Crop Improvement for Food and Nutrition Security in Southeast Asia Opportunities and Challenges for Gene Stacking and other Plant Breeding Techniques

Improving Nutritional Quality of Food Crops using Conventional Plant Breeding Techniques - Opportunities and Challenges

Ashish Wele, HarvestPlus USA.

Consequences Mineral & Vitamin Deficiencies

**Vitamin A deficiency**
- Supplements reduced child *mortality* by 23%
- 375,000 children go blind each year

**Iron deficiency**
- *Impaired cognitive abilities* that cannot be reversed
- 82% of children < 2 years in India are anemic

**Zinc deficiency**
- increased *incidence/severity diarrhea/pneumonia; stunting*
- 2 billion people at risk; 450,000 deaths per year

Indices of Inflation-adjusted Prices for Bangladesh 1973-75 = 100

Percent Changes in Cereal and Pulse Production and in Population Between 1965 and 1999

![Graph showing percent changes in cereal and pulse production and population between 1965 and 1999.](image)
A Primary Role of Agriculture Is To Provide Nutrients for Healthy Populations

50% Increase in All Food Prices
Share of Total Expenditures

Calcium Deficiency in Bangladesh
**Biofortification - A Piece of the Puzzle**

- Supplementation
- Commercial Fortification
- Dietary Diversity
- Agricultural Interventions

**TOP FIVE SOLUTIONS**

<table>
<thead>
<tr>
<th>TOP FIVE SOLUTIONS</th>
<th>CHALLENGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Micronutrient supplements for children (vitamin A and zinc)</td>
<td>Malnutrition</td>
</tr>
<tr>
<td>2 The Doha development agenda</td>
<td>Trade</td>
</tr>
<tr>
<td>3 Micronutrient fortification (iron and salt iodization)</td>
<td>Malnutrition</td>
</tr>
<tr>
<td>4 Expanded immunization coverage for children</td>
<td>Diseases</td>
</tr>
<tr>
<td>5 Biofortification</td>
<td>Malnutrition</td>
</tr>
</tbody>
</table>

**Portfolio of Micronutrient Interventions**

- Portfolio analysis by Keith Lividini and Jack Fiedler of IFPRI/HarvestPlus, comparing biofortification and fortification
  - Zambia (vitamin A)
  - Bangladesh (zinc)
  - Rajasthan (iron)
- Methodology
  - ex-ante simulation model
  - nationally representative food expenditure surveys, disaggregation by:
    - urban/rural,
    - farm/non-farm within rural, farm size
    - Income group
  - planning horizon of 30 years to assess discounted costs per disability-adjusted life year saved (DALY)

**Copenhagen Consensus (2008)**

- Cost-effective: central one time investment

![Photo: ICRISAT](image-url)
Provitamin A Maize is Competitive with Fortification in Zambia (Stand Alone)

Cost per DALY Saved of 6 Vitamin A Interventions in Zambia, 2013-2042

- Vitamin A-rich orange sweet potato (OSP) was released to 24,000 households in Mozambique and Uganda from 2007-2009
- Findings from the project have shown high rates of adoption and consumption, resulting in increased vitamin A intakes among women and children
- Distribution of OSP has been scaled-up in Uganda by HarvestPlus to reach 225,000 households by 2016

Impact on vitamin A intakes

Vitamin A OSP Reduces Diarrhea (Two Years After Extension Stopped)

- Diarrhea is one of the leading causes of death in children < 5 in developing countries.
- Eating orange sweet potato (OSP) reduces the incidence and duration of diarrhea in children.
  - For children < 3 likelihood of developing diarrhea was reduced by more than 50% and duration of diarrhea reduced by more than 25%.
  - For children < 5 likelihood of developing diarrhea was reduced by more than 40% and duration of diarrhea reduced by more than 10%.
Ten Bean Varieties Released in Rwanda

