Improving Nutrient Use Efficiency with 4R Nutrient Stewardship

Dr. Adrian Johnston
IPNI – Asia & Africa Vice President

Seminar on Sustainable Fertilizer Management, 16-17 September 2013, Beijing, China

IPNI Mission “to develop and promote scientific information about the responsible management of plant nutrition for the benefit of the human family.”

In 2012 IPNI had 140 R&D projects
75% supporting increasing crop yields, or intensification
Food Security and Fertilizer Use?

• Long-term studies: provide invaluable information about crop response to fertilization...
  - Integrate the effects of year, climate, pest and disease stress, etc.
• Suggest 40 to 60% of crop response is due to commercial fertilizer.

What is 4R?
Source, rate, time, and place describe any nutrient application
2. 4R technologies and practices

Right Source

Scientific Principle:
• Ensure a **balanced supply** of plant-available nutrients, utilizing all available sources (organic and inorganic).

Practices:
• Credit nutrients from manures and composts
• Credit nutrients from previous crops
• Assess use of enhanced-efficiency sources
  • Inhibitors of urease and nitrification
  • Coated fertilizers
Access to a range of fertilizer products is often a major challenge for small holders

Balanced nutrition And FUE in China

<table>
<thead>
<tr>
<th>Reference</th>
<th>Crop</th>
<th>Treatment</th>
<th>N</th>
<th>NPK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhu, 1994</td>
<td>Barley</td>
<td>N recovery by crop, %</td>
<td>28</td>
<td>51</td>
</tr>
<tr>
<td>Jin, 2001</td>
<td>Wheat (11 yrs)</td>
<td></td>
<td>31</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Corn (5 yrs)</td>
<td></td>
<td>35</td>
<td>66</td>
</tr>
</tbody>
</table>
### IPNI field validation of NE maize
Northeast & Northcentral China

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>n</th>
<th>Grain yield (t/ha)</th>
<th>Fertilizer rate (kg/ha)</th>
<th>Profit (USD/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>P₂O₅</td>
</tr>
<tr>
<td>2010</td>
<td>FP*</td>
<td>138</td>
<td>8.6</td>
<td>225</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>NE</td>
<td>138</td>
<td>8.7</td>
<td>138</td>
<td>50</td>
</tr>
<tr>
<td>2011</td>
<td>FP</td>
<td>185</td>
<td>10.0</td>
<td>222</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>NE</td>
<td>185</td>
<td>10.6</td>
<td>161</td>
<td>49</td>
</tr>
<tr>
<td>2012</td>
<td>FP</td>
<td>138</td>
<td>10.6</td>
<td>235</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>NE</td>
<td>138</td>
<td>10.9</td>
<td>167</td>
<td>63</td>
</tr>
</tbody>
</table>

*FP – farmers practice  
NE – Nutrient Expert

Xu et al., 2013

### Slow & Controlled Release Fertilizers

1. Synthetic organic compounds containing N  
   - urea-formaldehydes, IBDU, triazines, etc.

2. Physical coating or barrier around soluble N fertilizer  
   - Sulfur-coated or polymer-coated urea.

3. Stabilized materials  
   - urease and nitrification inhibitors
**Rice Response**
Six site years of data, China - 2009-10

- Yield response was on average approximately 2.0 t/ha
- With CRU max yield was achieved at the lowest N rate (50%)
- The linear portion of the response curve was significantly different between the two N sources, CRU showing a greater response.
- Both site and site x treatment were significant, but of no agronomic significance.
- Split application of Urea (40% basal+60% later) yielded 7.4 t/ha, and CRU (40% urea basalt+60% CRU basal) yielded 7.0 t/ha, showing no advantage.
- Urea never did yield as high as CRU with rice, and high CRU rates lost yield.
- Using urea alone, the N rate response is appropriate, but the advantage of CRU is clearly demonstrated in the yield response and high N use efficiency.

**Nitrogen Rate and Source Effects on N\textsubscript{2}O Emissions in No-till Continuous Corn**

- 20 to 50 % reduction possible with N source selection

Right Rate

Scientific Principle:
• Assess soil nutrient supply and plant demand for nutrients.

Practices:
• Soil testing
• Deletion plots
• Balance crop removal with inputs
• Determine crop yield potential
• Assess fertilizer:crop price ratios

How to make “science-based” fertilizer recommendations for farmers?
• Soil testing has always been the standard approach to making fertilizer recommendations.
• Soil testing allows us to achieve ‘site-specific nutrient management’ (SSNM) on any given field.
• SSNM helped us avoid the known over- or under application which occurs when we use a blanket recommendation.
• Only problem is…getting soil testing done on small-holder farms
IPNI Supports Site-Specific Nutrient Management (SSNM)

- **SOIL BASED:** Rely mainly on soil testing, classical, destructive, and more static

- **PLANT BASED:** Rely mainly on plants as indicators, new, non-destructive, and more dynamic

The Process of Developing a DSS

1. **Decision Rules**
2. **SSNM**
3. **QUEFTS Model**
4. **Nutrient Expert DSS**
China - Nutrient Expert impact on Fertilizer N recommendations

- Summer maize: N saved by -24~131kgN/ha, average 94kg/ha (40.1%)
- Winter wheat: N saved by 95-177kg N/ha, average 135kg/ha (48.3%)

Right Time

Scientific Principle:
- Assess the timing of crop uptake, soil nutrient supply, weather, loss risks and field operation logistics.

