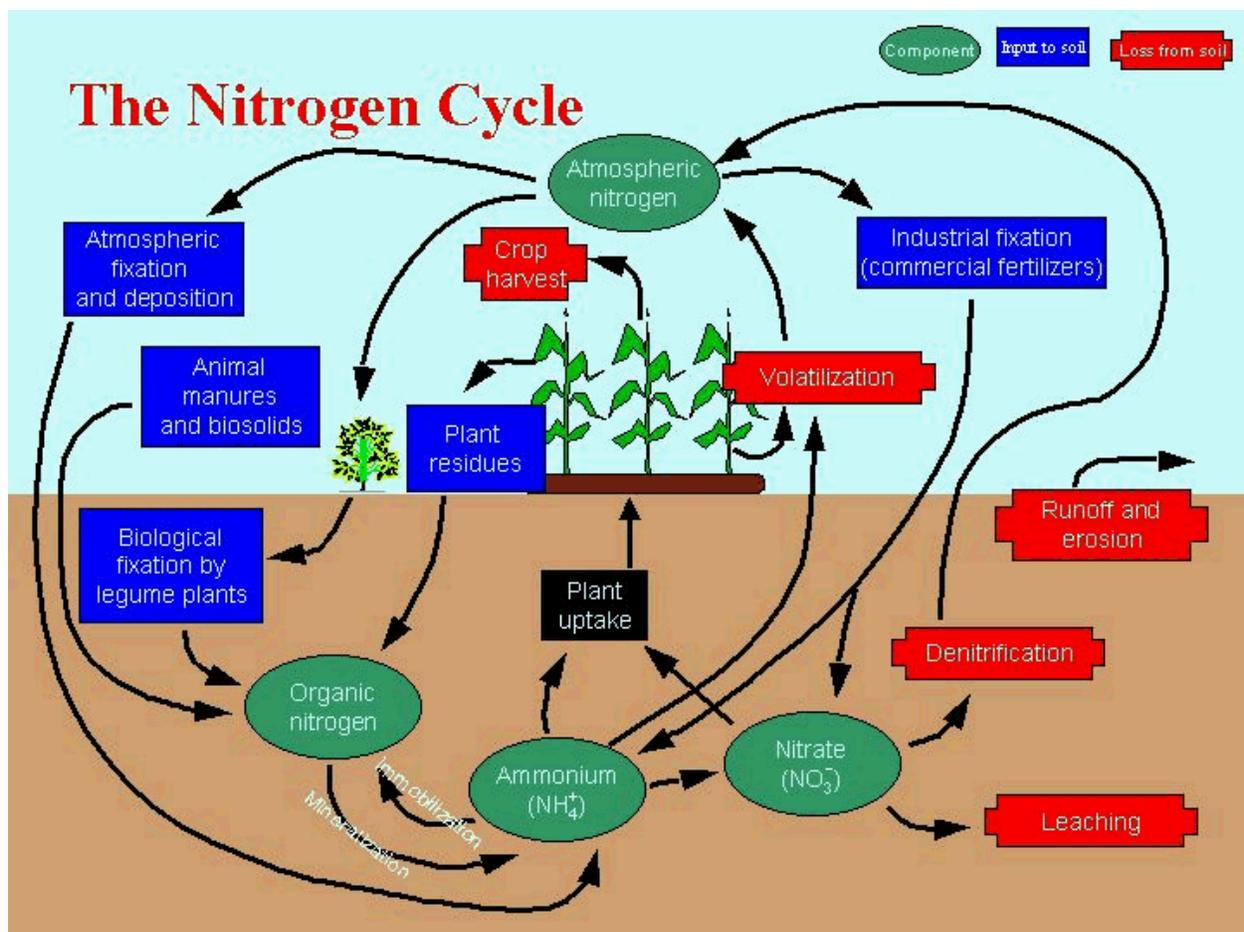


Figure 1 The Nitrogen Cycle

Modern technology in allowing the manufacturing of synthetic nitrogen (the Haber-Bosch process) has allowed a large scale access to use of N<sub>2</sub> in the atmosphere as the major source of nitrogen, unfortunately becoming mass pollutants in both water and the atmosphere.

There are many different types of enhanced nitrogen fertilizers in today's market. Enhanced nitrogen, also known as slow-release or controlled-release nitrogen has many benefits to many different sectors. Environmentally, enhanced nitrogen fertilizer is an active tool to help sustain the environment while growing food for the world. For the farmer, the cost of these products is becoming more justifiable as the price of urea increases, due to the decrease in environmental losses that these enhanced fertilizers provide. As well, these products have often shown an increase in yield when applied, sometimes up to 20% (Baylock et al, 2005).

The objective of this trial is to better understand the effects of enhanced nitrogen in Western Canadian soils. By comparing three different nitrogen inhibitors under the same conditions, this trial will provide a better understanding of which product benefits Saskatchewan soils more, and how all products compare to conventional urea.

## **2. Enhanced Nitrogen Fertilizers**

As seen in figure 1, there are a number of pathways, mostly involving nitrogen transformations, which potentially result in losses from the nitrogen cycle and have ecological and cost-related consequences. The longer the N is in the soil solution before plant uptake, the greater the potential for losses, particularly under wet conditions (Grant, 2005). The five most common N losses, erosion, leaching, denitrification, volatilization, and immobilization, are generally somewhat amenable to control through management practices (Frye, 2005).

**Soil erosion** removes nitrogen in many forms by transporting mineral and organic soil particles, soil microorganisms, and both inorganic and organic forms of nitrogen dissolved in the surface runoff water that produces the erosion (Frye, 2005).

**Leaching**, usually of  $\text{NO}_3^-$ , is one of the most important nitrogen-loss pathways in humid climates. Large quantities of nitrogen can be lost from soil by leaching, resulting in both undesirable economic and environmental consequences.

**Denitrification** is the major reductive fate of  $\text{NO}_3^-$ , the product of nitrification, in most soil environments. It is a multi-step process catalyzed by distinct enzymes for each step, producing gaseous forms of nitrogen including  $\text{N}_2\text{O}$  and  $\text{N}_2$  (Frye, 2005).

