New Fertility Product - ESN: Controlled-Release Nitrogen for Enhanced Nitrogen Efficiency and Improved Environmental Safety
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Abstract
Controlled and slow-release nitrogen (N) fertilizers have been commonly used in high-value applications such as turf grasses, container-grown nursery stock and vegetable production. Traditional controlled-release products have not been economical for use in production of major grain crops because of high cost and low crop prices. Agrium, a major N manufacturer in North and South America, has developed an economical polymer-coated controlled-release urea fertilizer: ESN, for use in field crops. Release of N from the polymer-coated fertilizer is a diffusion process. Coupling N release with temperature and soil moisture, two of the primary factors in the rate of crop growth and N demand, allows N release to be programmed to closely match crop needs. Research shows that controlled N release improves crop output per unit of applied N, reduces N losses to the environment, and gives a grower greater control over the fate of applied N. Research has also shown greater recovery of applied N, reduced leaching losses, and reduced nitrous oxide emissions with the use of ESN.

Introduction
Inefficient fertilizer use may contribute to environmental degradation, particularly in intensive agricultural systems where the recovery or use efficiency of nutrients by crops is relatively low. For example, it is estimated that nitrogen (N) use efficiency for cereal production worldwide is only 33% (Raun and Johnson, 1999). A portion of the N not used by the crop is presumed to be lost to the environment through denitrification, runoff, volatilization, leaching, and gaseous plant emissions. Such losses raise concerns about surface and groundwater contamination, and greenhouse gas emissions. Additionally, low use efficiency of nutrients applied as fertilizers results in producers receiving lower economic returns from their investment in fertilizer inputs.

Controlled release fertilizers (CRF) are fertilizers designed to slowly release nutrients at a rate that matches the demand of the crop plants. Such products can be used to maximize fertilizer use efficiency and minimize potential losses to the environment. Increased nutrient-use efficiency may also increase yield and quality of crops, thus providing an economic benefit for growers. 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. Development of polymer-coated fertilizers looks promising for future widespread use in agriculture since they can be designed to release nutrients in a manner closely matching crop demand. 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. The rate of nutrient release can be increased or decreased by manipulating properties of the polymer coating.

At present, the use of CRF in agriculture is limited, accounting for less than 1% of worldwide fertilizer consumption. The main reason for this is cost; CRF may range between 3 and 8 times the cost of a corresponding standard fertilizer. Current usage of CRF is limited primarily to non-agricultural markets such as turf grass. The exception to this is Japan, where CRF are widely used on agricultural crops such as rice and vegetables (Shaviv and Mikkelsen, 1993).

There is potential for the increased use of CRF in agriculture in North America if the cost of CRF production can be reduced and advantages such as increased nutrient recovery, improved crop yield and quality, and reduced environmental impacts can be consistently demonstrated. Controlled-release
fertilizers will be adopted most rapidly in locations where N losses are large, in crops where in-season N applications are common, and in crops with shallow rooting systems.

There have been a limited number of published studies that investigate the value of CRF on large acreage agricultural crops. Those that exist generally indicate there is significant value in using CRF under most conditions. For example, N fertilizer application rates on cotton may be reduced by 40% if controlled-release rather than conventional fertilizers are used (Howard and Oosterhuis, 1997). Trials using polymer-coated urea on winter wheat indicated that there was a 20% yield increase compared to growers’ standard practice; research on potatoes, onions and garlic has also shown a general increase in yield and quality when using CRF (Tindall and Detrick, 1999). 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 resulted in increased crop N uptake (Nyborg et al., 1993). Other western Canadian work (McKenzie et al., 2007 - in press) has shown successful use of CRF in winter wheat production for both seed-placement and side-band applications, and for seed-placement and side-band applications in both spring wheat and canola (Brandt et al., 2004). Other Canadian studies will be reviewed herein, many of which are in the completion year of their respective programs.

Controlled-release fertilizer will be adopted most rapidly in locations where N losses are large, in crops where in-season N applications are common, in crops with shallow rooting systems, and where seed placed fertilizer applications are common-place.

Much of the N applied in north American agriculture is applied in advance of crop uptake. The winter and spring weather in this geography is often characterized by precipitation in excess of evapotranspiration, and potential for N loss exists. Use of CRF has the potential to significantly improve N use efficiency in these production systems.

Nitrous oxide (N2O) has been identified as a major greenhouse gas and also as an ozone depleting substance. Within north and central America, about 54% of N2O–N emitted is attributed to fertilizer additions (IPCC, 1996). The processes by which N2O is produced in soil are transient, and quantification and management thereof are complicated. The Intergovernmental Panel on Climate Change has proposed various strategies for reducing N2O emissions from fertilizer applications (IPCC, 1996). One proposed approach is to adopt advanced fertilizer technologies such as the use of nitrification inhibitors and controlled-release fertilizers (Minami, 1994; McTaggart et al., 1994; Keerthisinghe et al., 1993; Bronson et al., 1992). Controlled-release fertilizers can reduce N2O emissions by releasing N closer to the time of plant uptake and therefore limiting the amount of N exposed to denitrifying conditions.