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Yield potential</th>
<th>Adaptation</th>
<th>Iron content</th>
<th>Maturity</th>
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<tbody>
<tr>
<td>IR00</td>
<td>Climber</td>
<td>4 t/ha</td>
<td>High altitude</td>
<td>91.6 ppm</td>
<td>110 Days</td>
</tr>
<tr>
<td>RIV 1004</td>
<td>Climber</td>
<td>3.8 t/ha</td>
<td>High altitude</td>
<td>91.7 ppm</td>
<td>110 Days</td>
</tr>
<tr>
<td>MAC 44</td>
<td>Climber</td>
<td>3.5 t/ha</td>
<td>Mid to low altitude</td>
<td>78 ppm</td>
<td>87 Days</td>
</tr>
<tr>
<td>RIV 2214</td>
<td>Bush</td>
<td>2.5 t/ha</td>
<td>Mid to low altitude</td>
<td>75 ppm</td>
<td>87 Days</td>
</tr>
<tr>
<td>RIV 2234</td>
<td>Bush</td>
<td>2.5 t/ha</td>
<td>Mid to low altitude</td>
<td>75 ppm</td>
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<tr>
<td>RIV 5028</td>
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<td>Mid to high altitude</td>
<td>81 ppm</td>
<td>110 Days</td>
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<tr>
<td>C40</td>
<td>Climber</td>
<td>3.5 t/ha</td>
<td>High altitude</td>
<td>94.8 ppm</td>
<td>115 Days</td>
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<tr>
<td>RIV 3017</td>
<td>Climber</td>
<td>4 t/ha</td>
<td>High altitude</td>
<td>94.6 ppm</td>
<td>110 Days</td>
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<tr>
<td>RIV 2007</td>
<td>Climber</td>
<td>3.5 t/ha</td>
<td>Mid to high altitude</td>
<td>93.7 ppm</td>
<td>106 Days</td>
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<tr>
<td>MAC 82</td>
<td>Regular</td>
<td>2.3 t/ha</td>
<td>Low altitude</td>
<td>97 ppm</td>
<td>110 Days</td>
</tr>
</tbody>
</table>

Incremental Changes in the Prevalence of Inadequate Zinc Intake, Bangladesh

Change in the Prevalence of Inadequate Zinc Intake Over 30 Years, Bangladesh

- Baseline: 73%
- Income and Diet: 63%
- High Zinc Rice: 25%
- Wheat Fortification: 26%

Changing Effectiveness with Increasing Levels of Farmers Adoption

Discounted Cost Per DALY Saved ($US) For Various Levels of Maximum Farmer Adoption over 30 Years, Bangladesh

Combining Biofortification and Fortification to Address Different Micronutrient Deficiencies

