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Pearl millet genetic variability for grain yield and micronutrients in the arid zone of India

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Abstract
Micronutrient deficiency has become a global threat and especially, people inhabiting in developing countries who predominantly feed on cereal diet are more prone to this micronutrient malnutrition. Millets are nutri-cereals which can combat with this malnutrition. Among all the millets, pearl millet (*Pennisetum glaucum* (L.) R. Br.) is a rich source of essential amino acids and minerals like Fe and Zn content. Improvement of pearl millet with micronutrients and grain yield can be aimed by exploiting the genetic variability existing in the population. Hence, the present study was aimed to understand the genetic variability and correlation of micronutrients, grain yield and other agronomic traits. The result from Analysis of Variance studied in 130 pearl millet lines revealed significant variation for all 13 traits under study. GCV and PCV were high for Fe content, grain yield and number of productive tillers/plant, which revealed the presence of larger variation for these traits. The correlation of grain yield with all the agronomic traits studied indicates that indirect selection of simply inherited agronomic traits can assist in effective selection for grain yield. Among micronutrients, the association Fe and Zn content was high and they did not show any significant correlation with other agronomic traits. Hence, Fe and Zn content can be enhanced together in the grain and at the same time, there is a chance of getting a line with high grain yield, high Fe and Zn content.

Keywords: pearl millet, Fe, Zn, variability, heritability, correlation

Introduction
Micronutrient malnutrition, also known as 'hidden hunger' is frightening the developing countries who mainly depend on cereal-based diets (Bouis and Welch 2010) [1]. Globally, one out of three persons, is suffering from ill health due to deficiencies of one or the other micronutrients (Saltzman *et al.*, 2013) [2]. This in turn is drawing the attention of people towards utilization of millets in their regular diet. Pearl millet is one of the millet crops, which is a rich source of fiber, protein, essential amino acids and minerals like Fe, Zn, P, Mg. These properties make this crop highly valued for daily consumption (Tara Satyavathi *et al.* 2015) [3]. Further, pearl millet is very hardy and can be grown in poor soils with low nutrients and less moisture where other cereals fail to grow. It can withstand drought and even salinity to some extent. It can survive with 25% of rainfall regime as against the rainfall demanded by other cereals like paddy. Hence, it can be grown in driest parts of India.

Development of new varieties over existing varieties is a continuous process to cater the needs of present and future. The challenge to today's crop improvement is not only to increase the yield potential of the crop but also to enhance micronutrient content in the grain. Any crop improvement initially looks for the amount of genetic variability existing in the population, so that it can be utilized further either by simple selection or though other breeding approaches. Selection will be effective when traits are highly heritable. Heritability of a trait provides an insight into the heritable variance which can be transferred to the next generation. Grain yield and micronutrient contents are complex traits governed by many genes and are influenced by the nearby environment (Owere *et al.*, 2015) [4]. Hence, direct selection for these traits is not worthy. Consequently, a sound knowledge on correlation of yield and micronutrients with morphological traits helps in indirect selection of these traits *via* highly heritable traits (Bezaweletaw *et al.*, 2006) [5]. Hence, in the present study 130 pearl millet breeding lines were studied for variability, heritability and correlation of yield, micronutrients and other important traits.

Material and Methods
In the present study, 130 pearl millet genotypes including two check varieties, *viz.*, Dhanshakti and ICMB 98222 were evaluated at ICAR-National Bureau of Plant Genetic Resources,

Regional Station farm, Jodhpur during *kharif*, 2014. Each genotype was sown in randomized block design with three replications. Spacing adopted was 70 × 15 cm sown in two rows of 4m length. Timely application of fertilizers and other recommended package of practices were followed to raise a good crop. Observations were recorded on 13 traits; number of days to 50% flowering, productive tillers per plant, panicle length in cm, panicle diameter in cm, plant height in cm, panicle yield per plant in g, thousand seed weight in g, grain yield per plant in g, total phosphorus content in mg/100g, grain Zn content in mg/kg, grain Fe content in mg/kg, grain Cu content in mg/kg and grain Mn content in mg/kg.

