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Date
April 24, 2013

Fertilizer Deep Placement Technology
A Useful Tool in Food Security Improvement

Speakers
Samba Kawa, USAID/BFS
Upendra Singh, IFDC
John H. Allgood, IFDC

Facilitator
Zachary Baquet, USAID Bureau for Food Security
Samba Kawa
USAID/BFS

Samba Kawa is an Agriculture Development Officer with USAID/BFS. Samba currently manages two USAID-funded programs being implemented by IFDC and SANREM. Prior to USAID Kawa had over 7 years of experience in seed multiplication, farmer training and agricultural extension and research while working with the Seed Multiplication Project. Samba was also a New York City Teaching Fellow and taught middle school science. Samba holds a Ph.D. in Soil Science from NC State University, Raleigh, an MS in Soil Science from China, an MA in Education from NYC and a B.Sc. from the University of Sierra Leone.
Upendra Singh
IFDC

Dr. Singh has extensive research experience in many aspects of soil fertility improvement. Dr Singh is leading the IFDC research activity to assess the environmental consequence of FDP technology vis-à-vis conventional surface application of urea on flooded rice. Over the last 20 years he has been responsible for the development of the lowland nitrogen model, phosphorus model, crop growth models and the Phosphate Rock Decision Support System. Dr Singh also coordinated the IFDC/IRRI Collaborative Program in Los Banos, Philippines from 1992-97, where his research was on appropriate nutrient management for rice-based cropping systems.
John H. Allgood has more than 35 years of experience in fertilizer marketing including marketing system design and development, human capacity building, institutional development, market information systems development, credit system development, and policy analyses. One of the many projects he manages is the Accelerating Agriculture Productivity Improvement (AAPI) Project in Bangladesh. The AAPI project is achieving rapid diffusion of FDP technology through a business model that incorporates interventions that build both supply and demand and that support sustainability through strong public and private sector linkages.
Fertilizer Deep Placement Technology Diffusion: A Case Study in Building Farmer Demand and Affording Farmer Access to High-Quality FDP Products
Accelerating Agriculture Productivity Improvement (AAPI) in Bangladesh

- **Goal** – Improve food security and accelerate income growth in rural areas by sustainably increasing agriculture productivity

- **Objectives** – Improve agriculture productivity through increased efficiencies
  - Improve farmer awareness and knowledge
  - Improve farmer access to technologies
  - Strengthen support systems needed for sustainability
Strategic Approach:

- Employ Market-Oriented Concepts:
  - Supply system development
  - Create awareness and demand for FDP products
- Achieve Stakeholder Participation at All Levels
  - Research and technology validation
  - Farmer education
  - Policy constraint alleviation
- Design and Implement M&E System and Information Dissemination
  - Measuring progress and impact
  - Lessons learned
FDP Technology Dissemination: Cross-Cutting Issues

- Capacity Building
  - Public Sector: NARS/MOA/DAE
  - Private: BFA/Other
- Gender Dimensions
- Environmental
How to Prepare USG

USG is produced from prilled or granular urea by pressing with rollers in a briquette machine to produce granules 1.8 and 2.7 grams.
Prilled Urea  

Urea Briquettes
Briquette Production in the Village
# AAPI End-of-Project Result Indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Units</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice area under FDP technology</td>
<td>Million ha</td>
<td>1.8</td>
</tr>
<tr>
<td>Farmers using FDP technologies</td>
<td>Million</td>
<td>3.5</td>
</tr>
<tr>
<td>Micro-enterprises producing USG and/or NPK briquettes</td>
<td>No.</td>
<td>1,800</td>
</tr>
<tr>
<td>Farmers using an applicator</td>
<td>Million</td>
<td>1</td>
</tr>
<tr>
<td>GOB savings from decreased application of urea</td>
<td>Million $</td>
<td>84.50</td>
</tr>
<tr>
<td>Increase in rice production</td>
<td>Million mt</td>
<td>3.32</td>
</tr>
<tr>
<td>Value of increase in rice production</td>
<td>Million $</td>
<td>1,100</td>
</tr>
<tr>
<td>Increased income per farm per annum</td>
<td>USD</td>
<td>262</td>
</tr>
</tbody>
</table>
## Boro 2013 AAPI Activities

