Nitrogen Management Training
for Certified Crop Advisers

Nitrogen Management in Wheat
Regulatory and Agronomic Background
Spring Wheat Production in California:

- **Acreage:**
  \[\approx 500,000 \text{ ac yr}^{-1}\] hard red/white;
  \[\approx 50,000 \text{ ac yr}^{-1}\] durum

- **50% grown for grain,** grain growers paid for quantity & quality

- **Yields:** \[\approx 5500-6000 \text{ lb ac}^{-1}\]

- **Protein standard in CA markets is 13%**

- **Average rates of N application = 150-175 lbs acre}^{-1}\]
Optimizing the rate, timing of N application:
• Improves fertilizer use efficiency
• Increases the value of the crop

N Costs and Regulations:

N costs as a proportion of material costs in wheat

- Nitrogen Costs ($84/A): 37%
- Other Material Costs ($50/A): 63%

*Based on 2008 UCCE Cost Study for irrigated wheat in Sac. Valley

N costs as a proportion of total, direct operating costs in wheat

- Nitrogen Costs ($100/A): 28%
- Other Costs ($251/A): 72%

*Based on 2008 UCCE Cost Study for irrigated wheat in Sac. Valley
Growth and N Demand in Wheat
Wheat N Demand Depends On:

• Growth and N uptake by the crop

• Realistic expected yields (given limits of planting date, growing season length, irrigation water availability)

• Class of wheat being grown:
  – Desirability of higher protein % in durums, hard wheat classes
  – Lower protein levels for soft wheats

• Soil characteristics impacting N release/supply
Wheat N Demand: Yield and Protein Content

• Across the west, amount of N (soil residual, mineralizable + fertilizer N) to reach peak yields reported ranges from 3.3 to 5 lbs/100 lbs of grain under various conditions.

• In the northwest, grain yields were maximized with 3.2-3.5 lbs N/100 lb grain, but requirements increased to 4.6-5.3 lbs N/100 lbs grain to reach 14% protein in hard wheats & durums.
Wheat N Demand: Timing Impacts Yield and Protein Content

Fertilizer N effects on yield and protein at various growth stages

**YIELD:**
- ↑ number of tillers and kernels per head
- ↑ biomass N for remobilization during grain fill

**PROTEIN:**
- ↑ kernel weight
- ↑ remobilization rate, direct

---

**Growth Stage**
- Early Leaf
- Tillering
- Stem Elongation (jointing to boot)
- Heading to Maturation

*Image courtesy: U. Kentucky*
Wheat N Demand: Timing

- Fertilizer N demand varies across the growing season.
- Total fertilizer N demand varies according to crop’s protein yield potential- importance of a reasonable yield expectation.

Water is more limiting than N.

- Soil supplies a large portion of N to the crop.

Yield = 7500 lb acre⁻¹; Protein = 11.5%
Wheat N Demand: Timing Impacts Yield and Protein Content

Yield

- Relative yield change (lb / acre)
- N fertilizer timing
- Preplant, Tillering, Boot/Heading, Flowering

Protein

- Relative protein change (%)
- N fertilizer timing
- Preplant, Tillering, Boot/Heading, Flowering
Applications of N at Tillering and Flowering boost grain fertilizer use efficiency relative to other application timings
- Dependent on water availability & timing
- Large range of possibilities (0.3 – 0.65)
Wheat N Demand: Irrigated Wheat

Timing: preplant - tillering
**Wheat N Demand: Irrigated Wheat**

- **Fertilizer N demand:**  
  \[960 \text{ lb ac}^{-1} - 360 \text{ lb ac}^{-1} = 600 \text{ lb ac}^{-1}\]  
  \[600 \text{ lb ac}^{-1} / 5.7 = 105 \text{ lb ac}^{-1}\]  
  \[105 \text{ lb ac}^{-1} / 0.5 \text{ (apparent N recovery in grain } \approx 63\% \text{ overall NUE)} = 210 \text{ lb ac}^{-1}\]

  2.6 lb N / 100 lb grain

- **Fertilizer N demand:**  
  \[960 \text{ lb ac}^{-1} - 360 \text{ lb ac}^{-1} = 600 \text{ lb ac}^{-1}\]  
  \[600 \text{ lb ac}^{-1} / 5.7 = 105 \text{ lb ac}^{-1}\]  
  \[105 \text{ lb ac}^{-1} / 0.4 \text{ (apparent N recovery in grain } \approx 50\% \text{ overall NUE)} = 263 \text{ lb ac}^{-1}\]

  3.7 lb N / 100 lb grain
Wheat N Demand: Supplementally Irrigated Wheat

5500 lb acre\(^{-1}\); 11% protein
- Protein yield = 605 lb ac\(^{-1}\)

2500 lb acre\(^{-1}\); 8% protein
- Protein yield = 200 lb ac\(^{-1}\)

