Nitrogen:
Implementing Management Improvements

Rob Mikkelsen, Western Director
IPNI Mission:

“to develop and promote scientific information about plant nutrient management for the benefit of the human family.”

Agrium Inc.

Office Chérifien des Phosphates Group

Arab Potash Company

PotashCorp

Belarusian Potash Company

Saskferco

Bunge Fertilizantes S.A

Simplot

CF Industries Holding, Inc.

Sinofert Holdings Limited

Intrepid Mining, LLC.

SQM

K+S KALI GmbH

Terra Industries, Inc.

Mosaic

Uralkali
Dr. Rob Mikkelsen
Western Region
Merced, CA
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The Nitrogen Cycle
Nitrogen Fertilizer Plays a Vital Role in Civilization

“Without the use of N fertilizers, we could not secure enough food for the prevailing diets of nearly 45% of the world’s population, or roughly 3 billion people…” [Smil, 2011]

Nitrogen-deficient plants are stunted, yellow, and poor yielding.
Nutrients ... a matter of balance
Why Improve Nitrogen Use Efficiency?

• Economics

• Environmental impacts
  – Nitrate in drinking water
  – Eutrophication & hypoxia
  – Biodiversity loss
  – Smog and PM$_{2.5}$ from ammonia emission
  – Ozone depletion – N$_2$O
  – Greenhouse gases – N$_2$O and CO$_2$
What are some of barriers impeding efficient use of N fertilizer?
Scarcity/Wealth of California Information
## California: Top Crop Commodities

### Crop Production Value (Millions)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Production Value (Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grapes (all)</td>
<td>2,937</td>
</tr>
<tr>
<td>Almonds (shelled)</td>
<td>2,343</td>
</tr>
<tr>
<td>Nursery Products</td>
<td>2,273</td>
</tr>
<tr>
<td>Alfalfa and other hay</td>
<td>1,797</td>
</tr>
<tr>
<td>Lettuce, (all)</td>
<td>1,580</td>
</tr>
<tr>
<td>Strawberries</td>
<td>1,578</td>
</tr>
<tr>
<td>Tomatoes (all)</td>
<td>1,317</td>
</tr>
<tr>
<td>Rice</td>
<td>1,183</td>
</tr>
<tr>
<td>Flowers/Foliage</td>
<td>1,015</td>
</tr>
<tr>
<td>Broccoli</td>
<td>663</td>
</tr>
<tr>
<td>Oranges</td>
<td>608</td>
</tr>
<tr>
<td>Pistachio</td>
<td>569</td>
</tr>
<tr>
<td>Walnuts</td>
<td>558</td>
</tr>
<tr>
<td>Carrots</td>
<td>517</td>
</tr>
<tr>
<td>Lemons</td>
<td>473</td>
</tr>
<tr>
<td>Celery</td>
<td>354</td>
</tr>
</tbody>
</table>

Where is the data to support fertilizer recommendations?
Nitrogen Use Efficiency

“…… estimated NUE for cereal production ranges from 30 to 35%.”

Improving Nitrogen Use Efficiency for Cereal Production (Agron. J. 91:357-363)

Recovery of $^{15}$N labeled fertilizer by Vitis vinifera L., cv. Cabernet Sauvignon: Effects of N fertilizer rates and applied water amounts

Alberto B. Iandolino$^{1,2}$ and Larry E. Williams$^{1,3}$

range from: 5 to 15%

: 27 to 33%

Spinach: 50 to 75%

http://cemonterey.ucdavis.edu/newsletters/ i b Monterey County Crop Notes b i 38279.pdf
# Common NUE Terms (Nitrogen Use Efficiency)

<table>
<thead>
<tr>
<th>Term</th>
<th>Calculation</th>
<th>Total uptake needed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial factor productivity</td>
<td>$PFP = \frac{Y}{F}$</td>
<td>No</td>
</tr>
<tr>
<td>Agronomic efficiency</td>
<td>$AE = \frac{(Y-Y_0)}{F}$</td>
<td>No</td>
</tr>
<tr>
<td>Partial nutrient balance</td>
<td>$PNB = \frac{U_h}{F}$</td>
<td>No</td>
</tr>
<tr>
<td>Apparent recovery efficiency by difference</td>
<td>$RE = \frac{(U-U_0)}{F}$</td>
<td>Yes</td>
</tr>
<tr>
<td>Internal utilization efficiency</td>
<td>$IE = \frac{Y}{U}$</td>
<td>Yes</td>
</tr>
<tr>
<td>Physiological efficiency</td>
<td>$PE = \frac{(Y-Y_0)}{(U-U_0)}$</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**F** – Amount of nutrient applied (as fertilizers, manures, etc.)

**Y** – Yield of harvested portion of crop with applied nutrient

**Y₀** – Yield in control with no applied nutrient

**Uₜ** – Nutrient content of harvested portion of crop

**U** – Total nutrient uptake in aboveground crop biomass with nutrient applied

**U₀** – Total nutrient uptake in aboveground crop biomass with no nutrient applied
Fertilizer N supports crop growth and soil fertility.
Efficient fertilizer Management

The “4R” strategy

Right Source
Right Rate
Right Time
Right Place

For the crop, field or field zone, and nutrient
4R Nutrient Stewardship

- Right Source, Right Rate, Right Time & Right Place
  - Linking practices to science for sustainability performance
ECONOMIC

- Net profit
- Return on investment
- Adoption

SOCIAL

- Yield
- Stability
- Soil productivity
- Farm income
- Working conditions
- Water & air quality

ECOLOGICAL

- Yield
- Nutrient balance
- Nutrient loss
- Soil erosion
- Biodiversity
- Ecosystem services
- Productivity
- Profitability
- Biophysical & Social Environment

- Source
- Rate
- Place
- Time

Resource use: Energy, Labor, Nutrient, Water
The basic scientific principles of managing crop nutrients are universal.
4R adopted by the fertilizer industry

Adopted by NRCS

Promoted by international ag agencies (FAO, IFA)
How to select the Right Rate?