**Ammonia volatilization** occurs during hydrolysis of urea and can result in losses of 10 to 50% of the nitrogen from surface-applied urea fertilizers. Surface-applied ammonia and urea fertilizers are a source of  $\text{NH}_3$  volatilization (Shaviv, 2001). Ammonia volatilization due to urease activity is given as one explanation for the loss of 3 to 50% of the nitrogen in unincorporated animal manures, such as poultry litter, when applied to near-neutral soils (Frye, 2005) The rate of conversion and hence the risk of denitrification and leaching losses increases with increasing soil temperature and moisture (Grant and Dowbenko, 2008).

**Nitrogen immobilization** represents a significant temporary loss in availability of nitrogen. Immobilization increases with the presence of substrate with a high C:N ratio; about 30 and higher) (Malhi et al, 2001). Rapid microbial growth, especially on a high C:N-ratio substrate is conducive to immobilization of inorganic nitrogen as the microorganisms assimilate the available nitrogen into amino acids. Although immobilization temporarily renders part of the inorganic nitrogen unavailable, it retards nitrogen loss from the soil (Frye, 2005).

By reducing these losses, we improve the NUE of the crop. One of the key ways to improve a crop's NUE is to avoid over-application of N, as N losses tend to be proportional to solution concentration (Grant, 2005). The issue with reducing applied amounts, however, is that farmers take into account how much of the application will be lost when applying, so to reach optimal yields, over application is often necessary. While split applications of N, timed to the demand of the crop, may improve the NUE, these multiple applications may be impractical for lower value crops in non-irrigated broad area agriculture, due to the extra cost associated with split application (Grant, 2005). To improve NUE, information is needed to reduce N losses. As well, increased knowledge into how to improve predictions of N requirements and N rates, matched more closely to crop needs to optimize crop yield, would aid in improved NUE (Grant, 2005). Enhanced efficiency nitrogen fertilizers (EEF's) act by reducing the exposure of the fertilizer to the pathways of loss for nitrogen in the plant-soil system. Most chemical N fertilizers supply N as ammonium ( $\text{NH}_4^+$ ), nitrate ( $\text{NO}_3^-$ ), or as urea, which converts rapidly to  $\text{NH}_4^+$  through the action of the urease enzyme. As seen in table 1, there are many types of EEF's on today's market, each with different processes that they affect to reduce the loss of fertilizers.

Type and Chemical	Common name(s)	Affected Process
<b>Stabilizers and Inhibitors</b>		
2-chloro-6 (trichloromethyl) pyridine (Nitrapyrin)	N-Source®, N-Serve®, Instinct®	Nitrification
Dicyandiamide (DCD)		"
4-amino-1,2,4-triazole hydrochloride (ATC)		"
N-butyl-thiophosphoric	Agrotain®	Volatilization

triamide (NBPT)		
Malic+ itaconic acid co-polymer with urea	Nutrisphere-N® (NSN)	Nitrification
<b>Controlled- and Slow- Release</b>		
Polymer-coated (PCU)	ESN®, Polyon®, Duration®	Release
Sulfur-coated	SCU	"
Polymer + sulfur-coated	Tricote, Poly-S®	"
Urea formaldehyde	Nitroform®	"
Methylene urea	Nutralene®	"
Triazone	N-Sure®	"
<b>Blends</b>		
NBPT + DCD	Agrotain®Plus, SuperU®	Nitrification, Volatilization
Methylene urea + triazone	Nitamin®, Nitamin Nfusion®	Release
<b>Other</b>		
Malic+ itaconic acid co-polymer with MAP	Avail®	Decreased P mineral precipitation

**Table 1 Common enhanced efficiency fertilizers (EEF`s). Source: Montana State**

**University. Olson-Rutz et al, 2009.**

## 2.1 Nitrification Inhibitors

Nitrification refers to the aerobic conversion of ammonia to nitrite ( $\text{NO}_2^-$ ) and nitrate  $\text{NO}_3^-$

(Grant and Dowbenko, 2008; Frye, 2005). Products that inhibit enzyme activity seek to delay the

breakdown of urea (hydrolysis) or the conversion of ammonium to nitrate (nitrification)(Ruark, 2010). Nitrification inhibitors slow the oxidation of  $\text{NH}_4^+$  to  $\text{NO}_3^-$  and so directly reduce the amount of  $\text{NO}_3^-$  produced (Grant, 2005), by reducing the activity of *Nitrosomonas* bacteria in the soil. These bacteria transform ammonium into nitrite, which in turn is oxidized to nitrate by *Nitrobacter* bacteria (Diez-Lopez et al, 2008) Because nitrate is negatively charged, it is not held on the cation exchange capacity (CEC), in contrast to ammonium which is positively charged and retained on the CEC. Because nitrate is soluble, it moves readily into solution where it can move by leaching below the rooting zone and into the groundwater. Products of the nitrification process are of environmental concern. The greenhouse gases nitrous oxide and nitric oxide ( $\text{NO}$ ) are intermediate products of the nitrification process. Nitrate can leach into the groundwater, leading to health concerns and eutrophication; under anaerobic conditions nitrate can be reduced to  $\text{N}_2\text{O}$  and  $\text{N}_2$  gasses and can be lost to the atmosphere. This process is termed denitrification. The higher the losses by leaching and denitrification, the lower the fertilizer use efficiency and the lower the economic benefit of the fertilizer applied (Grant and Dowbenko, 2008).

