Agronomic, Economic and Environmental Benefits of Nitrogen Fertilizer Management

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Collaborative 4 year study 2008-2012:

- ARD
  - ESD (Land Use)
  - RIAD (Food & Bio-Industrial Crops)
- AAFC – Lacombe, Beaverlodge
- Agrium
- ACIDF
Objectives

- Evaluate agronomic performance of urea, ESN and blend, based on crop yield, quality and crop growth, based on 4R fertilizer management system - “Right Product @ Right Rate, Right Time, Right Place™”
- Identify most appropriate use of ESN, urea and blend (spring versus fall application, soil moisture conditions and crop).
- Identify agro-climatic regions to use ESN, urea or blend.
- Identify agronomic rate limits of ESN, urea and blend application to reduce seedling damage.
Objectives

- Determine economic optimum rates, placement and timing of ESN, urea and blend application for crop yield and quality.
- Determine the impact of N management changes (N source, timing, placements and rates) on mitigation of N$_2$O emissions for Greenhouse Gas Offset Market.
- Update provincial Nitrogen fertilizer management recommendations.
- Update the AFFIRM software.
The Nitrogen Cycle

Atmospheric Nitrogen

Industrial Fixation (Commercial Fertilizers)

Volatilization \( \text{NH}_3 \)

Plant Uptake

Ammonium \( \text{NH}_4^+ \)

Nitrate \( \text{NO}_3^- \)

Leaching

Crop Harvest

Runoff and Erosion

Atmospheric Fixation

Animal Manures and Biosolids

Biological Fixation By Legume Plants

Organic and Microbial Nitrogen

Immobilization

Mineralization

Plant Residues

Crop Harvest

N\textsubscript{2}, N\textsubscript{2}O

Adapted from IPNI
ESN Background

Water moves in through the coating

N dissolves into solution inside the granule

Temperature Controlled Diffusion

N moves out through the polymer

Into Soil Solution

Polymer-coated Urea

Urea

ESN
Smart Nitrogen
A smarter source of nitrogen.
A smarter way to grow corn.
Study crop productivity, crop quality and maximum safe fertilizer rates:

• Compare effectiveness of N fertilizer sources - urea, ESN and blend (25% urea-75% ESN).

• Compare N fertilizer application time/placement - Fall Banded (FB), Spring Banded (SB), Spring Seed-Placed (SP) of urea and ESN - Spring Seed-Placed (SP) blend

• Crop response to increasing N fertilizer application rates.
Agronomic Research Design

Crops
• HRS Wheat – HR5602
• 2-row Barley – CDC Copeland
• RR Canola – 71-45 RR

Fertilizer Treatments
• Products – Urea vs ESN vs Blend
• Time – Fall vs Spring
• Place – Banded vs Seed Placed
• Rate – 0, 30, 60, 90, 120 kg/ha
Agronomic Research Locations

- 9 sites across Alberta
- 8 dryland; 1 irrigated
- Range of agro-ecological regions with various soil types and climatic regimes
- Continuously cropped or stubble fields
Crop Data

- Emergence, heading and maturity dates,
- Plant counts at about the 2-3 leaf stage,
- After harvest
  - percent grain moisture content,
  - grain yield,
  - test weight,
  - 1000 kernel weight,
  - grain protein
  - kernel plumpness and thins (barley)
  - percent oil (canola)
Field Site Data

**Soil Data**
- Fall soil samples prior to fall fertilizer application for complete laboratory analysis: NH$_4$-N, NO$_3$-N, P, K, S, pH, electrical conductivity (EC), organic matter, bulk density and estimated N mineralization (Hot KCl NH$_4$-N).
- Selected treatments were sampled in the spring and after harvest for NH$_4$-N, NO$_3$-N and soil moisture content.

