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Short Communication

Genetic diversity in barnyard millet (*Echinochloa frumentacea* Roxb.)

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Barnyard millet (*Echinochloa frumentacea* Roxb.) is an important staple crop of the Uttaranchal state and forms an integral part of the hill farming system. The crop is grown mostly on marginal lands without application of fertilizers and plant protection measures. Genotypic differences in yield [1] and climatic adaptation [2] cause wide variation in its performance at higher elevations in hills. In the present study genetic divergence [3,4] among existing genotypes of barnyard millet were investigated through D^2 statistics and canonical analysis. The materials of the present study comprised 18 improved strains of barnyard millet including three local checks collected from Garhwal and Kumaon Regions of the Uttaranchal State. The genotypes were grown during rainy season (*kharif* 2000 and 2001) in randomised block design with three replications. The plot size of 3.0 × 2.5m comprised 10 rows and the sowing was done in rows 22.5 cm apart at 10.0 cm plant to plant spacing. Observations were recorded on 14 morpho-physiological characters besides yield and yield components. The growing degree days (GDDs) have been used as an index of physiological maturity [5] and were calculated by subtracting the base temperature from the daily mean temperature [6]. The photothermal units were calculated as multiple of average length of day and the summation of degree days [7].

Data on yield components *viz.*, 1000 grain weight, number of grains per ear, number of productive tillers per plant, ear length and plant height were recorded on five randomly selected plants. Analysis of variance was performed on plot mean data. The genotypes were grouped into different clusters based on D^2 values. The D^2 matrix was subjected to the unweighted pair group method for arithmetic averages analysis (UPGMA) to generate a dendrogram using average linkage procedure. The correlations among different traits were determined and the path coefficient analysis was performed as per Dewey and Lu [8].

The average performance of barnyard millet cultivars in respect of different morpho-physiological characters, yield and yield components, is presented in Table 1. Highly significant differences (P = 0.01) for all traits were recorded, indicating substantial divergence in the collection. The average number of days taken to attain 50% flowering and 75% maturity was 48 and 81 days respectively, however, the range of maturity from 98-119 days has been reported [9]. The mean grain yield of trial was 15.06 q ha^{-1} with the range of 8.43 to 21.78 q ha^{-1}, while the biological yield ranged between 6.1-9.0 tonnes ha^{-1} with the average of 7.6 tonnes ha^{-1}.

Eighteen genotypes could be grouped in eight clusters based on D^2 values and their intra and inter cluster distances are presented in Table 2. Inter cluster D^2 is a measure of genetic distance between the two clusters and was observed to be the highest for VI and VIII (20.55) and the lowest between I and II (4.68). The composition of each cluster with respect to type and the distribution of genotypes through ordination procedures (canonical and UPGMA) are presented in Figures 1 and 2. Three genotypes were clustered in cluster 1 while as many as ten genotypes were clustered in group II. The clusters III to VIII were represented by a single genotype. The genotype K1 (developed at Coimbatore) and RAU11 (developed at Pusa) were found together in conjunction with VL entries in group II. The tendency of genotypes occurring in clusters cutting across distant places suggests that the geographical isolation was not the only factor causing genetic diversity. This is in conformity with the observations made by earlier workers [10, 11]. The three local entries, derived from Garhwal and Kumaon Himalayas were divided in individual clusters. Likewise international collections *viz.*, PRB 9602 and PRB 9402 fell into individual isolated clusters.

The barnyard millet breeding for higher grain yield and fodder yield along with earliness is important. KE 90 represented by cluster III embodies the genes for earliness as identified by different physiological indices,

Table 1. Variations of different morpho-physiological, yield and yield component traits in barnyard millet

Sl. No.	Character	Range	Mean	S.E.(m)
1.	Days to 50% flowering (DF)	40-54	48.00	0.7
2.	Days to 75% maturity (DM)	77-90	81.00	0.7
3.	Heat units for 50% flowering (HUF)	1150.4-1524.8	1380.10	17.7
4.	Heat units for 75% maturity (HUM)	2170.1-2542.9	2304.90	15.0
5.	Photothermal units for 50% flowering (PTUF)	5315.3-6983.1	6238.50	96.0
6.	Photothermal units for 75% maturity (PTUM)	9723.3-13770.4	10873.80	144.5
7.	No. of grains in a ear (NG)	1515-3832	2340.00	283.0
8.	1000 grain weight (TW)	1.89-4.28	3.27	0.3
9.	Grain yield (q ha^{-1})(GY)	8.43-21.78	15.06	2.1
10.	Biological yield (t ha^{-1}) (GY)	6.1-9.0	7.60	0.7
11.	Harvest index (HI)	12.9-31.2	21.80	2.6
12.	Plant height (cm) (PH)	106.9-180.7	159.80	9.5
13.	Ear length (cm) (EL)	15.4-24.8	21.10	1.2
14.	Weight of panicle (g) (WP)	6.7-14.7	9.30	1.0