As seen in table 1, a number of nitrification inhibitors are available on the market, such as 2-chloro-6 (trichloro-methyl) pyridine (Nitrapyrin), Dicyandiamide (DCD), and 4-amino-1,2,4-triazole hydrochloride (ATC). DCD and ATC are two of the most common commercial nitrification inhibitors that have been extensively studied for retarding the nitrification of applied N in soils (Aulakh et al, 2001). Also in this category is Nutrisphere-N (NSN), a combination of Malic+ itaconic acid co-polymer with urea. Specialty Fertilizer Products, the manufacturer of NSN, report increased plant N-availability due to a reduction in volatile ammonia loss and reduced nitrification. The product is reported to work by sequestering multivalent cations such as

nickel, copper and iron in the soil solution around the urea granule: Nickel is required for the urease enzyme to function. The sequestered nickel is not available to the enzyme and therefore the urease is ineffective at hydrolyzing the urea (Grant and Dowbenko, 2008). A new product, 3,4-dimethylpyrazole phosphate (DMPP) also shows promising results in trials. DMPP is a nitrification inhibitor developed by BASF (Limburgerhof Research Centre, Germany), which inhibits only the first stage of nitrification. Diez-Lopez et al (2008) found that treatments with DMPP maintained higher soil N levels than the urea treatments, as well as reduced N losses through  $\text{NO}_3^-$  leaching, using DMPP. Nitrotyrin and DCD are the two major nitrification inhibitors that have been evaluated and marketed in Canada (Grant and Dowbenko, 2008). Field studies conducted in north-central Alberta showed that ATC, nitrotyrin and thiourea were all effective in inhibiting nitrification of fall-banded urea fertilizer under conditions where the fall applications were subject to nitrification losses (Malhi and Nyborg, 1988). Nearly all of the fall (October) applied N was nitrified in the plots without inhibitors, while the Enhanced nitrogen products retained 31% of the applied N as  $\text{NH}_4^+$  in the spring (May). However, crop yields were not necessarily increased consistently with the use of the inhibitors. If fall fertilizer applications were banded late in the season when soil temperature was close to freezing, losses were minimal and use of the inhibitor provided no significant additional benefit. (Malhi and Nyborg, 1988).

Environmentally, nitrification inhibitors should provide benefits in areas where denitrification or leaching losses would otherwise be high. Nitrification produces both nitrous oxide and nitric oxide as intermediate products. Nitrous oxide is a potent greenhouse gas while nitric oxide can destroy stratospheric ozone (Frye 2005). Nitrate in the soil solution can move into ground and surface water, where it can create negative environmental and health effects. Slowing the

conversion of ammonium to nitrate will reduce the concentration of nitrate present in the soil solution and so reduce the potential production of gaseous nitrous oxide and the risk of nitrate leaching. Environmental benefits from nitrification inhibition can occur even under conditions where yield benefits are not observed (Grant and Dowbenko, 2008).

Both agronomic and environmental benefits of inhibition will be greatest under conditions that promote losses by leaching and denitrification, for example under wet soil conditions. Benefits are unlikely in dry or well-drained soils, where leaching and denitrification losses are limited. Adoption of use of nitrification inhibitors in the Canadian prairies has been low, primarily because they have not normally been shown to provide a significant benefit above traditional practices (Grant and Dowbenko, 2008). One reason for the lack of adoption of these products is that, until very recently, nitrogen fertilizer has been relatively inexpensive, thus growers have tended to use increased amounts to reach optimal yields, while still remaining profitable. Due to increased costs of nitrogen fertilizer, nitrification inhibitors could become more popular, as they could contribute to a higher NUE. As well, concern for environmental quality has been steadily rising for many years; educational efforts and societal pressure are going to encourage growers to adopt environmentally friendly management practices that conserve nutrients in the soil-plant system. A second important reason for the lack of mass adoption of these products is that they are inconsistent in field responses. Because nitrification inhibitors are reliant on many factors determining nitrogen losses from the soil relative to supply, growers who have used nitrification inhibitors don't consistently see a yield response when compared to urea (Frye, 2005).

## 2.2 Urease Inhibitors

One of the most promising ways to improve the efficiency of urea is to use a urease inhibitor (Watson 2005). Urea fertiliser is widely used in Canada, because it is the most concentrated granular N source available and it is of relatively low production cost in comparison to other nitrogen fertilizers. It is also used as a component in UAN. However, the efficiency of urea is decreased by losses of N as ammonia gas after the urea is hydrolysed at the soil surface by the reaction with the enzyme urease (Watson 2005). As well as monetarily affecting the farmer, the ammonia that is lost to the atmosphere from applied urea will eventually be deposited on land or in water causing eutrophication and acidification to the environment. If urea is placed too near the germinating seedling, it can lead to seedling damage, through both osmotic damage and direct ammonia toxicity (Grant and Dowbenko, 2008).

Urea itself is not directly damaging to seedlings or subject to volatilization loss. When urea is applied to the soil, it rapidly converts to ammonia ( $\text{NH}_3$ ) in a reaction catalyzed by the enzyme urease. The more rapidly the urea converts, the higher the concentration of  $\text{NH}_3$  present. The  $\text{NH}_3$  will also partially convert to  $\text{NH}_4^+$  and both  $\text{NH}_3$  and  $\text{NH}_4^+$  can damage germinating seedlings. Seedling damage and volatilization loss both increase with increasing concentration of  $\text{NH}_3$  in the solution and vary with fertilization level, soil properties and environmental conditions. (Grant and Dowbenko, 2008)

The Urease inhibitors slow the conversion (hydrolysis) of urea to ammonium ( $\text{NH}_4^+$ ), which will form from ammonia gas ( $\text{NH}_3$ ) reacting with water and other in the soil. The inhibitors therefore reduce the concentration of  $\text{NH}_4^+$  in the soil, in turn reducing the potential for  $\text{NH}_3$  volatilisation

or seedling damage (Olson-Rutz et al, 2009; Malhi et al, 2001). Delaying the conversion allows the urea to diffuse away from the application site, or gives more of a window for rain or irrigation to move the urea from the surface to the soil, and the  $\text{NH}_4^+$  concentration at the soil surface. This will increase the movement of urea throughout the soil (Watson, 2005) or move the urea away from the germinating seedling, reducing the potential toxicity, as well as reducing the ammonia volatilization that often occurs, especially under warm, high pH conditions (Grant and Dowbenko 2008; Olson-Rutz et al, 2009).

