Todays objectives – 4Rs of nitrogen

• Steps towards calculating an N rate
• Timing
• Source & legume rotations
• Placement
Realistic yield goal

• Use variety selection tools
• Past yields indication of future performance
• Having ability for in-season N application allows conservative yield estimate for pre-plant rate
Residual soil N: Timing of soil sampling

- Nitrogen fertilizer guidelines are based on spring soil samples for nitrate in Montana
- BUT, most sampling in MT occurs from late summer to late fall

Why is this a potential problem?
Soil nitrate can increase or decrease from November to April, Montana data based on 180 samples (Jones et al. 2011)

April - Previous November Nitrate Change (lb N/ac)
Fall soil tests can lead to over or under-fertilized fields

- High N crop residue and/or high O.M.
- High N on shallow or coarse soil
- Mineralization
- Over winter
- High Precip
- N leaching (or N₂ gas losses?)
- Under fertilized
- Over fertilized

Compare fall with spring a few times to see patterns of loss or gain for given pastures/rotation
Historical average AVAILABLE N rate guideline: when soil organic matter = 2%

- Dryland winter wheat
  2.6 lb N/bu @ 12.5% protein

- Spring wheat
  3.3 lb N/bu @ 14% protein

- MSU N rate calculation tool takes into account fertilizer costs, grain prices, and protein discounts to optimize net revenue.
  http://www.msueextension.org/econtools/nitrogen/index.html
Evaluate N management

• If winter wheat protein < 12.5%, likely yield limited by lack of N

• To gain 1 protein point (%) in winter wheat:
  ▪ + 22 lb N/ac with < 6” growing season precip
  ▪ + 33 lb N/ac with > 12” growing season precip

• If spring wheat protein < 13.2%, likely yield limited by lack of N
Variable rate N application (Zone or site specific farming)

• At this time economic advantage is inconsistent

• At simplest, divide field into zones of low, med, high productivity

• NDSU has bulletin series on Zone farming SF1176 series at www.ag.ndsu.edu/publications

Image adapted from IPNI 2012
N rate adjustments

- **Stubble**: small grains stubble high carbon to N (C:N). *Adjust fertilizer N* up or down?
  
  10 lb N/1000 lb stubble up to 40 lb N

- **Fallow**: assume ½ of stubble has decomposed over previous year when adjusting

- **After legume rotation**: Adjust fert up or down?
  
  Legumes credit (add) N

<table>
<thead>
<tr>
<th>Crop</th>
<th>N credit (lb N/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>40</td>
</tr>
<tr>
<td>Annual legume 1 x</td>
<td>~10</td>
</tr>
<tr>
<td>Annual legume &gt;3 x</td>
<td>~20</td>
</tr>
</tbody>
</table>
N rate adjustments (cont)

• SOM
  ▪ <1% SOM, add 15-20 lb N/acre
  ▪ >3% SOM, reduce 15-20 lb N/acre

• Tillage – No-till may require extra N for 6 to 15 years. Finer soils require longer end.
Questions?

On to *Timing*
N uptake by wheat for yield and protein
Timing depends on source

• Readily available [urea (46–0–0), urea ammonium nitrate (28–0–0)]
  ▪ shortly before seeding up to mid-tillering

• Slowly available (manure, slow-release N)
  ▪ take time to become available
  ▪ apply well before needed – e.g. fall
Use Nutrient Uptake figure to time top-dress

Example on per acre basis:

- 165 lb N total need
- 40 lb N in soil + 60 lb preplant N = 100 lb N = 60% total N required (100/165=0.60)
- (165 – 100) = 65 lb N needed to top-dress
Top-dress amount and timing based on wheat growth stage

For yield should top-dress 65 lb N more by mid-tillering to give time for N to become available and pushed into rootzone.
Split/In-season N Applications

- Fall broadcast supplies early growth needs
- In-season adjustment for estimated yield potential based on precip to date
  - Don’t apply 2\textsuperscript{nd} application if dry or substantial disease
  - Apply large 2\textsuperscript{nd} application if wet
  - Use chlorophyll meters (e.g., SPAD, GreenSeeker, and Crop Circle) and remote-sensing technologies to guide in-season N adjustments

- Later applications:
  - Potential to increase protein rather than yield
In-season N rate, timing, and dryland vs. irrigation affects protein boost

Dryland

Protein boost:
- Pre/during flowering = 1.3 x (lb N/bu) \( R^2 = 0.27 \)
- Post flowering = 0.6 x (lb N/bu) \( R^2 = 0.14 \)

Irrigated

Protein boost:
Pre/during or post flowering = 2.2 x (lb N/bu) \( R^2 = 0.68 \)

Ability to incorporate with rain or irrigation more important than exact timing at flowering
Broadcast before rain or irrigation (to minimize volatilization loss)

Soil Temp = 46°F
Surface soil was pre-moistened

$R^2 = 0.92$

Echo, Oregon
Holcomb et al. 2011
Late season N cautions

- High late season N on irrigated wheat – lodging
- After stem elongation less chance of lodging
- If risk of scab, avoid application within 5 days of flowering if irrigated or expected rainfall

Image from MT200806
To apply late season or not?

