Economics of Controlled Urea Fertilizer in Cropping Systems

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Abstract

Nitrogen fertilizers are chemical compounds given to plants to promote growth. However, their application can impact the environment through ammonia and greenhouse gas emissions, and through leaching which can lead to deterioration of water quality. To understand the nitrogen dynamics in the soil, a set of experiments were designed by Agriculture and Agri-Food Canada (AAFC) research scientists with funding received from the Environmental Technology Assessment for Agriculture (ETAA) and GAPS programs of AAFC, and Agrium, a fertilizer company. Research trials were conducted to assess the impact of urea with comparison being made between ESN (environmentally sensitive nitrogen) and uncoated urea. Trials were conducted in five provinces and eight research sites. Harrow was the only eastern Canada site. Experiments also included several fertilizer application rates, and at least two tillage systems – conventional and reduced tillage. Zone tillage was also included at Harrow, Ontario. The general conclusion from the foregoing set of data and analyses is that ESN application is a better economic choice for certain crops in some regions, but not in all regions or for all crops. Even a single crop was not found to generate a positive producer surplus in all regions. Reasons for these differences need further investigation.

Introduction

Application of fertilizer is warranted on grounds that it is an essential source of nutrients for the crop growth. However, fertilizer application can impact environment in an adverse manner. For example, application of nitrogen fertilizer is associated with greenhouse gas (GHG) emissions as well as environmental quality. A new product called ESN – for Environmentally Sensitive Nitrogen – has been developed by Agrium. This coated, controlled release fertilizer, compared to the conventional fertilizer (typically urea) has the potential to provide a 'win-win' situation to producers. It can enhance production as well as protect the environment. There was a perceived need for research to test the yield efficiency of the coated fertilizer relative to uncoated N-fertilizers under Canadian climate regimes, soil types, and tillage systems. This project was designed to test coated product claims in the Canadian agricultural context.

The primary objective of the analysis reported herein is to assess the economic desirability of applying coated fertilizer (ESN) to crops grown under different tillage systems and rotations. Analysis was completed for combinations of research site, crop, tillage and year of experimentation. Crops included in the ESN trials were: corn, barley, canola, hard red spring wheat, and winter wheat.

Information used in the economic analysis of the project was obtained from personal discussions with Mr. Ray Dowbenko of Agrium, Calgary, and various scientists at AAFC Research Stations coopering in the project.

Concept of Controlled Release Urea

Coated fertilizer, such as ESN, interacts with available moisture and the release of nutrients (such as nitrogen) is slower or more gradual than it is with uncoated fertilizers (such as uncoated urea). This has three advantages:

One, it can be applied in the fall (when fertilizer prices are typically lower),

Two, nitrogen is released slowly during the growing season, and thus is available to the plant at times when it is needed. The concept of this slow release is shown in Figure 1. This leads to reduced loss of nutrients to the environment, compared with uncoated urea. The nitrogen in the soil is subject to lower losses through denitrification, leaching below the root zone, or volatilization to the atmosphere before the plant roots can absorb it.

