OCTOBER 2014

IS/ISO 9001:2008 Organization

2014
International Year of
Family Farming

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Indian Farming

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Indian Farming 64(7): 32–34; October 2014

Dhanashakti

A high-iron pearl millet variety

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DIETARY deficiencies of iron (Fe) and zinc (Zn), leading to numerous adverse health consequences, are now increasingly being recognized as serious public health problems, affecting more than two billion people worldwide, particularly in populations of the developing countries which are heavily dependent on the staple cereals as a major source of their dietary energy and nutritional requirements. Despite impressive record of economic growth and agricultural production in India, about 80% of the pregnant women, 52% of the non-pregnant women, and 74% of the children in 6-35 months age group in the country suffer from iron deficiency. About 52% of the children below 5 years are zinc deficient. Cropping system-based dietary diversification and crop biofortification have been suggested as the two agricultural approaches to address this problem. Biofortification deals with the development of cultivars having higher levels of micronutrients, and it is of special significance due to its cost effectiveness and sustainability. In case of iron and zinc, biofortified cultivars have an additional advantage of unhindered acceptance since grains of these cultivars are no different in taste and appearance from those produced from low-iron cultivars normally grown.

The OPVs in pearl millet, like in other cross-pollinated crops, are genetically heterogeneous populations with significant variability for quantitative traits. Based on this premise, ICTP 8203 was subjected to three generations of progeny-based selection to improve for Fe content in its grain. One improved version of ICTP 8203 released open pollinated variety (OPV) under cultivation designated as ICTP 8203 Fe 10-2 (later named and released as Dhanashakti), was constituted by random mating selected, eleven S_3 progenies (derived through pedigree bulk advance from as many S_1 progenies) that had 92-165 ppm Fe density in grains produced by selfing. The selfed panicles of these progenies had 40-65% seed set, which were much higher than those observed in all the other high-Fe progenies. The main focus of selection was to develop a higher-Fe version of ICTP 8203, without compromising on grain yield and without changes in other traits.

Dhanashakti and ICTP 8203 were evaluated in 10 trials conducted by ICRISAT and MPKV, Rahuri in Maharashtra and Andhra Pradesh in 2010. In 2011, these varieties were re-evaluated in 39 trials (including 17 Adaptive and On-farm trials) conducted by the All India Co-ordinated Pearl Millet Improvement Project (AICPMIP), Mandor, Jodhpur; MPKV, Rahuri; and Nirmal Seeds Company in Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu in Peninsular India to assess Fe and Zn contents, and grain and stover yield. These were also evaluated for reaction to diseases, especially downy mildew. Open-pollinated grain samples received from these trials were analysed for Fe and Zn contents using an X-ray Fluorescence Spectroscopy (XRF) technique at ICRISAT.

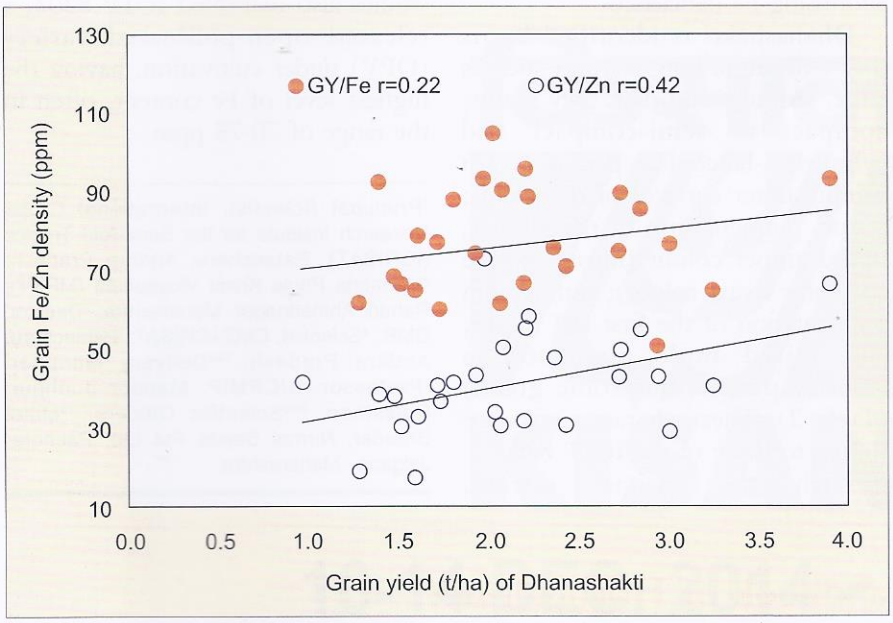
Based on the mean performance across the trials, and X-ray Fluorescence Spectroscopy (XRF) analysis of grain samples, Dhanashakti had 81 ppm Fe content,9% higher than ICTP 8203 (74 ppm), and 43 ppm Zn content (comparable with ICTP 8203) (Table 1). Later, analysis of these grain samples using more sensitive method of Inductively Coupled Plasma spectroscopy (ICP) showed that Dhanashakti had 72 ppm Fe content,

Development of biofortified cultivars of staple crops can make significant contributions to reducing micronutrient malnutrition and several associated adverse health consequences. Pearl millet variety Dhanashakti, bred for high iron content, is an early-maturing open-pollinated variety that has the highest level of iron content in any pearl millet cultivar produced so far. Dhanashakti also marks the first high-iron biofortified cultivar of any crop officially released and already adopted by farmers in the country.