**Meteorological Data**
- Precipitation – site recorded
- Nearest met station (ACIS) – daily, long-term normals
  - Precipitation, Air temperature, Relative humidity, Wind, Solar radiation
# Meteorological Summary

## Total Growing Season (May-September) Precipitation (mm)

<table>
<thead>
<tr>
<th>Site</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bow Island</td>
<td>286.6 (136)</td>
<td>176.3 (84)</td>
<td>361.3 (169)</td>
</tr>
<tr>
<td>Lethbridge (Dryland)</td>
<td>342.6 (136)</td>
<td>215.5 (85)</td>
<td>393.2 (156)</td>
</tr>
<tr>
<td>Lethbridge (Irrigated)</td>
<td>342.6 (136)</td>
<td>215.5 (85)</td>
<td>393.2 (156)</td>
</tr>
<tr>
<td>High River</td>
<td>372.9 (114)</td>
<td>242.1 (74)</td>
<td>323.0 (96)</td>
</tr>
<tr>
<td>Vegreville</td>
<td>238.6 (86)</td>
<td>100.5 (36)</td>
<td></td>
</tr>
<tr>
<td>Willingdon</td>
<td></td>
<td></td>
<td>365.1 (121)</td>
</tr>
<tr>
<td>Lacombe</td>
<td>297.2 (92)</td>
<td>208.3 (65)</td>
<td>457.6 (135)</td>
</tr>
<tr>
<td>Gibbons</td>
<td>211.5 (68)</td>
<td>167.5 (54)</td>
<td>317.5 (101)</td>
</tr>
<tr>
<td>Barrhead</td>
<td>220.4 (67)</td>
<td>157.7 (48)</td>
<td>293.1 (88)</td>
</tr>
<tr>
<td>Beaverlodge</td>
<td>197.5 (72)</td>
<td>186.2 (68)</td>
<td>195.1 (67)</td>
</tr>
</tbody>
</table>

( ) precipitation as % of long-term normal
Yield Response
High River, 2008

Wheat

Canola

Barley
Protein Response
Beaverlodge, 2008

Wheat

Canola

Barley

N Fertilizer Application

Grain Protein (%) | Seed Protein (%) | Barley Protein (%)
Seedling Injury Response
Beaverlodge, 2008

Wheat and Canola growth comparison with different N fertilizer applications and rates.
Agronomic Benefits

- Significant yield response to N rate for majority of sites and crops. Fertilizer form and time/placement also significant.
- Significant protein response to N rate at all southern sites and crops. Yield and protein response to fertilizer form and time/placement continued to varied by region (site) and crop.
- Seed placed urea causes the greatest seedling injury on canola and wheat, followed by barley.
- Blending ESN/Urea allows higher N rates without seedling injury.
- Seed placed ESN allowed for even higher rates N on all crops.
- Banded ESN is well protected - no volatilization and slow, gradual N release.

- Is N use efficiency and crop yield improved enough to offset the fertilizer price difference?
- Is N released from spring applied ESN fast enough to satisfy crop demands?
Simple Economic Analyses

Does the yield difference between ESN and urea offset the cost difference?

- Current price difference between ESN and Urea $130 - $170/tonne = $0.28 - $0.37/kg N
- Completed an economic analysis based on $0.35/kg N and the following crop prices

<table>
<thead>
<tr>
<th>Crop</th>
<th>$/tonne</th>
<th>$/kg</th>
<th>$/bu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canola</td>
<td>500</td>
<td>0.500</td>
<td>11.34</td>
</tr>
<tr>
<td>Malt Barley</td>
<td>225</td>
<td>0.225</td>
<td>4.90</td>
</tr>
<tr>
<td>CWRS Wheat</td>
<td>280</td>
<td>0.280</td>
<td>7.64</td>
</tr>
</tbody>
</table>
Yield and economic response of the ESN treatments (2008 – 2010)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Year</th>
<th>Yield Response</th>
<th>Economic Response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>Percent Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>2008</td>
<td>87</td>
<td>60.4%</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>73</td>
<td>50.7%</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>72</td>
<td>56.3%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>232</td>
<td>55.8%</td>
</tr>
<tr>
<td>Canola</td>
<td>2008</td>
<td>98</td>
<td>68.1%</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>93</td>
<td>64.6%</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>73</td>
<td>65.2%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>264</td>
<td>65.9%</td>
</tr>
<tr>
<td>Wheat</td>
<td>2008</td>
<td>76</td>
<td>52.8%</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>88</td>
<td>61.1%</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>70</td>
<td>54.7%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>234</td>
<td>56.2%</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Crop</th>
<th>Fall Banded ESN</th>
<th>Spring Banded ESN</th>
<th>Seed placed ESN</th>
<th>Seed placed Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>38.0%</td>
<td>39.8%</td>
<td>48.1%</td>
<td>56.5%</td>
</tr>
<tr>
<td>Canola</td>
<td>44.4%</td>
<td>46.3%</td>
<td>65.7%</td>
<td>72.2%</td>
</tr>
<tr>
<td>Wheat</td>
<td>35.2%</td>
<td>35.2%</td>
<td>54.6%</td>
<td>58.3%</td>
</tr>
</tbody>
</table>
Economic Benefits

- Seed placed ESN/urea blend > seed placed ESN > spring banded ESN > fall banded ESN

- Greatest economic benefits with ESN was for canola followed by wheat and barley.

