Variability for grain iron and zinc contents in pearl millet hybrids

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Citation: Velu G, Rai KN, Sahrawat KL and Sumalini K. 2008. Variability for grain iron and zinc contents in pearl millet hybrids. Journal of SAT Agricultural Research 6.

Introduction

Dietary deficiency of mineral micronutrients such as iron (Fe) and zinc (Zn) has been recognized as a worldwide human health problem, especially in the developing countries (Welch and Graham 2004). The pearl millet (*Pennisetum glaucum*) research program at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has undertaken to address this issue through the development of improved breeding materials with the elevated levels of these micronutrients for eventual use in cultivar development. Pearl millet, grown on 26 million ha in some of the most marginal arid and semi-arid tropical environments of Asia (11 million ha) and Africa (15 million ha), is a major source of dietary energy and nutritional security for a vast population in these regions. For example, a recent study showed that in major pearl millet growing states of India, pearl millet accounts for the largest share of Fe and Zn intake by the population, and it is also the cheapest source of these micronutrients compared to other cereals and even vegetables (Parthasarathy Rao et al. 2006). Another study showed a large genetic variability for these micronutrients among pearl millet germplasm accessions, breeding lines and improved populations, and identified some of the commercial open-pollinated varieties (OPVs) and hybrid parents with high levels of grain Fe and Zn contents (Velu et al. 2007). This article reports the preliminary results of a study conducted to examine the extent of variability for grain Fe and Zn in commercial and pipeline hybrids developed in India.

Materials and methods

The experimental material consisted of 52 pearl millet hybrids from 19 private seed companies and an early-maturing, popular public sector hybrid 'HHB 67-improved'. Those from the private seed companies included 35 hybrids under cultivation and 18 in the pipeline (7 of the pipeline hybrids were withdrawn later). The field trials were conducted during the 2006 rainy season and 2007 summer season in Alfisols at ICRISAT, Patancheru, India (hereafter referred to as environments) in a randomized complete block design (RCBD) with three replications. Each hybrid was grown in 2 rows of 4 m length with 75 cm spacing between the rows in 2006 rainy season and 60 cm spacing during 2007 summer season, and 15 cm spacing between plants within the row during both the seasons. The test plots received 75 kg ha^{-1} nitrogen [50% basal in the form of diammonium phosphate (DAP) and 50% topdressed at 20 days after sowing in the form of urea] and 35 kg ha^{-1} phosphorus. The Fe and Zn levels of soil were estimated in surface layer (0–15 cm) and sub-surface layer (15–30 cm) at the time of planting. The available (DTPA extractable-Fe) soil Fe varied from 12.2 mg kg^{-1}in the sub-surface layer (15–30 cm depth) to 14.6 mg kg^{-1} in the surface layer (1–15 cm depth) during the rainy season, and from 6.0 to 7.8 mg kg^{-1} in the sub-surface to surface layer during the summer season. The DTPA extractable-Zn varied from 2.2 mg kg^{-1} in the sub-surface layer to 3.7 mg kg^{-1} in the surface layer during the rainy season, and from 1.8 to 3.0 mg kg^{-1} in the sub-surface to surface layer during the summer season. Selfed grain samples, produced from harvests at physiological maturity, were analyzed for Fe and Zn contents in ICRISAT Analytical Laboratory using the method described by Sahrawat et al. (2002).

Results and discussion

There were highly significant differences (P <0.01) among the hybrids for both micronutrients (data not shown). The hybrid × environment interaction was also highly significant for both Fe and Zn, but its contribution to the mean square was only 14–28% of that contributed by difference among the hybrids. Also, the correlation coefficient between the two environments was positive and highly significant for grain Fe (r = 0.76; P <0.01) and

Zn content (r = 0.58; $P < 0.01$) indicating high levels of consistency of the ranking of hybrids across the two environments both for Fe and Zn contents.

The grain Fe content among hybrids ranged from 52.1 to 87.5 mg kg^{-1} in the rainy season, whereas it ranged from 41.7 to 86.2 mg kg^{-1} in summer season (Table 1). The average grain Fe content was 19% higher in rainy season (69.2 mg kg^{-1}) than that of summer season (58.2 mg kg^{-1}), which may be due to the Fe level in the soil, as the field used during the rainy season had 95% more Fe in the soil than the one used during the summer season. The average grain Zn content of the hybrids was comparable in rainy season and summer season. There was no difference in soil Zn content between the seasons.