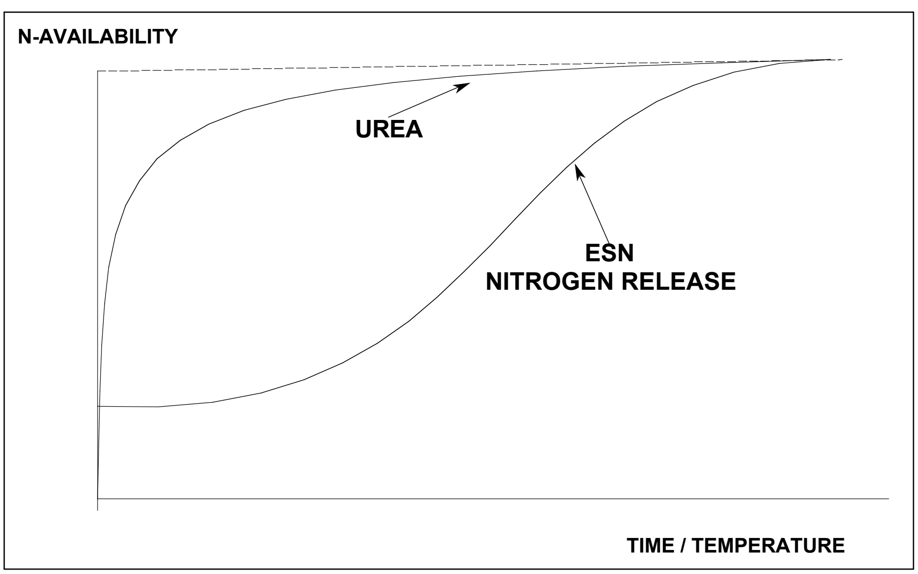

Figure 1. Nitrogen Release from Urea and ESN Urea

Three, relative to uncoated urea, application of ESN may result in higher crop yields for a given level of fertilizer application. As shown in Figure 2, yield of a crop, such as corn, can be shown to be consistently higher over all levels of fertilizer application. Thus, for a given level of yield, a producer may be able to apply a lower amount of coated, as compared to uncoated, fertilizer.

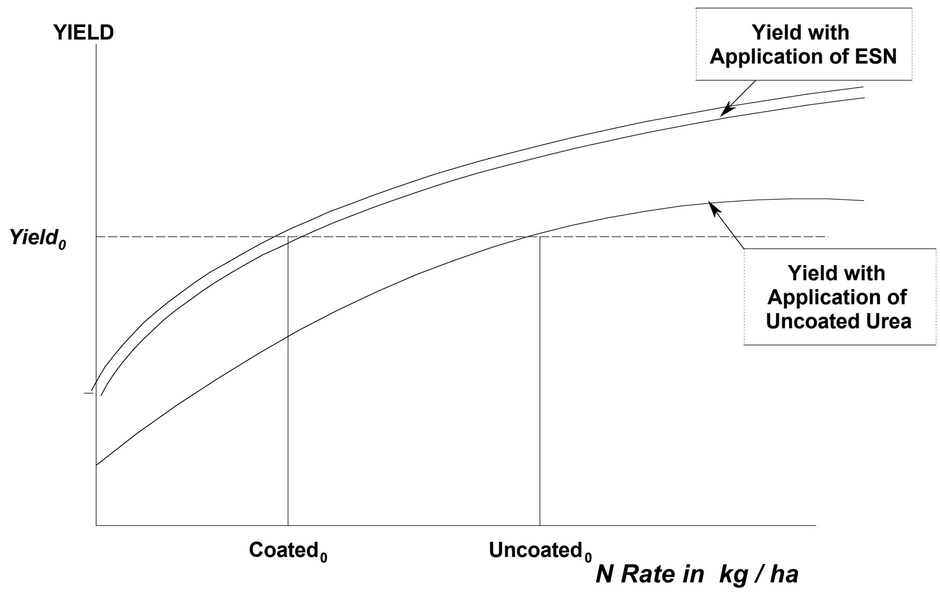

Figure 2. Relationship between Fertilizer and Crop Yields – Urea and ESN Urea

However, potential losses of N from the soil and hence potential benefits of ESN, are greatly affected by environmental conditions, with losses through denitrification and leaching being higher under wet conditions. Evaluation of the performance of ESN is needed over a range of Canadian conditions in order to determine the probability of economic and environmental benefits to use of the product.

This project was funded by the AAFC to test whether use of ESN is a desirable management practice under Canadian condition.

Study Methodology

The impact of ESN on plant growth, crop yield and quality of the product, livestock performance, as well as its environmental impacts has been studied extensively in North America. In the U.S. and Canada, a number of trials have been funded by Agrium for determining the yield and environmental benefits from using ESN as compared to uncoated or conventional urea. These are summarized in Agrium (2005). Agrium's (2005) summary of previous trials of ESN during 2000-2004 in the Midwest USA indicates an average yield increase of about 8.1 bushels/acre for corn with a 57 percent probability of obtaining a yield increase averaging about 16 bu/ac. These results were supported by 2005 trials, leading to the conclusion that ESN has a significantly better value proposition when compared against urea than when compared against anhydrous ammonia or ammonium nitrate.

For wheat and canola in Saskatchewan Malhi et al. (2003) have reported higher yields with coated (ESN) than with uncoated urea. Schwab et al. (2002) reported a similar study on wheat in Kentucky, where it was concluded that the yield from pre-plant applied polymer coated urea (ESN) was significantly higher than pre-plant applied urea or ammonium nitrate. According to this study, this indicated that the polymer coating did prevent at least some nitrogen loss.

For corn trials, Nelson and Motavalli (2006) report that in general, corn yields with polymer coated urea (ESN) were greater than or equal to non-coated urea yields. Based on the results of the study, they suggested that a reduced rate of polymer coated urea (ESN) may be justified for pre-emergence and side-dress application. However, such results were not supported for flooded rice where coated urea (ESN) did not result in greater yield (Golden et al. 2007).

