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N Anuradha
Acharya NG. Ranga Agricultural University, Agricultural Research Station, Vizianagaram, Andhra Pradesh, India

C Tara Satyavathi
Project Coordinating unit, ICAR-All India Coordinated Research Project on Pearl millet, Jodhpur, Rajasthan, India

C Bharadwaj
Division of Genetics, ICAR-Indian Agricultural Research Institute, New Delhi, India

Mukesh Sankar
Division of Genetics, ICAR-Indian Agricultural Research Institute, New Delhi, India

T Lakshmi Pathy
Division of Crop Improvement, ICAR-Sugarcane Breeding Institute, Coimbatore, Tamil Nadu, India

Correspondence
N Anuradha
Acharya NG. Ranga Agricultural University, Agricultural Research Station, Vizianagaram, Andhra Pradesh, India

Association of agronomic traits and micronutrients in pearl millet

N Anuradha, C Tara Satyavathi, C Bharadwaj, Mukesh Sankar, and T Lakshmi Pathy

Abstract
Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is one of the millet crops which is known for its nutritional value. Pearl millet improvement is possible through exploitation of genetic variability present in the population for grain yield and related traits. Moreover, understanding of association between grain yield and micronutrients help in simultaneous improvement of both traits. Hence, the present study was undertaken to know the genetic variability, heritability and association of grain yield with various agronomic traits along with micronutrients. Analysis of Variance of 130 pearl millet genotypes revealed significant variation for all the characters studied. Grain yield recorded genotypic coefficient of variation of 35.13 and phenotypic coefficient of variation 40.01, while Fe and Zn had a GCV of 29.91 and 24.68 respectively which indicates presence of high genetic variability for grain yield and micronutriets in the population. Heritability ranged from 0.69 (panicle diameter) to 0.94 (thousand seed weight). The association of grain yield with number of productive tillers per plant, panicle yield per plant. panicle length, plant height and panicle diameter was significant and is in positive direction. Hence, these traits can be exploited for simple selection. Grain Fe is highly associated with Zn, total phosphorus and Mn, while it does not have any significant association with grain yield. So, there is possibility to select simultaneously for higher micronutrient content without hampering high grain yield.

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

1. Introduction
Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is a drought tolerant C4 cereal grown as staple crop in many areas of African and Indian sub-continent. It can complete its life cycle with less amount of water requirement. Hence, it can provide us with food security in the changing scenario of climatic conditions. In addition, it is rich source of vitamins and minerals like iron, zinc and magnesium. Therefore it can also address nutritional sensitive agriculture, which aims at nutritional enhancement to combat the present situation of micronutrient malnutrition (Tara Satyavathi *et al.* 2014 [1] and Shukla *et al.* 2015 [2]).
The foremost pre-requisite in crop breeding is, exploitation of genetic variability existing in the crop for yield and related traits. This leads to the development of a better variety which can address the growing demand for increasing population. Characters like grain yield and micronutrients are governed by their genotypes and are also influenced by surrounding environment or season in which they grow. In particular, grain yield and micronutrients are drastically affected by the environmental conditions at the time of grain filling. Hence, direct selection of these traits may not be advisable. Association of these traits with simply inherited traits hasten up the selection process (Basavaraj *et al.*, 2017) [3]. Moreover, simultaneous improvement of grain yield with micronutrients is possible only when we know the relation existing between these traits. Hence, association of grain yield and related traits with micronutrients gives an insight in to the development of better lines with high grain yield and high micronutrient content.
The present investigation was aimed to explore genetic variability and association of grain yield, yield related traits and micronutrients in pearl millet.

Material and Methods
In the present study, 130 pearl millet genotypes including one open pollinated check variety, *viz.*, ICTP 8203Fe were evaluated at ICAR-Indian Agricultural Research Institute Research farm, New Delhi during *kharif*, 2014. Each genotype was sown in two rows of 4m length with

a spacing of 70 × 15 cm. The design was randomized block design with three replications. All the recommended package of practices were followed to raise a healthy crop. Observations were recorded on agronomic traits (plant height in cm, panicle length in cm, panicle diameter in cm, number of productive tillers per plant, panicle yield per plant in g, grain yield per plant in g, thousand seed weight in g, days to 50% flowering) and micro nutrients (grain Fe content in mg/kg, grain Zn content in mg/kg, total phosphorus content in mg/100g, grain Cu content in mg/kg, grain Mn content in mg/kg)

Analysis of variance and summary statistics were calculated as per Panse and Sukathme (1967) [4]. Phenotypic and genotypic coefficients of variation (PCV and GCV) were computed as per Burton and Devane (1953) [5]. Heritability in broad sense was computed as per Allard (1960) [6]. Genotypic and phenotypic correlations were calculated according to Falconer (1981) [7]. Heritability and genetic advancement were categorized into low, medium and high as per Johnson *et al.*, (1955) [8].