- Fertilizer N demand:
  
  \[
  605 \text{ lb ac}^{-1} - 200 \text{ lb ac}^{-1} = 405 \text{ lb ac}^{-1}
  \]
  
  \[
  405 \text{ lb ac}^{-1} / 5.7 = 71 \text{ lb ac}^{-1}
  \]
  
  \[
  71 \text{ lb ac}^{-1} / 0.5 = 142 \text{ lb ac}^{-1}
  \]

  2.6 lb N / 100 lb grain

- Fertilizer N demand:

  \[
  605 \text{ lb ac}^{-1} - 200 \text{ lb ac}^{-1} = 405 \text{ lb ac}^{-1}
  \]
  
  \[
  405 \text{ lb ac}^{-1} / 5.7 = 71 \text{ lb ac}^{-1}
  \]
  
  \[
  71 \text{ lb ac}^{-1} / 0.4 = 178 \text{ lb ac}^{-1}
  \]

  3.2 lb N / 100 lb grain
**Wheat N Demand: Rainfed Wheat**

4200 lb acre\(^{-1}\); 12.5% protein
• protein yield = 525 lb ac\(^{-1}\)

2500 lb acre\(^{-1}\); 8% protein
• protein yield = 200 lb ac\(^{-1}\)

**Fertilizer N demand:**

\[
\text{525 lb ac}^{-1} - \text{200 lb ac}^{-1} = \text{325 lb ac}^{-1}
\]

\[
\frac{325 \text{ lb ac}^{-1}}{5.7} = 57 \text{ lb ac}^{-1}
\]

\[
\frac{57 \text{ lb ac}^{-1}}{0.5} = 114 \text{ lb ac}^{-1}
\]

2.6 lb N / 100 lb grain

**Range of grain N demand:**

\[
114 - 263 \text{ lb ac}^{-1}
\]

• depending on:
  - water
  - fertilizer use efficiency

**Fertilizer N demand:**

\[
\text{3.4 lb N / 100 lb grain}
\]
Effect of late season nitrogen at flowering (coupled with an irrigation) on yield, protein, and nitrogen status:

<table>
<thead>
<tr>
<th>Site</th>
<th>Flowering N (lbs/acre)</th>
<th>Yield (lbs/acre)</th>
<th>Protein %</th>
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Variety: Yecora Rojo
Effect of Wheat Cultivar and location on Yield and Protein Content

Adapted from Steve Orloff UCCE 2011
Crediting Non-Fertilizer N Sources
Crediting Soil Nitrate-N:

• Method 1: Top 1 foot
  – ppm NO3-N x 4 or 5
    • Example: 12 ppm NO3-N x 4 or 5 ≈ 48 – 60 lb ac\(^{-1}\)

• Method 2: Top 2 feet
  – ppm NO3-N x 3.8 ≈ lb N ac\(^{-1}\) ft\(^{-1}\) of soil
    • Example: 12 ppm (1\(^{st}\) ft)x3.8 ≈ 46 lbs; 7 ppm (2\(^{nd}\) ft)x3.8 ≈ 27 lbs
      – Total ≈ 73 lb ac\(^{-1}\)
      – Or: 73 lb ac\(^{-1}\) x 0.75 ≈ 54 lb ac\(^{-1}\)

• Prior Crop:
  – Tomato residue estimated at 50 lb ac\(^{-1}\) returned, but probably reflected in soil nitrate test
  – Alfalfa contribution ≈ 100 lb ac\(^{-1}\) +
Crediting Organic N:

Multiple ways to estimate, many things to estimate...

- **In-season soil organic matter N mineralization:**
  - $0.8\%\text{ OM} \times 30\text{ lb N} / \%\text{ OM} \approx 24\text{ lb ac}^{-1}$

- **Manure:**
  - Example: For 5 tons dry manure/acre with 1.8% N:
    - $10,000\text{ lbs} \times 0.018$
      - $= 180\text{ lbs N/acre/year}$
    - Estimate 10% mineralization per season
      - $= 18\text{ lbs/acre/year available}$

Yield = 7500 lb acre$^{-1}$; Protein = 11.5%
Crediting Irrigation Water N:

For 3.0 ppm NO$_3^-$-N:

- **Method 1**: NO$_3^-$-N x 2.7/ft of applied water
  - For 14 inches of water:
    \[ 3.0 \times 2.7 \times \frac{14}{12} = 9.45 \text{ lb N / acre / yr} \]

- **Method 2**: NO$_3^-$-N x 0.23/inch of applied water
  - For 14 inches of water:
    \[ 3.0 \times 0.23 \times 14 = 9.66 \text{ lb N / acre / yr} \]
Nitrate Remaining in Soil After Harvest: Example

Scott Valley

West Side REC

lbs nitrate-N/acre

30B
120PP-50T30F
N Management Tools
Soil Nitrate Quick Test:

The Basic SOLVITA® Soil Response Color System

The patented gel-technology system indicates CO₂-respiration over a color range of 0 to 5 (see chart). In CO₂-Burst mode this corresponds to a range of 5 to 180 ppm CO₂-C. In BASAL mode it corresponds to a range of 0 – 55 ppm or 1 – 25 kg m⁻²/year as CO₂.