Reach of Fortification and Biofortification Vehicles, Bangladesh

- Rice: 99.98% Urban, 64% Rural
- Wheat Flour: 70% Urban, 66% Rural
- Vegetable Oil: 95% Urban, 70% Rural
But becomes the most cost-effective annually beginning in 10 years.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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</thead>
<tbody>
<tr>
<td>Year</td>
<td>PDS-A</td>
<td>OMS-1.4%</td>
<td>OMS-1.4% &amp; PDS-A</td>
<td>OMS-10%</td>
<td>PDS-E</td>
<td>10% &amp; PDS-E</td>
<td>HIB</td>
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<tr>
<td>2014</td>
<td>8.4</td>
<td>6.0</td>
<td>8.1</td>
<td>6.1</td>
<td>7.0</td>
<td>8.1</td>
<td>1,240,462.7</td>
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<tr>
<td>2015</td>
<td>8.6</td>
<td>6.1</td>
<td>8.2</td>
<td>6.3</td>
<td>7.1</td>
<td>8.2</td>
<td>6,559.7</td>
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<tr>
<td>2016</td>
<td>8.7</td>
<td>6.2</td>
<td>8.3</td>
<td>6.4</td>
<td>7.3</td>
<td>8.3</td>
<td>3,061.0</td>
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<td>2017</td>
<td>8.8</td>
<td>6.2</td>
<td>8.4</td>
<td>6.5</td>
<td>7.4</td>
<td>8.5</td>
<td>1,876.2</td>
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<tr>
<td>2018</td>
<td>8.9</td>
<td>6.3</td>
<td>8.5</td>
<td>6.6</td>
<td>7.5</td>
<td>8.6</td>
<td>523.7</td>
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<tr>
<td>2019</td>
<td>8.9</td>
<td>6.4</td>
<td>8.5</td>
<td>6.7</td>
<td>7.5</td>
<td>8.7</td>
<td>533.1</td>
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<tr>
<td>2020</td>
<td>9.0</td>
<td>6.4</td>
<td>8.6</td>
<td>6.8</td>
<td>7.6</td>
<td>8.8</td>
<td>19.1</td>
</tr>
<tr>
<td>2021</td>
<td>9.1</td>
<td>6.5</td>
<td>8.7</td>
<td>6.9</td>
<td>7.7</td>
<td>8.9</td>
<td>12.4</td>
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<tr>
<td>2022</td>
<td>9.1</td>
<td>6.6</td>
<td>8.8</td>
<td>6.9</td>
<td>7.8</td>
<td>9.0</td>
<td>10.2</td>
</tr>
<tr>
<td>2023</td>
<td>9.2</td>
<td>6.6</td>
<td>8.8</td>
<td>7.0</td>
<td>7.9</td>
<td>9.1</td>
<td><strong>8.9</strong></td>
</tr>
</tbody>
</table>

*Undiscounted Annual Cost per DALY Saved, by Scenario*

*The highlighted year, 2023, is the first year that HIB is more cost-effective than any of the other interventions.*

**Present Reach of Biofortification**

**Biofortified crops released in 27 countries**
- 18 in Africa, 4 in Asia, 5 in LAC

**In-testing in 43 countries**
- 26 in Africa, 8 in Asia, 9 in LAC

**Release Dates for Crops for Africa & Asia**

- **2007**
  - Sweetpotato
    - Vitamin A
    - Uganda

- **2011**
  - Cassava
    - Vitamin A
    - Nigeria & DRC

- **2012**
  - Beans
    - Iron
    - Rwanda & DRC
  - Maize
    - Vitamin A
    - Zambia

- **2013**
  - Rice
    - Zinc
    - Bangladesh
  - Wheat
    - Zinc
    - India | Pakistan 2015

- **2014**
  - Pearl Millet
    - Iron
    - India

**Lentil**

- Sorghum
- Banana
- Plantain
- Cowpea
- Potato
Fourteen Efficacy Trials either completed or in process

- High iron crops ✓ +
  - Meta-analysis completed for beans and pearl millet

- High pro-vitamin A crops ✓
  - Multiple efficacy trials completed for sweetpotato, maize, and cassava

- High zinc crops
  - Bioavailability studies positive, efficacy trials in the field

Iron Pearl Millet Reverses Iron Deficiency

- Lack of iron impairs mental development and learning capacity, and increases weakness and fatigue.

- A new study found that iron pearl millet was able to reverse iron deficiency in children aged 12-16 years in India within six months.

HIB is less cost-effective than Iron-Fortified Atta Wheat Flour, Rajasthan

<table>
<thead>
<tr>
<th></th>
<th>Cost per DALY Saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDS-Accessed</td>
<td>$9</td>
</tr>
<tr>
<td>PDS-Eligible</td>
<td>$7</td>
</tr>
<tr>
<td>Open Market Sales-2%</td>
<td>$8</td>
</tr>
<tr>
<td>Open Market Sales-10%</td>
<td>$7</td>
</tr>
<tr>
<td>High Iron Bajra</td>
<td>$56</td>
</tr>
</tbody>
</table>

Harvest Plus- Nirmal Seeds Biofortification Programme

- To create the awareness regarding the importance of IRON in human diet through rallies, banners, pamphlets
- To provide the best, easiest and cheap source for IRON in daily diet through staple food like Pearl millet.
- Field demonstration of new version of Pearl millet variety ICTP-8203 (Fe) in respect of yield potential, fodder quality, Iron content in comparison with the existing version.
- Foundation seed multiplication of the selected version of ICTP-8203 (Fe)
- Truthful seed production of ICTP-8203 (Fe)
- Extension activities for marketing of ICTP-8203 (Fe)
- Marketing of ICTP-8203 (Fe) with field demonstration and Hybrid Development programme.
Nirmal Seeds: Vital role in this Harvest Plus Project in India.

