Proceedings from the 6th Annual Nutrient Management Conference

6th Annual NITROGEN: MINNESOTA’S GRAND CHALLENGE & COMPPELLING OPPORTUNITY CONFERENCE

Sessions 9:00 a.m.-3:25 p.m.

GENERAL SESSION

8:30 a.m. Registration
9:00 a.m. Welcome Tom Rothman University of Minnesota
9:05 a.m. Lessons Learned in 2019, Opportunities for 2020
Angie Peltier Chrysais Meddlesman Brad Carlson University of Minnesota University of Minnesota
9:55 a.m. Importance of Urban and Non-urban Nutrient Reductions Dana Vanderbosch Minnesota Pollution Control Agency
10:30 a.m. Break
10:45 a.m. Modeling the Cost-effectiveness of Practices to Reduce Watershed Nutrient Loads Bill Lazarus University of Minnesota
11:45 Lunch

BREAKOUT SESSION #1

12:45 p.m. Evaluating N Stabilizers R. Jay Goos North Dakota State University
1:25 p.m. Recent findings in N Management Research Brad Carlson University of Minnesota
2:05 p.m. Irrigation and Nitrogen Management for Profitable Corn Production and Groundwater Quality Protection Vasu Sharma University of Minnesota
2:45 p.m. Where Do U of M Reex Come From? N Calculator Updates Dan Kaiser University of Minnesota

BREAKOUT SESSION #2

12:45 p.m. Minnesota’s Nutrient Reduction Strategy- Progress Toward Milestone Goals Glenn Skuta Minnesota Pollution Control Agency
1:25 p.m. Minnesota’s Groundwater Protection Rule Update Larry Gunderson Minnesota Department of Agriculture
2:05 p.m. Cover Crops, N Additions, and Soil Health Anna Cates University of Minnesota
2:45 p.m. Urea and Urea Additives Karina Fabritzi University of Minnesota
3:25 p.m. Adjourn

Thank you to all of our Supporters!
Evaluating nitrogen stabilizers, my experience

R. Jay Goos
North Dakota State University
• Nitrogen stabilizers 101
• Nitrogen stabilizers are fertilizer additives that slow
  – Urea hydrolysis
  – Nitrification
• Urea hydrolysis
• Urea manufacture

\[ 2 \text{NH}_3 + \text{CO}_2 \rightarrow \text{Urea} + \text{H}_2\text{O} \]
Manufacture takes place under high pressure and temperature

• Urea hydrolysis in soil

\[ \text{Urea} + \text{H}_2\text{O} \rightarrow 2\text{NH}_3 + \text{CO}_2 \]
Reaction catalyzed by an enzyme... urease
• Urease enzyme
  – Widely distributed in nature
  – Soil, microbes, and especially crop residues
• Kinetics of urea hydrolysis
  – Think...days
• When is urea hydrolysis of concern?
  – When urea-containing fertilizers are left on the soil surface
  – Part of the N can escape to the atmosphere
  – Ammonia volatilization
• What does a urease inhibitor do?
  – Slows urea hydrolysis by soil/crop residues
  – Gives the soil a better opportunity to absorb the
    NH₃ generated as NH₄⁺
  – Increases the opportunity for rainfall to
    incorporate the fertilizer

• So, the possible benefits of using a urease
  inhibitor are observed in a short time (< 2
  weeks)
• Nitrification

• Most of the N applied by farmers is reduced in nature (anhydrous ammonia, urea, proteins in manure or compost)

• Reduced forms of nitrogen eventually get oxidized by microbes in an aerated soil
  – End result….nitrate (NO$_3^-$)
  – This is the process of nitrification
For example, a farmer spreads urea in the spring, and tills it in....what happens?

