LARGE-SCALE ADOPTION AND PRODUCTIVITY IMPACTS OF IMPROVED LENTIL VARIETIES IN BANGLADESH

Objectives

■ Present a big-picture perspective on ICARDA’s role in improvement of lentils in Bangladesh

■ Document the spread of improved lentil varieties in main lentil-growing areas of Bangladesh
  - Farmer-reported (from household survey)
  - Expert panel (using techniques developed and refined in DIIVA studies)
  - DNA-testing of seed samples collected from household

■ Understand factors affecting adoption
  - Does variety-identification strategy affect results?

■ Discuss impacts of diffusion (Note: study looked at farm-level productivity effects, household-level effects on income, nutrition & dietary diversity, regional-level effects on output)
Background

- Bangladesh is characterized by a very high rate (26%) of child malnutrition where 41.3% of children are underweight (UNICEF, 2009 and IFPRI Hunger Index, 2012)
- Lentil is most widely consumed pulse in Bangladesh
  - *It is often referred to as a poor man’s meat as it is an important source of lean protein*
  - *Lentils are also good sources of potassium, calcium, zinc, niacin, vitamin K, folate and iron*
  - *Eating plenty of nutrient-dense foods like lentils can lessen the risk of many serious medical problems*
Lentils in Bangladesh

- Need to fit into rice-dominated system (in late 1970s and early 1980s, irrigation area expanded and rice moved into areas previously planted to lentils)

- In early 1980s, disease susceptibility of lentil landraces was a major factor constraining productivity; researchers noted a lack of genetic variability in traits of importance in local germplasm
  - Yield losses from Stemphylium blight (Stemphylium botryosum) > 80%, collar rot (Sclerotium rolfsii) 30-40 %, and rust (Uromyces fabae) 30-40 %. Blight and rust were the most prevalent problems
  - Intensive research on pulse production launched at BARI in 1979 in collaboration with ICARDA

- In early 1980s, BARI introduced improved varieties with disease resistance from India, but these could not fit into the short-season cropping systems

- Suitability in relay system in transplanted rice and in mixed planting system is important
Lentils in Bangladesh

- Grown after rainy season on conserved soil moisture; winter season is very short (100-110 days) and mild
  - Note: In South Asia region, approximately 11.5 million hectares of land are left fallow after rice

- Many competing dry winter crops are found, especially in areas with irrigation; lentil production has been pushed to marginal and sub-marginal lands

- Use of lentils as a relay crop is increasing, and several improved varieties have been selected based on their performance under relay conditions (relay cropping has extended lentil production to medium lowlands where lentil cropping after transplanted rice was nearly impossible)

- Much of lentil production is mixed/intercropped with other winter crops (wheat, mustard, barley and sugarcane)

- Area under lentil crop has been increasing since 2008 (73,000) -> 145,000 hectares(2015)
Major lentil-growing areas
ICARDA’s role in Bangladesh lentils

- Cooperation between ICARDA and PRC for lentil improvement began in late 1970s
  - In response to yield and disease crisis in Bangladesh lentil production
  - Due to limited success with direct introduction, the breeding strategy was revised to include hybridization. ICARDA took main role in mid-1980s in making crosses using improved landraces
  - During 1980s, ICARDA changed its breeding program to account for increased national capability; decentralization involved ICARDA developing segregated populations using parents from national programs and incorporating blight and rust resistance; nurseries consisting of genetically fixed materials and segregating populations were shipped to Bangladesh where selections were made under local conditions
  - More than 2000 germplasm accessions and breeding lines have been supplied to BARI

- Major improvements:
  - BARI-3 and BARI-4 varieties were introduced in 1996—resistance to rust and blight and suitability in cropping system were main criteria used during breeding
  - BARI-5 & 6 introduced in 2006, with a focus on cooking qualities and nutrient content
Lentil variety releases, PRC, Bangladesh