Based on the mean performance across the two environments, the Fe content among the hybrids varied from 46.9 to 85.0 mg kg^{-1} and Zn content varied from 36.4 to 69.9 mg kg^{-1} (Table 1). Twenty-six hybrids (half of the total hybrids in the trial) had more than 63.7 mg kg^{-1} Fe, well over the trial mean and the check hybrid 'HHB 67-improved'. Of these, 17 hybrids had Zn content well over the trial mean as well as over 'HHB 67-improved'. Eighteen hybrids had >70 mg kg^{-1} Fe, of which 11 hybrids had >50 mg kg^{-1} Zn. These levels represent twice more Fe content and 50% more Zn content than those reported in improved wheat (*Triticum aestivum*) cultivars (Graham et al. 1999). MLBH 504 had the highest level of Fe (85.0 mg kg^{-1}). It also had the highest level of grain Zn content (69.9 mg kg^{-1}). Another hybrid MRB 204 had 80.0 mg kg^{-1} Fe and 60.7 mg kg^{-1} Zn. MLBH-504 is cultivated on 50,000 ha in Maharashtra and Karnataka states of India (M Desai, deVGen Pvt Ltd., Hyderabad, personal communication). MRB-204 is cultivated on 300,000 ha in Maharashtra, Uttar Pradesh, Madhya Pradesh and Haryana states of India (AM Rao, MAHYCO, Jalna, personal communication). There were eight additional hybrids under cultivation that had >70 mg kg^{-1} Fe, of which four hybrids also had >50 mg kg^{-1} Zn content.

There was a highly significant positive correlation between the grain Fe and Zn content (r = 0.65; $P < 0.01$) (Fig. 1), indicating that either genetic factors for Fe and