- Urea hydrolysis turns urea into $\text{NH}_3$ and $\text{CO}_2$
- The soil simultaneously turns $\text{NH}_3$ into $\text{NH}_4^+$
- The kinetics of this....*days*

- Then, microbes convert the $\text{NH}_4^+$ into $\text{NO}_3^-$
- The kinetics of this....*about a month*
• Plants love nitrate.....what’s the problem?
  – Nitrate can leach into groundwater or into tile drains
  – Nitrate can be lost as N\textsubscript{2} and N\textsubscript{2}O if the soil becomes waterlogged (denitrification)

• What does a nitrification inhibitor do?
  – Slows the conversion of NH\textsubscript{4}\textsuperscript{+} to NO\textsubscript{3}\textsuperscript{-}, hopefully reducing loss from leaching or denitrification
• One problem with explaining urease and nitrification inhibitors to farmers
• Control vs. Inhibition
• Farmers understand *control*
  – Example: a soil-applied herbicide controls target weeds for 6 weeks, before weeds begin to reappear
  – The farmer got....6 weeks of *control*
  – Farmers want to know how long with this or that stabilizer will control urease or nitrification
  – It doesn’t work like that
• Control implies: *stopping something*
• Inhibition implies: *slowing something down*
• Nitrogen stabilizers provide inhibition, not control
Half-life without, ~2.4 days; with, ~ 7 days... ~65% inhibition
• The industry-standard urease inhibitor, NBPT
  – “Rusty key” analogy
• Originally available as Agrotain, but other brands available today
• READ THE LABEL, HOWEVER....some brands don’t give the % NBPT
Another product...
• So, with regard to NBPT-containing products
• NBPT is the industry-standard soil urease inhibitor
• But...make sure the actual % NBPT is on the label

• And...watch out for ineffective products
• Urease inhibitors and granular urea
• 10 mg urea granule, labeled rate of Agrotain Ultra (NBPT)
• Concentration of NBPT in the fertilizer reaction zone, single digits of ppm
• So, a standard rate for testing urease inhibitors for application to urea granules, soil concentration of 5 ppm in soil

• Usually a short-term incubation when screening potential urease inhibitors
3-soil average, 12 hour incubation
Goos, NDSU

Adapted from Goos, 2013a
• Evaluation of urease inhibitors, intact granules, urea hydolysis
• Evaluation of urease inhibitors, intact granules, ammonia volatilization
• Some general thoughts on urease inhibitors and granular urea
• Surface application of urea on no-till, use an effective urease inhibitor
• You don’t need a urease inhibitor if:
  – Urea is tilled in within a couple days
  – Significant rain is expected
• New products...
  – Limus and Anvol, effective
• Liquid fertilizers (UAN)
• Positives:
  – Only half of the N is urea, and subject to volatilization
  – Can be streamed/dribbled, shallowly injected
  – If sulfur is needed, ATS can slow volatilization
• What is definitely out:
  – Spraying on heavy crop residues
Average, bare soil and straw treatment, small and large droplet size
Goos, NDSU

- Goos, 2013b
• With UAN...
  – Surface banding/dribbling/streaming reduces contact with stubble
  – NBPT is effective
  – If S is needed, ATS can slow volatilization, but not as well as NBPT
• Nitrification inhibitors...
• Slow the conversion of ammonium to nitrate
• Most studies don’t show much of a yield benefit, and here is why...
• When does the use of a nitrification inhibitor benefit the farmer?

• We have to talk about dominoes
• When does the use of a nitrification inhibitor lead to a crop yield increase???

• All the "dominoes" need to line up:
  - 1. The N rate cannot be excessive
• When does the use of a nitrification inhibitor lead to a crop yield increase????

• All the "dominoes" need to line up:
  – 1. The N rate cannot be excessive
  – 2. Nitrogen loss by leaching or denitrification has to occur
• When does the use of a nitrification inhibitor lead to a crop yield increase?