5-yr study
Assessing residual soil nitrate?

http://www.cdfa.ca.gov/is/docs/Rains97.pdf
Dealing with spatial variability: WHY?

Nitrogen Demand by 5 acre Plot

<table>
<thead>
<tr>
<th>340 lbs</th>
<th>175 lbs</th>
<th>125 lbs</th>
<th>50 lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 lbs</td>
<td>225 lbs</td>
<td>100 lbs</td>
<td>100 lbs</td>
</tr>
<tr>
<td>225 lbs</td>
<td>175 lbs</td>
<td>75 lbs</td>
<td>50 lbs</td>
</tr>
<tr>
<td>280 lbs</td>
<td>200 lbs</td>
<td>50 lbs</td>
<td>50 lbs</td>
</tr>
</tbody>
</table>

Pistachio Yield

Whole Field Average N Demand = 150 lb N/A
Right Place:

Where are the roots?

How to manage 200 to 300 lb N/A for a crop with a 6-inch rooting depth?

How to manage 200 to 300 lb N/A for a crop with a 4-foot rooting depth?
Right Time?
Grape Phenology & Nutrient Uptake

General Nitrogen Requirement of Grapevine

Dormant  Bud Burst  Flowering  Berry Fill  Veraison  Post Harvest

YARA
Right Source?
N Source and Nitrous Oxide Emissions

No-till Cotton June 10 – Sept. 9, 2010

Cumulative Daily N₂O flux (g N₂O-N ha⁻¹)

- Ammonia
- Ammonium sulfate
- ESN
- No added N
Water Management is Key to Nitrogen Management
Water and nutrients must be carefully managed to avoid over-irrigation and poor nutrient application.

- 30cm
- 300L/100m/hr (0.4 gpm/100ft)
- 15,000 L/ha/hour

Chapin
Don’t forget other interactions!

Nitrogen fertilization is only one of many factors that must be managed to meet goals:

- Economic
- Environmental
- Social

A few examples…
Data are from 30th year of a long-term, irrigated study in Kansas (N: 161 lb/acre, P: 40 lb P₂O₅/acre, or both combined)

Corn grain yield response (bu/acre)

The difference non-limiting levels make to nutrient recommendations

4R Nutrient Stewardship

• Right Source, Right Rate, Right Time & Right Place
  – Linking practices to science for sustainability performance
4R Plant Nutrition – Decision Cycle

**Policy Level**

**Regional Level**
Agronomic scientists

**Farm Level**
Producers, Crop advisers, Dealers

**DECISION SUPPORT** based on scientific principles

**OUTPUT**
Recommendation of right source, rate, time, and place (BMPs)

**DECISION**
Accept, revise, or reject

**ACTION**
Change in practice

**EVALUATION of OUTCOME**
Cropping System Sustainability Performance

**LOCAL SITE FACTORS**
- Climate
- Policies
- Land tenure
- Technologies
- Financing
- Prices
- Logistics
- Management
- Weather
- Soil
- Crop demand
- Potential losses
- Ecosystem vulnerability
How to Reach the 80,000 Farmers?
Certified Crop Advisor

Ask your crop adviser if they are a CCA when you need a professional to Protect your interests.

Your Farm
Soil Stewardship
Water Quality

Certified Crop Advisers must meet examination requirements, education, experience, and ethical standards that assure you their competency as your partner to achieve the most from your farm.

Your farm is more than just a livelihood, it is your way of life.

Visit www.certifiedcropadviser.org/find to find a CCA near you.
Nebraska CCA Office (402) 476-1528
What Does The 4R Strategy Offer?

• **Source, rate, time, and place** “right” goals for sustainable production

• Checklist for proper nutrient management and opportunities to improve

• Balance the 4 “rights” to achieve appropriate performance indicators

• Involves academics, industry, and regulators

• Clear and simple communication
Who decides what is RIGHT?

• “a team of farmers, researchers, regulators, extension staff and agribusiness professionals.” -???

• An ethical question, more than scientific

• Input from ALL stakeholders on Performance Indicators, Benchmarks, Targets

Farmer (land manager) selects the PRACTICE

Dynamic site-specific decision on source, rate, time and place
Decision support for highest probability of performance
Adaptive management
The four fertilizer rights: placement

Scott Murrell (IPNI), Tony Vyn (Purdue), Guy Lafond (AAFC), Dave Finlayson (CFI),

Know your fertilizer rights

By Tom Bruulsema, International Plant Nutrition Institute, Guelph, ON, Canada; Jerry Lemunyon, USDA-NRCS, Fort Worth, TX; and Bill Herz, The Fertilizer Institute, Washington, DC

The four fertilizer rights:
Selecting the right source

By Robert Mikkelsen, International Plant Nutrition Institute, Merced, CA; Greg Schwab, University of Kentucky, Lexington; and Gyles Randall, University of Minnesota, Waseca

Selecting the right fertilizer rate: A component of 4R nutrient stewardship

By S.B. Phillips, International Plant Nutrition Institute, Owens Cross Roads, AL; J.J. Camberato, Purdue University, West Lafayette, IN; and D. Leikam, Fluid Fertilizer Foundation, Manhattan, KS

The four fertilizer rights: timing

By W.M. Stewart, International Plant Nutrition Institute, Norcross, GA; J.E. Sawyer, Iowa State University, Ames, IA; and M.M. Alley, Virginia Tech, Blacksburg, VA
more information about 4R nutrient stewardship:

nutrientstewardship.com

ipni.net