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Genetic improvement of grain iron and zinc content in pearl millet (*Pennisetum glaucum*) under varying environmental conditions

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ABSTRACT

Pearl millet [Pennisetum glaucum (L.) R. Br.] is a major kharif season cereal, grown primarily for grain production in the arid and semi-arid tropical regions. Iron and zinc deficiencies in foods have been reported which cause human health problems worldwide. Improving Fe and Zn content of food grain crops by breeding offers an effective and sustainable solution to minimize micronutrient malnutrition in poor communities. An understanding of the genetics of these micronutrients was studied at Rajasthan Agricultural Research Institute (RARI), Durgarura, Jaipur (Rajasthan), India, during Kharif-2015 in diallel fashion excluding reciprocals for grain yield and iron and zinc content using ten diverse inbreds. In the present study, ten inbred lines and their full diallel crosses were used. The general combining ability (GCA) effects of parents and specific combining ability (SCA) effects of hybrids showed significant differences for both of the micronutrients. However, the predictability ratio $(2\sigma^2gca/(2\sigma^2gca + \sigma^2sca))$ *was around unity both for Fe and Zn content, implying preponderance of additive gene action. Barring a few exceptions with one parent, hybrids did not outperform the parents having high Fe and Zn levels. This showed that there would be little opportunity, if any, to exploit heterosis for these mineral micronutrients in pearl millet. In general, high Fe and Zn levels in both of the parental lines would be required to increase the probability of breeding high Fe and Zn hybrids.*

Key Words: Pearl millet, diallel, grain iron and zinc, σ^2gca, σ^2sca

INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is a diploid species having 2n=14 chromosomes, belongs to the family Gramineae (Poaceae). It is an important cereal crop in arid and semi arid region of the world with micronutrient rich cereal especially in iron and zinc. Micronutrient malnutrition resulting from dietary deficiency of one or more micronutrients has been recognized as a serious human health problem worldwide. Dietary diversification raises an issue of diverse food affordability since a sharp increase in food prices will have a large impact on poor households. It also has problem of consumer acceptance in case dietary diversification calls for including foods which are not a part of conventional diets. Biofortification of staple crops, especially for mineral micronutrients, is a sustainable and cost-effective approach. It has great promise for improving the mineral nutritional status and health of poor populations in both rural and urban areas of the developing world. Biofortified varieties of staple crops improved for mineral micronutrients are also readily acceptable to consumers as their adoption does not call for change in dietary habits. Pearl millet is a highly cross-pollinated crop with open-pollinated varieties and hybrids as the two broad cultivar options. Hybrids are the most dominant cultivars in India, occupying >70% of area under improved pearl millet cultivars, with OPVs cultivated on limited scales. A preliminary study showed about two-fold differences for Fe and Zn densities among pearl millet hybrids under cultivation in India, with Fe density varying from 31 to 61 mg kg^{-1} and Zn density varying from 32 to 54 mg kg^{-1} (Rai *et al.*2013). An understanding of the nature of genetic variability and heterosis will have a direct bearing on devising effective hybrid breeding strategies for Fe and Zn density. There is limited information on genetic variability and heterosis for Fe and Zn density in pearl millet. While improving the Fe and Zn densities, it is important that genetic gains for these micronutrients are not made at the expense of grain yield and grain size. The main objective of this research was to examine the nature of genetic variability in relation to heterosis for Fe and Zn density. Since, there exists a wealth of

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literature on genetic variability and heterosis for grain yield and grain size, genetic variability and heterosis for these two traits were studied in the specific context of their associations with Fe and Zn densities.

MATERIALS AND METHOD

Ten genetically diverse inbreds of pearl millet viz., J-2340, MIR-525-2, RIB-192, RIB-494, RIB-3135-18, RIB 57, RIB-335/74, HBL-11, H-77/833-2-202 and G-77/107 were crossed in all possible combinations excluding reciprocals during summer 2015 to generate a diallel set. Ten parents' along with their 45 F1s were evaluated for grain yield and 13 yield components in a randomized block design with three replications at Rajasthan Agricultural Research Institute, Durgarura, Jaipur (Rajasthan), India, during kharif-2015. Each entry was sown in two rows of 4.0 m length having 50 x 15 cm crop geometry. All the recommended cultural practices were adopted to raise good crop of pearl millet. Observations were recorded on ten randomly selected competitive plants for each entry in each replication for these characters. The iron and Zinc content in grain were analyzed at ICRISAT using an energy-dispersive X-ray fluorescence Spectrometry (EDXRF) method (Paltridge *et al., 2012).* For the analysis of zinc and iron content the ear heads of the selected plants were harvested separately and then sun dried for seven days and stored for one to two months before analysis of iron and zinc content. Analysis of variance for combining ability was done environment wise following Griffing's (1956) Method II and Model I. The combining ability analysis of data pooled over the environments will be performed using the method elaborated by Singh (1973).