• All the "dominoes" need to line up:
  – 1. The N rate cannot be excessive
  – 2. Nitrogen loss by leaching or denitrification has to occur
  – 3. This nitrogen loss has to occur during a "sweet spot" of time
• When does the use of a nitrification inhibitor lead to a crop yield increase???

• All the "dominoes" need to line up:
  – 1. The N rate cannot be excessive
  – 2. Nitrogen loss by leaching or denitrification has to occur
  – 3. This nitrogen loss has to occur during a "sweet spot" of time
  – 4. The amount of N saved by the use of an inhibitor has to be large enough to lead to a measurable difference in yield
• The "sweet spot" of time

• Consider three loss scenarios
  – Scenario 1....N loss event happens shortly after N application
  – Scenario 2....N loss event happens during the period of time that the inhibitor is effective
  – Scenario 3....N loss event happens after the N is nitrified, with or without inhibitor
• The "sweet spot" of time....

Goos and Johnson, 1992
• Scenario 1....loss event happened shortly after application
  – No effect of a nitrification inhibitor expected
• Scenario 3....loss event happened after most of the N had nitrified, even with an inhibitor
  – No effect of a nitrification inhibitor expected
• Scenario 2...the “sweet spot” of time
• The "sweet spot" of time....

Scenario 1  Scenario 2  Scenario 3

3-site average, North Dakota, 1990

Goos and Johnson, 1992
• An example of all of the dominoes lining up....
• A fertilizer experiment set out in the fall of 1996
• Ammonia was applied in early October, on 12 inch centers. N rate was 75 lb N/A
• Additives were:
  – N-Serve at the recommended rate (0.5 lb/A)
  – N-Serve at 3 X the recommended rate
  – ATS at 15 lb S/A
• Soils were somewhat poorly drained
• The fall was normal, a bit on the dry side...
• Band samples taken about 3 weeks later, 23-24 October

• Nitrification was proceeding slowly, and would essentially cease in another week or so
• Both N-Serve and ATS were slowing nitrification, and the soil froze for the winter with a difference in the soil ammonium content between the minus and plus inhibitor treatments....the “sweet spot”

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Aqua</td>
<td>54</td>
<td>32</td>
<td>43</td>
</tr>
<tr>
<td>Aqua + NP</td>
<td>80</td>
<td>63</td>
<td>72</td>
</tr>
<tr>
<td>Aqua + 3X NP</td>
<td>88</td>
<td>68</td>
<td>78</td>
</tr>
<tr>
<td>Aqua + ATS</td>
<td>76</td>
<td>54</td>
<td>65</td>
</tr>
</tbody>
</table>

Goos and Johnson, 1999
• The fall was normal, but the winter was NOT
• The winter of 1996-1997....nothing like it before, or (thankfully) since.
  – Average snowfall in Fargo is about 3 feet
  – Previous record snowfall in Fargo, about 6 feet
  – That fall application of N went through a "worst case scenario" for overwinter losses
• Band samples taken in the spring, how much mineral N (ammonium + nitrite + nitrate-N) made it through such an awful winter?????

<table>
<thead>
<tr>
<th></th>
<th>Site 1</th>
<th>Site 2</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Aqua</td>
<td>7</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Aqua + NP</td>
<td>22</td>
<td>31</td>
<td>27</td>
</tr>
<tr>
<td>Aqua + 3X NP</td>
<td>37</td>
<td>41</td>
<td>39</td>
</tr>
<tr>
<td>Aqua + ATS</td>
<td>29</td>
<td>36</td>
<td>33</td>
</tr>
</tbody>
</table>

• Site 2 was planted to wheat.

Goos and Johnson, 1999
• Yield and NUE data, one site...