- Variation within sites, between sites and between years is high, but there are indications of regional differences.

- Regional climatic conditions will play a significant role in economic benefits of ESN vs urea.

- The challenge - reliably prediction of where, when and for which crop the economic benefits of using ESN over urea.
Environmental Potential

- Improved N Fertilizer management to reduce N$_2$O emissions and minimize nitrate leaching.
- 3 sites for N$_2$O monitoring
- All sites monitored for residual nitrate levels.
N₂O Monitoring Results
Barrhead, 2009

### Daily N₂O Flux (g N ha⁻¹ day⁻¹)

**Fall Banded Treatments**
- F-C-0
- F-E-120
- F-E-60
- F-U-120
- F-U-60

Chambers installed just after fall banding.
No sampling over winter.

May 22 Seed  
Sept 1 Harvest

### Cumulative N₂O Emissions (g N ha⁻¹)

**Fall Banded Treatments**
- F-C-0
- F-E-120
- F-E-60
- F-U-120
- F-U-60

Chambers installed just after fall banding.
No sampling over winter.

May 22 Seed  
Sept 1 Harvest

### Daily N₂O Flux (g N ha⁻¹ day⁻¹)

**Spring Banded Treatments**
- S-C-0
- S-E-120
- S-E-60
- S-U-120
- S-U-60

Chambers installed just after spring banding and seeding.

May 22 Seed  
Sept 1 Harvest

### Cumulative N₂O Emissions (g N ha⁻¹)

**Spring Banded Treatments**
- S-C-0
- S-E-120
- S-E-60
- S-U-120
- S-U-60

Chambers installed just after spring banding and seeding.

May 22 Seed  
Sept 1 Harvest
N₂O Monitoring Results
Barrhead, 2010

**Fall Banded Treatments**
- Chambers installed just after fall banding
- No sampling over winter

**Spring Banded Treatments**
- Chambers installed just after spring banding and seeding

**Cumulative N₂O Emissions (g N ha⁻¹)**
- May 17 Seed
- Oct 7 Harvest

**Graphs and Data:**
- Daily N₂O Flux (g N ha⁻¹ day⁻¹)
- Cumulative N₂O Emissions (g N ha⁻¹)
## N$_2$O Emission Mitigation Summary

Impact of N fertilizer management change on mitigation of N$_2$O emissions (2008 – 2010)

<table>
<thead>
<tr>
<th>Management Change</th>
<th>60 kg N/ha</th>
<th>120 kg N/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Std Dev</td>
</tr>
<tr>
<td>Fall Urea ---&gt; Fall ESN</td>
<td>3.3%</td>
<td>36.5%</td>
</tr>
<tr>
<td>Fall Urea ---&gt; Spring Urea</td>
<td>-66.3%</td>
<td>16.8%</td>
</tr>
<tr>
<td>Fall ESN ---&gt; Spring ESN</td>
<td>-65.6%</td>
<td>16.8%</td>
</tr>
<tr>
<td>Spring Urea ---&gt; Fall ESN</td>
<td>291.1%</td>
<td>254.1%</td>
</tr>
<tr>
<td>Spring Urea ---&gt; Spring ESN</td>
<td>5.4%</td>
<td>36.2%</td>
</tr>
</tbody>
</table>

Positive average values indicate increased emissions; negative average values indicate reduced emissions.
Expected Outcomes

Agronomic, Economic & Environmental Benefits

Increase Nitrogen use efficiency:
- Increase crop productivity
- Reduce fertilizer use and cost
- Reduce seedling damage

Reduce N Losses:
- NH$_3$ volatilization
- N$_2$O mitigation
- Carbon-offset market (NERP)

Reduce risks to surface & ground water:
- Matching agronomic requirements
- Reduce residual nitrogen in soil
Next Steps

- Project extended for one more field season to replace lost sites
- Continue data analysis
- Soil N mineralization estimation
- Yield response model
- Economic analysis
- Update AFFIRM software to 5R level
Thank You

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