N-(*n*-butyl) thiophosphoric triamide (NBPT), is the most common urease inhibitor, and is the only one currently commercially available in Canada. It is effective in soils that have high potential for volatilization (high pH, sandy texture) and/or not enough moisture to draw the urea away from vulnerable seedlings when seed-placed. Agrotain has successfully passed extensive toxicological and environmental tests, and the inhibitor degrades after approximately 10-14 days (Watson, 2005). Since NBPT degrades in 10-14 days, it can only delay urea hydrolysis for several days to a couple of weeks, however, this often provides time for sufficient rainfall to move the urea into the soil where it is much less susceptible to volatilization. NBPT-urea appears to be even more effective at reducing volatilization on coarse than fine soils (Olson-Rutz et al, 2009). Three formulations containing NBPT are produced by Agrotain International. Agrotain is a clear green mixed solvent additive containing 20-25% of the active ingredient NBPT, which is typically mixed and applied with urea or UAN (Watson, 2005). Agrotain Plus is a dry concentration containing both NBPT and the nitrification inhibitor dicyandiamide (DCD) that is designed to be added to UAN for surface applications. Super U is granular urea pre-coated with DCD and NBPT. Inclusion of both the nitrification inhibitor and the urease inhibitor should

reduce the potential for losses by volatilization, denitrification and leaching (Grant and Dowbenko, 2008).

Many of the soils on the Canadian prairies are highly calcareous, increasing the potential benefit from use of urease inhibitors. Unlike nitrification inhibitors, numerous field trials in the US involving 22 universities and 7 private research companies realized an average 14.2 bu per ac increase in yield in NBPT-urea treatments (Watson, 2005). Ammonia losses and the potential benefit derived from use of Agrotain were higher when urea rather than UAN was the fertilizer source; losses tend to be higher from urea than UAN because only a portion of the N in the UAN is in the form of urea and hence is less susceptible to losses (Grant and Dowbenko, 2008).

In studies at Brandon, Manitoba, NBPT reduced  $\text{NH}_3$  volatilization from no-till soils, even with 25 mm of simulated rain at 2 and 7 days after urea application. The NBPT delayed, but did not eliminate hydrolysis of urea and its effectiveness decreased with time. Delay of hydrolysis increases the chance of rain moving the urea into soil before significant volatilization loss occurs (Malhi et al, 2001). In western Canada, weather conditions normally become warmer and drier later in the spring, so risk of volatilization losses and seedling damage increase as fertilizer applications and seeding operations are delayed. Therefore, there is likely to be increasingly greater benefits of using NBPT as the season progresses. Again, because of the effect of temperature and moisture, use of urease inhibitor may be beneficial with in-crop applications of fertilizer to increase fertilizer rates when growing conditions improve after seeding, or to enhance grain protein content of wheat in anticipation of a protein premium added to grain price (Malhi et al, 2001).

In the Canadian prairies, there are large areas of pastures and forages where urea may be broadcast on heavy residues and left unincorporated. Surface applications of urea or UAN may also be used for production of winter cereals and as split applications to synchronise N supply with crop uptake or to increase protein content of wheat. In management systems where surface application is used, urease inhibitors may be effective in increasing fertilizer use efficiency and economics of production (Grant and Dowbenko, 2008).

No-till is a popular management practice in the prairies. Under no-till, surface applications cannot be incorporated and the efficiency of surface applied urea may be very low due to the lack of incorporation and the presence of large amounts of crop residue (Malhi et al., 2001).

In-soil banding will reduce the potential for volatilisation losses and so benefits are not likely to be great when Agrotain is used with in-soil bands. However, if fertilizers are banded in the fall, use of urease inhibitors might be beneficial in slowing the release of ammonia and its subsequent conversion to nitrate, thus reducing the risk of nitrate leaching or denitrification (Grant and Dowbenko, 2008). Combination of a urease inhibitor with a nitrification inhibitor could provide an additional benefit, substantially increasing the length of time that the fertilizer could be in the soil before significant losses occurred (Grant and Dowbenko, 2008).

NBPT has been used on a wide variety of crops, primarily recommended for pre-plant surface application of urea and urea-containing fertilizers, but can be used in pre-emergent, top-dressing, or other post planting applications. It has shown potential as a seed safener on small grain cereals and canola, when these crops are in close proximity with relatively high levels of urea. A combination of NBPT and DCD, a nitrification inhibitor, is available commercially, as a product called Super U (Watson, 2005).

Economically, the field use of these products depends on the price differential between urea and the additional cost of the amendment versus the amount of N saved from  $\text{NH}_3$  losses, the yield difference, and the value of the crop (Watson, 2005).

