Improving Nutrition through Agriculture: Cost-Effectiveness of Biofortification

Dr. Howarth Bouis
Director, HarvestPlus

Chairs: Meera Shekar and Steven Jaffee

October 6, 2015
Improving Nutrition through Agriculture: Cost-Effectiveness of Biofortification

Howarth Bouis, PhD
Director, HarvestPlus
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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
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 for India, Pakistan, Bangladesh, developing countries, and the world.](chart.png)
Indices of Inflation-adjusted Prices for Bangladesh
1973-75 = 100
Share of Energy Source & Food Budget in Rural Bangladesh

- Non-Staple plants
- Fish and Meat
- Energy Source
- Food Budget

Staple foods
Non-Staple Food Prices in India Have Risen by 50% Over 30 Years
50% Increase in All Food Prices
Share of Total Expenditures

Before
- Staples
- Non-Food

After
- Staples
- Non-Food
A Primary Role of Agriculture Is To Provide Nutrients for Healthy Populations

Before

Supply of Nutrients From Agriculture

After

Supply And Fortification

Nutrient Gap

Supplementation And Fortification

Supplementation And Fortification
Calcium Deficiency in Bangladesh
Biofortification – A Piece of the Puzzle

Supplementation

Commercial Fortification

Dietary Diversity

Agricultural Interventions
Cost-effective: central one time investment
<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)
Provitamin A Maize is Competitive with Fortification in Zambia (Stand Alone)

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

- Vegetable Oil: $4
- Child Health Weeks: $15
- Sugar: $18
- Biofortified VAM: $24
- Wheat Flour: $34
- Maize Meal: $129

Cost per DALY Saved
Combining nutrition interventions in Zambia? → Fortified oil with orange maize most effective

Figure P-6A: The 31 Vitamin A Program Portfolios with Discounted Cumulative Costs per DALY Saved of Less than $50 Plus CSBOMW, 2013-2042
Arrayed by Decreasing Cost-Effectiveness. Efficiency-based DALY Estimates

<table>
<thead>
<tr>
<th>O: Oil</th>
<th>B: Biofortified VAM</th>
<th>S: Sugar</th>
<th>C: Child Health Week</th>
<th>W: Wheat Flour</th>
<th>M: Maize Meal (B&amp;R)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Discounted US $ per DALY Saved, 2013-2042</td>
<td>71</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Bar chart showing the cost-effectiveness of different interventions.
Biofortification and Fortification: Complementarity/Overlap of Reach: Zambia

Reach from Maize Consumption and Sugar Consumption, Zambia

<table>
<thead>
<tr>
<th></th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar Reach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar only</td>
<td>9%</td>
<td>14%</td>
</tr>
<tr>
<td>Both</td>
<td>48%</td>
<td>59%</td>
</tr>
<tr>
<td>Maize only</td>
<td>35%</td>
<td>21%</td>
</tr>
<tr>
<td>None</td>
<td>8%</td>
<td>6%</td>
</tr>
<tr>
<td>Total Maize Reach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar only</td>
<td>9%</td>
<td>14%</td>
</tr>
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<td>21%</td>
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<tr>
<td>None</td>
<td>8%</td>
<td>6%</td>
</tr>
<tr>
<td>Additional Reach Maize</td>
<td></td>
<td></td>
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<tr>
<td>Sugar only</td>
<td>9%</td>
<td>14%</td>
</tr>
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<td>35%</td>
<td>21%</td>
</tr>
<tr>
<td>None</td>
<td>8%</td>
<td>6%</td>
</tr>
</tbody>
</table>
Zambia Number of DALYs Saved by Area

Number of Undiscounted DALYs Saved with Biofortification in Zambia by Rural/Urbam Area

- Urban
- Rural

2013: 0
2015: 0
2017: 2,000
2019: 4,000
2021: 6,000
2023: 8,000
2025: 10,000
2027: 12,000
2029: 14,000
2031: 16,000
2033: 18,000
2035: 20,000
2037: 22,000
2039: 24,000
2041: 26,000

Total DALYs Saved by 2041:
- Urban: 45,101 (57%)
- Rural: 34,716 (43%)
High Zinc Rice is More Cost-Effective Than Wheat Flour Fortification

Cumulative, Discounted Cost per DALY Saved of Three Zinc Program Portfolios, 2013-2042

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>Cost per DALY Saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF: Fortified Wheat Flour</td>
<td>$264</td>
</tr>
<tr>
<td>HZR: High Zinc Rice</td>
<td>$79</td>
</tr>
<tr>
<td>WF+HZR</td>
<td>$165</td>
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</table>
Incremental Changes in the Prevalence of Inadequate Zinc Intake, Bangladesh

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

<table>
<thead>
<tr>
<th></th>
<th>Prevalence of Inadequate Intake</th>
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<tbody>
<tr>
<td>Baseline</td>
<td>73%</td>
</tr>
<tr>
<td>Income and Diet</td>
<td>63%</td>
</tr>
<tr>
<td>+ High Zinc Rice</td>
<td>26%</td>
</tr>
<tr>
<td>+ Wheat Flour Fortification</td>
<td>25%</td>
</tr>
</tbody>
</table>
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