Table 2. Average inter and intra cluster D^2 values in barnyard millet

	I	II	III	IV	V	VI	VII	VIII
I	**4.13**	4.68	5.71	7.56	11.29	9.45	9.36	14.57
II		**4.29**	6.12	8.32	8.82	9.14	7.38	15.16
III			**0**	7.74	11.97	9.97	8.60	14.80
IV				**0**	13.43	10.93	9.49	16.38
V					**0**	12.00	14.37	19.33
VI						**0**	16.26	20.55
VII							**0**	15.74
VIII								**0**

Table 3. Path-coefficient analysis among different traits in barnyard millet

Character	DF	DM	HUF	HUM	PTUF	PTUM	NG	TW	PH	EL	WP
Days to 50% flowering (DF)	**0.136**	−0.198	−1.545	2.462	1.787	−2.525	−0.161	0.044	−0.017	0.100	0.086
Days to 75% maturity (DM)	0.095	**−0.285**	−1.122	2.881	1.215	−2.925	−0.157	0.108	−0.102	0.294	0.026
Heat units for 50% flowering (HUF)	0.135	−0.206	**−1.555**	2.469	1.921	−2.318	−0.145	0.055	−0.054	−0.072	0.084
Heat units for 75% maturity (HUM)	0.106	−0.261	−1.222	**3.142**	1.353	−3.069	−0.157	0.103	−0.127	0.222	0.035
Photothermal units for 50% flowering (PTUF)	0.128	−0.182	−1.572	2.238	**1.899**	−2.054	−0.179	0.079	−0.058	−0.063	−0.080
Photothermal units for 75% maturity (PTUM)	0.110	−0.268	−1.158	3.097	1.253	**−3.114**	−0.137	0.111	−0.152	0.292	0.018
No. of grains in a ear (NG)	0.077	−0.157	-0.788	1.726	1.194	−1.499	**−0.286**	0.140	−0.074	0.070	0.098
1000 grain weight (TW)	−0.027	0.138	0.386	−1.444	−0.671	1.549	0.179	**−0.223**	0.008	0.221	0.018
Plant height (PH)	−0.009	0.106	0.303	−1.457	−0.399	1.727	0.077	−0.006	**0.274**	−0.294	0.043
Ear length (EL)	−0.021	0.132	-0.177	−1.099	0.187	1.431	0.031	−0.078	0.127	**−0.634**	0.029
Weight of panicle (WP)	0.092	−0.059	-0.103	0.875	1.193	−0.440	−0.220	0.032	−0.092	−0.144	**0.127**

however, it is poor in yield. On the contrary genotype PRB 9402 in cluster IV embodies high yield potential and harvest index. An interspecific hybridization programme involving *Echinochloa frumentacea* KE90 and *Echinochloa crusgalli* PRB 9402 can be undertaken to select high yielding and early maturity segregants.

Path coefficient analysis (Table 3) revealed that heat units at maturity (HUM), photothermal units at 50% flowering (PTUF), plant height and weight of the panicle had high direct effect on grain yield and can be considered as the important selection criterion while selecting plants in the segregating generations.

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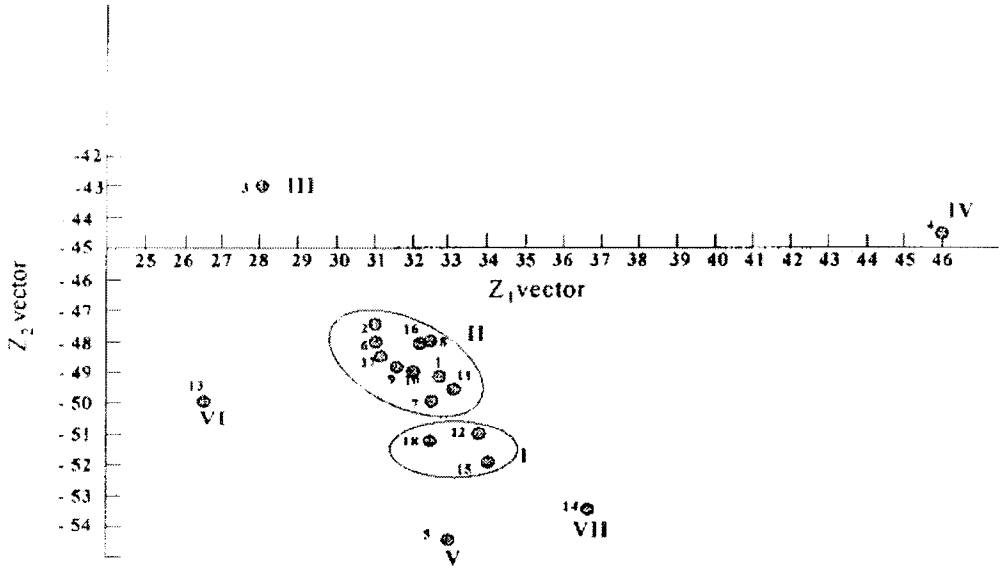

Fig. 1. Grouping of genotypes based on canonical roots
1. VL 188, 2. VL 189, 3. KE 90, 4. PRB 9402, 5. PRB 9602, 6. RAU 11, 7. K1, 8. VL 29, 9. VL 158, 10. VL 180, 11. VL 182, 12. Sainji L, 13. Atrola L, 14. Raipur L, 15. VL 183, 16. VL 184, 17. VL 186, 18. VL 187