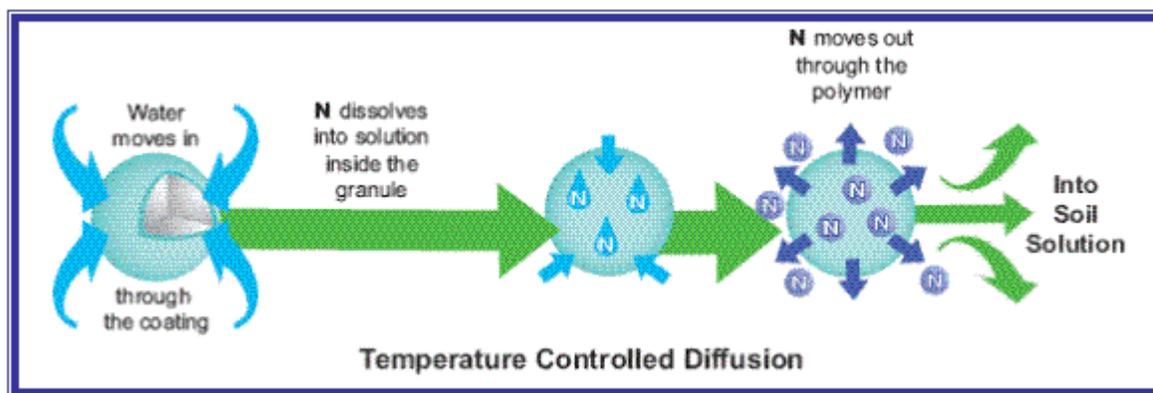
### **2.3 Controlled Release Nitrogen**

Controlled release nitrogen fertilizer products also hold potential for improving fertilizer use efficiency, enhancing economics of production and reducing the risk of negative environmental effects for movement of N into the air or water (Grant and Dowbenko, 2008). Controlled release products release the fertilizer into the soil solution at a controlled rate, minimising the time that the fertilizer is in the soil solution before crop uptake, and therefore reducing the susceptibility to loss. With controlled release urea fertilizers incorporated or banded into the soil, there is less risk of loss by denitrification and leaching. With surface applications, the concentration around the granule is reduced by the slow release, leading to a lower soil pH and smaller ammonia concentration gradient, which should reduce volatilization (Grant and Dowbenko, 2008). By slowing down the release of N, significantly higher N rates can be safely seed-placed with a polymer-coated urea. Another benefit of ESN is the potential for reduced N losses resulting in higher N use efficiency by crops. This could lead to higher yield and higher protein levels with their associated premium payments (Barker 2008). There are two popular coated SRF products: sulfur-coated urea and polymer coated urea (PCU).

Controlled or slow release fertilizers can generally be classified into three types: inorganic compounds of low solubility, low solubility organic N-compounds and coated water-soluble fertilizers. The first two categories have limited potential for agricultural use because their rate of nutrient release is difficult to predict and depends upon factors such as soil type, moisture

content, microbial activity and history of previous usage (Grant and Dowbenko, 2008). Sulfur coated urea releases N into the environment through biological oxidation of the S coating, fractures in the S coating, and dissolution through the moderately porous membrane. The polymer coated products encapsulate urea granules with polymers. Over time, water moves through the polymer coating, dissolving the urea. The N solution then slowly dissolves out through the polymer coating. The PCU products are considered “controlled” release because the thickness of the polymer coating effectively controls the release rate and delay (soil temperature is also a controlling factor). Types of PCU include ESN® (Agrium Inc, Calgary, AB), Polyon® (Agrium Inc, Calgary, AB), and Nutricote® (Chisso-Asahi Fertilizer Co., Ltd, Tokyo, Japan) (Ruark, 2010). Polymer-coated fertilizers appear more promising, since they can be designed to release nutrients in a manner closely matching crop demand. The release rate is determined by polymer chemistry, thickness, coating process, temperature and moisture so the release can be highly controlled and designed to match plant uptake. The polymers used are generally very durable and exhibit consistent release rates that are predictable when average temperatures and moisture conditions can be accurately predicted. Currently the only lower-priced controlled release formulation registered in Canada that may be cost-effective for broad-acre production systems is ESN (Environmentally Smart Nitrogen – Agrium), which has a polymer coating that releases urea fertilizer into the soil solution at a rate limited by moisture but controlled by soil temperature. (Grant and Dowbenko, 2008). Different from Agrotain, this product is pre-coated, and contains 44% N, less than the competing products (Urea, Super U, and Nutrisphere N) which all contain 46%. The rate of release is designed to match the nitrogen uptake pattern of the crop being produced. By closely matching the time of N release into the solution to the uptake pattern of the growing crop, the concentration of nitrate and the length of time the nitrate is present in

the soil solution before crop uptake are both minimised. As seen in Figure 2, the water penetrates the polymer coating in successive layers, and the N dissolves into solution inside the granule, and then moves out through the polymer into the soil solution.



**Figure 2 How ESN works: Thomas, J., Mid-Sask Ag. Available online: <http://www.midsaskagservices.com/html/expert.html>**

Benefits from use of controlled release urea will increase with the potential for N loss. Since losses of N from in-soil applications increase with increasing moisture, benefits from use of controlled release fertilizers are also likely to be greatest under wet, warm conditions. As well, due to the layered coating, Agrium states that up to three times as much ESN can safely be seed placed when compared to Urea (Grant and Dowbenko, 2005). PCU products are designed to provide good control over release in soils and to match plant demand, thus they are expected to provide high NUE and to minimize adverse effects on the environment. The use of PCU can also help in saving labour and/or application costs, and can improve crop quality and yields (Shaviv, 2001).

Many of the experiments using PCUs compared similar levels of nutrients supplied by common fertilizers, ignoring the potential to reduce application levels, and still maintain or even increase yield levels. In Western Canada, fall application of polymer-coated urea on barley resulted in

decreased nitrate accumulation and fertilizer-N loss, while spring application of polymer-coated urea increased crop N uptake (Baylock et al, 2005). As well, Baylock et al, 2005, found that controlled-release N (CRN) produced greater yields in the majority of comparisons throughout the U.S. Corn Belt when applied pre-plant at the same N rate as pre-plant applications of conventional N sources. Yield increases in excess of 24 bu/acre generally coincide with conditions conducive to high N-loss potential, as these areas are generally the most improved with the use of CRN. They observed that CRN fertilizers have the potential to significantly improve N-use efficiency while maintaining crop productivity, and that CRN can be more efficient for grain crops without sacrificing yield. Finally, Baylock et al demonstrated that CRN can be applied to corn in the U.S. Corn Belt at significantly lower rates (25-35% less) than conventional N sources without sacrificing crop yield.

Environmentally, there will be less waste of N to leach into the ground water or volatilize, however, Shaviv, (2001) states that the impact of the coating substances spread into the soil should be considered, particularly with repeated high rates.

With ESN urea running at \$0.10 to \$0.12 more per pound compared to uncoated urea at an N application rate of 60 lbs N/ac, the yield advantage of applying ESN in the fall has to equate to an extra \$7.00 per acre ( $\$0.12 \text{ per pound} \times 60 \text{ pounds per acre N rate}$ ) or so to recoup the investment. With uncoated urea applied in early spring performing just as well as ESN coated urea applied in the fall in a single shoot application, the decision to use ESN will likely come down to a balance of convenience, the cost of a floater application in the spring and risk management (Barker, 2008).

