DEVELOPMENT

Zinc Wheat

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Target Micronutrient		Zinc; secondary trait: iron	
Target Countries		India, Pakistan	
Baseline (parts per million, ppm)		25 ppm	
Target Increment		12 ppm (increased from original target, 8 ppm)	
Target Level in Crop		37 ppm	
Nutrition Factors		**Original Assumption**	**Measured/ Revised[1]**
Wheat Consumption, grams/day (dry weight)	Women	400 g/d	208g/d
	Children	200 g/d	72 g/d
Zinc Retention (%)		90%	90%
Zinc Absorption (%)		25%	15%
Absorbed Incremental Zinc as % of EAR		40%	20%

Releases		
1st Wave	+4–8 ppm (33–66% target increment)	Commercialized: India, 2014; Planned release: Pakistan, 2015
2nd Wave	+8–12 ppm (66–100% target increment)	Planned release, 2016
3rd Wave	>+12 ppm (>100% target)	Planned release, 2018

[1]Punjab, India

Breeding to Date: During HarvestPlus Phase I (Discovery, 2003–2008), initial screening of more than 3,000 germplasm accessions by the International Maize and Wheat Improvement Center (CIMMYT) found ranges of 20–115 ppm zinc (and 23–88 ppm iron) in wheat, with the highest levels found in landraces; high-zinc genotypes were selected to initiate crosses (1). Multi-environment testing was conducted to evaluate the most promising germplasm and verify that mineral accumulation was stable across sites and generations. While variances were associated with environmental effects, high heritabilities were observed for zinc and iron concentrations across environments (2). Research efforts continue to identify quantitative trait loci (QTLs) associated with grain zinc content and examine how to increase zinc loading in the grain (3). In Phase II (Development, 2009–2013), the validity and precision of various mineral analysis methods were studied, and X-ray fluorescence (XRF) spectrometry calibrations and standards were developed for high-throughput screening (4).

Breeding programs at CIMMYT, the National Agricultural Research System (NARS), and agricultural universities in India and Pakistan have assumed full operational scale. Breeding efforts focus on transferring the zinc trait from diverse sources into locally adapted, agronomically competitive germplasm, considering consumer preferred end-use quality attributes. Resistance to the yellow rust Yr27 was mandatory in germplasm developed under HarvestPlus, and as sources for resistance to the stem rust race Ug99 became available, resistance to Ug99 was built into zinc wheat. Mainstreaming of the zinc trait at CIMMYT, as a percentage of the global wheat breeding effort, and at Indian and Pakistani partner NARS is estimated at 25–30%.

Breeding effectiveness in developing zinc wheat for India and Pakistan was optimized by the selection of 100–150 promising advanced lines at CIMMYT each year, based on grain yield and grain zinc, for testing in genotype-by-environment (GxE) trials for agronomic attributes and grain zinc at 10–15 sites in India and at 5 sites in similar agroecologies in Mexico and Pakistan (HarvestPlus South Asia Screening Nursery). The best 40–50 emerging leads are then yield tested in multi-location yield trials (HarvestPlus South Asia Yield Trial) at >20 sites in India and Pakistan. In India and Pakistan, partners engaged are the public sector NARS and several private seed companies.

In India, six 1st-wave leads, selected on the basis of multi-location performance and zinc data, were commercialized for test marketing in 2013 and will be more widely commercialized in 2014. In Pakistan, three candidate varieties were submitted to official registration trials in 2012; at least one 1st-wave variety is expected to be released in 2015.

Future Releases: Lines being evaluated for 2nd-wave commercialization demonstrate 75–100% of the zinc target. Agronomic and zinc data from multiple sites will be used to identify the best performers, and intensive on-farm, mini-kit testing of several candidate lines will determine which leads will be commercialized based on performance and farmers' preference. Commercialization of 2nd-wave varieties is anticipated in 2016.

Capacity building: XRF machines have been installed at three NARS partners in India (DWR, PAU, and BHU) and one in Pakistan (PARC). Since 2012, the mineral analysis of all wheat samples produced is done by XRF in country, resulting in reduced analysis costs and time savings.

Regional Testing: Starting in 2014, a zinc wheat nursery will be distributed to collaborators throughout India through the All India Coordinated Wheat Trial system and tested under various production conditions, including different planting dates. By substituting temporal-by-spatial environmental variation in large-scale regional GxE testing, testing steps can be eliminated and time-to-market shortened by 1–2 years.

HarvestPlus is also engaging seed companies in GxE testing and commercialization of zinc wheat and supporting companies in developing their own zinc varieties for commercialization by analyzing seed companies' advanced wheat lines for zinc free of charge.

Highlights:

- The first zinc wheat lines were commercialized for test marketing in India.
- In-country capacity for mineral analysis has been established in India and Pakistan.

Challenges:

- Grain yield and mineral density are affected by environmental and GxE effects, but these interactions are not well understood.

First-Wave Varieties for India and Pakistan[1]

Variety Name	Commercial-ization/ Release Year	Country	Zinc Increase	Comments on Agronomic Properties
BHU1	2014 Commercial-ization	India	+4–10 ppm	4.97 t/ha; 84 days to heading and 126 days to maturity
BHU3			+6–8 ppm	4.36 t/ha; 83 days to heading and 125 days to maturity
BHU5			+4–5 ppm	3.26 t/ha, 86 days to heading and 128 days to maturity
BHU6			+4–9 ppm	3.44 t/ha, 78 days to heading and 119 days to maturity
BHU17			+6–10 ppm	4.1 t/ha, 81 days to heading and 122 days to maturity
BHU18			+6–9 ppm	3.9 t/ha, 87 days to heading and 131 days to maturity
NR-419	2015	Pakistan	+7–9 ppm	4.5 t/ha, 93 days to heading and 130 days to maturity
NR-420			+7 ppm	3.4 t/ha, 86 days to heading and 128 days to maturity
NR-421			+14 ppm	3.6 t/ha, 78 days to heading and 119 days to maturity

[1]First wave: 50–66% target increment

1. Xu, Y; et al. 2011. Review: Breeding wheat for enhanced micronutrients. *Can. J. Plant Sci* 91: 231–237.
2. Velu, G; et al. 2012. Performance of biofortified spring wheat genotypes in target environments for grain zinc and iron concentrations. *Field Crops Research* 137: 261–267.
3. Velu, G; et al. 2013. Biofortification strategies to increase grain zinc and iron concentrations in wheat. *Journal of Cereal Science* in press.
4. Paltridge, NG; et al. 2012. Energy-dispersive X-ray fluorescence analysis of zinc and iron concentration in rice and pearl millet grain. *Plant Soil* 361(1–2): 251–260.