Analysis of variance and summary statistics were calculated as per Panse and Sukathme (1967) [6]. Phenotypic and genotypic coefficients of variation (PCV and GCV) were computed as per Burton and Devane (1953) [7]. Heritability in broad sense was computed as per Allard (1960) [8]. Heritability and genetic advancement were categorized into low, medium and high as per Johnson *et al.*, (1955) [9]. Genotypic and phenotypic correlations were calculated according to Falconer (1981) [10].

Results and Discussion

The accomplishment in crop improvement depends on the nature and extent of variability present in the crop. In addition to genetic variability, information on heritability and genetic advance together helps in predicting the phenotypic expression of characters in succeeding generations (Johnson *et al.*, 1955) [9].

The results from ANOVA (table 1) revealed presence of large variability for 130 pearl millet lines under study for all the 13 characters considered. Substantial variation was reported by earlier workers (Sumathi *et al*., 2010, Govindaraj *et al*., 2011) [11, 12]. All the summary statistics were presented in table 2. Coefficient of variation was maximum (17.17%) for grain yield/ plant, followed by panicle yield (16.93%). Grain yield ranged from 6.90 to 17.17 g, while the mean was 25.00 g. The difference of flowering among different genotypes was from 33.73 to 66.75 days with a mean of 54.23 days. Total P ranged from 180.6 to 451.9 g/100g, while Fe and Zn content in the grain ranged from 23.27 to 121.63 and 20.3 to 86.00 mg/kg respectively. PCV and GCV were given in Table 2. GCV ranged from low to high. Highest GCV and PCV were observed for Fe content followed by grain yield and number of productive tillers/plant representing more variability of these traits among pearl millet lines. Days to 50% flowering had low GCV and PCV indicating lesser variability of this trait in the population. Similar findings were reported earlier by Sumathi *et al*., 2010 [11], and Kumar *et al*., (2017) [13]

Heritability was high for all the traits studied whereas GAM ranged from moderate to high. High heritability with high GAM indicates preponderance of additive genes which respond to selection. Similar findings of high heritability and high GAM for agronomic traits was reported by Meena Kumari and Nagarajan (2008) [14], Kumar *et al*., (2017) [13] and for micronutrients, Govindaraj *et al*., 2011 [12] reported both heritability and GAM to be high. High heritability with moderate GAM was observed for days to 50% flowering indicating the presence of both additive and non additive genes.

Correlation of different traits gives us the knowledge on being inheriting together from generation to generation. It help us to do indirect selection for complex traits like yield *via* other biometrical traits which are closely and positively associated. Grain yield was highly and significantly correlated (both phenotypic and genotypic correlation, Table 4 & 5) in positive direction with all agronomic traits except days to 50% flowering. These findings are in congruence with earlier workers (Singh and Singh, 2015and Manoj *et al*., 2016) [15, 16] Grain yield also showed significant positive correlation (phenotypic) with Fe, Zn, Cu and Mn content but, genotypically the grain yield was correlated with Fe content only indicating the role of environment for association of Zn, Cu and Mn content with grain yield. Both phenotypic and genotypic correlation of grain yield with total phosphorus content of the grain yield was significant but in negative direction, indicating that there should be a compromise at one point while selecting for high grain yield and total phosphorus content.

Further, phenotypic and genotypic correlation between Fe and Zn content was highly significant and was in positive direction, indicating that these two traits can be improved simultaneously. Rai *et al*. 2015 [17] and Govindaraj *et al*., 2011 [12] & 2016 [18] also reported positive association of Fe and Zn content.

Table 1: ANOVA of 130 pearl millet genotypes

Source of Variations	df	Mean Squares												
		PH	PL	PD	NPT	PY	GY	TSW	DFF	Zn	Fe	TP	Cu	Mn
Replications	2	6.82	0.83	0.04	0.39	122.36	3.99	0.03	0.29	74.49	67.16	568.08	0.30	6.39
Treatments	129	1604.00**	42.05**	0.68**	1.20**	468.36**	231.99**	9.58**	51.89**	506.96**	1267.36**	7940.67**	10.65**	28.83**
Error	258	78.91	1.41	0.03	0.09	72.80	18.43	0.11	3.86	20.28	32.03	352.47	0.31	1.82