### 3. Materials and Methods

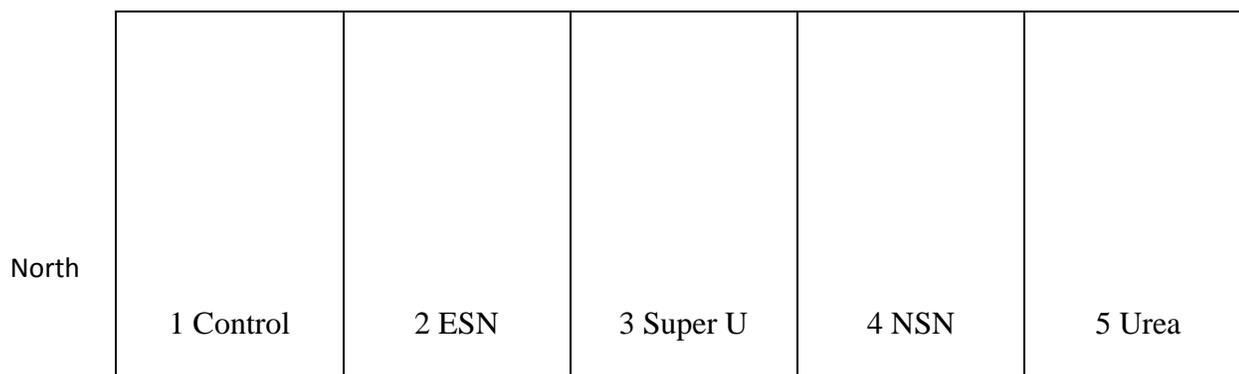
#### 3.1 Experimental Design

This study was conducted in the Dark Brown soil zone near Plenty, Sk. with three different enhanced nitrogen products: 1) Super U, which is a blend of two types of inhibitors, N-Butylthiophosphoric triamide (NBPT) which is a urease inhibitor, and Dicyandiamide (DCD) which is a nitrification inhibitor; 2) Nutrisphere N, which uses a stabilizer/ inhibitor of Malic+ itaconic acid co-polymer with urea as a nitrification inhibitor; and 3) ESN, which is a polymer-coated urea that affects the rate of release. This site was located at NW-17-32-20 and was a heavy clay textured soil of Regina association; a gently rolling heavy textured soil on glacial lake clay deposits. The land is owned and farmed by Barry Weenk.

Prior to seeding the trial, a soil sample from 0-30cm was taken from across the experiment to characterize the site, as well as to have a reference later in the growing season. The trial was then set up with four replicates of the three enhanced fertilizer products as well as a conventional urea treatment and an unfertilized control. The trial was seeded using an 80 ft Seed Hawk seeder. The nitrogen products, Super U, Nutrisphere, and ESN, were obtained from Agrotain, Simplot, and Gmac's Ag Team respectively, and were applied as granular products using a side band method that places the fertilizer 2.5 cm to the side of the seed. The crop seeded was Nexera 845 CL canola from Dow Agrosiences, and the canola was seeded on durum stubble at 2.5 cm depth (1in).

The products were applied at the time of seeding (May 30) using a side banding application of 45 kg actual N/ ha (40 lbs N/ac). Sulphur and phosphate were applied in a blanket application of 15-27-0-11 at a rate of 400 lbs/ac across all treatments. Each replicate plot was 30 ft long by 80 ft

wide, therefore it was 9600 ft<sup>2</sup>, and equalling .22 acres total (0.09 hectares). Due to the width of the seeding unit, it was difficult to randomize trials throughout the reps, therefore each trial was seeded through to create the four replicates of each treatment in one block (see figure 2).



Therefore, my plots went as follows;

North

1A	2A	3A	4A	5A
1B	2B	3B	4B	5B
1C	2C	3C	4C	5C
1D	2D	3D	4D	5D

**Figure 3-The arrangement of treatments in the trial.**

**Treatments: 1(control); 2(ESN); 3(Super U); 4(NSN); 5(Conventional Urea)**

The trial was farmed according to normal practices by the producer with the rest of the field. It was sprayed with a full rate application of Odyssey to control broad-leaf weeds in mid June; no other pesticide applications followed in this season.

When harvesting the trial, on Sept 19, there were two 1m<sup>2</sup> samples hand harvested out of each treatment plot. These samples were dried and thrashed, and the yield was taken. As well, a tissue sample were completed for tissue analysis using 0.25 g of plant tissue digested in sulphuric acid and peroxide according to the method of Thomas et al (1967). This method was used to

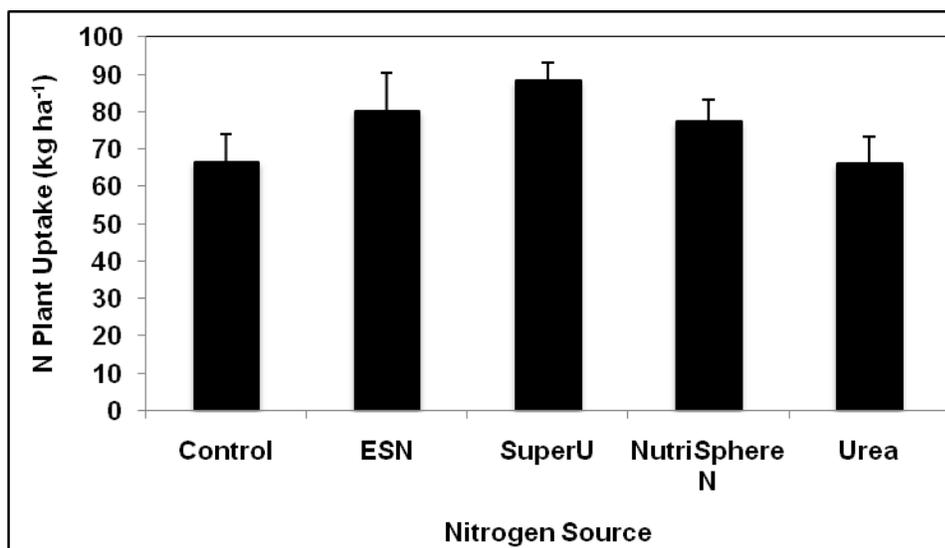
determine the N and P content in grain and straw. Three weeks after harvest, in mid-October, the soil was sampled at both 0-30 cm and a 30-60cm using a hand-held auger. These samples were also analyzed for ammonium and nitrate using 2M KCl extract on 5 g of soil in 50 mL of 2M KCl solution (Keeney and Nelson, 1982). It is important to note that this field was in severe drought and cold conditions from seeding (May 30) until mid-July. Emergence was very patchy and it froze after the herbicide application, causing stress on the field. Sufficient moisture followed for the remainder of the season and the crop had an opportunity to recover.

