Achieving efficient N fertilizer management in California spring wheat

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Outline

• Overview of spring wheat production in California with emphasis on Sacramento Valley conditions

• How does management influence crop N requirements?

• Constructing a N budget for wheat

• How can in-field tools assist in determining site-specific, real-time crop N needs?
Background: Spring wheat production in California

- **Acreage:**
  - \( \approx 500,000 \text{ ac yr}^{-1} \) hard red/white;
  - \( \approx 60,000 \text{ ac yr}^{-1} \) durum

- 50% grown for grain

- **Yields:** \( \approx 5500-6000 \text{ lb ac}^{-1} \)

- Grain growers receive payment for quantity ± quantity

- **Protein (quality) varies by region:** \( \approx 11-14\% \)

Image courtesy: California Wheat Commission
Nitrogen-related management in CA spring wheat

- Irrigation varies by region:
  - More opportunistic in the Sacramento Valley
  - More standard in the southern part of the state and Intermountain area

- Many growers split N applications between sowing and tillering-stem elongation
  - Total rates: 100 – 225 lb acre$^{-1}$

Image courtesy: California Wheat Commission
Why should we care about site-specific N management in wheat?
Why should we care about site-specific N management in wheat?

Optimizing the rate, timing of N application:

• Improves fertilizer use efficiency
• Increases the value of the crop

*Based on 2008 UCCE Cost Study for irrigated wheat in Sac. Valley
Why should we care about site-specific N management in wheat?

- N management plan implementation

### NITROGEN MANAGEMENT PLAN WORKSHEET

<table>
<thead>
<tr>
<th>NMP Management Unit: _____________________________</th>
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</thead>
<tbody>
<tr>
<td>1. Crop Year (Harvested): __________________</td>
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<tr>
<td>2. Member ID# ________________________________</td>
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<td>3. Name: ____________________________</td>
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<tr>
<td>4. APN(s): ________________________________</td>
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<tr>
<td>5. Field(s) ID Acres __________________________</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>CROP NITROGEN MANAGEMENT PLANNING</th>
<th>N APPLICATIONS/CREDITS</th>
<th>15. Recommended/Planned N</th>
<th>16. Actual N</th>
</tr>
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<tr>
<td>6. Crop</td>
<td>47, Nitrogen Fertilizers</td>
<td></td>
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<tr>
<td>7. Production Unit</td>
<td>57, Organic Material N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Projected Yield (Units/Acre)</td>
<td>58, Nitrogen Credit (est)</td>
<td></td>
<td></td>
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<tr>
<td>9. N Recommended (lbs/ac)</td>
<td>59, Nitrogen Credit (est)</td>
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<tr>
<td>10. Acres</td>
<td>51, Total N Applied (lbs per acre)</td>
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<td>52, Total N Applied (lbs per acre)</td>
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<td>53, Total N Applied (lbs per acre)</td>
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<td>54, Total N Applied (lbs per acre)</td>
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<tr>
<th>Post Production Actuals</th>
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<tbody>
<tr>
<td>11. Actual Yield (Units/Acre)</td>
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<tr>
<td>12. Total N Applied (lbs/ac)</td>
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<tr>
<td>13. ** N Removed (lbs N/ac)</td>
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<tr>
<td>14. Notes:</td>
</tr>
<tr>
<td>20. Available N in Manure/Compost (lbs/ac estimate)</td>
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<tr>
<td>21. Available N in Manure/Compost (lbs/ac estimate)</td>
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<tr>
<td>22. Total Available N Applied (lbs per acre)</td>
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<tr>
<td>23. Nitrogen Credits (est)</td>
</tr>
<tr>
<td>24. Available N carryover in soil; (annualized lbs/acre)</td>
</tr>
<tr>
<td>25. N in Irrigation water (annualized, lbs/ac)</td>
</tr>
<tr>
<td>26. Total N Credits (lbs per acre)</td>
</tr>
<tr>
<td>27. Total N Applied &amp; Available</td>
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</tbody>
</table>


Wheat response to N fertilizer addition at various growth stages is generally well-understood.
## METHODS

<table>
<thead>
<tr>
<th>Fertilizer treatments</th>
<th>PREPLANT</th>
<th>TILLERING</th>
<th>BOOT</th>
<th>FLOWERING</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of N fertilizer applied</td>
<td>0 - 100%</td>
<td>0 - 100%</td>
<td>0 - 50%</td>
<td>0 - 20%</td>
<td>0 - 335 kg/ha</td>
</tr>
</tbody>
</table>

