DEVELOPMENT

Iron Pearl Millet

Kedar Rai (ICRISAT)

Target Micronutrient		Iron; secondary trait: zinc	
Target Country		India; secondary countries: West Africa	
Baseline (parts per million, ppm)		47 ppm	
Target Increment		30 ppm	
Target Level in Crop		77 ppm	
Nutrition Factors		**Original Assumption**	**Measured/Revised[1]**
Pearl Millet Consumption, grams/day (dry weight)	Women	300 g/d	244 g/d
	Children	150 g/d	72 g/d
Iron Retention (%)		90%	95%
Iron Absorption (%)		5%	7-7.5%
Absorbed Incremental Iron as % of EAR		60%	60%

Releases		
1st Wave (OPV)	71 ppm (92% target increment)	Commercialized: India, 2012; Released: 2013
2nd Wave (Hybrid)	~69 ppm (88% target increment)	Commercialized: India, 2014
3rd Wave (Hybrid)	>77 ppm (>100% target)	Planned: 2016

[1]Maharashtra, India

Breeding to Date: During HarvestPlus Phase I (Discovery, 2003–2008), initial screening of germplasm accessions by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) found ranges of 30–76 ppm iron (and 25–65 ppm zinc) in pearl millet; high-iron genotypes were selected to initiate crosses (1). High correlation between iron and zinc content indicated good prospects for simultaneous selection for both micronutrients. Both micronutrients are largely under additive genetic control, implying that iron hybrids will require both parental lines to have high-iron density. Genotype-by-environment (GxE) testing was used to evaluate the most promising local germplasm and potential parents and verify that mineral accumulation was stable across sites and generations (2). In Phase II (Development, 2009–2013), breeding lines and germplasm with >90 ppm iron and >60 ppm zinc were validated. The validity and precision of various mineral analysis methods were studied, and near-infrared reflectance spectroscopy (NIRS) was calibrated for iron (2). X-ray fluorescence (XRF) spectrometry calibrations and standards were developed for high-throughput and cost-effective large-scale screening (3).

The breeding program at ICRISAT has assumed full operational scale. A full breeding pipeline initially included open-pollinated variety (OPV) development and now concentrates on hybrids and hybrid-parent development. Almost all iron sources identified are based on *iniadi* germplasm (early-maturing, large-seeded landrace materials from a geographic area adjoining Togo, Ghana, Burkina Faso, and Benin) or have a large proportion of *iniadi* germplasm in their parentage.

The major focus of the breeding program is to develop higher yielding, high-iron hybrids with stable yield and iron performance for the different agroecological zones in India. Major traits include drought tolerance, resistance to downy mildew, and end-use quality traits. Research partners in India include 5 State Agricultural Universities and 15 seed companies. HarvestPlus engages State Agricultural Universities and seed companies in GxE testing of hybrids and inbred lines developed at ICRISAT and encourages them to develop their own high-iron hybrids for commercialization by analyzing seed company hybrids and inbred lines for iron free of charge. Mainstreaming of the iron trait at ICRISAT is estimated at 40–45%.

Photo: A.S. Rao (ICRISAT)

An iron OPV, ICTP 8203-Fe, was commercialized as Truthfully Labeled Seed (TLS) by Nirmal Seeds in 2012 rainy season in Maharashtra and officially released for Maharashtra state in 2013. Due to its high iron content and wide adaptation, ICTP 8203-Fe was notified as “Dhanshakti” in February 2014 for cultivation in all pearl millet-growing states of India.

Future Releases: Two agronomically competitive hybrids with up to 90% of the iron target increment, developed at ICRISAT, have been identified as leads for 2nd-wave commercialization/release. These are being multiplied by two commercial seed companies, Nirmal Seeds and Shakti Vardhak, for commercialization as TLS in 2014.

Capacity Building: In 2010, ICRISAT's analytical capacity was strengthened by implementing XRF spectrometry for mineral analysis; a back-up XRF was installed in 2012. To date, more than 45,000 pearl millet samples from ICRISAT's breeding program, the Indian National Agricultural Research System (NARS), and private sector collaborators were assayed for iron and zinc.

Regional Testing: The improved variety ICTP 8203-Fe is expected to perform as well as ICTP 8203 in Namibia and Zimbabwe.

Highlights:

- The first iron OPV, ICTP-8203-Fe, was commercialized in Maharashtra by Nirmal Seeds in 2012.
- Competitive iron hybrids approaching 90% of target increment will be commercialized in 2014.
- In-country capacity for mineral analysis has been established in India.

Challenges:

- Seed companies dominate the seed market for pearl millet hybrids in India, and approximately 95% of the area under improved cultivars (OPVs and hybrids) in India is planted to hybrids. The 1st-wave release, an OPV, was limited in its potential impact.
- There is a large environmental effect on iron and zinc density, and the environmental factors are not yet well understood. Mineral density is not only related to levels of micronutrients in the soil.
- The correlation between iron and grain yield is often negative, though only low to moderate and not always statistically significant. There is need for broader partnership and multi-environment data generation.

First- and Second-Wave Cultivars Commercialized in India

Cultivar Name	Year	Iron Content* (% target)	Comments on Agronomic Properties
ICTP 8203-Fe	2012€	71 ppm (92%)	2.2 t/ha grain yield (11% more than ICTP 8203); no change in zinc content; flowering time (45 days)
Hybrid #7	2014¥	66 ppm (86%)	3.6 t/ha grain yield (38% more than ICTP 8203); 36 ppm zinc content; flowering time 48 days (3 days later than ICTP 8203)
Hybrid #12	2014¥	72 ppm (94%)	3.7 t/ha grain yield (41% more than ICTP 8203); 39 ppm zinc content; flowering time 48 days (3 days later than ICTP 8203)

*Average across two year (i.e. two rainy seasons), ICP-OES data.

€ Conducted in 42 locations during 2010 and 2011.

¥ Conducted in 31 locations during 2011 and 2012.

1. Velu, G; et al. 2007. Prospects of breeding biofortified pearl millet with high grain iron and zinc content. *Plant Breeding* 126(2):182–185.
2. Rai, KN; Govindaraj, M; Rao, AS. 2012. Genetic enhancement of grain iron and zinc content in pearl millet. *Quality Assurance and Safety of Crops & Foods* 4(3):119–125.
3. 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.