- 5%: $3,753
- 10%: $2,111
- 20%: $797
- 30%: $557
- 40%: $419
- 50%: $272
- 60%: $199
- 70%: $158
- 80%: $97
- 82.1%: $79
Comparison of Annual Biofortification and Fortification Costs, Bangladesh
Combining Biofortification and Fortification to Address Different Micronutrient Deficiencies

Reach of Fortification and Biofortification Vehicles, Bangladesh

<table>
<thead>
<tr>
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<th>Rural</th>
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<tr>
<td>Rice</td>
<td>99.98%</td>
<td>99.98%</td>
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<tr>
<td>Wheat Flour</td>
<td>64%</td>
<td>66%</td>
</tr>
<tr>
<td>Vegetable Oil</td>
<td>70%</td>
<td>95%</td>
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HIB is less cost-effective than Iron-Fortified Atta Wheat Flour, Rajasthan

Cost per DALY Saved of High Iron Bajra and 4 Atta Flour Fortification Scenarios, Rajasthan 2014-2043

<table>
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<th>Scenario</th>
<th>Cost per DALY Saved</th>
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<tr>
<td>PDS-Accessed</td>
<td>$9</td>
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<tr>
<td>PDS-Eligible</td>
<td>$7</td>
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<tr>
<td>Open Market Sales-2%</td>
<td>$8</td>
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<tr>
<td>Open Market Sales-10%</td>
<td>$7</td>
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<tr>
<td>High Iron Bajra</td>
<td>$56</td>
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But Becomes the most cost-effective Annually Beginning in 10 years

<table>
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<th>Scenario #:</th>
<th>1</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tbody>
<tr>
<td>Year</td>
<td>PDS-A</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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<td>2014</td>
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<td>2015</td>
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<td>7.8</td>
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<td><strong>7.0</strong></td>
<td><strong>7.9</strong></td>
<td><strong>9.1</strong></td>
<td><strong>8.9</strong></td>
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<td>8.9</td>
<td>7.0</td>
<td>8.0</td>
<td>9.2</td>
<td>7.6</td>
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<td>6.7</td>
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<td>9.2</td>
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<td>8.9</td>
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<td>7.1</td>
<td>8.4</td>
<td>9.6</td>
<td>5.4</td>
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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.
Release Dates for Crops for Africa & Asia

Sweetpotato
Vitamin A
Uganda 2007

Cassava
Vitamin A
Nigeria & DRC 2011

Beans
Iron
Rwanda & DRC 2012

Maize
Vitamin A
Zambia 2012

Pearl Millet
Iron
India 2012

Rice
Zinc
Bangladesh 2013

Wheat
Zinc
India | Pakistan 2015 2013
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

Sorghum
Banana
Cowpea
Potato
Lentil
Present Reach of Biofortification

NUTRITIOUS STAPLE FOOD CROPS: WHO IS GROWING WHAT?

These crops have been conventionally bred to be rich in essential vitamins and minerals that are needed for good health.
Human Nutrition Efficacy Trials

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
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.
Orange Sweet Potato

- 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

**Figure 5** Impact of REU Intervention on mean vitamin A intakes (μg Retinol Activity Equivalents (RAE)/day), Mozambique and Uganda

- **Mozambique**
  - Children 6-35 mths.
  - Children 3.5-6 yrs.
  - Women

- **Uganda**
  - Children 6-35 mths.
  - Children 5-7 yrs.
  - Women

Legend:
- Impact
- Control at project end
• 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>Names</th>
<th>Pictures</th>
<th>Type</th>
<th>Yield potential</th>
<th>Adaptation</th>
<th>Iron content</th>
<th>Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>RWV 3316</td>
<td></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>RWV 3006</td>
<td></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></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>RWR 2245</td>
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<td>Bush</td>
<td>2.5 t/ha</td>
<td>Mid to low altitude</td>
<td>75 ppm</td>
<td>87 Days</td>
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<td>RWR 2154</td>
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<td>Bush</td>
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<td>Mid to low altitude</td>
<td>75 ppm</td>
<td>87 Days</td>
</tr>
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<td>RWV 1129</td>
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<td>Climber</td>
<td>3.5 t/ha</td>
<td>Mid to high altitude</td>
<td>81 ppm</td>
<td>110 Days</td>
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<tr>
<td>Cab2</td>
<td></td>
<td>Climber</td>
<td>3 t/ha</td>
<td>High altitude</td>
<td>94.8 ppm</td>
<td>115 Days</td>
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<tr>
<td>RWV 3317</td>
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<td>Climber</td>
<td>4 t/ha</td>
<td>High altitude</td>
<td>74 ppm</td>
<td>110 Days</td>
</tr>
<tr>
<td>RWV 2887</td>
<td></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>
</tr>
<tr>
<td>MAC 42</td>
<td></td>
<td>Climber</td>
<td>3.5 t/ha</td>
<td>Mid to high altitude</td>
<td>91 ppm</td>
<td>81 Days</td>
</tr>
</tbody>
</table>
Rwanda: Location of combined activities in 2014
What is the Way Forward? Mainstreaming

Photo: Neil Palmer (CIAT)
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
"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
1. Biofortification and fortification are complimentary in that they reach different populations and complement each other to provide near universal reach.

2. Global leaders recognize that biofortification works – the evidence is no longer in question.

3. The next challenge is taking this proven intervention to scale.
Questions and Answers
Continue the conversation

Comment on today’s topic: Cost-effective Biofortification

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#food4all

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