FERTILIZER SOURCES
Cabin Fever - Agronomy Day
January 13, 2015

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MSU Soil Fertility Extension
Today’s goals

• Present pros and cons of various fertilizer sources
<table>
<thead>
<tr>
<th>Source</th>
<th>Immediately available</th>
<th>May increase availability &amp; reduce environmental losses</th>
<th>Used for in-season adjustments</th>
</tr>
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</table>
## Generalizations on different nutrient sources

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</tbody>
</table>
Nutrient sources are not equally plant available

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>“Immediately” available</th>
<th>Growing season</th>
<th>Several Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Urea (46-0-0)</td>
<td>ESN, SuperU</td>
<td>Legume residue manure</td>
</tr>
<tr>
<td></td>
<td>UAN (28-0-0, 32-0-0, liquid)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CAN (27-0-0)</td>
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<tr>
<td></td>
<td>AS (21-0-0-24)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>MAP (11-52-0)<em>, MAPS (16-20-0-13)</em></td>
<td>Phosphate rock Ca-phosphate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DAP (18-46-0)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>APP (10-34-0, liquid)*</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>MESZ (12-40-0-10-Zn1)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>Potash (KCl 0-0-60)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>Ammonium Sulfate (21-0-0-24)</td>
<td>Elemental sulfur Ca-sulfate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>APS (16-20-0-13)</td>
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* Get tied up in mineral form making some unavailable to plants
Those more plant available are more easily lost
Plant availability affects timing and placement – discussed later
The basic N Cycle

Fixation ➔ Plant Uptake ➔ Harvest

Volatilization: \( \text{NH}_3 \)

Leaching: \( \text{N}_2 \text{Gas} \)

Denitrification: \( \text{NO}_3^- \)

How N can leave a soil
Fertilizers and the basic N Cycle

- **NH₄⁺**: Plant Uptake
- **NO₃⁻**: Fixation → Plant Uptake

Volatilization: **NH₃**

Urea: Urea inhibitors slow conversion, e.g. Agrotain

UAN: Nitrification inhibitors slow conversion, e.g. N-serve

Control or slow release e.g. ESN, Nitamin

Leaching: N₂ Gas

Denitrification
Plant N uptake, ideal N release, urea N release

Urea N release data from Engel, unpub.
EEFs strive to supply N closer to plant uptake curve

ESN adapted from Beres unpub
Agrotain N release from Engel, unpub
Different N sources have different volatilization and leaching loss potential

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<tr>
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<tr>
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Effect of N source on volatilization

Washington
Soil Temp = 50°F
Koenig unpub. data

150 lb N/acre on turf in late Sept.

- 0 N
- AN
- Dry Urea
- UAN Dribble Band
- PCU
- NBPT-urea

Days After Application

NH₃ Volatilization (mmol per day x 10⁴)

0 to 2
0.15 inch rain
2 to 5
0.37 inch rain
5 to 8

Graph showing NH₃ volatilization levels after different N sources and time periods following application.
UAN volatilization with and without Agrotain®

% of surface applied N volatilized over 7 days

<table>
<thead>
<tr>
<th></th>
<th>Check</th>
<th>UAN</th>
<th>UAN+Agrotain</th>
</tr>
</thead>
<tbody>
<tr>
<td>May (74°F)</td>
<td>0</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>July (86°F)</td>
<td>0.6</td>
<td>50</td>
<td>16</td>
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Grant et al. 1996, Manitoba
Does NBPT (Agrotain ®) decrease volatilization losses in Montana (Engel et al)?

• Based on 17 studies:
  Average N lost from urea: 18.1%
  Average N lost from NBPT-urea: 6.5%

• Worst case-conditions for loss:
  moist surface with only sprinkles for weeks (Fertilizer Fact #59)
  snow covered surface (Fertilizer Fact #60)
NBPT (Agrotain®) reduces N loss

NH$_3$ losses observed for late-fall and winter app > than spring, even though temperatures were colder; mitigation by NBPT ≈ 63%

Take home:
1. NBPT has best chance of success when used during high risk conditions.
2. Spring applications have less potential for loss because higher chance for large rain event after application.
NBPT with broadcast urea can increase WW grain protein

Coffee Creek, MT
Engel unpub data

90 lb N/acre

Urea
Urea with NBPT

NBPT sig increased protein from 0.4 to 0.8% points in all years.
NBPT only increased yield with fall broadcast in 2012.
Source, placement and timing study at Moccasin

- Worst-case scenario for leaching – soils ~ 18” deep. 21.6 inches of precipitation from Oct 2010 to Sep 2011
- Placement: Broadcast, seed-placed
- Sources (selected, for all see Fertilizer Fact 62):
  - Regular urea
  - Super U (w/ urease and nitrification inhibitors)
  - Urea mixed with Agrotain and N-serve (nit inhib)
  - ESN with seed (only in fall)
Effect of source and placement (fall applied) on WW grain yield under high risk leaching conditions