Advancements in coating technology have decreased production costs for polymer-coated fertilizers to a level that can be economical for use on commodity grain crops where much of the N fertilizer in North America is used. Agrium (Calgary, Alberta, Canada) has developed an economical, polymer-coated controlled-release urea fertilizer, called ESN®, for field crops. Nitrogen release from ESN is by diffusion through the polymer coating, rather than by biological decomposition of the coating. Coupling N release with temperature and soil moisture, primary factors in crop growth and N demand, allows the N supply to be more closely programmed to crop needs.

The objective of this paper is to briefly review several of the studies (being) conducted in western Canada, comparing the performance of ESN, a controlled release N fertilizer, with conventional N management on commodity grain crops.
Study Review and Methodology

A) A large number of field trials were conducted across western Canada from 1998 to 2000 to determine if ESN could maintain crop yields, and increase grain N and N use efficiency compared to the current practice of pre-plant banding of urea N fertilizer (Haderlein et al., 2001). This work showed that crop uptake of N from seed-placed ESN was sufficient to provide yields similar to those of pre-plant banded urea N (figure 1). Uncoated urea placed in the seed row significantly reduced plant stand densities as compared to the control at 8 of 11 sites (data not shown); plant stands with seed-placed ESN were not significantly different from side-band applied urea.

Grain N concentrations of the ESN treatments were higher, on average, than those from banded urea, resulting in 4.2% higher N use efficiency across the entire N application range from 25 to 100 kg ha⁻¹ (figure 2). Higher levels of removal of N in grain from ESN, as compared to banded urea (figure 3), resulted in less residual N remaining in the soil (data not shown), and limits the possibility of N losses due to denitrification and leaching.

Figure 1. Spring wheat yield as affected by N source and application method (Haderlein et al., 2001).
B) Brandt et al. (2004) conducted a large number of field trials comparing the use of seed-placed ESN, seed-placed Agrotain treated urea, side-band applied urea and seed-placed uncoated urea, for both spring wheat and canola production (figure 4a – d).
These researchers concluded that ESN “showed a great deal of promise as a means of making seed-placed N safer.” ESN provided a margin of safety roughly equivalent to side-band applied urea, and greater than that afforded by the use of Agrotain. ESN reduces potential for both salt and free ammonia injury, whereas Agrotain reduces only the potential for free ammonia injury.

C) McKenzie et al. (2007, in press) conducted several years’ work on the use of ESN as a N management tool for winter wheat production in southern Alberta. Their work suggested that all N requirements may be applied at seeding, precluding the need for spring N top-dressing.

Applied at seeding as a side-band application, urea and ESN performed similarly. Applied in a seed-row application, ESN outperformed urea as N rates increased. Averaged across rates, ESN out-yielded urea when side-band applied by about 1.4 bushels per acre. When seed-placed, ESN out-yielded urea by about 6.4 bushels per acre (figure 5).

Generally, greater yield advantages for ESN over urea occurred at the application rates of 30, 60 and 90 kg/ha N rates for side-band application, and at 60, 90 and 120 kg/ha N application rates for seed-placed application.
D) Grant et al. (unpublished) have conducted three years of ESN research at 9 sites across Canada. This group evaluated the effectiveness of ESN against urea, in improving yield and reducing N loss to the environment.

Tables 1 and 2 would suggest that where N loss potential conditions exist – ESN use can be beneficial. And where N loss conditions do not exist – there is low expectation of beneficial (yield – wise) ESN use. With low soil temperatures and reduced soil moisture, release of N from ESN may be somewhat restricted. This can be overcome by blending ESN with either urea or ammonium sulphate, supplying both early and later season N. As well, use of ESN in a blend will lower overall per acre cost of use.

Table 1. ESN and urea yield comparisons under dry conditions (Grant, 2006; unpublished).