RESULTS AND DISCUSSION

The analysis of variance for combining ability using observations pooled over three environments on parents and F_1's revealed that variance due to general and specific combining ability were significant for all the characters i.e. grain yield per plant, and Fe and Zn content (Table: 1). This indicates that both additive and non additive gene effects are involved in the inheritance of the characters under study. The GCA variance was greater than SCA variances for panicle length, harvest index, test weight and Fe content indicating the preponderance of additive gene action in the characters. The variance due to environments/sowing dates was significant for all the above characters except productive tillers and panicle girth indicating strong influence of environment in the expression of these characters. The variance due to GCA x environment and SCA x environment were significant for all the above characters except for days to 50% flowering, plant height, panicle length, grain yield and test weight in GCA x environment indicating that combining ability of the progenies are influenced by the environments. SCA x environment variance was higher than variance due to GCA x environment interaction for days to 50% flowering, days to maturity, productive tillers per plant, panicle girth, biological yield per plant, dry fodder yield per plant, grain yield per plant suggesting that, for these characters GCA was comparatively more stable. . Similar findings were obtained by Sheoran *et al.*, (2000), Akanchalekum and Afribeh (2005), Shanmuganathan and Gopalan (2006), Rohitashwa *et al.*, (2006), Chotaliya *et al.*, (2010) and Yadav *et al.*, (2012) and Chaudhary *et al.*, (2012).

Table 1: Pooled analysis of variance for combining ability in pearl millet evaluated in three environments

S. No.	Source of variance	d.f.	Grain yield/ plant	Mean sum of square	
				Fe content	Zn Content
1	GCA	9	48.003 **	375.786**	29.211**
2	SCA	45	77.051 **	74.596**	47.270**
4	GCA x Envn.	18	2.891	31.617**	50.820**
5	SCA x Envn.	90	6.391*	26.776**	33.845**
6	Error	324	2.881	0.004	0.023

andsignificant at 5% and 1% level of significance, respectively*

As the p x e interaction was significant for all the traits, the combining ability analysis was carried out for each environment separately, which has been presented in Table: 2. The combining ability analysis revealed that GCA and SCA were significant for all the characters i.e. days to 50% flowering, days to maturity, productive tillers per plant, plant height, panicle length, panicle girth, biological yield per plant, dry fodder yield per plant, grain yield per plant, harvest index, test weight and Fe and Zn content in all the three environments, except GCA for days to 50% flowering in E_1indicating the importance of both additive and non additive gene effects in the genetic control for all the characters studied. However, the GCA: SCA variance ratio being less than the unity showed that the non-additive gene action was more important for all the traits in all the three environments. It have also been reported by several workers Joshi *et al.*, (2001), Rasal and Patil (2003), Shanmuganathan and Gopalan (2006), Rohitashwa *et al.*, (2006) and Chaudhary *et al.*, (2012).

Table 2: Analysis of variance for combining ability in individual environment (sowing dates) in pearl millet

S. No.	Source of variance	d.f.	Env.	Mean Sum of Squares		
				Grain yield/plant	Fe content	Zn content
1	GCA	9	E_1	28.015**	113.778**	17.534**
			E_2	12.755**	97.941**	47.121**
			E_3	13.042**	227.302**	66.196**
2	SCA	45	E_1	51.921**	40.103**	34.525**
			E_2	24.406**	47.626**	44.033**
			$^E3$	13.506**	40.419**	36.402**
3	Error	105	$^E1$	5.138	0.004	0.041
			E_2	2.065	0.003	0.014
			E_3	1.441	0.004	0.015
	GCA/SCA		E_1	0.040	0.236	0.042
			E_2	0.039	0.171	0.089
			E_3	0.080	0.468	0.068

andsignificant at 5% and 1% level of significance, respectively*

Estimates of general (gi) and specific combining ability effects (Sij) under all the three environments are very useful for suitable parents and crosses for grain yield and quality parameters. Higher grain yield per plant is desirable in pearl millet; hence positive combining ability effects are desirable. The GCA effects ranged from -1.645 (H77/833-02-202) to 2.510 (RIB-3135-18) in E_1, from -1.431 (G.77/107) to 2.030 (RIB-3135-18) in E_2 and from -1.699 (G.77/107) to 1.479 (RIB-3135-18) in E_3. For iron content the GCA effects ranged from -4.035 (MIR-525-2) to 6.207(G.77/107) in E_1, from -2.933 (RIB-335/74) to 4.689 (H77/833-02-202) in E_2 and from -4.429 (RIB-192) to 8.207 (G.77/107) in E_3. Similarly the SCA effects ranged from -14.296 (P7x P9) to 10.931(P2 x P6) in E_1, from -12.242 (P7 x P9) to 15.749 (P4 x P6) in E_2 and from -15.188 (P9 x P10) to 13.337(P1 x P10) in E_3 and The GCA effects for zinc content ranged from -1.792 (HBL-11) to 2.049(RIB-335/74) in E_1, from -3.077 (MIR-525-2) to 2.905 (H77/833-02-202) in E_2 and from -3.010 (RIB.192) to 3.184 (RIB-494) in E_3. Parents RIB-3135-18 exhibited positive significant GCA effects in all the three environments for grain yield, RIB-57, HBL-11, H77/833-02-202 and G.77/107 for iron content, J-2340, RIB-192, RIB-335/74 and G.77/107 in E_1, RIB-192, RIB-494, RIB-3135-18, RIB-57, HBL-11 and H77/833-02-202 in E_2 and J-2340, MIR-525-2, RIB-494, H77/833-02-202 and G.77/107 in E_3 for zinc content. Hence may be regarded as desirable in all the three environments. Crosses P1 x P2, P2 x P6, P4 x P6, P5 x P9, P6 x P7 and P7 x P9 for grain yield, P1 x P10, P3 x P8 and P3 x P9, P4 x P10, P6x P8, P6 x P9, P6 x P10, P7x P10 and P8 x P9 for iron content and P1 x P10, P2 x P4 and P7 x P10 for zinc content exhibited positive significant SCA effects in all the three environments hence, may be regarded as desirable.