** Significant at 1% level

Where PH: Plant height in cm, PL: Panicle length in cm, PD: Panicle diameter in cm, NPT: Number of productive tillers per plant, PY: Panicle yield per plant in g, GY: Grain yield per plant in g, TSW: Thousand seed weight in g, DFF: Days to 50% flowering, Fe: Grain Fe content in mg/kg, Zn: Grain Zn content in mg/kg, TP: Total P content in mg/100g, Cu: Grain Cu content in mg/kg, Grain Mn content in mg/kg

Table 2: Summary statistics of 130 pearl millet genotypes

Character	PH	PL	PD	NPT	PY	GY	TSW	DFF	Zn	Fe	TP	Cu	Mn
Mean	112.60	19.96	2.12	1.98	50.41	25.00	8.93	54.23	42.75	55.73	306.69	7.29	15.03
C.V.	7.89	5.96	7.75	14.80	16.93	17.17	3.67	3.62	10.53	10.16	6.12	7.61	8.97
C.D. 5%	14.28	1.91	0.26	0.47	13.72	6.90	0.53	3.16	7.24	9.10	30.18	0.89	2.17
Minimum	64.35	12.91	1.16	0.99	26.9	8.88	4.67	33.73	20.3	23.27	180.6	4.14	9.69
Maximum	165.78	31.13	3.29	3.55	89.36	48.87	12.85	66.75	86	121.63	451.9	15.35	23.92

Table 3: Genetic parameters of 130 pearl millet genotypes

Trait	PH	PL	PD	NPT	PY	GY	TSW	DFF	Zn	Fe	TP	Cu	Mn
GCV	20.02	18.44	22.04	30.74	22.78	33.75	19.91	7.38	29.80	36.42	16.40	25.47	19.97
ECV	7.89	5.96	7.75	14.80	16.93	17.17	3.67	3.62	10.53	10.16	6.12	7.61	8.97
PCV	21.52	19.38	23.35	34.14	28.38	37.87	20.24	8.22	31.60	37.81	17.50	26.59	21.89
H^2 (Broad Sense)	86.56	90.55	89.08	81.09	64.43	79.43	96.71	80.57	88.89	92.78	87.77	91.80	83.23
Genetic Advance	43.21	7.21	0.91	1.13	18.99	15.49	3.60	7.40	24.74	40.27	97.06	3.67	5.64
GAM	38.38	36.15	42.85	57.02	37.67	61.97	40.32	13.64	57.87	72.26	31.65	50.28	37.53

Where PH: Plant height in cm, PL: Panicle length in cm, PD: Panicle diameter in cm, NPT: Number of productive tillers per plant, PY: Panicle yield per plant in g, GY: Grain yield per plant in g, TSW: Thousand seed weight in g, DFF: Days to 50% flowering, Fe: Grain Fe content in mg/kg, Zn: Grain Zn content in mg/kg, TP: Total P content in mg/100g, Cu: Grain Cu content in mg/kg, Grain Mn content in mg/kg.

Table 4: Phenotypic correlation of yield and related traits in 130 pearl millet genotypes

Trait	PH	PL	PD	NPT	PY	GY	TSW	DFF	Zn	Fe	TP	Cu
PL	0.402**											
PD	0.216**	0.410**										
NPT	0.326**	0.283**	0.334**									
PY	0.216**	0.238**	0.389**	0.467**								
GY	0.225**	0.356**	0.576**	0.516**	0.690**							
TSW	0.077^{NS}	0.202**	0.427**	0.164**	0.170**	0.184**						
DFF	-0.110*	0.059^{NS}	-0.062^{NS}	-0.120*	-0.241**	-0.088^{NS}	-0.136**					
Zn	-0.028^{NS}	0.021^{NS}	0.024^{NS}	0.014^{NS}	0.121*	0.120*	0.051^{NS}	0.015^{NS}				
Fe	-0.020^{NS}	0.015^{NS}	0.026^{NS}	0.059^{NS}	0.126*	0.171**	0.154**	-0.074^{NS}	0.643**			
TP	-0.050^{NS}	-0.184**	-0.190**	-0.200**	-0.111*	-0.220**	-0.150**	0.080^{NS}	0.119*	0.159**		
Cu	0.143**	0.150**	-0.027^{NS}	0.051^{NS}	-0.015^{NS}	0.116*	-0.060^{NS}	0.105*	0.004^{NS}	0.021^{NS}	-0.058^{NS}	
Mn	0.108*	0.019^{NS}	0.034^{NS}	0.051^{NS}	0.083^{NS}	0.193**	-0.013^{NS}	0.041^{NS}	0.078^{NS}	0.112*	-0.046^{NS}	0.512**