Oct 2010 through Sept 2011 precipitation: 21.6”

Yield (bu/acre)

- Urea
- U + Agrotain®
- U + Agrotain®+N-serve®
- Super-U®
- ESN®

Grain Protein (%)

- Urea
- U + Agrotain®
- U + Agrotain®+N-serve®
- Super-U®
- ESN®

Fertilizer Fact 62, Moccasin, MT
Take home messages of Moccasin study

- In wet year, enhanced efficiency fertilizers produced similar or higher yields and protein than conventional urea
- In dry year, yields and protein were similar for EEFs and conventional urea (data not shown), so EEF net revenue would be worse.
EEFs increase safe rate with seed

Data from Mahli et al. 2003
Slow- and controlled-release fertilizers for the northern Great Plains

• No consistent benefit shown (Walsh et al 2013)
• Fall broadcast PCU may increase yield over fall broadcast conventional urea, especially in a wet year when urea may leach overwinter
• If apply in fall to reduce spring work load (and save the marriage), then extra cost might be worth it
• PCU release tends to be too slow in late winter early-spring applications
• PCU allow for higher rate seed-placed
Dry vs. liquid N: Foliar N as an in-season boost to yield and grain protein

How much foliar liquid urea is taken up via leaves at flowering?

- 8-11% is taken up by leaves, vs. 37-67% of soil applied N taken up by plant in same study (Rawluk et al. 2000)
- ½ inch rain (have you been living right?) or irrigation needed to soak N into soil
- If scab risk, do not irrigate within 5 days of flower
Source and rate of N affect leaf burn

32% UAN causes more flag leaf burn and reduced grain yield than equal amount of N from foliar urea

- UAN max suggested rate 30 lb N/ac
- Foliar urea max suggested rate 45 lb N/ac

Brown & Long 1988, Parma, ID, irrigated winter wheat
Fertilizer leaf burn – added caution

• Reduce to 20 lb N/ac max if combined with herbicide
• Leaf damage increased with:
  Surfactant + more than 20 lb N/ac of 28-0-0 UAN
  Urea + Agrotain®
  Sulfur

http://www.msuweeds.com/assets/Annual-Results/2010-Results/Wheat/2010ResultsWT02-10.pdf

• Less leaf burn at beginning of stem elongation than at 2nd node visible, but may not translate to increased yields (Phillips 2004)
Questions?
Legumes benefit companion crop and total yield at all N rates

Dryland, Eckville, AB
Malhi et al. 2004
Pulse/legume rotations: A potentially very economical N source, in the long run.

Allen et al., 2011, Culbertson
Pulse/legume rotations benefit protein before yields

Allen et al., 2011, Culbertson
Do legumes grown prior to winter wheat increase grain protein?
Legume green manure (LGM) study near Bozeman

- No-till pea forage/legume green manure-wheat vs. fallow-wheat
- Spring or winter wheat planted in even years. 2010 was wettest of wheat years.
- 2 N rates: Full (3 lb available N/bu) and ½
- *No wheat yield or protein differences between after fallow and pea forage/pea manure in first 6 years of study (3 pea cycles)*
LGM study near Bozeman: Grain yield in 8th year (2010)

@ 12% moist

Grain yield (bu/ac)

Full N Rate

Half N Rate

Fallow

Green Manure
LGM study near Bozeman: Grain protein in 8th year

Pea cover crop after 4 CC-wheat rotations saved 124 lb N/acre compared to fallow.
Economics of integrating pulse crops into wheat systems

West of Bozeman (16” annual)  
Miller et al. in press
2-year net return (2012 – 2013) after 1 rotation at Big Sandy

Fertilizer Fact 68

N. Gray helped soil sample this!
N credit from pulse/legumes

- N Credit = The amount of fertilizer N to back off from a standard recommendation (e.g., lb N/bu of yield goal) when previous crop is a pulse grain, based on spring soil sampling.
- Adjust yield goal – will be lower after legumes than fallow due to water use, but higher than after small grain
Estimated N credit from pulse/legume

- Grain pulse grown once: 10 lb N/ac
- Grain pulse grown 3 or more times on same field in 10 year period: 20-30 lb N/ac
- Legume cover crop grown once: 20-30 lb N/ac (higher if moist)
- Legume cover crop grown 3 or more times: 30-50 lb N/ac
- If fall soil test (rather than spring), increase all of above by 10 lb N/ac (due to overwinter N mineralization)
**Example N rate calculation (based on Big Sandy study results)**

