FERTILIZER TECHNOLOGY UPDATE

- New Fertilizer products

Yuncong Li
TREC-Homestead

Apopka, FL, February 29, 2012
Outline

- Problems with fertilizer production and use
- Nano fertilizers
- Slow release fertilizers
- Liquid fertilizers
- Bio-fertilizers/organic fertilizer
- Zero-P fertilizers/dry granular fertilizers
- Magical/mysterious products
Problems with fertilizer production and use:

- Total use & price are continuously increasing
- Use efficiency is still low
- Pressure is coming from regulation/environmental concerns
Fertilizer Prices

Increase of 356 percent

Source: National Agricultural Statistics Service, USDA.
Input Prices Index Paid by Farmers 2005-2008
(1990-92=100)

<table>
<thead>
<tr>
<th>Category</th>
<th>2005</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuels</td>
<td>216</td>
<td>345</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>164</td>
<td>310</td>
</tr>
<tr>
<td>Seeds</td>
<td>168</td>
<td>237</td>
</tr>
<tr>
<td>Farm Machinery</td>
<td>173</td>
<td>198</td>
</tr>
<tr>
<td>Wage Rates</td>
<td>165</td>
<td>185</td>
</tr>
<tr>
<td>Feed</td>
<td>184</td>
<td>184</td>
</tr>
<tr>
<td>Ag. Chemicals</td>
<td>123</td>
<td>137</td>
</tr>
</tbody>
</table>

Source: Economic Research Service/USDA
The Fertilizer Institute:

- Increase global demands: 11%N, 13%P, 17%K (2001-2006)
- Ethanol production needs more fertilizers
- High transportation costs
- Values of US Dollar falls
World Nutrient Use

Source: IFA May 2008
World Fertilizer Consumption Growth
Increasing Global Demand for the Three Primary Nutrients

Cumulative Growth % YOY

Source: Fertecon, PotashCorp
## Top 10 Consuming Countries, ‘000 t
### 2006 data

<table>
<thead>
<tr>
<th>Country</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>31,810</td>
<td>11,958</td>
<td>5,600</td>
</tr>
<tr>
<td>India</td>
<td>13,774</td>
<td>5,537</td>
<td>4,657</td>
</tr>
<tr>
<td>USA</td>
<td>11,970</td>
<td>4,147</td>
<td>3,460</td>
</tr>
<tr>
<td>Pakistan</td>
<td>2,650</td>
<td>3,149</td>
<td>2,335</td>
</tr>
<tr>
<td>Indonesia</td>
<td>2,350</td>
<td>969</td>
<td>1,005</td>
</tr>
<tr>
<td>Brazil</td>
<td>2,297</td>
<td>867</td>
<td>802</td>
</tr>
<tr>
<td>Australia</td>
<td>2,200</td>
<td>635</td>
<td>731</td>
</tr>
<tr>
<td>Germany</td>
<td>1,758</td>
<td>608</td>
<td>601</td>
</tr>
<tr>
<td>Turkey</td>
<td>1,599</td>
<td>600</td>
<td>502</td>
</tr>
<tr>
<td>Vietnam</td>
<td>1,407</td>
<td>570</td>
<td>443</td>
</tr>
</tbody>
</table>

Source: [http://www.fertilizer.org/ifa/Home-Page/STATISTICS](http://www.fertilizer.org/ifa/Home-Page/STATISTICS)
The Fertilizer Institute:

- Increase global demands: 11%N, 13%P, 17%K (2001-2006)
- Ethanol production needs more fertilizers
- High transportation costs
- Values of US Dollar falls
World Fertilizer Use by Crop Type

Estimates for 2006/07

Source: IFA
Fuel, All Fertilizers and Nitrogen Price Index
January 2000 – June 2009 (1982 = 100)

Problems with fertilizer production and use:

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- Use efficiency is still low
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**N fertilizer recovery efficiency using on-farm measurements**

**Opportunity for improvement**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Region</th>
<th>Number of farms</th>
<th>Avg N rate, kg/ha</th>
<th>Recovery, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>NC USA</td>
<td>56</td>
<td>103</td>
<td>37</td>
</tr>
<tr>
<td>Rice</td>
<td>Asia-farmer</td>
<td>179</td>
<td>117</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Asia-researcher</td>
<td>179</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Wheat</td>
<td>India-poor weather</td>
<td>23</td>
<td>145</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>India-good weather</td>
<td>21</td>
<td>123</td>
<td>49</td>
</tr>
</tbody>
</table>