<table>
<thead>
<tr>
<th>Activities</th>
<th>Units</th>
<th>Accomplished</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer Training</td>
<td>Batches (40/Batch)</td>
<td>2,828</td>
</tr>
<tr>
<td>Technology Demonstrations</td>
<td>Number</td>
<td>482</td>
</tr>
<tr>
<td>Stakeholders Workshop</td>
<td>Number</td>
<td>40</td>
</tr>
<tr>
<td>Bill Board (Established different period)</td>
<td>Number</td>
<td>12</td>
</tr>
<tr>
<td>Field Days (Planned)</td>
<td>Number</td>
<td>67</td>
</tr>
<tr>
<td>Crop Cuts (Planned)</td>
<td>Number</td>
<td>1,466</td>
</tr>
<tr>
<td>• Demo plots (435)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Trial plots (31)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Farmers plots (1,000)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Boro 2012 (Dry Season Rice)

<table>
<thead>
<tr>
<th></th>
<th>Guti Urea Applied Plot</th>
<th>Broadcasted Urea Applied Plot</th>
<th>Yield Increment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice Yield (kg/ha)</td>
<td>4,624</td>
<td>4,005</td>
<td>619</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Guti Urea Applied Plot</th>
<th>Broadcasted Urea Applied Plot</th>
<th>Urea Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea Application (kg/ha)</td>
<td>167</td>
<td>269</td>
<td>102</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Guti Urea Applied Plot</th>
<th>Broadcasted Urea Applied Plot</th>
<th>Value of Urea Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Urea ($/ha)</td>
<td>3,674</td>
<td>5,380</td>
<td>$21</td>
</tr>
</tbody>
</table>
Demand Growth of *Guti* Urea under AAPI
– cumulative –
Supply Growth of *Guti* Urea under AAPI

- **2010**: Low supply growth
- **2011**: Moderate supply growth
- **2012**: Significant supply growth

The graph shows the growth in machines and urea usage for *Guti* Urea under AAPI from 2010 to 2012.
Urea Briquette Shop
## Payback Period: Urea Briquette Producer Investment

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total variable cost per mt (US $)</td>
<td>262</td>
</tr>
<tr>
<td>Selling price per mt (US $)</td>
<td>275</td>
</tr>
<tr>
<td>Contribution (to fixed cost) (US $)</td>
<td>13</td>
</tr>
<tr>
<td>Payback sales volume (mt)</td>
<td>179</td>
</tr>
<tr>
<td>Payback period (months)</td>
<td>18-24</td>
</tr>
</tbody>
</table>

*Source: Urea Briquette Producers Survey, January 2013.*

NOTE: Total cost is US $2,320 and planned useful life is 7.5 years.
## AAPI Results Achieved through December 2012

<table>
<thead>
<tr>
<th>Result Indicators</th>
<th>Units</th>
<th>Target</th>
<th>Actual</th>
<th>% of Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Guti</em> Urea Manufactured/Sold</td>
<td>Metric Ton</td>
<td>-</td>
<td>252,817</td>
<td>-</td>
</tr>
<tr>
<td><em>Guti</em> Urea Dealers/Machines Installed</td>
<td>Number</td>
<td>730</td>
<td>897</td>
<td>123%</td>
</tr>
<tr>
<td>Farmers Applied <em>Guti</em> Urea in last three rice seasons</td>
<td>Number</td>
<td>2,516,732</td>
<td>4,125,860</td>
<td>164%</td>
</tr>
<tr>
<td>Rice Area under <em>Guti</em> Urea in last three rice seasons</td>
<td>Hectare</td>
<td>1,258,366</td>
<td>1,317,652</td>
<td>105%</td>
</tr>
</tbody>
</table>
### AAPI Results Achieved through December 2012