Table 3: Top three parents and crosses for grain yield per plant and related traits in pearl millet in E_1, E_2 and E_3 environments

	Characters	Env.	Per se performance		GCA	SCA	Heterobeltiosis
			Parents	F_1 s			
1	Grain yield per plant	E_1	RIB-192	P5 x P9	RIB-3135-18	P5 x P9	P1 x P2
			HBL-11	P5 x P10	RIB-335/74	P4 x P6	P6XP7
			H77/833-2-202	P4 x P6	HBL-11	P1 x P2	P5XP9
		E_2	RIB-192	P5 x P9	RIB-3135-18	P5 x P9	P5XP9
			HBL-11	P5 x P10	MIR-525-2	P1 x P2	P6XP7
			H77/833-2-202	P1 x P2	RIB-192	P5 x P10	P5XP10
		E_3	H77/833-2-202	P6 x P7	RIB-3135-18	P6 x P7	P6XP7
			HBL-11	P2 x P6	RIB-335/74	P5 x P10	P2XP6
			RIB-192	P1 x P2	MIR-525-2	P7 x P9	P6XP10
2	Fe Content	E_1	H77/833-2-202	P6 x P10	G77/107	P2 x P6	P6 x P8
			G77/107	P6 x P8	H77/833-2-202	P5 x P7	P2 x P6
			RIB-3135-18	P1 x P10	HBL-11	P6 x P8	P1 X P7
		E_2	H77/833-2-202	P4 x P6	G77/107	P1 x P2	P4 x P6
			HBL-11	P1 x P10	H77/833-2-202	P1 x P10	P1 x P10
			RIB-3135-18	P8 x P9	HBL-11	P3 x P8	P1 x P2
		E_3	G77/107	P8 x P9	G77/107	P1 x P10	P4 x P6
			H77/833-2-202	P1 x P10	H77/833-2-202	P8 x P9	P8 x P9
			HBL-11	P6 x P9	HBL-11	P6 x P9	P6 x P8
3	Zn Content	E_1	RIB-335/74	P5 x P10	RIB-353-74	P5 x P10	P2 x P6
			RIB-3135-18	P1 x P10	J-2340	P1 x P3	P1 x P3
			J-2340	P3 x P4	G77/107	P3 x P7	P3 x P4
		E_2	RIB-335/74	P8 x P9	RIB-192	P4 x P6	P4 x P6
			RIB-3135-18	P4 x P6	H77/833-2-202	P8 x P9	P8 x P9
			H77/833-2-202	P6 x P9	HBL-11	P6 x P9	P1 x P4
		E_3	MIR-525-2	P4 x P9	RIB-494	P6 x P7	P4 x P8
			J-2340	P4 x P8	H77/833-2-202	P4 x P8	P4 x P9
			H77/833-2-202	P4 x P6	G77/107	P4 x P9	P6 x P7

Highly significant mean sum of square due to GCA and SCA in all the three environments indicate that all the characters were controlled by both additive and non-additive gene effects. Variance of GCA/variance of SCA ratio was less than unity for all the characters which showed preponderance of non-additive gene actions in all the three environments. Parent RIB-3135 followed by RIB-335/74, MIR-525-2 and RIB-192 were found to be uniformly best parent across the environments for grain yield per plant with Fe and Zn content, while parent G77/107 was found to be uniformly undesirable parent across the environment with high negative effects. Parent HBL-11, RIB-57 and H77/833-2-202 were found to be a better general combiner across the environments for Fe content, parent G77/107 was found to be a better general combiner for both Fe and Zn content. In the present study, crosses with high SCA effects involving good x good general combiners were P1 x P2, P2 x P5,P2 x P6, P2 x P7, P4 x P7, P5 x P9, P6 x P7 and P7 x P9 ($E_{1,}$ E_2 and E_3 environments), P5 x P10 and P3 x P8 (E_1 environment), P5 x P10 (E_2 environment) and P3 x P8 (E_3 environment) for grain yield per plant and related traits (Table: 3). These crosses offer good promise for improvement of respective component trait and ultimately grain yield in respective environment. The transgressive segregants could be isolated in higher frequency from these crosses and utilize to generate inbred lines using conventional breeding method for further crop improvement programmes.

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