*Cassman et al., 2002*
The result of applying the definition of agronomic efficiency for N to P

- The highest “efficiency” occurs when inadequate amounts are applied at low soil test levels
- Building soil test levels to optimum reduces “efficiency”
- “Efficient” P use means reduced profitability, water use efficiency, N use efficiency, and land use efficiency
Problems with fertilizer production and use:

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New fertilizer technology

- New fertilizers
  - High use efficiency
  - Relatively low price
  - Minimal environmental impact
  - Renewable
Fertilizer Technology Used Worldwide, But Few New Products Since 1970s

ScienceDaily (Aug. 26, 2008) — About 75% of fertilizers and fertilizer technology used around the world today were developed or improved during the 1950s to 1970s by scientists and engineers at the Tennessee Valley Authority (TVA) in the United States, says John Shields, a former TVA official. Shields is now Interim Director of IFDC, An International Center for Soil Fertility and Agricultural Development, based in Muscle Shoals, Alabama.

"An investment of $41 million in fertilizer research through 1981 returned an incredible $57 billion to U.S. agriculture," Shields says. "That doesn't include benefits of the technology to the rest of the world."

But inadequate public funding caused closure of the TVA fertilizer research program in the early 1990s. Today, publicly funded fertilizer research and development...
Calls for New Fertilizer Research

Dr. Norman Borlaug (1970 Nobel Laureate):

"I am concerned about the state of the fertilizer industry itself. With the price of energy increasing, we need to find cheaper, more effective ways to nourish food crops ...... the fertilizer industry needs to do everything in its power to minimize that cost. Farmers are paying way too much for fertilizer products ...... because much of the nutrients in applied fertilizers are never used by the crop. Nutrient losses to the environment are high with consequences for global warming and water pollution.”
Calls for New Fertilizer Research

Peter McPherson, President of the National Association of State Universities and Land-Grant Colleges (NASULGC):

"The world needs a major research effort to improve the effectiveness of fertilizer production and use. Fertilizer is a commodity industry and it is unlikely the industry alone will undertake the research. Some public investment is probably required."
Calls for New Fertilizer Research

Dr. Norman Borlaug (served on the IFDC Board of Directors from 1994 to 2003):

"Work should begin now on the next generation of fertilizer products using advanced techniques such as nanotechnology and molecular biology, especially in conjunction with plant genetics research. 'Smart' fertilizer products that will release nutrients only at the time and in the amount needed should be developed."
Nano fertilizers

- Using Google Scholar:
  - 2070 articles
  - 60 patents

- There is no refereed article on nano fertilizer (using Agricola database)
Carbon nanotubes (CNTs) were found to penetrate tomato seeds and affect their germination and growth rates. Analytical methods indicated that the CNTs are able to penetrate the thick seed coat and support water uptake inside seeds, a process which can affect seed germination and growth of tomato seedlings.

- University of Arkansas

Credit: ACS/ACS Nano (2009)
P-enriched Biochar with nanotechnology

Dr. Bin Gao
Dr. Norman Borlaug (served on the IFDC Board of Directors from 1994 to 2003):

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Technology and Biotechnology for Better Nitrogen Use Efficiency in Corn

Fred Below

Crop Physiology Laboratory
University of Illinois
Typical Corn Response to Fertilizer N

Average of 78 on-farm locations
Same yield with lower N requirement

Grain yield (Mg ha\(^{-1}\))

Fertilizer N rate (kg ha\(^{-1}\))

<table>
<thead>
<tr>
<th>Grain yield (Mg ha(^{-1}))</th>
<th>0</th>
<th>56</th>
<th>112</th>
<th>168</th>
<th>224</th>
<th>280</th>
<th>330</th>
</tr>
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<tbody>
<tr>
<td>5.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Nitrogen & Biotech Traits

Data from 2008
## Rootworm Bt on N use

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>NUE</th>
<th>Uptake</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/kg N</td>
<td>%</td>
<td>kg/kg N</td>
</tr>
<tr>
<td>DK 61-69</td>
<td>25.9*</td>
<td>71*</td>
<td>36.4</td>
</tr>
<tr>
<td>DK 61-72</td>
<td>17.0</td>
<td>52</td>
<td>33.1</td>
</tr>
<tr>
<td>DK 63-42</td>
<td>31.7*</td>
<td>71*</td>
<td>44.6</td>
</tr>
<tr>
<td>DK 63-46</td>
<td>22.4</td>
<td>56</td>
<td>40.1</td>
</tr>
</tbody>
</table>