<table>
<thead>
<tr>
<th>Result Indicators</th>
<th>Units</th>
<th>Target</th>
<th>Actual</th>
<th>% of Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incremental Rice Production</td>
<td>Metric Ton</td>
<td>983,287</td>
<td>863,432</td>
<td>88%</td>
</tr>
<tr>
<td>Increased Value of Rice</td>
<td>Million US $</td>
<td>314.65</td>
<td>299.88</td>
<td>95%</td>
</tr>
<tr>
<td>Urea Saved</td>
<td>Metric Ton</td>
<td>120,114</td>
<td>120,237</td>
<td>100%</td>
</tr>
<tr>
<td>Value of Urea Saved</td>
<td>Million US $</td>
<td>40.83</td>
<td>67.43</td>
<td>165%</td>
</tr>
<tr>
<td>GOB Savings on Urea Subsidy</td>
<td>Million US $</td>
<td>22.89</td>
<td>42.47</td>
<td>186%</td>
</tr>
</tbody>
</table>
Sustainability of Progress
(Opportunities and Challenges)

- Farmer Education
- Ease of Application
- Technology Promotion
- Economic Returns
- Product Enhancement (NPK) and Performance
- Extension to Other crops
- GOB Policy
- Profitability
- Quality Control
- Business Linkage Development
- Dealer Capacity (Knowledge) Building

*Demand-Side

*Supply-Side
Injector-Type
Self-Loaded Applicator
Applicator in Field Operation
Single Row Applicator
Single Row Applicator Field Operation
Deep Placement Technology: Sub-Surface Application of Urea

- **Goal of APPI**— Improve food security and accelerate income growth in rural areas by sustainably increasing agriculture productivity.

- Global food security is challenged by many issues, including weather and climate variability, degraded soils and persistent poverty.

- **Objective**— Improve agriculture productivity through increased efficiencies of resources.
How Deep Placement Works?

Negligible Floodwater
Urea-N, NH$_4^+$-N, NO$_3^-$-N

Gaseous Loss
Negligible Ammonia Volatilization
Less N$_2$, N$_2$O, NO

Oxidized Soil Zone

10 cm

(Reduces Diffusion)

NH$_3$-N

CO$_2$

USG

Urea-N → NH$_4^+$-N → NO$_3^-$-N

(High NH$_3$ concentration)

Negligible NO$_3^-$-N Leaching Loss

Denitrification

Reduced Soil Layer

Urea-N Leaching Loss
N Balance for UDP and Split Applied Urea in Wetland Rice. IRRI-IFDC

**Split Application**
- In Grain: 23%
- In Straw: 9%
- In Soil: 33%
- Unaccounted: 35%

**Deep Placed Urea Briquette**
- In Grain: 42%
- In Soil: 31%
- In Straw: 23%
- Unaccounted: 4%
Productivity Gains with Deep Placement

Urea Briquette

NPK Briquette
Grain Yield Increases:

Research Trials on UDP Conducted by Bangladesh Research Institutions (BRRI, BARI, and BINA)

(Source: Annual reports, Bhuiyan et al., 1998)
**Consistent Yield Increase – Across Seasons**

Comparison of Rice Grain Yield with Urea Briquette Deep Placement and Broadcast Split Urea Application from 2009-2010 Demonstration Plots

![Graph showing grain yield comparison](image)

\[ Y = 0.975 + 1.04x \quad (r^2 = 0.83, N = 315) \]

- **Aus 2009**
- **T. Aman 2009**
- **Boro 2010**
- **Boro 2009**
Gains in Sub-Saharan Africa

Rice Grain Yield (t ha⁻¹)

- Niger
- Nigeria
- Madagascar
- Mali
- Senegal
- Burkina
- Rwanda
- Togo
- MEAN

Legend:
- UDP
- Urea
- Yield difference
Rice Grain Yield, Nangarhar, Afghanistan

**Tillage Practice**
- Conventional Tillage
- Zero Tillage

**Rice Grain Yield (t ha⁻¹)**

- Urea LCC with var. Kunduz-1
- UDP with var. Kunduz-1
- Urea LCC with var. Basmati-385
- UDP with var. Basmati-385