### Field 1
- Fully irrigated
- Variety: hard white
- Soil: Entisol, preplant NO3-N = 1 ppm, 0 - 60 cm

### Field 2
- Not irrigated
- Supplemental irrigation
- Variety: hard red
- Soil: Alfisol, preplant NO3-N = 10 ppm, 0 - 60 cm

**Gradients (HIGH to LOW):**
- Nitrogen availability
- Water availability
• Rate of fertilizer N demand varies across the growing season [TIMING MATTERS].

• Total fertilizer N demand varies according to the protein yield potential of the crop [WHAT IS A REASONABLE YIELD EXPECTATION?].

  Water is more limiting than N [IRRIGATION?].

• [SOIL] supplies a large portion of N to the crop.

Yield = 7500 lb acre⁻¹; Protein = 11.5%
TIMING MATTERS

A. Preplant N only

B. Tillering-Flowering N
  • 16% higher yield
  • > 1% higher protein
Timing of N application affects YIELD

- Applications of N at Tillering and Flowering significantly boost yields compared to Preplant and late-Boot/early-Heading applications
- Assuming sufficient water follows N application
Timing of N application affects PROTEIN

- Applications of N at Flowering boost grain protein content relative to other application timings
  - Assuming sufficient water follows N application
  - Assuming crop has sufficient yield potential
Timing of N application affects FERTILIZER USE EFFICIENCY

- Applications of N at Tillering and Flowering boost grain fertilizer use efficiency relative to other application timings
  - Interacts strongly with water availability & timing
  - Large range of possibilities (0.3 – 0.65)
Overall demand for fertilizer N by irrigated wheat in the Sacramento Valley

Timing: preplant - tillering
Overall demand for fertilizer N by irrigated wheat in the Sacramento Valley

- Fertilizer N demand:
  - $960 \text{ lb ac}^{-1} - 360 \text{ lb ac}^{-1} = 600 \text{ lb ac}^{-1}$
  - $600 \text{ lb ac}^{-1} / 5.7 = 105 \text{ lb ac}^{-1}$
  - $105 \text{ lb ac}^{-1} / 0.5 = 210 \text{ lb ac}^{-1}$

  2.6 lb N / 100 lb grain

- Fertilizer N demand:
  - $960 \text{ lb ac}^{-1} - 360 \text{ lb ac}^{-1} = 600 \text{ lb ac}^{-1}$
  - $600 \text{ lb ac}^{-1} / 5.7 = 105 \text{ lb ac}^{-1}$
  - $105 \text{ lb ac}^{-1} / 0.4 = 263 \text{ lb ac}^{-1}$

  3.7 lb N / 100 lb grain

8000 lb acre$^{-1}$; 12% protein
Overall demand for fertilizer N by supplemental irrigated wheat in the Sacramento Valley

- 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:

\[
\begin{align*}
605 \text{ lb ac}^{-1} - 200 \text{ lb ac}^{-1} & = 405 \text{ lb ac}^{-1} \\
405 \text{ lb ac}^{-1} / 5.7 & = 71 \text{ lb ac}^{-1} \\
71 \text{ lb ac}^{-1} / 0.5 & = 142 \text{ lb ac}^{-1}
\end{align*}
\]

2.6 lb N / 100 lb grain

Fertilizer N demand:

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

3.2 lb N / 100 lb grain
Overall demand for fertilizer N by rainfed wheat in the Sacramento Valley

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

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

Range of N rates:

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

- depending on:
  - water
  - fertilizer use efficiency

Fertilizer N demand:

\[
\begin{align*}
525 \, \text{lb ac}^{-1} - 200 \, \text{lb ac}^{-1} &= 325 \, \text{lb ac}^{-1} \\
325 \, \text{lb ac}^{-1} / 5.7 &= 57 \, \text{lb ac}^{-1} \\
57 \, \text{lb ac}^{-1} / 0.5 &= 114 \, \text{lb ac}^{-1}
\end{align*}
\]

2.6 lb N / 100 lb grain

Fertilizer N demand:

\[
\begin{align*}
525 \, \text{lb ac}^{-1} - 200 \, \text{lb ac}^{-1} &= 325 \, \text{lb ac}^{-1} \\
325 \, \text{lb ac}^{-1} / 5.7 &= 57 \, \text{lb ac}^{-1} \\
57 \, \text{lb ac}^{-1} / 0.4 &= 143 \, \text{lb ac}^{-1}
\end{align*}
\]

3.4 lb N / 100 lb grain
How much N will the SOIL supply?