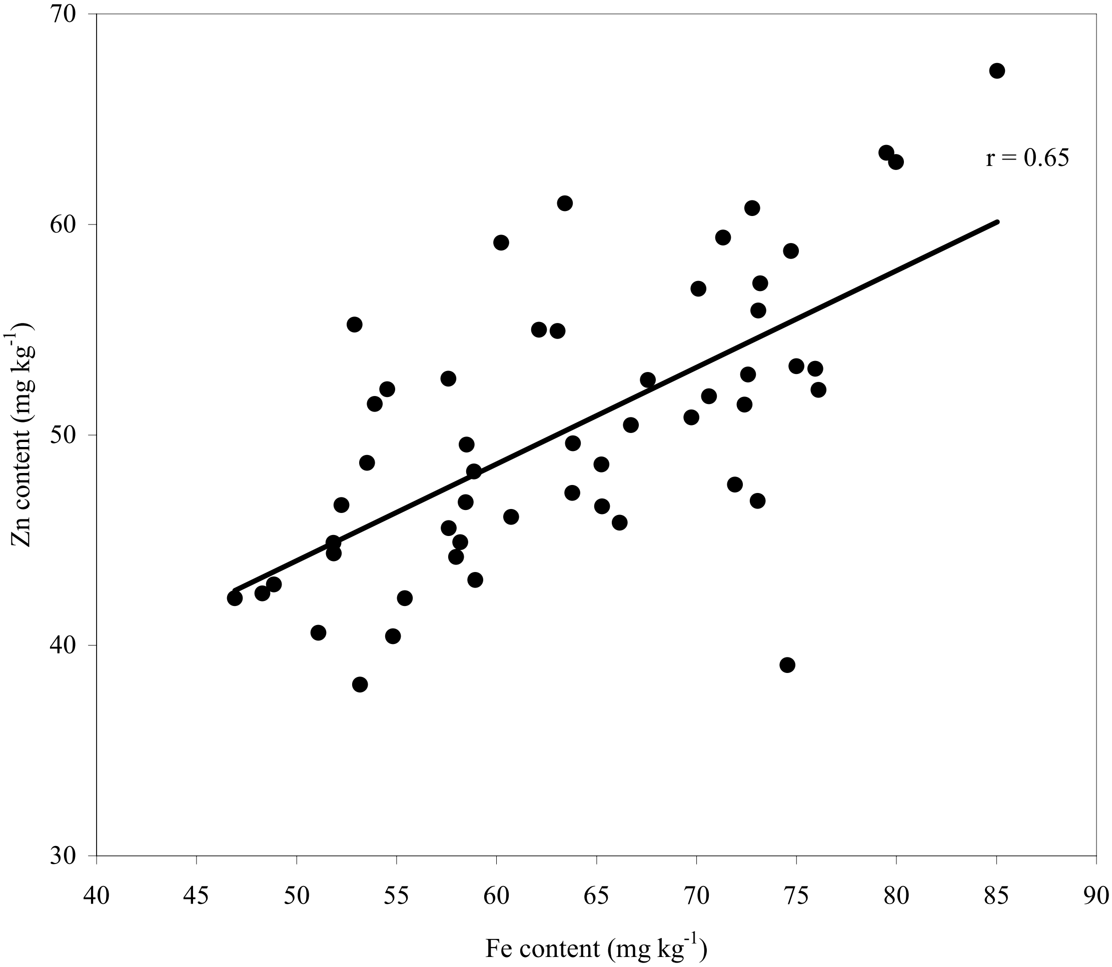

Figure 1. Relationship between grain iron (Fe) and zinc (Zn) contents in commercial hybrids of pearl millet (data are mean of 2006 rainy season and 2007 summer season, ICRISAT, Patancheru, India).

Table 1. Grain iron (Fe) and zinc (Zn) contents of pearl millet commercial hybrids, 2006 rainy season and 2007 summer season, ICRISAT, Patancheru, India.

		Fe content (mg kg^{-1})			Zn content (mg kg^{-1})		
Hybrid	Status (2006/07)	Rainy 2006	Summer 2007	Mean	Rainy 2006	Summer 2007	Mean
MLBH 504	Cultivation	83.9	86.2	85.0	67.3	72.4	69.9
MRB 204	Cultivation	83.6	76.4	80.0	63.0	58.3	60.7
Rasi 3043	Withdrawn	87.5	71.5	79.5	63.4	55.7	59.5
X 3011	Pipeline	74.5	77.7	76.1	52.1	67.3	59.7
9332	Cultivation	82.8	69.1	76.0	53.1	41.3	47.2
Nodai 6364	Cultivation	85.8	64.2	75.0	53.3	46.6	49.9
MLBH 65	Pipeline	82.8	66.6	74.7	58.7	44.6	51.7
Nandi 3	Cultivation	75.2	73.9	74.6	39.1	33.8	36.4
KH 302	Cultivation	81.0	65.4	73.2	57.2	40.5	48.9
PAC 931	Cultivation	81.1	65.1	73.1	55.9	55.7	55.8
Rasi 2246	Withdrawn	83.5	62.6	73.1	46.9	39.3	43.1
9333	Cultivation	80.8	64.7	72.8	60.8	45.8	53.3
825	Pipeline	82.2	63.0	72.6	52.9	39.9	46.4
B 2301	Cultivation	74.0	70.8	72.4	51.4	52.8	52.1
9330	Withdrawn	75.6	68.3	71.9	47.6	41.5	44.6
Euro 315	Pipeline	81.2	61.4	71.3	59.4	54.4	56.9
Euro Chetak	Cultivation	69.8	71.5	70.6	51.8	65.3	58.6
MRB 2210	Cultivation	77.4	62.8	70.1	56.9	47.1	52.0
70	Cultivation	81.8	57.7	69.8	50.8	39.4	45.1
XM 32	Cultivation	76.0	59.1	67.6	52.6	43.8	48.2
Kaveri 456 Boss	Cultivation	77.8	55.7	66.7	50.5	45.1	47.8
9533	Cultivation	72.6	59.8	66.2	45.8	35.8	40.8
Bio 2800	Cultivation	74.5	56.0	65.3	48.6	36.4	42.5
JKBH 729	Pipeline	70.0	60.5	65.3	46.6	51.0	48.8
9555	Cultivation	72.0	55.6	63.8	49.6	35.8	42.7
Rasi 3136	Cultivation	67.1	60.5	63.8	47.2	43.8	45.5
MP7127	Cultivation	71.5	55.3	63.4	61.0	38.0	49.5
MBH 163	Cultivation	61.3	64.8	63.1	54.9	60.3	57.6
MLBH 267	Cultivation	64.7	56.7	60.7	46.1	42.1	44.1
GK 1051	Pipeline	65.8	54.7	60.2	59.1	55.5	57.3
9444	Cultivation	62.3	55.6	58.9	43.1	36.8	40.0
GK 1044	Cultivation	60.3	57.4	58.9	48.3	40.0	44.1
JKBH 26	Cultivation	63.5	53.5	58.5	49.5	47.2	48.4
MDBH 318	Pipeline	62.1	54.8	58.5	46.8	34.6	40.7
Rasi 3021	Cultivation	62.6	53.8	58.2	44.9	38.8	41.8
Nandi 5	Cultivation	61.2	54.8	58.0	44.2	47.1	45.7
8492	Cultivation	62.3	52.9	57.6	45.6	34.1	39.9
MLBH 75	Cultivation	61.9	53.3	57.6	52.7	39.6	46.2
Kaveri 44K77	Pipeline	58.5	52.3	55.4	42.2	36.5	39.4
XM 34	Withdrawn	54.1	55.5	54.8	40.4	49.7	45.1
Rasi 2234	Pipeline	66.8	42.2	54.5	52.2	44.9	48.5
JKBH 676	Cultivation	61.2	46.7	53.9	51.5	45.2	48.3
MLBH 308	Cultivation	60.7	46.4	53.5	48.7	36.0	42.4
777	Withdrawn	57.2	49.1	53.2	38.1	41.7	39.9
8510	Withdrawn	61.7	44.1	52.9	55.2	41.4	48.3
BBH 111 (Hi Pearl 51)	Cultivation	56.8	47.0	51.9	44.4	37.4	40.9
NITYA-ARJUN	Pipeline	56.7	47.0	51.9	44.9	40.1	42.5
7701	Cultivation	53.9	48.3	51.1	40.6	34.5	37.5
BBH 11 (Hi Pearl 41)	Cultivation	54.4	43.3	48.9	42.9	41.5	42.2
Euro 306	Pipeline	52.1	44.5	48.3	42.5	34.3	38.4
Nodai 6337	Cultivation	52.1	41.7	46.9	42.2	41.0	41.6
Check							
HHB 67-improved	Cultivation	70.1	54.2	62.1	55.0	42.4	48.7
7688	Withdrawn	57.1	47.4	52.3	46.7	35.6	41.1
Mean		69.2	58.2	63.7	50.3	44.3	47.3
CV (%)		9.5	7.4	–	10.2	10.3	–
LSD ($P = 0.05$)		10.6	9.8	–	8.3	8.5	–