**LSD (.05) = 0.67**
Less Weeds (Labor, Herbicide)

Weed Control

[Ȳ_{BRD}=11.5] > [Ȳ_{UDP}=6.94]**

KSa = 11.26 **
Improved N Efficiency

— Partial Factor Productivity

Comparison of Partial Factor Productivity
(Grain Yield with Soil N and Fertilizer N per kg Applied N)
for 2009-2010 Demonstration Plots

Grain Yield (kg) per kg N Applied using Prilled Urea

Grain Yield (kg) per kg N applied using UDP

Y = 49.1 + 0.925 x
(r² = 0.38, N = 315)

1:1 Line

Aus 2009
T. Aman 2009
Boro 2010
Boro 2009
## Improved N Efficiency

### Apparent N Recovery (%)

<table>
<thead>
<tr>
<th>Country</th>
<th>Urea Deep Placement</th>
<th>Farmer Practice-Urea</th>
<th>Technology</th>
<th>AE&lt;sub&gt;N&lt;/sub&gt;</th>
<th>VCR</th>
<th>AE&lt;sub&gt;N&lt;/sub&gt;</th>
<th>VCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Niger</td>
<td>59</td>
<td>3.5</td>
<td>AE&lt;sub&gt;N&lt;/sub&gt;</td>
<td>36</td>
<td>3.5</td>
<td>59</td>
<td>5.9</td>
</tr>
<tr>
<td>Nigeria</td>
<td>70</td>
<td>4.8</td>
<td>AE&lt;sub&gt;N&lt;/sub&gt;</td>
<td>49</td>
<td>4.8</td>
<td>70</td>
<td>7.0</td>
</tr>
<tr>
<td>Madagascar</td>
<td>63</td>
<td>5.5</td>
<td>AE&lt;sub&gt;N&lt;/sub&gt;</td>
<td>44</td>
<td>5.5</td>
<td>63</td>
<td>8.0</td>
</tr>
<tr>
<td>Mali</td>
<td>64</td>
<td>3.3</td>
<td>AE&lt;sub&gt;N&lt;/sub&gt;</td>
<td>41</td>
<td>3.3</td>
<td>64</td>
<td>6.7</td>
</tr>
<tr>
<td>Senegal</td>
<td>69</td>
<td>3.5</td>
<td>AE&lt;sub&gt;N&lt;/sub&gt;</td>
<td>50</td>
<td>3.5</td>
<td>69</td>
<td>7.3</td>
</tr>
<tr>
<td>Burkina</td>
<td>44</td>
<td>3.1</td>
<td>AE&lt;sub&gt;N&lt;/sub&gt;</td>
<td>31</td>
<td>3.1</td>
<td>44</td>
<td>4.3</td>
</tr>
<tr>
<td>Rwanda</td>
<td>46</td>
<td>3.5</td>
<td>AE&lt;sub&gt;N&lt;/sub&gt;</td>
<td>35</td>
<td>3.5</td>
<td>46</td>
<td>4.6</td>
</tr>
<tr>
<td>Togo</td>
<td>33</td>
<td>2.7</td>
<td>AE&lt;sub&gt;N&lt;/sub&gt;</td>
<td>28</td>
<td>2.7</td>
<td>33</td>
<td>3.2</td>
</tr>
<tr>
<td>Mean</td>
<td>56</td>
<td>3.7</td>
<td>AE&lt;sub&gt;N&lt;/sub&gt;</td>
<td>39</td>
<td>3.7</td>
<td>56</td>
<td>6.0</td>
</tr>
</tbody>
</table>

**LSD = 14.6**
Environmental Gains with Deep Placement

- Deep Placement = reduced zone soil placement

- Point Placement = high ammoniacal N concentration (NH₄-N > 3,000 ppm) ➔ inhibition of nitrification

- Less N Loss = N Fertilizer Savings

4-Barrels Energy  ➔  1 ton Urea  ➔  980 kg CO₂ Equivalent GHG Emission

Air (80% Nitrogen) ➔ Ammonia ➔ Urea

Energy and Feedstock (Natural Gas) ➔ Energy (Natural Gas) and Carbon Dioxide
Reduced N Loss

Changes in Floodwater N Content (g m⁻²) over time after fertilizer application.