Practices:
- Split-application for increased FUE
- At a commercial scale, split application must fit in with planting operations and crop development
Effects of level, time, and splitting of urea on the yield of irrigated direct seeded rice. George Ghobrial, 1980, Plant + Soil

“As compared to other treatments of time of urea application, topdressing of urea at maximum tillering and panicle initiation stages significantly improved nitrogen use efficiency by promoting production of more panicles per unit land area, and increasing grain weight.”

So why do so few farmers in China not split N application?

• High residual soil N levels…considerable IPNI research has shown there is no advantage when the soil already has sufficient N supply to meet the crop needs for split application.

• LABOUR…LABOUR…LABOUR
Maize-Wheat in Karnataka
Maize equivalent yields – kg/ha/yr

<table>
<thead>
<tr>
<th>Net Ret:</th>
<th>$791</th>
<th>$901</th>
<th>$930</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE-N:</td>
<td>25</td>
<td>29</td>
<td>31</td>
</tr>
</tbody>
</table>

Maize Equiv Yld (kg/ha/yr)

Right Place

Scientific Principle:
• Place nutrients where they are accessible to the crop.

Practices:
• Site-specific sensing technologies
• Starter placement near seedlings
Fertilizer Placement is Critical in Semi-Arid Agriculture...Canada, Australia, S.America

Tillage Effect on Fertilizer N Placement Response
Spring Barley – Alberta, CANADA

65 N – Malhi, 1991
Improving FUE with Placement

• On nutrient deficient soils, placement can play an important role in improving yield and NUE.
• On nutrient surplus soils, placement is of little significance.
• Placement of fertilizer is a challenge in small holder farms

4R Nutrient Stewardship to close the Yield Gap

• Achieving future food security will require increased yields
• Local solutions are required
• Current technology exits to capture significant yield increases
• Combining technologies is critical to increasing success
Precision Farming Tool Adoption in North America – 2013 Survey Results

Increasing returns or reducing costs is the dealer priority to adoption of PF tools/services

Tools used by Dealers:
- Light bars and auto steering being used by 60-65%
- Soil sensors or GreenSeeker technology, <10%
- GPS enabled sprayer booms, 53%

Tools requested by farmers:
- Variable rate fertilizer application, 75%
- Soil sampling with GPS, 78%
- Variable rate lime application, 67%
- Variable rate pesticide application, 45%
- Satellite/aerial imagery, 65%
Precision Farming Tool Adoption in North America – 2013 Survey Results

Barriers to Adoption continue to exist:

• The equipment required changes quickly
• Finding employees qualified to deliver the service
• Demonstrating value to the grower…?
• Cost of equipment
• Cost of employees to deliver the service

The 4Rs influence many performance indicators

• social, economic and environmental performance

• influenced by crop and soil management as well

• whole system outcomes
Making 4R Nutrient Stewardship Work in China

- Nutrient Expert Decision Support System software provides the opportunity to integrate the 4R principles into a fertilizer recommendation.
- This has proven particularly successful where soil testing infrastructure is weak, expensive or not timely for multiple cropping systems.

Nutrient Expert recommendation:
- tailored to location-specific conditions
- consistent with 4R approach

<table>
<thead>
<tr>
<th>Growth stage</th>
<th>Days after planting</th>
<th>Soil moisture</th>
<th>Fertilizer sources</th>
<th>Weight of full bag (kg)</th>
<th>Amount (bags)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal</td>
<td>0</td>
<td>sufficient</td>
<td>14-14-14</td>
<td>50</td>
<td>6.5</td>
</tr>
<tr>
<td>V6</td>
<td>25</td>
<td>sufficient</td>
<td>Urea</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>V10</td>
<td>35</td>
<td>sufficient</td>
<td>Urea</td>
<td>50</td>
<td>2</td>
</tr>
</tbody>
</table>

Other sources of nutrients:
- Crop residue (maize): High
- Organic fertilizer: 0 t
Complicated vs Complex Challenges

• Developing more appropriate, science-based nutrient recommendations in China is really a “complicated” challenge for the Chinese agriculture industry.

• More importantly, the “complex” challenge is developing an agriculture system where growing food grains allows a farmer to make a good living!

Thank you