Results and Discussion

Genetic variability studies outline the basis for crop improvement. It helps us to know the main root cause of variation and also the sensibility in expression of various traits to the environment can be understood. Breeding programme is based on whether a traits expression can be easily transferred to the next generation or not.

The outcome from ANOVA (Table 1) revealed presence of enormous variability ($p < 0.01$) in 130 pearl millet genotypes under study for all agronomic and micronutrient traits included. Considerable variation was reported earlier for agronomic (Govindaraj *et al.*, 2009 and Govindaraj *et al.*, 2010) [9, 10] and micronutrient traits (Velu *et al.*, 2008) [11]. The range of variation (Table 2) was high in all 13 traits studied. Grain yield ranged from 12.11 to 56.39 g, while Fe content ranged from 27.29 to 125.01 mg/kg, whereas Zn content ranged from 27.9 to 86.2 mg/kg. Early flowering was noticed in PPMDMGMP 8 (38 days) and G73-107 (65 days) was very late in flowering. Highest grain yield (data not provided) was recorded in PPMI 1161 (58.69 g) with an average yield of 32.86 g. PPMFeZMP 199 (125.01 mg/kg) had high Fe, followed by PPMI 1102 (115.53 mg/kg), while, high Zn was found in PPMI 265 (86.20 mg/kg) followed by PPMI 1285 (83.7 mg/kg) and PPMI 708 (83.3 mg/kg).

PCV of all the traits was higher than GCV (Table 4) indicating the role of environmental variation. GCV was high and ranged from 12.21% for days to 50% flowering to panicle yield (35.30%) and grain yield (35.13%). Higher PCV and GCV for all the traits studied indicates presence of larger variability for these traits among pearl millet genotypes which offer a possibility of selection towards crop improvement. Similar findings were reported by Govindaraj *et al.*, 2010 [10], Subi and Idris (2013) [11] and Yaqoob (2015) [12].

Heritability of characters gives an insight of how best a selection can be effective in terms of inheritance. But, heritability in combination with genetic advance as per cent mean (GAM) gives more reliable estimate of selection. In the present study both heritability and GAM were high for all the characters studied including micronutrients. High heritability with high GAM indicates predominance of additive genes which responds well to simple selection. Hence, direct selection for these traits is rewarding. Similar results of high heritability and high GAM for grain yield related traits and micronutrients were reported earlier by Govindaraj *et al.*, 2010 [10] Yaqoob (2015) [13] and Govindaraj *et al.*, 2011 [14]. However moderate heritability for grain yield and related traits was observed by Bhasker *et al.*, (2017) [15].

Association of various characters gives an insight on simultaneous selection of characters. In this study, both phenotypic and genotypic correlations (Table 4 & 5) were significantly high and were in positive direction for grain yield with panicle length, panicle diameter, number of productive tillers per plant, panicle yield and plant height. Similar findings of correlation of grain yield with agronomic traits was reported by Vagadiya *et al.*, (2010) [15] and Manoj *et al.*, (2016) [16]. This means selection for these traits will lead to simultaneous improvement in grain yield. Genotypic correlation of grain yield was significant and negative with Zn content, but no such relation existed for phenotypic correlation. Thousand seed weight, Cu and Mn content showed positive significant phenotypic correlation with grain yield, but there was no association with Fe content. Grain Fe is highly associated (genotypic correlation) with Zn, total phosphorus and Mn, while it does not have any significant association with grain yield. Positive significant association of Fe and Zn was also reported by Velu *et al.*, 2008 [11] and Govindaraj *et al.*, 2009 [9]. Since, there is no association of grain yield with Fe, selection for high Fe in the grain may not hinder selection for high grain yield.

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	73.2	3.838	0.029	0.107	246.5	10.858	0.005	0.441	111.2**	12.726	102.973	6.947**	3.352
Treatments	129	1255.345**	42.057**	0.542**	1.693**	1557.243**	439.318**	7.937**	161.006**	418.631**	936.358**	6542.164**	11.967**	39.17**
Error	258	124.394	3.245	0.07	0.179	117.627	39.584	0.161	5.436	21.611	44.475	776.829	0.742	1.426

** 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	116.49	23.23	2.41	2.54	62.06	32.86	9.14	58.97	46.61	57.65	327.30	8.24	17.48
C.V.	9.57	7.75	10.98	16.66	17.48	19.15	4.39	3.95	9.97	11.57	8.52	10.45	6.83
C.D. 5%	17.93	2.90	0.43	0.68	17.44	10.11	0.65	3.75	7.47	10.72	44.81	1.38	1.92
Minimum	62.48	12.87	1.52	1.13	21.41	12.11	6.02	38.35	27.9	27.29	177.01	3.90	8.24
Maximum	160.73	31.38	3.34	4.77	122.06	56.39	13.37	65.07	86.2	125.01	437.66	13.51	30.26

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 3: Genetic parameters of 130 pearl millet genotypes.