Although this review is not exhaustive, it does suggest many benefits may occur from the use of polymer coated urea (ESN). However, none of these studies contain or report economic analysis. This remains to be a major gap in the literature.

Economic evaluation of the project technology was based on experimental results for various crops and research sites. Details are shown in Table 1. Trials were conducted on seven sites. These included four crops – corn, canola, barley and wheat, and four tillage systems – conventional till, Reduced till, No till, and Zone till. Zone tillage is indirect loosening of an area of soil between two coulter blades which are stagger mounted on either side of a planter row (Yetter 2004-2006). Various trials were conducted over the three year period 2004 to 2006. In some cases, data for 2003 were also available and used in the analysis.

Table 1. Details on Experimental Sites and Crops

Research Station	**Crop and Tillage[1], by Year**		
	2004	**2005**	**2006**
Agassiz, BC	Corn (CT & RT)	Corn (CT & RT)	Corn (CT & RT)
Beaverlodge, BC & AB	Barley (CT & RT)	Canola (CT & RT)	RS[2] Wheat (CT & RT)
Lacombe, AB	Barley (CT & RT)	Canola (CT & RT)	Barley (CT & RT)
Melfort, SK	HRS[2] Wheat (CT & RT)	Canola (CT & RT)	Barley (CT & RT)
Swift Current[3], SK	HRS[2] Wheat (CT, RT, NT)	HRS[2] Wheat (CT, RT, & NT)	HRS[2] Wheat (CT, RT, & NT)
Brandon[4], MB	HRS[2] Wheat (CT & RT)	Canola (CT & RT)	HRS[2] Wheat (CT & RT)
Harrow, ON	Corn (CT, NT and ZT)	Corn (CT, NT and ZT)	Corn (CT, NT and ZT)

[1] CT = Convention tillage; RT = Reduced tillage; NT = No tillage; ZT = Zone tillage; [2] Hard Red Spring Wheat; [3] Three Sites; [4] Two sites.

Four N rates -- 0, 0.5, 1.0, and 1.5 times the estimated N rate for 90 percent of optimum crop yield for each location were applied. N application was based on recommended levels for each region, and therefore differed by region. Recommended application rates for each site are presented in Table 2.

Economic analysis of ESN fertilizer was undertaken from the accounting stance of Canadian society. Social welfare was equated to that of producers since Canada is a price taker, and the price of products to the consumer would not change as a result of application of the technology in Canada. With this accounting stance, a technology would be deemed economically desirable if there was a gain in the level of producer surplus (or net farm income) for the farmer.

Table 2. Base Fertilization rates for Study Sites

Site	Soil	Texture (0-15cm)	Precipitation (mm)	pH	Base Fertilizer Application N-Rate (kg/ha)
Agassiz		Silt loam	1,755	6.1	150
Beaverlodge	Dark Gray Luvisol	Loam		5.84	50
Lacombe	Black Chernozem	Loam	446	6.21	60
Melfort	Dark Grey Luvisol	Silty clay	413	6.16	60
Swift Current SPARC, SK	Brown Chernozem	Loam	377	6.34	30 - 40
Manitoba, ISF	Black Chernozem	Clay loam	465	7.81	50
Manitoba, ZTF	Black Chernozem	Clay loam	472	7.47	50
Harrow		Sandy clay loam	876	6.3	150

The economic assessment methodology involved estimation of net farm income for each combination of crop, location, tillage, fertilizer type and application rate, and year of observation individually, and as the change in pairs of selected treatments (where appropriate), as shown in Table 1. The long-run producer surplus (net farm income) was calculated as follows:

$$LRPScst = Pc * YLDcst - COPcst \qquad (1)$$

Where, *LRPS* is long-run producer surplus per ha;

P is the price per unit (generally on a per tonne basis) of the given crop;

CST refers to the crop, research site (which refers to a province for data on price of agricultural commodities, but research stations for biophysical details), and tillage treatment under consideration, respectively;

Yld is yield of the crop per unit of area (ha), and

COP is cost of production per unit of area (ha).