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

• One method (top 1 foot)
  – ppm NO3-N x 4 or 5
    • Example: 12 ppm NO3-N x 4 or 5 ≈ 48 – 60 lb ac⁻¹

• Second method (top 2 feet):  
  – ppm NO3-N * 3.8 ≈ lb N ac⁻¹ ft⁻¹ of soil
    • Example: 12 ppm (1ˢᵗ ft)*3.8 ≈ 46 lbs; 7 ppm (2ⁿᵈ ft)*3.8 ≈ 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 +
How much N will the SOIL supply?

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

- In-season soil organic matter N mineralization:
  - 0.8% OM % * 30 lb N / % OM ≈ 24 lb ac⁻¹

- Other sources:
  - irrigation
  - manure

Yield = 7500 lb acre⁻¹; Protein = 11.5%
Key management variables to consider when determining N fertility at various growth stages

Fertilizer N effects on yield and protein at various growth stages

YIELD:
- number of tillers and kernels per head

PROTEIN:
- biomass N for remobilization during grain fill
- remobilization rate, direct

Rainfall?

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

yield potential
irrigation
site fertility
variety
end use
premium / discount

yield potential
water status
soil N status
plant N status
logistics

yield potential
water status
plant N status
logistics

yield potential
water status
plant N status
logistics

Image courtesy: S. Orloff
What tools are available to assist in real-time N management in wheat?
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What tools are available to assist in real-time N management in wheat?
Objective: Develop decision support tools that inform whether and how much N to apply at any given point in the crop cycle.

Crop Stages: pre-plant; tillering; mid-season; flowering
Management variables that can be approximated by low-cost, in-field technologies

Fertilizer N effects on yield and protein at various growth stages

**YIELD:**
- number of tillers and kernels per head

**PROTEIN:**
- biomass N for remobilization during grain fill
- remobilization rate, direct

---

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

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<table>
<thead>
<tr>
<th>Preplant</th>
<th>Early Leaf</th>
<th>Tillering</th>
<th>Stem Elongation</th>
<th>Heading to Maturation</th>
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<tbody>
<tr>
<td>yield potential</td>
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<td>irrigation</td>
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<td>site fertility</td>
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<td>plant N status</td>
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<td>soil N status</td>
<td>soil N status</td>
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<tr>
<td>premium / discount</td>
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</tbody>
</table>
Management variables that can be approximated by low-cost, in-field technologies

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
- Preplant
- Early Leaf
- Tillering
- Stem Elongation (jointing to boot)
- Heading to Maturation

protein?

yield potential
plant N status
In-field measurement devices

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
Methods: Calibrate across N and water gradients at key points during crop growth
Results: Calibration

**Flowering reading and protein outcome**

![Calibration Diagram 1](image1)

**Flowering reading and protein outcome**

![Calibration Diagram 2](image2)
Results: Decision support

*For $7.50/bu wheat with $0.01/lb premium or discount / % above or below target (11%).
Summary

1. N demand varies across the season & from field-to-field, depends on water availability, timing.

2. The timing of N application can influence yield, protein and fertilizer use efficiency.

3. The use of in-field sensors provided actionable, real-time information as to the protein and protein-yield outcomes of the crop.

4. Combining information from more than one sensor resulted in additive information that improved the in-season ability to predict outcome.
DIY 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
If a suite of 3-4 in-field tests/measures at flowering could predict your ability to add 1% protein to your wheat crop with 60-70% accuracy, how much extra time would you be willing to invest to accomplish this on a 100 acre wheat field?

A. None
B. 30 minutes
C. 1 hour
D. 2 hours
E. 4 hours
On an annual basis, how much would you be willing to invest in tools/tests that would enable this type of decision?

A. Nothing
B. $10
C. $100
D. $1000
E. $10000
Is calibrating in-field diagnostic tools for improved fertility management something you are interested in...

A. Participating in actively
B. Participating in casually
C. Learning more about
D. Not interested

A. 33%
B. 28%
C. 33%
D. 6%
Acknowledgments

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