<table>
<thead>
<tr>
<th>Site</th>
<th>Crop</th>
<th>N rate (kg ha⁻¹)</th>
<th>ESN (t ha⁻¹)</th>
<th>Urea (t ha⁻¹)</th>
<th>Inc. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lacombe</td>
<td>Canola</td>
<td>30</td>
<td>3.22</td>
<td>3.24</td>
<td>-0.62</td>
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<tr>
<td></td>
<td></td>
<td>60</td>
<td>3.22</td>
<td>3.21</td>
<td>0.31</td>
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<tr>
<td></td>
<td></td>
<td>20</td>
<td>2.42</td>
<td>2.46</td>
<td>-1.63</td>
</tr>
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<td></td>
<td></td>
<td>40</td>
<td>2.6</td>
<td>2.55</td>
<td>1.96</td>
</tr>
<tr>
<td>Swift Current</td>
<td>Wheat</td>
<td>60</td>
<td>2.58</td>
<td>2.62</td>
<td>-1.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30</td>
<td>5.64</td>
<td>5.67</td>
<td>-0.53</td>
</tr>
<tr>
<td>Lacombe</td>
<td>Barley</td>
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<td>6.44</td>
<td>6.46</td>
<td>-0.31</td>
</tr>
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<td></td>
<td></td>
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<td>-7.76</td>
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<td>2.31</td>
<td>2.32</td>
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<tr>
<td>Swift Current</td>
<td>Wheat</td>
<td>45</td>
<td>2.3</td>
<td>2.36</td>
<td>-2.54</td>
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</table>
Table 2. ESN and urea yield comparisons under wet conditions (Grant, 2006; unpublished).

<table>
<thead>
<tr>
<th>Wet conditions – yield advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>N rate (kg ha⁻¹)</td>
</tr>
<tr>
<td>Site</td>
</tr>
<tr>
<td>Brandon-ISF</td>
</tr>
<tr>
<td>Brandon-ZTF</td>
</tr>
<tr>
<td>Beaverlodge</td>
</tr>
<tr>
<td>Brandon-ISF</td>
</tr>
<tr>
<td>Brandon-ZTF</td>
</tr>
<tr>
<td>Harrow</td>
</tr>
</tbody>
</table>

Benefit of ESN was similar to split N application

Figure 6. Canola yield as influenced by N source and timing (Grant, 2006; unpublished).

Across prairie research sites, ESN and split applied urea applications were both effective at increasing crop yield as compared to pre-plant applied urea, under wetter production conditions. The use of ESN mostly precluded the need for in season top-dress (split application) application of urea.
Fall applied ESN proved to be more consistently beneficial as compared to spring applied ESN. Fall applied ESN tended to consistently out perform fall applied urea (figure 7). Fall applied ESN generally showed reduced soil nitrate concentrations in the fall and early spring, as compared to similarly applied urea; this would reduce the risk potential of leaching and denitrification of N, prior to plant uptake (data not shown).

E) Burton et al. (2003) found that ESN treatments had the lowest average gross and net nitrous oxide emissions (N$_2$O), and had the lowest N$_2$O emission rate, as a percentage of applied fertilizer. While N$_2$O losses were generally greatest from fall applied conventional N sources, fall applied ESN produced N$_2$O emissions similar to other spring N applications.

Measurements by Grant et al. (2006; unpublished) indicate that N$_2$O emissions tended to be lower with ESN (“coated urea”) as opposed to uncoated urea (figure 8). Further, ammonia losses tended to be lower with ESN as opposed to uncoated urea.
For the western Canadian prairies and upper tier northern U. S. farming areas, ESN applied at spring seeding can be expected to release about 35 to 50% of its N within the first 25 – 30 days after application. The balance of ESN-N is released evenly over the next 30 to 40 days. Pre-plant or applied at seeding ESN–N is protected from potential spring N loss mechanisms.

Fall applied ESN (first week of September to first week October) can be expected to release about 35 to 50% of its N within a similar time period. The balance of ESN-N remains encapsulated, in the urea form, or in the ammonium – N form, thereby being protected from potential over winter and early spring loss conditions.

Both soil temperature and soil moisture governs ESN-N release. Cool conditions at seeding will slow the release of N from ESN. As well, lack of contact with soil moisture may also affect the release rate; ESN should be applied such that it has soil contact.

Given cool prairie spring conditions, N availability from ESN may be limited in the early growing season. It is recommended that a blend of ESN and readily available N (e.g. urea or ammonium sulphate), be used to supply immediate early season crop N needs, and ESN-N for season long feeding of your crop. This allows the crop’s entire N needs to be applied early without fear of loss; and to provide a steady supply of N as the crop develops, and its N uptake demand increases.

Your blend percentage of ESN–N can be adjusted for your individual growing conditions, and your crop’s N uptake demand timing.
**Conclusion**
ESN protects against N loss and improves N use efficiency. Current (Canadian and US) research supports ESN as an agronomic, environmental and economic alternative N program. Research indicates benefits for both fall and spring applied ESN over conventional N sources, where N loss potential exits. ESN is also a management option for use in increasing spring wheat protein content. Canadian research shows that ESN-N is a suitable management tool for safely increasing rates of seed-placed fertilizer N.

ESN can be used in your N program to match crop N uptake profile, while protecting that N from loss prior to crop uptake.

ESN performance, like any other fertilizer material, can be affected by weather conditions, individual farming practice and management style. ESN can be expected to out-perform traditional N sources, where N loss conditions exist.

**Acknowledgements**
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References


