DEVELOPMENT

# Zinc Rice

Parminder Virk (CIAT – HarvestPlus)

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|---|---|---|---|
| **Target Micronutrient** | | Zinc; secondary trait: iron | |
| **Target Countries** | | Bangladesh, India | |
| **Baseline** (parts per million, ppm) | | 16 ppm | |
| **Target Increment** | | 12 ppm (increased from original target, 8 ppm) | |
| **Target Level in crop** | | 28 ppm | |
| **Nutrition Factors** | | **Original Assumption** | **Measured/ Revised[1]** |
| Rice Consumption, grams/day (dry weight) | Women | 400 g/d | 422 g/d |
| | Children | 200 g/d | 169 g/d |
| Zinc Retention (%) | | 90% | 90% |
| Zinc Absorption (%) | | 25% | 20% |
| Absorbed incremental zinc as % of EAR | | 40% | 36% |
| **Releases** | | | |
| 1st Wave | +6–8 ppm (33–66% target increment) | Planned release: Bangladesh, 2013; India, 2015 | |
| 2nd Wave | +8–12 ppm (50–75% target increment) | Planned release: 2015 | |
| 3rd Wave | >+12 ppm (>100% target) | Planned release: 2017 | |

[1] Bangladesh

**Breeding to Date:** Initial screening of 939 rice genotypes by the International Rice Research Institute (IRRI) found zinc concentrations of 15–58 ppm zinc (and 7.5–24 ppm iron) in unpolished rice grain (1). Because zinc is spread throughout the endosperm, estimates of zinc in unmilled rice are reliable indicators of zinc in milled rice; this is not the case for iron, as much of the iron in the aleurone layer is lost during milling (2). Genotype-by-environment (GxE) testing was used to evaluate the most promising germplasm and verify that mineral accumulation was stable across sites and generations. Positive correlation between iron and zinc allows for simultaneous improvement of both minerals. Research efforts continue to identify quantitative trait loci (QTLs) associated with grain zinc content and better understand zinc uptake, transport, and remobilization into the grain (3). In HarvestPlus Phase II (Development, 2009–2013), the validity and precision of various mineral analysis methods were studied, and inductively-coupled plasma (ICP) approaches were developed for zinc and iron in rice. X-ray fluorescence (XRF) spectrometry calibrations and standards were developed for high-throughput screening (4).

Breeding programs at IRRI and the Bangladesh Rice Research Institute (BRRI) have assumed full operational scale for breeding of zinc rice. A full breeding pipeline consists of germplasm in early- to late-development stages and elite line final products. At the Indian National Agricultural Research System (NARS), a breeding pipeline is being developed, focusing on varieties for the *kharif* season. Due to geographical proximity and agroecological similarity, adaptation of Bangladesh high-zinc rice leads in Eastern India can be expected. Rice hybrids and respective parental inbreds were assessed for zinc; however, zinc hybrid breeding is not currently planned. Mainstreaming of the zinc trait at IRRI and BRRI is estimated at 25% of the rice breeding effort.

HarvestPlus has screened more than 7,500 rice lines and identified several high-zinc genotypes among unadapted sources for use as donor parents in the zinc breeding program to produce competitive zinc-dense varieties with high yield, abiotic and biotic stress tolerance, and end-use quality attributes required for adoption. Breeding effectiveness at BRRI is accelerated by introduction of more than 3,000 early and advanced high-zinc lines from IRRI each year, selected based on grain yield and grain zinc, for GxE testing under local conditions.

In Bangladesh, the first zinc rice *aman* variety, "BRRI dhan 62," was released in 2013. It has 20 ppm zinc and is the shortest duration *aman* rice variety ever released. At least one zinc rice *boro* variety with 22–24 ppm is expected to be released in 2014. In India, the first varieties are expected to be commercialized in 2015.

**Future Releases:** The major focus is on developing higher yielding, zinc pure-line varieties for both *boro* and *aman* seasons with stable yield performance across different agroecological zones, including cold tolerance at seedling stage and heat tolerance at post flowering stage in the main *boro* season.

Resistance to diseases such as bacterial leaf blight and blast is an integral part of the breeding program. User preferred quality traits such as high amylose, long and slender grains, and short duration are also combined with competitive yield.

**Capacity Building:** XRF machines have been installed at BRRI and Indian NARS. Since 2011, the mineral analysis of all rice samples produced is done by XRF in country, resulting in reduced analysis costs and time savings.

**Regional Testing**: Competitive high-zinc rice varieties and elite lines are tested regionally through IRRI's International Network for Genetic Evaluation of Rice (INGER), a germplasm dissemination and evaluation tool. Agronomic and grain zinc data from large-scale GxE testing at multiple sites allow higher effectiveness in targeted breeding for yield and zinc stability based on adaptive pattern, as well as the identification of fast-track candidates and parents for breeding.

Starting in 2013, a zinc rice nursery was distributed to collaborators throughout India through the All India Coordinated Rice Improvement Project and tested under various production conditions. 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.

**Highlights:**

- BRRI dhan 62, a modern, short duration, and medium slender grained zinc rice variety for *aman* (rainfed) season, was released ahead of schedule in 2013.
- In-country capacity for mineral analysis has been established in Bangladesh and India.

**Challenges:**

- Grain yield and mineral density are affected by environmental and GxE effects, but these interactions are not well understood.
- Limited genetic variation for zinc and iron in rice constrains increases that can be realized through conventional biofortification.

***First-Wave Varieties for Bangladesh***

| Variety Name | Zinc Content[1] | | Grain Yield (% over check) | | Growth Duration[2] (days) |
|---|---|---|---|---|---|
| | ppm | Zinc Increase | t/ha (6 sites[1]) | t/ha (11 sites[2]) | |
| ***Aman* Variety – Released in 2013** | | | | | |
| BRRI dhan 62 | 19.6 | +7.9 ppm | 4.2 | | 100 |
| ***Boro* Varieties – At least one expected to be released in 2014** | | | | | |
| BR7840-54-3-1 | 24.7 | +7.9 ppm | 5.63 (100%) | 6.32 (102%) | 147 |
| BR7840-54-2-5-1 | 22.7 | +5.9 ppm | 5.87 (104%) | 6.31 (102%) | 148 |
| BR7840-54-1-2-5 | 23.6 | +6.8 ppm | 5.81 (103%) | 6.42 (103%) | 140 |
| *BRRI dhan 28 (Control)* | *16.8* | - | *5.62 (100%)* | *6.21 (100%)* | *144* |

[1] Mean across 6 sites of PVS trials during 2011/12 *boro* season (Zn measured by XRF)
[2] Mean across 11 sites of ALART trials during 2011/12 *boro* season.

1. Graham, RD; et al. 1999. Breeding for micronutrient density in edible portions of staple food crops: conventional approaches. *Field Crop Res* 60:57–80.
2. Sison, MEGQ; Gregorio, GB; Mendioro, MS. 2006. The effect of different milling times on grain iron content and grain physical parameters associated with milling of eight genotypes of rice (Oryza sativa). *Philippine Journal of Science* 135(1):9–17.
3. Palmgren, MG; et al. 2008. Zinc biofortification of cereals: problems and solutions. *Trends Plant Sci* 13:464–473.
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.