The COP was estimated using all fixed and variable costs and required four other sets: (1) Cost of production of various crops at various locations; (2) Price of fertilizers – coated and uncoated; (3) Price premium for protein content of wheat; and, (4) Price of all crops. In order to obtain base simulation results, several assumptions were made. Many of these were required in light of weak or unavailable data. These include:

1. Yields used in the base estimate are the average of the yields during the period of observation.
2. Further analysis of protein content of HRS wheat was predicated on the relationship between this variable and application of coated fertilizer. If these results were inconclusive, no further analysis of protein contents was undertaken.
3. The adoption of coated fertilizer does not require any new equipment. The same equipment can be used for uncoated as well ESN fertilizer.
4. The fixed costs of farm operations do not change as a result of adoption of new fertilizer technology.
5. Blended application of fertilizer involves ESN and uncoated fertilizers in equal proportion of active ingredient.
6. Any yield increases affect transportation, storage, and drying costs of the farm business. All other cost items were assumed to be unaffected by changes in yield under a given field trial.
7. Prices were assumed to be the middle range – product prices were current as of May 2007, while fertilizer prices were those at spring 2007. The ESN prices were as discussed above.
8. Fall application cost of fertilizer was obtained after applying fall discounts. No discount was used for spring application.

Base estimates for a combination of location, crop, tillage, and year of observation were further examined or assessed using sensitivity analysis. Details are shown in Table 3. Detailed fertilizer prices assumed are listed in Table 4.

Table 3. Sensitivity Analysis of Economic Performance of ESN and Uncoated Urea Fertilizers

Simulation	Crop Prices	Fertilizer Prices	Fertilizer Price
Low Input Prices	Current	Low ESN & coated	28% fall discount
High Input Prices	Current	High ESN & coated	28% fall discount
No fall discount	Current	Current	No discount
Low crop prices	Minimum crop	Current	28% fall discount
High crop prices	Maximum crop	Current	28% fall discount

Table 4. N-Fertilizer Prices for Sensitivity Analysis, $/kg of Active Ingredient

Fertilizer	West			East		
	Low	Current	High	Low	Current	High
ESN	$1.21	$1.60	$1.73	$0.87	$1.19	$1.73
Uncoated Urea	$0.87	$1.24	$1.50	$1.19	$0.87	$1.50
Blended N-fertilizer	$1.04	$1.42	$1.61	$1.03	$1.03	$1.61

Results of Economic Benefits from Application of ESN

The impact of ESN fertilizer application is compared across all crop-region specific results in this section. Results are compared on the following three criteria: Relative yield gains resulting from application of coated fertilizer; relative change in producer surplus from application of coated fertilizer; and timing and nature of application (other than those considered above). Within each of these three criteria, a number of indicators were developed for comparison purposes.

On the basis of differences in the yield of various crops from the application of ESN (over and above of urea), a set of consistent results in favor of ESN were not obtained. Nonetheless, there were some situations where the application of ESN did result in higher yields, which include:

- Canola at Beaverlodge in 2005;
- HRS wheat at Beaverlodge in 2006;
- Canola at the ISF site in Manitoba over the 2005 period;
- Barley at Beaverlodge under reduced tillage in 2004;
- Corn production at Harrow under no-till, and,
- Winter wheat production at Harrow under no-till.

Let us first examine the performance of ESN and uncoated urea when both are applied at the same rate. In terms of superior economic performance of the ESN, there were some similarities with the yield summary presented above. However, there were fewer situations where ESN fertilizer application performed better than uncoated urea. Using a gain of at least 5 percent in estimated producer returns from using the ESN fertilizer (over and above the uncoated one), the following crop-research sites-year combinations were observed to be economically positive for ESN use:

- Canola at Beaverlodge in 2005 under conventional and reduced tillage;
- HRS Wheat at Beaverlodge in 2006 under conventional tillage;
- HRS wheat at the ISF site in Manitoba (average 2004 and 2006) under conventional tillage;
- HRS wheat at ZTF site (average 2004 and 2006) under conventional tillage;
- Canola at the ZTF site in 2005 under conventional and reduced tillage;
- Corn at the Harrow site (average 2004 to 2006) under no –till system;
- Winter wheat at the Harrow site (average 2004 to 2006) under reduced tillage.

In terms of the second criterion – difference in producer surplus from ESN application at the 1.0 times rate and the uncoated urea at the 1.5 time rate, there were some instances noted where profitability of using ESN fertilizer is desirable. These include the following crop-research site-year-tillage combinations:

- Beaverlodge – canola and HRS wheat under conventional tillage;
- HRS wheat at Swift Current under conventional tillage;
- ISF site, Manitoba – HRS wheat under conventional and reduced tillage;
- ZTF, Manitoba site – HRS wheat and canola

In these situations, producers do not have to increase the rate of application of uncoated urea fertilizer to make the same or higher level of economic gains. This would be deemed as a 'win-win' situation since higher producer returns are associated with lower environmental damage from fertilizer (N-leaching, atmospheric deposition).