#### 4. Results and Discussion

Sample Number	Organic Matter	Available N (ppm)	Available P (ppm)	Available S (ppm)	pH	CEC meq/100g
1A	3.3	54	18	14	6.8	27.2
1B	3.3	17	14	11	7.4	24.9
1C	3.5	10	15	8	7.9	30.6
1D	3.5	14	14	9	7.8	30.3
2A	2.9	12	10	15	7.8	36.5
2B	3.5	18	15	10	7.8	33.4
2C	2.9	11	14	13	8	35
2D	2.8	13	14	11	8	39.3
3A	3.2	10	13	11	7.5	29
3B	3.8	19	14	8	7.7	31.4
3C	2.9	11	12	27	7.7	34.4
3D	3.5	12	14	10	7.5	31.9
4A	3.3	12	9	7	7.4	30.6
4B	3.1	33	8	10	6.9	24.5
4C	3.2	10	13	13	7.7	35.2
4D	3.2	12	7	6	7.5	28
5A	4	10	12	11	7.2	27.5
5B	3.2	13	9	10	7.4	31.1
5C	3.2	7	10	9	7.9	34.8
5D	3.1	14	15	8	7	30.1

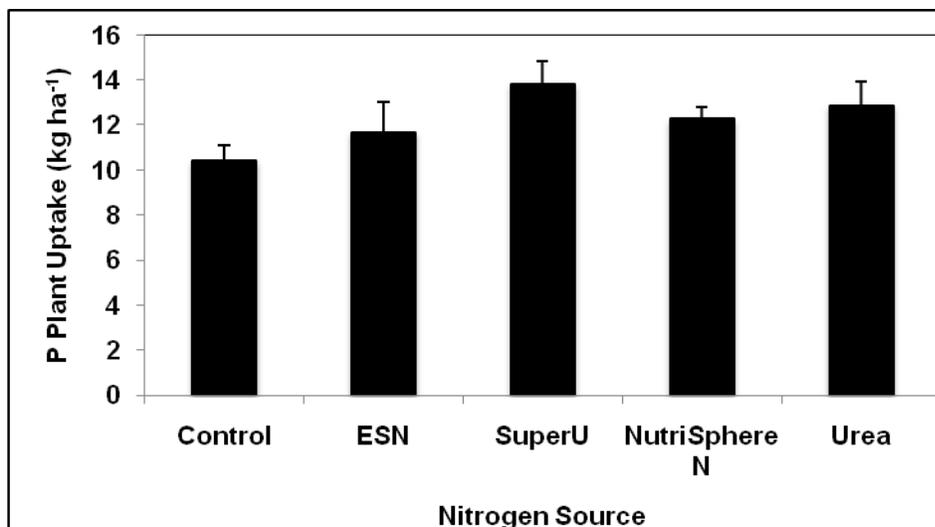
**Table 2 Pre-seed Soil Sample A&L Canada Laboratories, London, Ont.**

Table 2 shows the nutrients available in the soil prior to seeding the canola. It shows the relatively high organic matter content across the trial, as well as the high pH. The Cation Exchange Capacity (CEC) numbers are provided to better understand the uniformity of cation distribution in the soil, and is directly related to the clay and organic matter content. Overall, the soil properties were quite uniform across the experimental site and among the different treatment blocks.



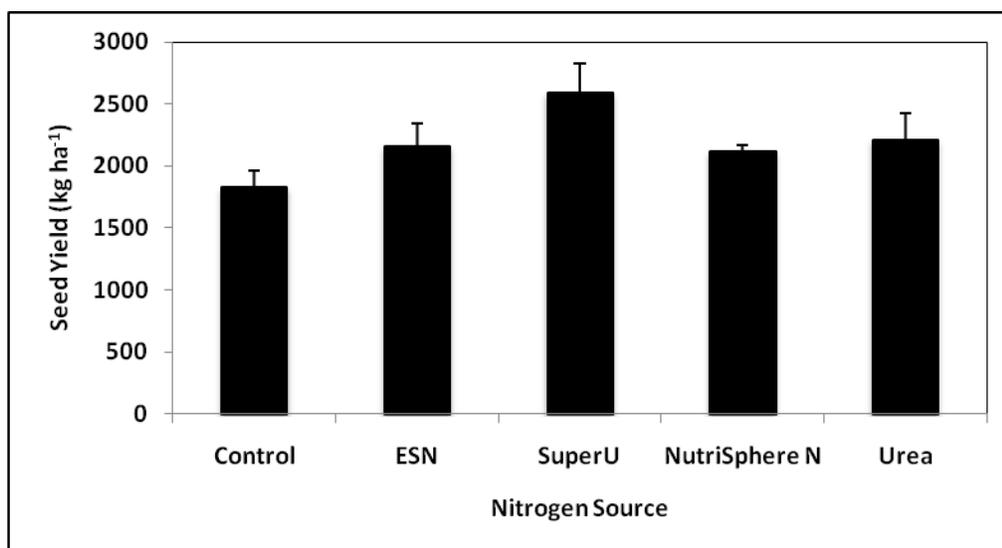
**Figure 4 Plant nitrogen uptake, Plenty, Sk.**

Due to the extreme drought conditions in this area in the early part of the cropping season, the crop was very slow to germinate and emerge. The Super U treatment had the highest nitrogen uptake (Figure 4) averaging 88 kg N per hectare followed, in order, by ESN at 80, NSN averaging 77, and finally, Urea and the unfertilized control, both averaging 66 kg per hectare.