*different from non-RW counterpart P < 0.05*
Need high P-efficient varieties in FL
Calls for New Fertilizer Research

Dr. Norman Borlaug (served on the IFDC Board of Directors from 1994 to 2003):

"Work should begin now on the next generation of fertilizer products using advanced techniques such as nanotechnology and molecular biology, especially in conjunction with plant genetics research. 'Smart' fertilizer products that will release nutrients only at the time and in the amount needed should be developed."
Slow- or Controlled-release fertilizers
## Slow-release fertilizers/Controlled-release

<table>
<thead>
<tr>
<th>Water-soluble</th>
<th>Slow-release</th>
<th>Controlled-release</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium nitrate</td>
<td>Non-coated</td>
<td>Coated</td>
</tr>
<tr>
<td>Dissolves all at once</td>
<td>Slowly decomposes to soluble N</td>
<td>Nutrients “leak” through coating</td>
</tr>
</tbody>
</table>

**Ammonium Nitrate**
- 33.5% N
- Very soluble
- Highly leachable
- Subject to volatilization
- Low acidity
- High salt index – 2.99

**Nitroform**
- Urea formaldehyde
- Insoluble organic
- 38% N; 65-71% WIN
- Biological N release – Rate influenced by soil temperature
Controlled-release fertilizer (CRF)

At soil temperatures under 25°C, a CRF must meet three criteria:

1) less than 15% of the CRF nutrients should be released in 24 hours,
2) less than 75% should be released in 28 days, and
3) at least 75% should be released by the stated release time (40–360 days).
Slow-release fertilizers:

- Urea-formaldehyde (UF) – 38% N
- Isobutylidene diurea (IBDU) – 32% N
- Crotonylidene diurea (CDU) – 32.5% N
Slow-release fertilizers

Nitamn 42G

RC 24-0-0

Nitamn 30L
Controlled-release fertilizers
Coating Technology of CRFs

- Polymer (polyethylene, polyesters)
- Sulfur
- Sulfur plus polymer
Sulfur Coated Urea (SCU) Fertilizers
Schematic Diagram-The processing for Controlled-Release fertilizer (polymer coated fertilizer)
Polymer coated fertilizers

CRF-9 month - Brown
CRF-6 month - Pale brown
4. Nutrient release from Controlled-Release fertilizer
Edge of lawn burned by excess fertilizer
Guaranteed not to burn
Why does a CRF burn plants?

- Release too quick
  - Poor quality of products
  - High temperature in FL
### Main characteristics of the CRFs used

<table>
<thead>
<tr>
<th>Product</th>
<th>Stated NPK analysis</th>
<th>N derived from</th>
<th>Release claimed (days)</th>
<th>Release Tested (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>18-6-8</td>
<td>AN, AP, PN</td>
<td>140</td>
<td>104</td>
</tr>
<tr>
<td>F3</td>
<td>15-7-15</td>
<td>AN, AP, PN</td>
<td>90-120</td>
<td>84</td>
</tr>
<tr>
<td>F4</td>
<td>20-8-10</td>
<td>AN, AP, PN</td>
<td>180</td>
<td>114</td>
</tr>
<tr>
<td>F5</td>
<td>15-9-12</td>
<td>AN, AP, PN</td>
<td>120-150</td>
<td>114</td>
</tr>
<tr>
<td>F6</td>
<td>16-6-11</td>
<td>AN, Mono-Ammonium Phosphate</td>
<td>150-180</td>
<td>168</td>
</tr>
</tbody>
</table>

Henry Mayer et al. 2011
CRF research at our laboratory
Large size CRFs
Polymers from agricultural wastes

Dr. Zhaohui Tong
Liquid fertilizers
UF researchers discover ‘green’ pesticide effective against citrus pests

Discovered a key amino acid essential for human nutrition is also an effective insecticide against caterpillars that threaten the citrus industry.
Amino Acid NPK fertilizer-TREC
Bio-fertilizers
Plant Growth Promoting Rhizobacteria

Dr. Shouan Zhang
Phosphate-Solubilizing Bacteria

Mechanisms of P solubilization by phosphate solubilizing bacteria
adopted from Ahemad & Khan 2011
Iron-Solubilizing Bacteria

The siderophore shuttle iron delivery mechanism. Adopted from Stintizi et al. (2002)
Summary

- The best approach to improve fertilizer use efficiency is to invent new fertilizers and to breed new varieties.

- It is time for breakthrough of new type of Fertilizers because of high fertilizer price and tight regulations.
Thank you!