<table>
<thead>
<tr>
<th></th>
<th>Fallow</th>
<th>Grain pulse grown 1x</th>
<th>Legume cover crop grown 1x</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW yield goal</td>
<td>45</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>(bu/ac)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring soil N</td>
<td>80</td>
<td>55</td>
<td>65</td>
</tr>
<tr>
<td>(lb/ac)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total soil N</td>
<td>45 x 2.6 =</td>
<td>35 x 2.6 = 91</td>
<td>45 x 2.6 = 117</td>
</tr>
<tr>
<td>recommended</td>
<td>117</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(bu/ac x 2.6 lb/bu)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N credit (lb/ac)</td>
<td>0</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>Fertilizer N</td>
<td>117-80-0=47</td>
<td>91-55-10=26</td>
<td>117-65-25=27</td>
</tr>
<tr>
<td>(lb/ac)</td>
<td></td>
<td></td>
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</table>
Questions?
Phosphorus

• Phosphate P is equally ‘available’ to the plant, whether in dry granular or liquid form

• Soil chemistry determines how much gets taken up by plant
  ▪ Alkaline soils with high Ca bind P to create mineral form unavailable to plants – liquids can produce higher yields on highly calcareous soils (> 20% CaCO₃)
  ▪ Limited independent replicated work done on specialty products Avail® or Carbond® for cereals in Montana and the western U.S. Inconsistent results.
Pre-plant plus foliar P offers most consistent yield benefit

Oklahoma, fine silty loam
Olsen P 6 ppm, TSP incorporated preplant
Mosali 2006

60 lb P₂O₅/ac preplant
4 lb P₂O₅/ac foliar
P with S and Zn

- MESZ – 12-40-0-10 plus Zn in a single granule
  - Half of S as sulfate, half as elemental-S
  - 1% Zn
  - Potential benefit of having more even distribution of nutrients and nutrient mix available to plant
  - Work in Ontario and Iowa on corn, potatoes in Minnesota found no benefit of MESZ as starter over using Urea+MAP+Zn. If S lacking, then add that too.
  - Producer needs to determine if convenience is worth the extra cost
Conventional/chemical vs. Plant/manure compost

**Conventional**
- No carbon
- Easy to store
- Higher nutrient concentration
- Custom formulated
- Easy to use
- Liquid or solid available

**Manure or Manure Compost**
- Bulkier
- Nutrient content low but diverse
- Nutrient content difficult to quantify
- Supplies organic matter

Both are available in forms that supply specific nutrients (e.g., bone/blood meal for P)
So many choices

- Lack of independent replicated studies make it difficult to provide recommendations
- There are more new products coming out than resources to test them
- If it seems too good to be true, it probably is
- Conduct strip trials to test a product on your farm.
- See *Enhanced Efficiency Fertilizers* for partial list of those available and mechanism
  ([http://landresources.montana.edu/soilfertility/publications.html](http://landresources.montana.edu/soilfertility/publications.html))
How should a grower choose between 2 products with similar benefits? Determine cost per lb nutrient

Ex: How much ammonium sulfate (21-0-0-24) is needed to supply 100 lb N/acre?

- \[ \frac{100 \text{ lb N/acre}}{0.21 \text{ lb N/lb AS}} = 476 \text{ lb AS/acre} \]
- $385/ton AS = $0.19/lb AS
- $0.19 \times 476 = $90.5/acre for AS
How much would 100 lb N/acre as urea cost, with $460/ton urea?

Urea (46-0-0) at 100 lb N/acre

- $\frac{100 \text{ lb N/acre}}{0.46 \text{ lb N/lb urea}} = 217 \text{ lb urea/acre}
- $460/\text{ton urea} = $0.23/\text{lb urea}
- $0.23 \times 217 = $50/\text{acre for urea} (\text{recall } $90/\text{acre for ammon sulfate})

Other considerations, e.g.:
- Constraints on timing, placement, equipment
Summary

• NBPT (Agrotain®) helps reduce urea loss to volatilization and can increase grain protein

• Slow and controlled release fertilizers:
  ▪ Tend to be more beneficial in wet than dry conditions
  ▪ Likely release too slow when spring applied to cereals
  ▪ Are safer than urea to seed place

• Foliar applications are useful for in-season adjustments, but best followed by rain or irrigation
Summary (cont.)

• All else being equal, select source based on cost per unit of nutrient (e.g., lb N)
• In the long run, legumes in rotation are an excellent economical source of N
For more information

Fertilizer Facts 45, 51, 59, 60, 62, 63 & 66:
http://landresources.montana.edu/fertilizerfacts

Extension Publications:  http://landresources.montana.edu/soilfertility/

Factors Affecting Nitrogen Fertilizer Volatilization (EB0208)

Management to Minimize Nitrogen Fertilizer Volatilization (EB0209)

Enhanced Efficiency Fertilizers (EB0188)

Urea volatilization research website
http://landresources.montana.edu/ureavolatilization

Cover crops research website
http://landresources.montana.edu/soilfertility/covercrops.html