Sensitivity Analysis

Sensitivity of ESN fertilizer relative to uncoated urea fertilizer was undertaken. Details are not shown here on account of space consideration. Although magnitude of change in producer surplus did change as assumptions related to fertilizer price and product price were modified, the basic conclusions remained unchanged.

Table 5. Summary of Relative Producer Surplus (PS) for Application of ESN Fertilizer for Various Crops and Research Sites

Research Site	Crop	Year	Difference in PS at Mid Point N-Rate Level ($ per ha)		Percent of Mid-N-Rate PS		Difference in PS for ESN (N=Mid) and Uncoated (N=High)** $ per ha	
			CT	RT	CT	RT	CT	RT
Agassiz	Corn	2004 to 2006	-$93	-$72	-39.1	-79.0	-$60	-$100
Beaverlodge	Barley	2004	-$50	$0	-40.6	-0.2	-$116	-$0
	Canola	2005	$120	$87	122.7	360.5	$10	-$105
	HRS Wheat	2006	$31	-$14	5.8	-3.6	$7	-$22
Lacombe	Barley	2004 & 2006	-$25	-$43	-8.5	-12.7	-$44	-$55
	Canola	2005	-$10	-$28	-2.6	-7.5	-$395	-$324
Swift Current	HRS Wheat	2004 to 2006	-$3	-$11	-5.3	-12.9	$27	-$5
Melfort	HRS Wheat	2004	-$41	-$95	-88.1	-92.5	-$93	-$44
	Canola	2005	-$66	-$96	-219.7	-124.1	-$12	-$39
	Barley	2006	-$6	-$0	-5.9	0	-$34	$2
ISF	HRS Wheat	2004 & 2006	-$16	$0	16.5	0.4	$5	$4
	Canola	2005	$11	-$72	2.3	-16.5	-$7	-$60
ZTF	HRS Wheat	2004 & 2006	$99	$8	5.5	4.0	$6	$27
	Canola	2005	-$47	$91	9.8	15.0	$17	$22
Harrow	Corn*	2004 to 2006	-$32	$15	-9.1	6.4	NA	NA
	Winter Wheat	2004 to 2006	-$83	$13	-37.1	9.9	NA	NA

* Average of pre-planting and side-dress applications

Summary and Conclusions

Although the results of the study are not as conclusive as found in the literature, some conclusions can still be drawn.

- At four research sites and crop combinations: Agassiz (corn), Beaverlodge (Barley), Lacombe (Barley) and Melfort (HRS Wheat), evidence collected did not support the conclusion that application of ESN fertilizer is economically more desirable.
- At Melfort (Canola), although yield with application of ESN did increase, the rate of fertilization was not cost-effective. The producer surplus in this case was not positive.
- Tillage systems did not make a difference in terms of economic desirability of ESN fertilizer for: Beaverlodge (Canola), and ZTF (HRS wheat) site.

- There were instances where producer surplus was higher under reduced (or no till) tillage than under conventional tillage. These situations included: ZTF (Canola), and Harrow (Corn and Winter Wheat).
- Fall application of ESN fertilizer resulted in positive producer surplus estimates greater than for spring application. This was noted for: Beaverlodge (HRS Wheat), Lacombe (Canola), Melfort (Barley), and ISF (HRS Wheat) sites.
- Blended application of ESN and uncoated urea was observed to be a better choice for some situations than application of uncoated urea. These include Lacombe (Canola under both tillage systems), Swift Current (HRS wheat (under reduced tillage), and ISF (HRS wheat under reduced tillage).
- In some situations, application of lower rate of ESN was as profitable, if not more profitable than the application of uncoated urea at a higher rate. This results in higher profitability of crop production, and a lesser amount of fertilizer used. The latter will likely result in less environmental damage due to N losses.

Thus, it appears that ESN application is a better economic choice for certain crops in some regions, but not in all regions or for all crops. Even the same crop was not found to generate a positive producer surplus for all regions. Reasons for these differences need further investigation. In addition, a long series of data are needed to establish superiority of one treatment over the other. Weather and related conditions can affect these results from one period to another. Continuation of this type of research has the promise of yielding conclusive evidence for the ESN fertilizer.

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