<table>
<thead>
<tr>
<th>Variety</th>
<th>Release Year</th>
<th>Germplasm (Originating organization)</th>
<th>Characteristics</th>
<th>Maturity</th>
<th>Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARI-1</td>
<td>1991</td>
<td>Local selection (BARI/ICARDA)</td>
<td></td>
<td>105-110</td>
<td>1.7-1.8</td>
</tr>
<tr>
<td>BARI-2</td>
<td>1993</td>
<td>ICARDA (BARI/ICARDA)</td>
<td>High yield and rust resistance</td>
<td>105-110</td>
<td>1.5-1.7</td>
</tr>
<tr>
<td>BARI-3</td>
<td>1996</td>
<td>Local cross (BARI/ICARDA)</td>
<td>High yield and rust resistance; thin seed coat</td>
<td>100-105</td>
<td>1.5-1.7</td>
</tr>
<tr>
<td>BARI-4</td>
<td>1996</td>
<td>ICARDA (BARI/ICARDA)</td>
<td>SB and rust resistance; high in iron</td>
<td>110-115</td>
<td>1.6-1.7</td>
</tr>
<tr>
<td>BARI-5</td>
<td>2006</td>
<td>ICARDA (BARI/ICARDA)</td>
<td>Resistant to SB and rust, tolerant to foot rot</td>
<td>110-115</td>
<td>1.4-1.6</td>
</tr>
<tr>
<td>BARI-6</td>
<td>2006</td>
<td>ICARDA (BARI/ICARDA)</td>
<td>Tolerant to SB and rust; high in iron</td>
<td>105-110</td>
<td>2.2-2.3</td>
</tr>
<tr>
<td>BARI-7</td>
<td>2011</td>
<td>ICARDA (BARI/ICARDA)</td>
<td>Tolerant to SB and rust; micronutrient-dense variety</td>
<td>110-115</td>
<td>1.8-2.3</td>
</tr>
<tr>
<td>BINA-4</td>
<td>2009</td>
<td>ICARDA (BINA/ICARDA)</td>
<td>Moderately resistant to rust, foot and root rot; good cooking quality</td>
<td>96-102</td>
<td>1.8</td>
</tr>
<tr>
<td>BINA-5</td>
<td>2011</td>
<td>BINA</td>
<td>Tolerant to blight and rust, red color, good cooking quality; crude protein (29-30%)</td>
<td>99-104</td>
<td>2.1</td>
</tr>
<tr>
<td>BINA-6</td>
<td>2011</td>
<td>BINA</td>
<td>Tolerant to blight and rust, red color, good cooking quality, crude protein (30-31%)</td>
<td>105-110</td>
<td>1.9</td>
</tr>
<tr>
<td>BINA-7</td>
<td>2013</td>
<td>BINA (BINA/ICARDA)</td>
<td>Tolerant to blight and rust, red color, good cooking quality, high in crude protein</td>
<td>100-112</td>
<td>2.2-2.4</td>
</tr>
</tbody>
</table>
Estimates of diffusion of lentil MVs

- Alternative sources of information
  - Farmer-reported (from household survey)
  - Expert panel (using techniques developed and refined in DIIVA studies)
  - DNA-testing of seed samples collected from household
Brief information on sample

- Representative of 10 Districts in Western Bangladesh where lentil production is most common (10 Districts account for about 75% of total lentil area)

- Multi-stage sampling with weighting based on estimates of area under lentils: 10 Districts, 20 Upazillas, 52 Villages
  - At village level, complete listing of lentil-growing households was conducted; 10 households selected at random

- Power analysis based on ability to identify adoption of improved varieties (95% confidence and a minimum of 3% precision)—864 household surveys needed; 1000 households surveyed

- Survey included farm-household information, field-level information (on as many as 3 lentil fields) and village survey
  - DNA samples of lentils from all lentil fields (from seeds post-harvest)
  - Substantial follow-up on village survey through regular contact with local extension
What about the spread of improved varieties in Western Bangladesh? (BAU/ICARDA survey, 2015)

- Depends on definition of “improved variety”
  - *Including 1996 releases*-> Almost 100% of farmers grow improved variety; 99.4% of lentil area is covered by improved lentils
  - *When 2006 is used as cutoff*, slightly above 45% of farmers grow improved variety
  - *Local varieties are practically non-existent*
  - *ICARDA-related varieties represent 96% of total farmer adoption*

- Only five improved varieties (BARI3, BARI4, BARI5, BARI6, BARI7) were claimed to be used by farmers (all ICARDA-related)
  - *BARI6, BARI3 & BARI4 cover 31.2% 29.9% and 22.4% of the lentil area*
  - *Latest varieties (BARI7) cover only 3.7% of area*
Diffusion of improved varieties: Does method of estimation matter?

