Breeding biofortified crops to alleviate micronutrient malnutrition

Parminder Virk
Hidden hunger is caused by a lack of vital minerals and vitamins in the diet. HarvestPlus focuses on **three** critical micronutrients recognized by the World Health Organization as most lacking in the diets of the poor (Vitamin A, Zinc & Iron).
Hidden Hunger

2 billion+ affected
Hidden Hunger addressed by

HarvestPlus - an interdisciplinary, global alliance of more than 200 scientific and implementation partners in over 40 countries

HarvestPlus is a joint venture between two CGIAR Centers, the International Center for Tropical Agriculture (CIAT) based in Cali, Colombia and the International Food Policy Research Institute (IFPRI) based in Washington, D.C.
Biofortification: breeding food crops that are more nutritious

Food-Based Strategies Can Reduce Hidden Hunger
Breeding to Consumption

- Research/Breeding of Biofortified Varieties
- Formal release by governments
- Seed Multiplication
- Transfer of Seeds to Farmers
- Production / Post-harvest Handling
- Promotion Education Consumption
Breeding Biofortified Crops

- Conventional Breeding
- Utilizing Genomic Tools
Lycopene Epsilon Cyclase $LCYE$
affects ratio of carotenoids

$\beta$-hydroxylase $HYDB1$ large effect on $\beta$-carotene levels & $\beta$-carotene / total carotenoids ratio

$HYDB3$ 3$^{rd}$ gene

Non destructive - Leaf or Seed DNA
QTL mapping for grain Zn in wheat

PBW 343 x Kenya Swara population

Seri M82 x Synthetic population

QTL detection on chromosome 2B for high zinc content in different environments

QTL detection on chromosome 3A for high zinc content in different environments

Hao et al, 2014 Mol breeding

QTL mapping, GWAS, Genomic Selection - CIMMYT
ICP-MS

Identify differentially expressed genes

Correlate differential gene expression with Zn to identify candidate genes

XRF & ICP-MS PRAY panels

Identify candidate regions and SNPs via GWAS

Search transcriptomic data for GWAS candidates

Identify markers in candidate genes (e.g. SNPs, SSRs)

Develop assay for high throughput screening with marker set

Validate markers in a suitable population

Transcriptomics

GWAS

RICE

Flinders University & IRRI
Constitutive Overexpression of the *OsNAS* Gene Family Reveals Single-Gene Strategies for Effective Iron- and Zinc-Biofortification of Rice Endosperm

Alexander A. T. Johnson¹,², Bianca Kyriacou²,³, Damien L. Callahan⁴, Lorraine Carruthers², James Stangoulis³, Enzo Lombi⁵, Mark Tester²

Biofortified indica rice attains iron and zinc nutrition dietary targets in the field

Kurniawan R. Trijatmiko¹,¹⁰, Conrado Dueñas¹, Nikolaos Tsakirpaloglou¹, Lina Torrizzo¹, Felichi Mae Arines¹, Cheryl Adeva¹, Jeanette Balindong¹, Norman Oliva¹, Maria V. Sapasap¹, Jaime Borrero², Jessica Rey¹, Perigio Francisco¹, Andy Nelson³,⁴, Hiromi Nakanishi⁵, Enzo Lombi⁶, Elad Tako⁷, Raymond P. Glahn⁷, James Stangoulis³, Prabhjit Chadha-Mohanty¹, Alexander A. T. Johnson⁹, Joe Tohme², Gerard Barry¹ & Inez H. Slamet-Loedin¹,¹¹
>130 varieties released in 25 countries
In-testing in 55 countries
Crops Released: Africa

2007
OSP
ProVitamin A
Uganda

2011
Cassava
ProVitamin A
Nigeria
DR Congo

2012
Maize
ProVitamin A
Nigeria
Zambia

Beans
Iron (Zinc)
Rwanda
DR Congo

Crops are high-yielding and with other traits farmers want
Crops Released: Asia

Pearl Millet
Iron (Zinc)
India

Rice
Zinc
Bangladesh
India

Wheat
Zinc
India (TLS)
Pakistan (2015)

Crops are high-yielding and with other traits farmers want
Biofortification is an evidence-based intervention linking agriculture and nutrition.