**Figure 5 Plant phosphorus uptake, Plenty Sk**

The P plant uptake is shown in figure 5. Adding nitrogen increases plant demand for P. The Super U treatment that had the highest yield and N uptake also had the highest Plant P uptake, at 13.8 kg P per hectare. Urea treatment followed at 12.83 kg per hectare, Nutrisphere N at 12.2 kg P per hectare, ESN at 11.7 kg P per hectare, and finally the control unfertilized treatment at 10.4.



**Figure 6 Seed yield, Plenty Sk**

The Super U product produced the highest yield at 2586 kg per hectare (Figure 6). This was significantly higher than the control, with ESN, NSN and Urea producing similar yields at 2154 kg per ha, 2115 kg per ha, and 2210 kg per ha respectively, resulting in about 400 kg/ha greater yield than the unfertilized control which produced an average seed yield of 1822 kg per ha. Lack of moisture at this site likely lead to the limited response to N fertilizer, and therefore affected the yield.

<b>0-30</b>		<b>NO<sub>3</sub></b>			<b>NH<sub>4</sub></b>		
<b>Treatment</b>		<b>ug/g</b>	<b>Mean</b>	<b>Standard Deviation</b>	<b>ug/g</b>	<b>Mean</b>	<b>Standard Deviation</b>
Control	1A	5.89			9.72		
Control	1B	3.50			10.59		
Control	1C	3.53			8.90		
Control	1D	4.32	4.31	1.12	6.99	9.05	1.53
ESN	2A	5.72			9.43		
ESN	2B	3.31			9.51		
ESN	2C	4.46			11.63		
ESN	2D	3.61	4.27	1.08	9.08	9.91	1.16
NSN	3A	4.07			9.28		
NSN	3B	4.09			9.73		
NSN	3C	4.82			10.53		
NSN	3D	4.98	4.49	0.48	10.27	9.95	0.56
SuperU	4A	4.94			9.53		
SuperU	4B	4.65			10.46		
SuperU	4C	4.47			10.39		
SuperU	4D	3.79	4.46	0.49	11.15	10.38	0.66
Urea	5A	4.12			10.60		
Urea	5B	3.56			9.25		
Urea	5C	4.08			8.32		
Urea	5D	3.70	3.87	0.28	9.31	9.37	0.94

**Table 3. 0-30 cm post-harvest soil sample residual NO<sub>3</sub> and NH<sub>4</sub>**

Table 3 shows the residual  $\text{NO}_3$  and  $\text{NH}_4$  present in the soil post-harvest in the 0-30 cm soil core. We can see that the highest amount of plant available N remaining in the soil solution is present in the Super U treatment. However there is no statistical difference between the treatments.

<b>30-60 cm sample</b>		<b>NO<sub>3</sub></b>			<b>NH<sub>4</sub></b>		
		<b>ug/g</b>	<b>Mean</b>	<b>Standard Deviation</b>	<b>ug/g</b>	<b>Mean</b>	<b>Standard Deviation</b>
Treatment							
Control	1A	3.78			10.05		
Control	1B	3.63			10.80		
Control	1C	3.02			8.80		
Control	1D	3.01	3.36	0.40	9.59	9.808	0.84
ESN	2A	2.98			12.75		
ESN	2B	2.81			9.63		
ESN	2C	3.32			11.96		
ESN	2D	2.96	3.02	0.21	10.86	11.301	1.36
NSN	3A	3.59			9.48		
NSN	3B	4.03			10.30		
NSN	3C	4.30			10.43		
NSN	3D	4.78	4.17	0.50	9.74	9.9878	0.45
SuperU	4A	4.03			10.43		
SuperU	4B	4.00			9.96		
SuperU	4C	3.72			10.75		
SuperU	4D	3.93	3.92	0.14	10.65	10.447	0.35
Urea	5A	2.83			10.26		
Urea	5B	2.75			9.87		
Urea	5C	3.08			8.86		
Urea	5D	2.96	2.90	0.15	8.92	9.4787	0.70

**Table 4 30-60 cm post harvest soil sample residual NO<sub>3</sub> and NH<sub>4</sub>**

Table 4 shows the residual NO<sub>3</sub> and NH<sub>4</sub> present in the soil post-harvest in the 30-60 cm soil core. Again, the treatments are all statistically very similar.

## 5. Conclusion

In the trial the Super U treatment had the highest yield and nitrogen uptake, likely due to decreased ammonia volatilization attributable to the urease inhibitor contained in the product. Drought conditions with low soil moisture for the first part of the growing season would make the urea susceptible to volatile ammonia losses. Even a light shower may give enough moisture for hydrolysis of urea but not provide sufficient moisture to completely convert ammonia gas

into ammonium ions. Because of the increased nitrogen uptake and yield in the Super U treatment, it required more P to complete its life cycle; therefore the Super U treatment showed the most P uptake. The ESN and NSN products both require moisture to initiate their breakdown processes. Under dry conditions, ESN and NSN may not provide a significant benefit over in-soil banded uncoated urea, and although they have a slight increase in recovered  $\text{NO}_3$  and  $\text{NH}_4$  in the soil, the difference over urea is likely not enough to be cost effective. All treatments proved to be effective in producing yield and contributing to N uptake when compared to the unfertilized control, however residual N from previous cropping years and the blanket P and S application allowed the unfertilized treatment to yield quite well. The lack of moisture reduced the yield potential for the N fertilized treatments, and kept the yields lower than initially expected. In drought years, due to the chemical composition, Super U could provide a quicker source of nitrogen to the plant compared to ESN or NSN. The nitrogen enhancer choice in dry years in Saskatchewan based on results of this experiment is the urease inhibitor.

Suggested future research on this topic would include repeating this experiment under environmental conditions to provide information for Western Canadian soils in warmer, wetter spring conditions compared to the severe early season drought as observed in this trial. Also, the same trial space could be seeded to a cereal the following growing season to better understand the residual N available from each product. Finally, this experiment should be conducted over a variety of soil zones and types to better understand the abilities and fit of each product throughout Western Canada.

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