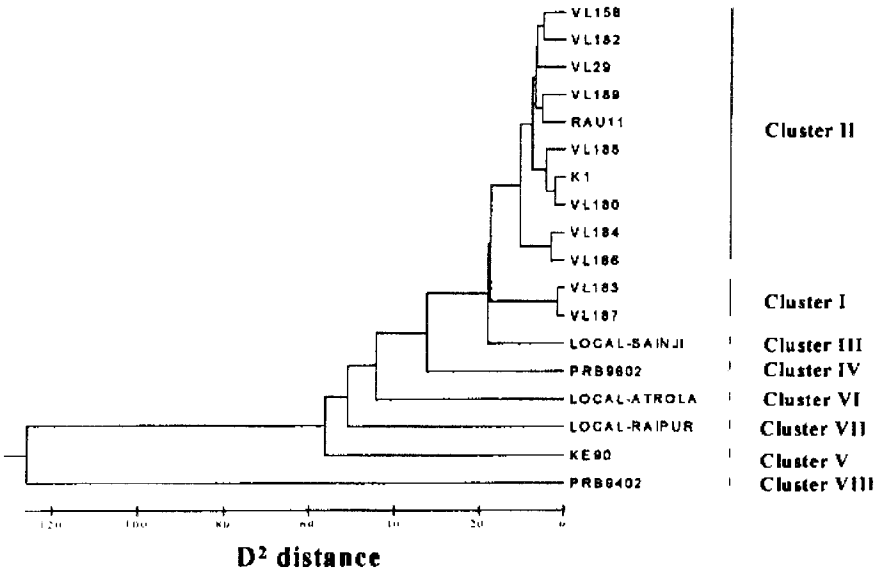

Fig. 2. Clustering using UPGMA

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Association studies in barnyard millet (Echinochloa frumentacea (Roxb.) Link) for early maturity and yield contributing traits at high altitude region. Electronic Journal of Plant Breeding. READ. R. Prabu, C. Vanniarajan, M. Vetrivanthan, R. P. Gnanamalar, R.Shanmughasundaram & J. Ramalingam. Diversity and stability studies in barnyard millet (Echinochloa frumentacea (Roxb). Link.) germplasm for grain yield and its contributing traits.Â Diversity study using principal component analysis in barnyard millet (Echinochloa frumentacea(Roxb.) Link). Electronic Journal of Plant Breeding. READ. Victor Allan, S. Geetha, Mani Vetriventhan, & Vania C R Azevedo. Genetic diversity analysis of geographically diverse landraces and wild accessions in Sorghum. Echinochloa frumentacea (Indian barnyard millet, sawa millet, or billion dollar grass) is a species of Echinochloa. Both Echinochloa frumentacea and E. esculenta are called Japanese millet. This millet is widely grown as a cereal in India, Pakistan, and Nepal. Its wild ancestor is the tropical grass Echinochloa colona, but the exact date or region of domestication is uncertain. It is cultivated on marginal lands where rice and other crops will not grow well. The grains are cooked in water, like rice... 18. FlajÅ¡man, M.; Å tajner, N.; Kocjan AcË‡ko, D. Genetic diversity and agronomic performance of Slovenian landraces of proso millet (Panicum miliaceum L.). Turk J. Bot. 2019, 11, 185â€“195. [CrossRef].Â 44. Dhanalakshmi, R.; Subramanian, A.; Thirumurugan, T.; Elangovan, M.; Kalaimagal, T. Genetic variability and association studies in barnyard millet (Echinochloa frumentacea (Roxb.) Link) germplasm under sodic soil condition. Electron.Â Arunachalam, P.; Vanniarajan, A.; Nirmalakumari, A. Consistency of barnyard millet (Echinochloa frumentacea) genotypes for plant height, duration and grain yield over environments. Madras Agric. J. 2012, 99, 11â€“13. PDF | Barnyard millet (Echinochloa frumentacea) is an unexplored nutri-rich crop that thrives well in harsh environments and supports many small farmers | Find, read and cite all the research you need on ResearchGate.Â Gene effects and heterosis for grain Fe and Zn content in barnyard millet (Echinochloa frumentacea (Roxb.) link). August 2020. Genetika 52(2):621-639. Barnyard millet has two cultivated species. Echinochloa frumentacea (Indian barnyard millet) and E. utilis (Japanese barnyard millet) which are grown widely as minor cereal in India, China, Japan, Africa and Nepal. In India, the cultivation of barnyard millet is mainly confined to Tamil Nadu, Andhra Pradesh, Karnataka and Uttarakhand. The yield level of barnyard millet is as high as 10 t haâˆ’ 1 in Japan, whereas in India it is 1.5â€“2 t haâˆ’ 1. Hence, there is great scope for exploiting its potential in Indian conditions (Channappagoudar et al., 2008). Yield potential of the popular released barnyard millet variety (PRI-1) is more than 2500 kg haâˆ’ 1, but the present maximum state average yields are very low, around 1138 kg/ha.