- Flag leaf N concentration (sampled at heading) < 4.2%
- Chlorophyll readings
  - Irrigated spring wheat at heading < 93 to 95% of well-fertilized reference plot
  - Not a reliable tool in dryland winter wheat in our region
Protein increase gained by top-dressing 40 lb N/acre at heading on SW increases at lower flag leaf N

Relationship between protein response to N topdressed and flag leaf N in irrigated sw. Fertilizer Fact 12
Flag leaf sampling

• When?
  Collect at first sign of flowering

• Numbers?
  Randomly select 50-75 flag leaves per field

• How and where send?
  Overnight to a lab w/ fast turnaround (e.g., 1 day turn-around)

• Is this a common way to determine whether to topdress or is it Clain’s hair brain idea?
  Agvise analyzed ~15,000 flag leaf samples in 2009 and ~30,000 in 2010 (Dietrich, pers. comm.)
Questions?

On to *Source and Placement*
Different N sources have different volatilization and leaching loss potential

<table>
<thead>
<tr>
<th>Source</th>
<th>Volatilization</th>
<th>Leaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium nitrate, CAN, ammonium sulfate</td>
<td>less</td>
<td>≈</td>
</tr>
<tr>
<td>UAN (solution 28 or 32)</td>
<td>less</td>
<td>≈</td>
</tr>
<tr>
<td>Enhanced Efficiency Fertilizers (EEFs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urease inhibitors (NBPT: AgrotaIn, ContaiN )</td>
<td>less</td>
<td>≈</td>
</tr>
<tr>
<td>Nitrification inhibitors (DCD: Guardian DF; nitrapyrin: N-Serve, Instinct)</td>
<td>≈</td>
<td>less</td>
</tr>
<tr>
<td>Combinations (SuperU)</td>
<td>less</td>
<td>less</td>
</tr>
<tr>
<td>Controlled release polymer coated (ESN)</td>
<td>less</td>
<td>less</td>
</tr>
<tr>
<td>Slow release (Nitamin, N-Sure, N-Demand)</td>
<td>≈</td>
<td>less?</td>
</tr>
</tbody>
</table>
NBPT with broadcast urea can increase WW grain protein

90 lb N/acre

Coffee Creek, MT
Engel unpub data

NBPT sig increased protein by about 0.4 to 0.8% points for both years. NBPT only increased yield in Fall 2012.
EEFs increase safe rate with seed

Graph showing the relationship between grain yield (bu/acre) and application rate (lb N/acre) for Urea, Urease inhibitor, and Polymer-coated. The graph is based on data from Saskatchewan Malhi et al. 2003.
Slow- and controlled-release for the northern Great Plains

- No consistent benefit shown
- Fall broadcast controlled release may increase yield over broadcast urea, especially in a wet year when urea may leach overwinter
- If fall application to reduce spring workload is important, then extra cost might be worth it
- Release tends to be too slow with late winter to early-spring application (McKenzie et al., 2007)
- Consider blending with urea
Nitrification inhibitors

- Potential benefit with fall-banded urea where:
  - high precip with leaching in sandy soils
  - denitrification (nitrate $\rightarrow$ N$_2$ gas) in water logged/clay soils

- Benefits less likely in dry or well drained soils
- An alternative is fall subsurface large urea granules
Urea conversion to nitrate is faster when soil is wet and warm

Chen et al. 2010, clay-loam pH 8.3
Inhibitors can delay denitrification (nitrate $\rightarrow$ $N_2$ gas)

Take home: Less loss to N gas when urea applied later OR used with inhibitors

<table>
<thead>
<tr>
<th>N source and subsurface banding time</th>
<th>Early winter NO$_3^-$ (lb/acre in top 12&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No N</td>
<td>d</td>
</tr>
<tr>
<td>Urea mid-Sep</td>
<td>a</td>
</tr>
<tr>
<td>Urea late-Sep</td>
<td>c</td>
</tr>
<tr>
<td>Urea early-Oct</td>
<td>d</td>
</tr>
<tr>
<td>Urea+NBPT+DCD mid-Sep</td>
<td>b</td>
</tr>
</tbody>
</table>

Tiessen et al. 2006, Manitoba, clay-loam
Nitrapyrin slows dairy manure nitrification

Calderon et al. 2005, silt-loam, pH 6.1, soil water content 68% pores filled, incubated at 72F
Instinct II reduces fertilizer conversion in soil to nitrate (nitrification inhibitor)

P. Miller, unpub data, 2015
MSU Post Farm, 16” rainfall zone

N banded 2” below surface
Instinct II: dryland spring wheat grain yield

Protein was also not affected by Instinct II

N banded 2” below surface

P. Miller, unpub data, MSU Post Farm, 16” rainfall zone. 2015 was drier than average.
Under irrigation, Instinct II reduced NO$_3^-$ available in the soil

Scherder et al., 2015, Ephrata, WA, 7.4”, UAN sidedress dribble stream bar
In dryland, Instinct II had no influence on NO\textsubscript{3} available in the soil.