All Solvita kits work with a basic visual color system, as shown below. By using the Solvita Digital Color Reader (DCR) the soil test values can be measured accurately and precisely determined.

Sequence of Typical Soil Solvita Test Results:
Greenness Test:
Spectral Sensors:

atLEAF chlorophyll meter
- SPAD proxy (660 and 940 nm)
- proxy for yield leaf N concentration
- Retail: ≈ $250

Trimble Greenseeker handheld
- NDVI (660 and 770 nm)
- Suitable proxy for yield potential?
- Retail: ≈ $500
Spectral Sensors: Calibration

Flowering reading and protein outcome

- AtLeaf chlorophyll index vs. Protein (%)
  - Field 1, fully irrigated
  - Field 2, supplemental irrigation
  - Field 2, not irrigated

- GReenseeker NDVI vs. Protein yield (kg/ha)
  - Field 1, fully irrigated
  - Field 2, supplemental irrigation
  - Field 2, not irrigated

Results: Calibration

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<tr>
<th>AtLeaf</th>
<th>GReenseeker NDVI</th>
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Spectral Sensors: Decision Support

**Combined sensor indication of response**

NET $\approx$ $40 / \text{acre}$

*For 4 ton crop with a $0.50 / \text{cwt}$ premium/discount per % above or below target (11%).
Spectral Sensors: Do-It-Yourself Calibration?

300 lb ac\(^{-1}\)
200 lb ac\(^{-1}\)
100 lb ac\(^{-1}\)
50 lb ac\(^{-1}\)
Field rate

Field rate + 50%

Image courtesy: Oklahoma State University
N Management Strategies
## Split Application:

<table>
<thead>
<tr>
<th>Pre-Plant</th>
<th>50 lbs N Tillering</th>
<th>50 lbs N Joint</th>
<th>50 lbs N Boot</th>
<th>50 lbs N Flowering</th>
<th>Total lb N/Acre</th>
<th>Protein %</th>
<th>Yield Tons/A</th>
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### Blanca Grande (HWW) 515

- Protein: 10.3, 11.0, 11.4, 12.8, 12.4, 12.7, 13.5, 12.7, 12.8, 13.5, 13.4, 13.1, 13.0, 13.5, 13.0, 13.5, 0.57, 0.57, 3.19
- Yield Tons/A: 3.37, 3.96, 4.05, 4.16, 3.77, 4.34, 4.22, 4.14, 4.00, 4.25, 4.08, 4.33, 4.40, 4.24, 4.51, 0.41, 0.41, 6.93
## Split Application: Results Cont’d.

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<th>Pre-Plant</th>
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5500 lb acre\(^{-1}\); 11% protein

- **N Demand:**
  
  3.2 lb N / 100 lb grain
  
  \[\approx 176 \text{ lb N} \times 1.25 \text{ (straw)}\]
  
  \[\approx 220 \text{ lb N}\]

- **N Credit:**
  
  Irrigation NO3-N
  
  = 3.5 ppm
  
  Irrigate 4”, 2 times
  
  = 8” × 0.23 × 3.5
  
  \[\approx 6 \text{ lb N}\]
Other Small Grains:

• Barley and Oats require substantially less N
  • Optimal yields can be achieved between 50 and 120 lb N / acre

• Durum wheat may require 130% N to achieve quality targets
  • Good timing can help
Components of N Application Decision Plan:

• Evaluate N needs based on realistic yield goal
  – Realistic, long-term averages adjusted for changing conditions or capabilities
• Consider credits from prior crops, amendments, irrigation water NO$_3^-$-N
  – Estimate organic N contribution from crop residue, which varies and will not fully show up in soil tests
• Resist tendency to apply “just a little more” than necessary for yield goal
  - Consider a 5-10% lower rate based on efficiency gained from split applications at appropriate growth stages
Emphasize split applications to better impact yield & protein:

- Lower application rates pre-plant
  - Avoid losses from slow initial growth, earlier rain/irrigations
  - Initial higher infiltration rates allow more water and soluble nutrients to move

- Split applications better matched to periods of:
  - Higher plant uptake
  - Critical growth stages
  - Reduced soil water infiltration rates

- Late season N applications
  - Evaluate impacts on grain protein
  - Evaluate potential for losses below root zone with deep soil sampling
Reduce fallow period / pre-plant N applications

- Inefficient because separate from periods of plant uptake
- Avoid losses during pre-plant or early growth period, when soil water storage capacity can be limited with rainfall

In-field sensors for real-time protein-yield info

- Multiple sensors for improved predictability

Soil Nitrate-N testing

- Not all soil N is in nitrate form, but under most conditions, much of readily available N is in nitrate form
- N mineralization can supply about 5-40% of needs
- Soil testing can help:
  - Give confidence in making better use of stored soil N
  - Limit waste
  - Protect against leaching losses

Summary Improved N Management Approach:
University of California

Nitrogen Management Training
for Certified Crop Advisers

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University of California
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