Photo: EMBRAPA

Photo: CIAT
What is the evidence that Biofortification actually works?

Iron-rich Pearl Millet Reverses Iron Deficiency in Children

A Randomized Trial of Iron-Biofortified Pearl Millet in School Children in India

Julia L Finkelstein,7 Saurabh Mehta,7 Shobha A Udipi,4 Padmini S Ghugre,4 Sarah V Luna,3 Michael J Wenger,3,5 Laura E Murray-Kolb,6 Eric M Przybyszewski,3 and Jere D Haas3,*

3Division of Nutritional Sciences, Cornell University, Ithaca, NY; 4S.N.D.T. Women’s University, Mumbai, India; 5University of Oklahoma, Norman, OK; and 6The Pennsylvania State University, University Park, PA

What is the evidence that Biofortification actually works?

‘Orange’ vitamin A maize increases vitamin A storage in children’s bodies

Biofortified orange maize is as efficacious as a vitamin A supplement in Zambian children even in the presence of high liver reserves of vitamin A: a community-based, randomized placebo-controlled trial

First published October 8, 2014, doi: 10.3945/ajcn.114.087379
What is the evidence that Biofortification actually works?

Using Agriculture to Improve Child Health: Promoting Orange Sweet Potatoes Reduces Diarrhea

KELLY M. JONES and ALAN DE BRAUW*
International Food Policy Research Institute, Washington, United States

A large-scale intervention to introduce orange sweet potato in rural Mozambique increases vitamin A intakes among children and women

Christine Hotz¹,²*, Cornelia Loechli³, Alan de Brauw⁴, Patrick Eozenou¹, Daniel Gilligan⁴, Mourad Moursi¹, Bernardino Munhaua³, Paul van Jaarsveld⁵, Alicia Carriquiry⁶ and J. V. Meenakshi¹
What is the Way Forward? Mainstreaming
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
Mainstreaming Through Key Stakeholders

- National governments & regional frameworks (e.g. Brazil, Nigeria, Rwanda)
- Seed companies (e.g. Nirmal in India)
- Wholesaling, retailing
- International NGOs (e.g. World Vision)
- Multi-lateral agencies (e.g. World Food Program, Codex)
- International financial institutions
NGOs

• HarvestPlus works closely with NGOs (national, regional and international) for delivery activities in Asia and Africa where the markets are not mature for:
  – Seed production
  – Seed distribution
  – Promotions of biofortified crops in the communities
  – Capacity buildings e.g. Training programs
**Crop Development, Testing & Commercialization Partnership**

**Public Sector:**
- DWR - (ICAR)
- IARI - Delhi
- PAU - Ludhiana
- BHU - Varanasi
- CIMMYT

**Private Sector:**
HPlus in beginning to initiate partnership with food companies for value added products

In India – Test marketing zinc wheat flour in collaboration with millers; Orange maize cereal (Kellogg's)

In Zambia – Vita-A maize flour through retailers and flour mill association (in partnerships with government)

In LACs Baby food (Nestle)
Create demand in particular for main channel processed products such as flour in generating pull in market development.
Cumulative Reach: 4 million Farming Households = access to Biofortified Food for 20 million
World Food Prize for Combating Malnutrition

- Biofortification recognized as a Global Intervention
Donors

United Kingdom Department for International Development (DFID)
Bill & Melinda Gates Foundation

Asian Development Bank (ADB)
Austrian Ministry of Finance
Canadian International Development Agency (CIDA)
European Commission
The International Fertilizer Group
International Life Sciences Institute (ILSI)
Royal Danish Ministry of Foreign Affairs (DANIDA)
Swedish International Development Agency (SIDA)
Syngenta Foundation for Sustainable Agriculture
United States Agency for International Development (USAID)
United States Department of Agriculture
The World Bank
World Food Programme
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