- Zero N
- 78(:14:25) Prilled Urea
- 78(:14:25) Urea Briquette
- 78:14:25 NPK Briq.

Graph highlights the reduction in floodwater N content over days after fertilizer application, showing differences in loss mechanisms:

- Negligible Floodwater Urea-N, NH₄⁺-N, NO₃⁻-N
- Negligible Ammonia Volatilization
- Less N₂, N₂O, NO

LSD = 0.015
Cumulative Ammonia Volatilization Loss from Guthrie Soil

Environmental Gains with Deep Placement
Agricultural $\text{N}_2\text{O}$ Emissions

- $\text{N}_2\text{O}$ contribution to global warming was about 6% in 2007.
- Agricultural accounts for 10-27% of the total $\text{N}_2\text{O}$ emission

![Anthropogenic $\text{N}_2\text{O}$ Emission](chart)

- Total
- Agriculture
- Stationary & Mobile Combustion
- Biomass Burning
- Nitric & Adipic Production
- Other

Tg N
Importance of Quantifying N$_2$O Emission

Ravishankara et al. (2009)

N$_2$O Largest Remaining Ozone Threat

<table>
<thead>
<tr>
<th>Compound</th>
<th>1987 (kilo tons/yr)</th>
<th>2008 (kilo tons/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N$_2$O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFC-11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFC-12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFC-113</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1211</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1301</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCl$_4$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH$_3$CCl$_3$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH$_3$Br</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Methodology

- Continuous measurement using Gas Filter Correlation N₂O analyzer (Model 320EU, Teledyne API) and Chemiluminescence NO-NOx Analyzer (Model 200E, Teledyne API)
- Data recorded using CR3000 (Campbell Scientific)
- Each chamber (57.1 liter) is sampled 8 times a day (3 hour interval)
- Chamber remains closed only for 40 minutes during each sampling time
Nitrous Oxide (N$_2$O) Emission

N$_2$O emission prior to flooding, during lowland rice crop, and during post-harvest drying.
NO Emission During Cropping Cycle

NO Emission During Preplant (43 days) and Flooded Rice (224 days)

NO emission during preplant stage is higher than during rice cropping. Urea application had higher emissions than zero N and UDP treatments.
N₂O emission during preplant stage is higher than during rice cropping. Urea application had higher emissions than zero N and UDP treatments.
Long-Term Effect of Urea Deep Placement on Soil Health
Comparison of Organic Matter Content with UDP and Urea

1% increase in C for 10 cm soil depth = 10 t ha\(^{-1}\) C
Long-Term Effect – Total Soil N Content

Comparison of Soil Total Nitrogen with UDP and Urea
Summarizing - Deep Placement Resulted In:

- Reduced N loss (up to 50%)
- Improved rice grain yield (15-35%); also for upland crops
- Less N fertilizer use (25-40%)
- Up to 50 kg additional rice grain per kg N
- Significantly higher P recovery
- Increased C sequestration (roots, algae)
- Much of N₂O and NO emission occurred during the preplant stage when soil was saturated/flooded prior to rice transplanting
- Both N₂O and NO emissions were significantly lower with UDP compared to urea
- Less weeding with UDP

Implications for CDM: N fertilizer, N₂O-NOx, CO₂ fixed
Future Research

Urea application ➔ 100 kg CO₂ Equiv GHG per ton rice

- Continuous field level quantification of N₂O-NOx emission in rice-based cropping. USAID supported project at two sites in Bangladesh by May 2013.

- Quantify CO₂ capture from deep-placed urea briquette.

- Quantify residual effect/revise recommendations.

- Increased applicator options.