Table 1. Micronutrient contents, agronomic performance, and disease reaction of pearl millet varieties Dhanashakti and ICTP 8203 in trials during 2010-2011

Trait	No. of trials	Dhanashakti		ICTP 8203	
		Mean	Range	Mean	Range
Micronutrients					
Fe (ppm)	44	81	49 - 120	74	39 - 105
Zn (ppm)	44	43	18 - 73	42	17 - 68
Agronomic performance					
Grain yield (t/ha)	42	2.20	0.65 - 5.65	1.97	0.63 - 4.30
Dry stover yield (t/ha)	10	5.30	1.90 - 6.80	4.70	1.70 - 6.50
Time to flowering (days)	25	45	40 - 55	45	38 - 56
Plant height (cm)	25	190	182 -197	183	171 - 195
Disease reaction					
Downy mildew incidence (%)	2	1.3	0.0 - 2.5	2.6	0.8 - 4.4
Blast severity (1-9)*	1	6.0	-	8.0	-
Rust severity (%)	1	12.0	-	20.0	-

*on scale from 1 (resistant) to 9 (susceptible)



Grain Fe/Zn density and grain yield of high-iron variety Dhanashakti

again 9% higher ICTP 8203 (66 ppm). Interestingly, Dhanashakti produced mean grain yield of 2.2 t/ha which was 11% higher grain yield than that of ICTP 8203 (1.97 t/ha). Also, it gave 5.3 t/ha of dry stover yield that was 13% higher than that of ICTP 8203 (4.7 t/ha). While both varieties were similar for time taken to 50% flowering (45 days), Dhanashakti was 7 cm taller than ICTP 8203, which could have contributed to its higher stover yield. Limited testing showed that both varieties were equally and highly resistant to downy mildew, and Dhanashakti had slightly better resistance to blast and rust.

Three general concerns regarding biofortified cultivars are: (1) extent to which micronutrients can vary across environments, (2) whether micronutrients would decline at higher grain yield levels, and (3) whether the bioavailability of Fe in high-Fe biofortified cultivars will be less than those in low-Fe cultivars. The multi-location data on Fe and Zn contents at varying grain yield levels addressed these issues. Both the Fe and Zn contents varied considerably from one environment to others as was the case for grain yield and other quantitative traits (Table 1). For 27 common locations for which data on grain yield as well as grain Fe/Zn contents were available, there were no indications that Fe and Zn contents would decline as grain yields increased. In fact, there was significant and positive, albeit low, correlation between grain yield and Fe content (r=0.22), and moderate positive correlation between grain yield and Zn content (r=0.42). Large-scale efficacy trials using Dhanashakti and low-Fe local cultivars, and conducted on school children in India and on adult women in Benin in Western Africa have shown that there were no significant differences between Dhanashakti and low-Fe cultivars as far as the bioavailability of Fe is concerned.

ICTP 8203 had been officially released for Peninsular India, and had been widely adopted in Maharashtra and Karnataka. However, it had also

A field view of pearl millet high-iron variety Dhanashakti

Large globular grains and shining panicles of pearl millet variety Dhanashakti

Table 2. Key morphological features of pearl millet variety Dhanashakti

Morphological trait	Measurement / score/unit
Anthocyanin coloration of first leaf sheath	Present
Leaf-sheath pubescence	Absent
Anther colour	Purple, cream
Node pubescence	Present
Node pigmentation	Mixed (purple and green)
Internode pigmentation	Green
Panicle exsertion	Complete
Anthocyanin pigmentation of glume	Present
Panicle bristles	Absent
Panicle shape	Cylindrical - lanceolate
Seed colour	Grey
Seed shape	Globular

been adopted on small scales in parts of Uttar Pradesh and Rajasthan. Based on its superior performance with respect to Fe and Zn contents, as well as grain and dry stover yields, Dhanashakti was released and notified vide SO 1146(E) dated April 24, 2014 for cultivation in the states of Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Rajasthan, Gujarat, Haryana, Uttar Pradesh and Delhi. Commercial production of Dhanashakti was initiated by Nirmal Seeds Company even before its official release, marketing its Truthfully Labelled Seeds under the brand name ICTP 8203 Fe, and reaching 25,000 farmers in Maharashtra in 2012. In 2013, Nirmal Seeds Company marketed this variety to 35,000 farmers. Dhanashakti being superior to ICTP 8203 for Fe density as well as for grain yield, and similar to ICTP 8203 for other traits, will find rapid farmers' adoption in states where ICTP 8203 had been adopted. It may also be suitable for cultivation in other drought-prone environments, and has now been included in the Nutri-Farm Pilot Project for addressing Fe deficiency.

Dhanashakti is identified by its major distinguishing features such as large, globular and dark grey grains; compact to semi-compact and cylindrical-lanceolate panicles with shining outer surfaces of the grains; purple pigmentation of the glumes, mixed anther colour (mostly purple and some cream colour); anthocyanin pigmentation of the first leaf sheath; and mixed node pigmentation (mostly purple, but some green) (Table 2). These characteristics are similar to those of the ICTP 8203.

With the official release, Dhanashakti now can be produced by public-sector seed agencies for which adequate quantities of breeder seed can be obtained from ICRISAT and MPKV.

SUMMARY

Pearl millet, in general, has higher Fe and Zn content than other major cereals such as wheat, rice, maize and sorghum. Studies conducted at ICRISAT under the HarvestPlus Challenge Program of the CGIAR showed large variability for Fe and Zn contents in the breeding lines, hybrid parents, hybrids, improved populations and germplasm. These studies also identified ICTP 8203, a released open-pollinated variety (OPV) under cultivation, having the highest level of Fe content, often in the range of 70-75 ppm.

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