Trait	PH	PL	PD	NPT	PY	GY	TSW	DFF	Zn	Fe	TP	Cu	Mn
GCV	16.67	15.48	16.46	27.97	35.30	35.13	17.61	12.21	24.68	29.91	13.39	23.47	20.30
ECV	9.57	7.75	10.98	16.66	17.48	19.15	4.39	3.95	9.97	11.57	8.52	10.45	6.83
PCV	19.22	17.32	19.79	32.56	39.39	40.01	18.15	12.84	26.62	32.07	15.87	25.69	21.41
H^2 (Broad Sense)	0.75	0.80	0.69	0.74	0.80	0.77	0.94	0.91	0.86	0.87	0.71	0.83	0.90
Genetic Advance	34.68	6.63	0.68	1.26	40.44	20.88	3.22	14.11	21.97	33.13	76.21	3.64	6.92
GAM	29.77	28.52	28.21	49.51	65.17	63.54	35.20	23.93	47.14	57.46	23.28	44.17	39.62

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	0.353**											
PD	0.154**	0.207**										
NPT	0.070^{NS}	0.151**	0.025^{NS}									
PY	0.189**	0.207**	0.128*	0.394**								
GY	0.237**	0.292**	0.231**	0.565**	0.750**							
TSW	0.114*	0.053^{NS}	0.394**	-0.124*	0.099^{NS}	0.104*						
DFF	0.198**	0.129*	0.129*	-0.086^{NS}	-0.086^{NS}	-0.003^{NS}	-0.182**					
Zn	0.013^{NS}	-0.061^{NS}	0.210**	-0.099^{NS}	0.011^{NS}	-0.029^{NS}	0.209**	0.114*				
Fe	0.054^{NS}	0.001^{NS}	0.254**	-0.141**	0.051^{NS}	0.033^{NS}	0.219**	0.126*	0.679**			
TP	0.148**	-0.009^{NS}	-0.024^{NS}	-0.088^{NS}	-0.034^{NS}	-0.060^{NS}	-0.008^{NS}	0.202**	0.289**	0.270**		
Cu	0.083^{NS}	0.120*	0.028^{NS}	0.083^{NS}	-0.015^{NS}	0.160**	-0.067^{NS}	0.073^{NS}	0.034^{NS}	-0.061^{NS}	-0.097^{NS}	
Mn	-0.018^{NS}	0.039^{NS}	0.167**	0.033^{NS}	0.077^{NS}	0.164**	0.097^{NS}	0.167**	0.244**	0.204**	0.062^{NS}	0.200**

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 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	0.496**											
PD	0.214**	0.258**										
NPT	0.166**	0.159**	0.007NS									
PY	0.267**	0.304**	0.139**	0.546**								
GY	0.306**	0.356**	0.136**	0.700**	0.821**							
TSW	0.114*	0.088NS	0.442**	-0.118*	0.101*	0.093NS						
DFF	0.244**	0.167**	0.109*	-0.091NS	-0.130*	-0.036NS	-0.243**					
Zn	0.023NS	-0.060NS	0.174**	-0.104*	-0.086NS	-0.152**	0.207**	0.099NS				
Fe	0.078NS	0.033NS	0.218**	-0.155**	-0.035NS	-0.081NS	0.213**	0.106*	0.683**			
TP	0.184**	-0.004NS	-0.031NS	-0.114*	-0.048NS	-0.084NS	0.000NS	0.192**	0.365**	0.349**		
Cu	0.093NS	0.156**	-0.154**	0.056NS	-0.092NS	0.000NS	-0.118*	0.041NS	-0.049NS	-0.170**	-0.114*	
Mn	-0.022NS	0.056NS	0.077NS	0.002NS	0.030NS	0.047NS	0.079NS	0.154**	0.214**	0.158**	0.074NS	0.093NS

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.

Conclusion

Significant variation for all 13 traits studied was observed in the present study among 130 pearl millet genotypes. GCV and PCV were high for all traits studied indicating presence of high variability in the present population. Among all 13 traits studied, highest variability was exhibited by panicle yield and grain yield. Grain yield was highly associated with number of productive tillers per plant, panicle weight, panicle length, panicle diameter and plant height which are predominantly controlled by additive gene action. Hence, selection of grain yield via these traits is effective. Grain Fe was correlated with grain Zn, total phosphorus and Mn. So, there is a possibility for selection for high grain yield and high micronutrient contents.

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