Fine-tune Nitrogen Management Using 4R Stewardship

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4Rs of Nutrient Stewardship for N

- Right rate
- Right source
- Right timing
- Right place
N cycle in the soil-plant-atmosphere system

Soil Fertility and Fertilizers, Havlin et al., 2005
Mineralization = organic N to mineral N (NH$_4^+$)
Immobilization = mineral N to organic N by microbes
Denitrification = nitrate to gaseous NO, N$_2$O, or N$_2$
Volatilization = Gaseous NH$_3$ loss to the atmosphere
  (NH$_4^+$ to NH$_3$ at high pH >7.6 and urea to NH$_3$)
NH$_4^+$ Fixation = movement of ammonium into clays
Nitrification = NH$_4^+$ to NO$_3^-$
Nitrate leaching = movement of nitrate in water below root zone
Fall-applied Fertilizers
What’s Up With Fall Applied Aqua?

Site Information

- Location: Wilke Farm, Ritzville
- Rotation: WW-SF
- SOM: 2.2%
- Total N need for yield goal: 270 lb/ac for yield goal 100 bu/acre
- Total mineral-N in 4-ft depth: 135 lbs/acre
- N Form: Aqua
- N Timing: Preplant in September
- N Rate: 90 lbs N/ac
Reactions of Aqua Ammonia in Soil

\[ \text{NH}_3 + \text{NH}_3 \rightarrow \text{NH}_4^+ + \text{NH}_3 \]

Retention zone

Fixation

Leaching

Immobilization

Denitrification

Nitrification

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

\( \text{N}_2 \)

\( \text{N}_2\text{O} \)

\( \text{NH}_3 \)

Absorbed on CEC

Run off

\( \text{NH}_4^+ \)
What’s Up With Fall Applied Aqua?

Soil depth (foot)

Total Mineral-N (lbs N /acre)

0 10 20 30 40

1 2 3 4

Apr.

6 11 27 30
What’s Up With Fall Applied Aqua?

<table>
<thead>
<tr>
<th>Soil depth (foot)</th>
<th>Nitrate-N (lbs N /acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td>14</td>
<td>86</td>
</tr>
</tbody>
</table>

- Apr.
- Sept.
Daily Rainfall Sept. 1st – Dec. 5th

Total rainfall in Oct. = 4.86 inch
Total rainfall in Nov. = 1.38 inch
Your poll will show here

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or
Open poll in your web browser
What’s Up With Fall Applied Aqua?

<table>
<thead>
<tr>
<th>Soil depth (foot)</th>
<th>30</th>
<th>67</th>
<th>121</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Mineral-N (lbs N /acre)</td>
<td>4</td>
<td>11</td>
<td>22</td>
</tr>
</tbody>
</table>

- N available early in season
- N available later in season
What’s Up With Fall Applied Aqua?

Soil test N for 1st foot soil (lbs N/acre)

- **April**:
  - NO3-N: 11
  - NH4-N: 19

- **September**:
  - NO3-N: 78
  - NH4-N: 8

- **December**:
  - NO3-N: 59
  - NH4-N: 62

Legend:
- NO3-N
- NH4-N
What’s Up With Fall Applied UAN28?

Site Information

- Location: PCFS Farm, Pullman
- Rotation: WW
- Yield goal: 150 bu/acre
- N Form: UAN 28
- N Rate: 0, 72, 120 lbs N/ac
What’s Up With Fall Applied UAN28?

- A solution of Urea and NH₄NO₃
- 50% NO₃NH₄ : 50% Urea → 25% NO₃⁻ + 75% NH₄⁺
- % by weight:
  - UAN 32: 45% NH₄NO₃ + 35% Urea + 20% Water
  - UAN 30: 42% NH₄NO₃ + 33% Urea + 25% Water
  - UAN 28: 40% NH₄NO₃ + 30% Urea + 30% Water
Your poll will show here

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Total Preplant Soil Mineral-N by Sampling Depth

- Toe Slope
- Summit
- Slope
Preplant Soil NH$_4^+$-N & NO$_3$-$N$ by Sampling Depth

**Sampling depth**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tr>
<td><strong>Toe Slope</strong></td>
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<tr>
<td>1</td>
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<td>10</td>
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<td>14</td>
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<td>2</td>
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<td>10</td>
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<td>10</td>
<td>3</td>
<td>14</td>
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<tr>
<td>Total N=136 lb/a</td>
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<table>
<thead>
<tr>
<th><strong>Slope</strong></th>
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<tr>
<td>1</td>
<td>71</td>
<td>52</td>
<td>57</td>
<td>36</td>
<td>51</td>
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<tr>
<td>2</td>
<td>118</td>
<td>24</td>
<td>10</td>
<td>11</td>
<td>69</td>
<td>98</td>
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<tr>
<td>3</td>
<td>26</td>
<td>26</td>
<td>20</td>
<td>7</td>
<td>30</td>
<td>75</td>
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<tr>
<td>Total N=458 lb/a</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th><strong>Summit</strong></th>
<th>1</th>
<th>2</th>
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<th>5</th>
<th>6</th>
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<tbody>
<tr>
<td>1</td>
<td>69</td>
<td>20</td>
<td>7</td>
<td>30</td>
<td>75</td>
<td>24</td>
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<tr>
<td>2</td>
<td>98</td>
<td>30</td>
<td>7</td>
<td>75</td>
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<td>3</td>
<td>69</td>
<td>20</td>
<td>7</td>
<td>30</td>
<td>75</td>
<td>24</td>
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<tr>
<td>Total N=431 lb/a</td>
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</tbody>
</table>

Soil test N (lbs/acre)
Daily Rainfall Oct. 1st - Nov. 30th?