Year: 2011-12:
- Awareness programmes in major Pearl millet growing districts of Maharashtra and Rajasthan with Twenty Seven On farm and Adaptive trials of five different versions. Small farmers gatherings and mega functions with PVS Selected ICTP-8203-10-2 version of pearl millet with elevated iron levels named as Dhanashakti.

Year 2011-12:
- Simultaneous multiplication of foundation seed of 5 versions of ICTP-8203 (Fe).

Year 2012:
- The selected version ICTP-8203 Fe 10-2 was multiplied on 221.6 ha area with 150 growers. The training programme for retailers/distributors and sales/marketing team.

Kharif 2012:
- 110 comparative trials of Dhanashakti and original version 10.76% grain yield advantage with excellent nonsticky roti with good fodder quality as compared to original version. 38300 packets of 3 kg and 92600 packets of 1.5 kg were available in the market for first marketing season K-2012 in the name of DHANASHAKTI.

Achievements:
- 177 tons in 2012-13,
- 142 tons in 2013-14 and
- 363 tons in rainy season 2014-15
- 500 tons in 2015
in major Pearl millet growing states in India.

Visit of Dr. Howarth Bouis and Dr. Wolfgang H. Pfeiffer to Nirmal Seeds on the occasion of Silver Jubilee 2013.

Visit of Prof. M S Swaminathan and Dr. Wolf to Nirmal Seeds on the occasion of Silver Jubilee 2013.
Wheat Bio fortification Programme

- Participation in Wheat Biofortification in the year 2012-13
- Received 3HPYT comprising 50 entries in R-2012-13 from CIMMYT
- During the season (R-2013-14) received 4th HPYT and 5th HPAN trials under Harvest Plus project.
- Two Zinc rich varieties identified viz Abhay and Akshay.
- During current season 2014-15 250 trials were conducted in seven major states (MP, UP, BR, CG, JH, MS, GJ) with simultaneous seed multiplication programme.

What is the Way Forward? Mainstreaming

Mainstreaming Through Key Stakeholders

- Seed companies (*Nirmal in India*)
- International financial institutions (*World Bank, IFAD*)
- Multi-lateral agencies (*World Food Program, Codex*)
- National governments (*Brazil, China, India*)
- Regional frameworks (*African Union*)
- International NGOs (*World Vision*)

Challenges for Phase 3 (2014-18)

Mainstream Breeding

- Make breeding for minerals and vitamins “core” breeding objectives at CGIAR Centers and NARS
  - Develop markers
  - Lower costs of breeding
  - All elite breeding lines should have the relevant genes that convey the high mineral and vitamin traits; any cross will contain these genes

Additional Efficacy Evidence

- 1,000 Days – mothers pre-pregnancy and infants
Challenges for Phase 3 (2014-18)

Scale up Delivery in Target Countries
- 9 target countries (adding Ethiopia)
- Develop specific deployment strategies
- Establish in-country staff/office
- Establish networks of collaborators and stakeholders
- New releases from breeding pipeline
- Measure cost-effective impact

Endorsements for the Kigali Declaration

Recognition of Evidence and Impact Potential

“We can see that after years of scientific research we are just at the point where the research is no longer being argued or debated, but we are at that tipping point where we can start taking the product of all of that work and push it out into the world at scale.”

Rachel Kyte, Vice President and Special Envoy for Climate Change, World Bank