- Panels of experts over-estimated area covered by more than 23 percentage points

<table>
<thead>
<tr>
<th>Method</th>
<th>Area Weighted Adoption</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH Survey</td>
<td>49.0%</td>
</tr>
<tr>
<td>Expert</td>
<td>69.1%</td>
</tr>
<tr>
<td>DNA</td>
<td>45.4%</td>
</tr>
</tbody>
</table>
Expert panel estimates diverge from other methods

DNA Fingerprinting
Household survey
Expert Estimates
Farmer knowledge of variety grown was good

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of samples</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total matched samples</td>
<td>1511</td>
<td>89.20%</td>
</tr>
<tr>
<td>Total mismatched samples</td>
<td>168</td>
<td>9.92%</td>
</tr>
<tr>
<td>Total Unmatched</td>
<td>15</td>
<td>0.89%</td>
</tr>
<tr>
<td>• NA (DNA samples went bad and hence varieties were not identified)</td>
<td>3</td>
<td>0.18%</td>
</tr>
<tr>
<td>• Ungrouped (DNA of these samples did not match the DNA of all the samples obtained from BARI and BINA)</td>
<td>12^</td>
<td>0.71%</td>
</tr>
<tr>
<td>Total sample</td>
<td>1694</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

^Note = all 12 of these varieties were identified by farmers as local varieties and the research team is convinced that they indeed are.
Does farmer mis-identification matter?

- Estimated models of adoption (probit) and area planted (double-hurdle) to examine whether inferences vary by method of identification
  - Improved variety=post-2006 release (insufficient observations when 1996 is used)
  - Standard sets of variables: Farmer characteristics, farm and field characteristics, community (including key prices) and area fixed effects
  - Do wealth (from asset index) and landholdings affect adoption and area planted to improved varieties?
    - Adoption outcome: Farmer-identified MV-> fifth (upper) wealth quintile 14 percentage points more likely than lowest to adopt; more owned land associated with lower likelihood of adoption. **Neither of these is significant when using DNA-verified dependent variable.**
    - Area planted outcome: Farmer-identified MV-> fifth quintile has 37 percent more land planted to MVs compared to lower quintile. **Wealth variable is not significant when using DNA-verified dependent variable.**
    - Area planted: Differences in other marginal effects when using farmer-identified compared to DNA-verified outcomes are not significant

- Despite relatively high degree of correspondence, an important inference is changed (wealth matters), but most parameters and significance are not affected
  - **Probit results show more sensitivity to classification**
Technology impacts

- Alternative counterfactual scenarios exist
  - *Without research leading to 2006 releases?*
    - No significant yield difference between post- and pre-2006 releases (t-test p=.80)
    - Cost of production is nearly identical
    - Still examining other differences
  - *Without research leading to 1996 releases?*
    - Likely would have led to elimination of short-season lentil growing due to declining yields and disease susceptibility
    - Post-1996 releases have clear yield advantage (but sample size in household survey is small)
      - *Roughly 45% yield gain for improved varieties, holding inputs (labor, land, fertilizer, mechanical) constant*
      - *Households planting pre-1996 varieties differ from norm*

- Little evidence of yield impact in post-2006 releases compared to prior releases
  - *1996 releases solved rust and blight problems; later releases focused on consumption traits*

- But production landscape would be quite different without 1996- and onward releases
Thank You!
Annex XI: Analysis of Seed Homogeneity using DNA Fingerprinting of 4 grains from each of a Sub-sample of 100 seed samples

<table>
<thead>
<tr>
<th>Description</th>
<th>Yes</th>
<th>No</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are all four seed samples the same as that identified by initial DNA fingerprinting work?</td>
<td>89</td>
<td>11</td>
<td>100</td>
</tr>
<tr>
<td>% of each case</td>
<td>89%</td>
<td>11%</td>
<td>100%</td>
</tr>
<tr>
<td>All or some of the new seed samples that are found to be different from those identified by initial DNA fingerprinting are the same as the variety identified by the farmer</td>
<td>4</td>
<td>7(64%)</td>
<td>11 (36%)</td>
</tr>
<tr>
<td>The heterogeneous sample has 25% mix of the variety identified by the farmer</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>The heterogeneous sample has 50% mix of the variety identified by the farmer</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>The heterogeneous sample has 75% mix of the variety identified by the farmer</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Number of seeds out of 4 which are different from that identified by the initial DNA fingerprinting work = 25% =</td>
<td>1</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Number of seeds out of 4 which are different from that identified by the initial DNA fingerprinting work = 50% =</td>
<td>2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Number of seeds out of 4 which are different from that identified by the initial DNA fingerprinting work = 75% =</td>
<td>3</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Weighted average number of seeds that are heterogeneous (out of 4 seeds)</td>
<td></td>
<td></td>
<td>1.45</td>
</tr>
<tr>
<td>Weighted average rate of heterogeneity (i.e., number of seeds out of 4 that are different from that identified by the initial DNA fingerprinting work on all the 1964 sample seeds)</td>
<td></td>
<td></td>
<td>36%</td>
</tr>
</tbody>
</table>
Aggregate lentil production, Bangladesh