Where PH: Plant height in cm, PL: Panicle length in cm, PD: Panicle diameter in cm, NPT: Number of productive tillers per plant, PY: Panicle yield per plant in g, GY: Grain yield per plant in g, TSW: Thousand seed weight in g, DFF: Days to 50% flowering, Fe: Grain Fe content in mg/kg, Zn: Grain Zn content in mg/kg, TP: Total P content in mg/100g, Cu: Grain Cu content in mg/kg, Grain Mn content in mg/kg.
** significant at 1% level

Table 5: Genotypic correlation of yield and related traits in 130 pearl millet genotypes

Trait	PH	PL	PD	NPT	PY	GY	TSW	DFF	Zn	Fe	TP	Cu
PL	0.360**											
PD	0.157**	0.380**										
NPT	0.270**	0.219**	0.277**									
PY	0.258**	0.292**	0.506**	0.643**								
GY	0.166**	0.345**	0.599**	0.535**	0.818**							
TSW	0.029^{NS}	0.173**	0.414**	0.124*	0.204**	0.147**						
DFF	-0.237**	-0.026^{NS}	-0.170**	-0.289**	-0.377**	-0.228**	-0.213**					
Zn	-0.025^{NS}	0.032^{NS}	0.037^{NS}	0.031^{NS}	0.081^{NS}	0.067^{NS}	0.059^{NS}	0.030^{NS}				
Fe	-0.032^{NS}	0.016^{NS}	0.028^{NS}	0.081^{NS}	0.089^{NS}	0.126*	0.160**	-0.091^{NS}	0.654**			
TP	-0.049^{NS}	-0.192**	-0.203**	-0.210**	-0.161**	-0.257**	-0.156**	0.109*	0.121*	0.165**		
Cu	0.085^{NS}	0.101*	-0.100*	-0.042^{NS}	-0.032^{NS}	0.053^{NS}	-0.101*	0.034^{NS}	0.016^{NS}	0.023^{NS}	-0.047^{NS}	
Mn	0.029^{NS}	-0.054^{NS}	-0.034^{NS}	-0.035^{NS}	-0.043^{NS}	0.044^{NS}	-0.061^{NS}	-0.069^{NS}	0.026^{NS}	0.061^{NS}	-0.052^{NS}	0.517**

Where PH: Plant height in cm, PL: Panicle length in cm, PD: Panicle diameter in cm, NPT: Number of productive tillers per plant, PY: Panicle yield per plant in g, GY: Grain yield per plant in g, TSW: Thousand seed weight in g, DFF: Days to 50% flowering, Fe: Grain Fe content in mg/kg, Zn: Grain Zn content in mg/kg, TP: Total P content in mg/100g, Cu: Grain Cu content in mg/kg, Grain Mn content in mg/kg.
** significant at 1% level

Conclusion

All the traits studied had significant genetic variation in the present study among 130 pearl millet genotypes. GCV and PCV ranged from low to high for traits studied indicating presence of low to high variability in the current population. Fe content, grain yield and number of productive tillers/ plant exhibited higher variability and days to 50% flowering showed lesser variability. Both phenotypically and genotypically, grain yield was highly associated with all agronomic traits studied which are less influenced by environment and predominantly controlled by additive genes. Hence, selection of simply inherited agronomic traits can assist in effective selection for grain yield. Grain yield was not significantly associated with any of the micronutrients. Grain Fe was highly correlated with grain Zn content indicating their coinheritance. So, there is a possibility for selection for high grain yield and high micronutrient contents. The present study implies that Fe and Zn content can be enhanced together in the grain and at the same time, there is a possibility to get a genotype with high grain yield, high Fe and Zn content.

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