Total rainfall in Oct. = 5.69 inch

Total rainfall in Nov. = 1.71 inch
Your poll will show here

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Current Soil $\text{NH}_4^+\text{-N} \ & \ \text{NO}_3\text{-N}$ in First Foot Soil Depth

Soil test N for first foot soil in December (lbs N/acre)

- **Summit**
- **Slope**
- **Toe Slope**

<table>
<thead>
<tr>
<th>N Rate (lbs N/acre)</th>
<th>PP 0 72 120</th>
<th>PP 0 72 120</th>
<th>PP 0 72 120</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10 93 27</td>
<td>9 38 15</td>
<td>8 58 16</td>
</tr>
<tr>
<td>72</td>
<td>70 39 10</td>
<td>49 49 8</td>
<td>75 90 8</td>
</tr>
<tr>
<td>120</td>
<td>39 93 27</td>
<td>90 49 8</td>
<td>90 90 8</td>
</tr>
</tbody>
</table>
Daily Rainfall Sept. 1st - Nov. 28th

Daily rainfall from Sept. 1st – Dec. 5th 2016

Ritzville
Pullman

September
October
November
Factors that Favor Denitrification

- Poor soil structure.
- Soil alternately wet and dry.
- Recent additions of easily decomposed carbon such as an alfalfa crop plowed down.
- Flooding.
- pH greater than 5.0, and the higher the pH the quicker the denitrification.
  - pH < 5.5 = NO favored
  - pH < 5.5-6.0 = N₂O favored
  - pH > 6.0 = N₂ favored
Factors that Favor Denitrification

Effect of soil water content (% of water-holding capacity) on denitrification in soil (Havlin et al., 2005)
Factors that Favor Denitrification

Relationship between denitrification capacity and water-soluble organic C (Burford & Bremner, 1975)

Effect of soil pH on denitrification in soil (Havlin et al., 2005)
Gravimetric water content sampled on Nov. 28th (%)

- **Toe Slope**: 32.4
- **Slope**: 27.3
- **Summit**: 24.7
Table 4. Nitrogen use efficiency of soft white winter wheat grown in Washington as affected by N application timing and method.

<table>
<thead>
<tr>
<th>N rate</th>
<th>N timing‡</th>
<th>1990</th>
<th>1991</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Pullman</td>
<td>Farmington</td>
</tr>
<tr>
<td>kg ha⁻¹</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>84</td>
<td>100% fall</td>
<td>23.0</td>
<td>23.3</td>
</tr>
<tr>
<td></td>
<td>50% fall-50% PI</td>
<td>24.4</td>
<td>23.5</td>
</tr>
<tr>
<td></td>
<td>100% PI</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>100% TD</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>112</td>
<td>100% fall</td>
<td>22.0</td>
<td>21.1</td>
</tr>
<tr>
<td></td>
<td>50% fall-50% PI</td>
<td>22.5</td>
<td>21.1</td>
</tr>
<tr>
<td></td>
<td>75% fall-25% PI</td>
<td>21.4</td>
<td>21.1</td>
</tr>
<tr>
<td></td>
<td>75% fall-25% TD</td>
<td>22.2</td>
<td>21.0</td>
</tr>
<tr>
<td></td>
<td>CV, %</td>
<td>3.80</td>
<td>0.70</td>
</tr>
</tbody>
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Orthogonal contrasts

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
<th>1991</th>
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</thead>
<tbody>
<tr>
<td>84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100% fall vs. 50% fall-50% PI</td>
<td>*</td>
<td>NS</td>
</tr>
<tr>
<td>100% fall vs. all others</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100% fall vs. all others</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>75% fall-25% PI vs. 75% fall-25% TD</td>
<td>†</td>
<td>NS</td>
</tr>
</tbody>
</table>

†, *, ** Significant at the 0.10 and 0.05, and 0.01 probability levels, respectively; NS = not significant.
‡ PI, TD: spring application by spoke-wheel point injection (PI) or topdressed (TD), respectively.
Fig. 4. Aboveground plant recovery of fertilizer and soil N over the growing season for (a) 112 kg fall-applied labeled N ha\(^{-1}\) and (b) 56 kg fall-applied labeled N ha\(^{-1}\)-56 kg PI-applied labeled N ha\(^{-1}\) at Pullman, 1991.
Fig. 5. Aboveground plant recovery of fertilizer and soil N over the growing season for (a) 112 kg fall-applied labeled N ha$^{-1}$ and (b) 56 kg fall-applied labeled N ha$^{-1}$–56 kg Pl-applied labeled N ha$^{-1}$ at Farmington, 1991.
The N required to increase grain protein from 12% to 14% for different yield levels as affected by NUE

Brown et al. PNW578
Protein of Ute hard red winter wheat as affected by foliar applied urea or UAN 32 in 3 years of study at Parma, ID
Hard red spring wheat protein increase from 40 lbs late season applied N/acre as affected by flag leaf N percentage at heading