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield bu/A</th>
<th>Total N uptake in grain + straw lb/A</th>
<th>Nitrogen fert. use efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>23.4</td>
<td>34.6</td>
<td>--</td>
</tr>
<tr>
<td>Aqua</td>
<td>37.0</td>
<td>52.9</td>
<td>24</td>
</tr>
<tr>
<td>Aqua + NP</td>
<td>45.0</td>
<td>72.2</td>
<td>50</td>
</tr>
<tr>
<td>Aqua + 3X NP</td>
<td>45.9</td>
<td>72.5</td>
<td>50</td>
</tr>
<tr>
<td>Aqua + ATS</td>
<td>47.3</td>
<td>77.0</td>
<td>56</td>
</tr>
</tbody>
</table>

Goos and Johnson, 1999
• All of the dominoes lined up...
  – The N rate was not excessive
  – Nitrogen loss occurred
  – The loss event occurred during the "sweet spot" of time, when there was a difference in the ammonium level in the soil
    • Soil was frozen during the "sweet spot" of time
  – The loss was big enough to reduce yield
  – There was a **big** payoff from using an inhibitor
• So, where do nitrification inhibitors fit?
• A tough call, as there are alternatives
  – Avoiding fall application, instead of using ammonia + N-Serve
  – Split application
• But, there can be small benefits of a nitrification inhibitor, apart from N loss prevention
  – Keeping N shallower in the soil
<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>NH4-N in soil, ppm</th>
<th>N uptake, lb/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1</td>
<td>45</td>
</tr>
<tr>
<td>Calcium nitrate</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>10 mg urea gran.</td>
<td>9</td>
<td>105</td>
</tr>
<tr>
<td>10 mg urea-DCD</td>
<td>21</td>
<td>112*</td>
</tr>
<tr>
<td>100 mg urea gran.</td>
<td>20</td>
<td>112*</td>
</tr>
<tr>
<td>100 mg urea-DCD</td>
<td>68</td>
<td>114*</td>
</tr>
</tbody>
</table>

NH4-N in top six inches, 4 weeks after fertilization
*Significantly greater than calcium nitrate
3 sites, 1993
Goos, et al. 1999
• Some consideration with regards to products
• N-Serve, nitrapyrin, is still the “gold standard”
• Encapsulating nitrapyrin to make Instinct, does reduce its effectiveness somewhat
• DCD, rates needed much greater
<table>
<thead>
<tr>
<th>Inhibitor</th>
<th>Concentration of a.i.</th>
<th>% Inhibition</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-Serve</td>
<td>1 ppm</td>
<td>72</td>
</tr>
<tr>
<td>Instinct</td>
<td>5 ppm</td>
<td>79</td>
</tr>
<tr>
<td>DCD</td>
<td>25 ppm</td>
<td>73</td>
</tr>
</tbody>
</table>

Four soil average, 4 week incubation
Goos, 2019
• DCD shenanigans......watch out....
  – DCD needs to be added to molten urea during manufacture. SuperU is almost 1% DCD by weight
  – Surface-applied DCD products, the rate is just too low
• As with urease inhibitors, there are ineffective products out there
<table>
<thead>
<tr>
<th>Fertilizer source</th>
<th>% of N as ammonium after 4 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea</td>
<td>7</td>
</tr>
<tr>
<td>Urea + NSN-1</td>
<td>7</td>
</tr>
<tr>
<td>Urea + NSN-2</td>
<td>8</td>
</tr>
<tr>
<td>Urea + NZone</td>
<td>7</td>
</tr>
<tr>
<td>Urea + Instinct</td>
<td>30</td>
</tr>
<tr>
<td>SuperU</td>
<td>41</td>
</tr>
</tbody>
</table>

Intact pellets incubated with soil for 4 weeks, 3 soil average

Adapted from Goos and Guertal, 2019
• To summarize
  – Urease inhibitors are probably the easier decision
    • Strict no-till, broadcast urea granules
    • Use an effective product, and rate
  – Nitrification inhibitors, a more difficult decision
    • Particularly if split-application is practical for the farmer
    • Use an effective product, and rate
• Papers quoted:
  – Goos and Guertal, 2019, Agron. J. 111:1441-1447