Zn contents are linked, or that there are inter-connected physiological mechanisms for their uptake/translocation in the grains. The direction and intensity of correlation suggested a good possibility of simultaneous genetic improvement of both micronutrients. In order to realize maximum impact of micronutrient-dense cultivars, the micronutrients must be delivered in high-yielding cultivars with farmers' preferred traits such as early-maturity and large seed size. It was observed that there was a significant though weak and negative correlation between Fe and time to 50% flower ($r = -0.35$; $P < 0.05$), but none between Zn and time to 50% flower ($r = -0.22$). There were significant positive correlations between grain size and Fe ($r = 0.34$; $P < 0.05$), and between grain size and Zn content ($r = 0.35$; $P < 0.05$). These results indicate that breeding for grain Fe and Zn is unlikely to have any adverse effect on maturity and grain size in pearl millet.

Research is underway to identify germplasm with still higher grain Fe and Zn contents for use in breeding hybrids and OPVs exceeding the micronutrient levels observed in these commercial hybrids. However, the grain Fe and Zn contents of these hybrids are already far higher than those reported in other cereals. This then could be used to develop awareness of the nutritional values of these hybrids that should prove useful in promoting their cultivation and the consequent improvement in the nutritional security of pearl millet farmers and consumers.

Acknowledgment. This research was partially supported by HarvestPlus Challenge Program of the Consultative Group on International Agricultural Research (CGIAR).

References

Graham RD, Senadhira D, Beebe S, Iglesias C and **Monasterio I.** 1999. Breeding for micronutrient density in edible portions of stable food crops: conventional approaches. Field Crops Research 60:57–80.

Parthasarathy Rao P, Birthal PS, Reddy BVS, Rai KN and **Ramesh S.** 2006. Diagnostics of sorghum and pearl millet grains-based nutrition in India. International Sorghum and Millets Newsletter 46:93–96.

Sahrawat KL, Ravi Kumar G and **Rao JK.** 2002. Evaluation of triacid and dry ashing procedures for determining potassium, calcium, magnesium, iron, zinc, manganese and copper in plant materials. Communications in Soil Science and Plant Analysis 33:95–102.

Velu G, Rai KN, Muralidharan V, Kulkarni VN, Longvah T and **Raveendran TS.** 2007. Prospects of breeding biofortified pearl millet with high grain iron and zinc content. Plant Breeding 126:182–185.

Welch RM and **Graham RD.** 2004. Breeding for micronutrients in staple food crops from a human nutrition perspective. Journal of Experimental Botany 55:353–364.