Scherder et al., 2015, Plaza, WA, 16” precip., urea preplant incorporated.
Winter wheat grain yield increased with Instinct II® under irrigation (but not dryland).

Scherder et al., 2015, inland Pacific NW
UAN sidedress dribble stream bar, urea preplant incorporated
Legume cover crops

- Terminate by first bloom
- Comprise 50% of crop to provide plant available N (PAN)

Willamette Valley, Oregon
Sullivan and Andrews, 2012
After 4 rotations pea GM provides same net return as fallow, with less N

Miller et al., 2015
Considerations when fertilizing with manure

- Nutrient content is highly variable
- May provide more P and K than needed
- High N can reduce N-fixation by legumes
- Takes time to release nutrients
- Nutrients can be easily leached through the soil profile or volatilized if left on the surface
- May introduce weed seeds and contain residual herbicide
- Weight and bulk of transporting and applying wet manures to fields
Nutrient content of manure is variable.

Get manure tested for content.

Approximately how much total N, P, and K does 1/2” of manure compost supply?

<table>
<thead>
<tr>
<th>Removed by:</th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 season vegetables/acre</td>
<td>150</td>
<td>15</td>
<td>140</td>
</tr>
<tr>
<td>40 bu/acre wheat grain (dryland)</td>
<td>50</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>90 bu/acre wheat grain (irrigated)</td>
<td>113</td>
<td>56</td>
<td>34</td>
</tr>
<tr>
<td>1. Added by 1/2” manure</td>
<td>875</td>
<td>325</td>
<td>875</td>
</tr>
<tr>
<td>2. Added by 1/2” manure</td>
<td>150</td>
<td>20</td>
<td>150</td>
</tr>
</tbody>
</table>
### Nutrients removed by one season’s harvest (irrigated)

<table>
<thead>
<tr>
<th>Crop</th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
<th>N:P:K ratio</th>
<th>N:P:K if meet N w/ manure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetable (edible portion)</td>
<td>150</td>
<td>15</td>
<td>140</td>
<td>23:1:18</td>
<td>23:3.5:19</td>
</tr>
<tr>
<td>Wheat grain (90 bu/acre)</td>
<td>113</td>
<td>56</td>
<td>34</td>
<td>4.5:1:1</td>
<td>4.5:0.7:4</td>
</tr>
<tr>
<td>Pea (70 bu/acre)</td>
<td>153</td>
<td>47</td>
<td>61</td>
<td>7:1:2.5</td>
<td>7:1.2:6</td>
</tr>
<tr>
<td>Alfalfa (3 ton/acre)</td>
<td>144</td>
<td>33</td>
<td>159</td>
<td>10:1:9</td>
<td>10:1.5:8</td>
</tr>
<tr>
<td>Manure (1/2”)</td>
<td>875</td>
<td>325</td>
<td>875</td>
<td></td>
<td>6:1:5</td>
</tr>
</tbody>
</table>
Manure takes time to provide nutrients and available N from manure depends on source

Cumulative plant available N (% of total)

- **Poultry manure**
  - C:N < 13:1

- **Composted material**
  - C:N ≈ 20:1

- **Fresh manure solids**
  - C:N > 40:1

**Week**

1  2  3  4  5

**Year**

1  2  3  4
Placement

- Urea and ammonium based fertilizers – best subsurface placed
- Safe rates for seed placed
  - On-line resources to calculate
  - 50% higher with NBPT
  - 2-4 x higher with polymer coated
- Foliar application
  - Use practices to min leaf burn
  - < 30 lb N/ac of UAN
  - < 45 lb N/ac of liquid urea
  - Use less with herbicide, surfactant, sulfur, NBPT
Summary

- Use realistic yield goals and soil test N to calculate pre-plant N rate
- Adjust in-season for given year
- Apply early for yield, later for protein
- Select the source appropriate for conditions
- Use on-line tools for variety selection, optimal N rate, safe seed-placed rates, manure rates
Resources

• Variety selection tool [www.sarc.montana.edu/php/varieties/](http://www.sarc.montana.edu/php/varieties/)
• On soil fertility website [http://landresources.montana.edu/soilfertility/](http://landresources.montana.edu/soilfertility/)
  ▪ Safe rates for seed-placed – under Agriculture Links
  ▪ Manure rate calculators – under Agriculture Links
• Under Extension Publications
  ▪ *Nutrient Management in No-Till* (EB0182)
  ▪ *Enhanced Efficiency Fertilizers* (EB0188)
  ▪ *Nutrient Uptake and Timing by Crops* (EB0191)
  ▪ *Practices to Increase Wheat Grain Protein* (EB0206)
QUESTIONS?

This presentation and additional information on soil fertility topics is available at http://landresources.montana.edu/soilfertility

Photo by Andrew John