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IN VITRO AND *IN VIVO* SCREENING OF BARNYARD MILLET (*ECHINOCHLOA FRUMENTACEA* (ROXB.) LINK) GERMPLASM FOR SALINITY TOLERANCE

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Abstract

Soil salinity is one of the major abiotic stresses which play a detrimental role in crop production and productivity in semi arid and tropics. One of the important crops of this agro climatic zone is barnyard millet. This study was undertaken to screen barnyard millet germplasm for salinity tolerance under laboratory and field condition. A total of 31 barnyard millet accessions were screened along with two checks [MDU 1 and CO (KV)2] by top op paper method in four doses of Sodium chloride for tolerance to salinity stress at germination stage. Result of the experiment revealed that the variety MDU-1 and the germplasm accession BAR 119 were superior to other genotypes for all the seedling parameters. The traits germination percentage, promptness index and total seedling length had highly significant positive correlation with seed vigour index. Hence, these traits could be reliable indicators for selection under varying saline concentrations in seedling stage. The same set of genotypes were raised in saline sodic soil for evaluation of salt tolerance in field condition. Based on *per se* performance for yield component traits, the genotypes CO(KV)2, MDU-1, BAR 388, BAR 119 and BAR 193 were found to be superior. Thus, based on both lab and field studies, MDU 1 and BAR 119 were observed to posses better tolerance to salinity both during germination and crop growth phase. The characters grain yield per plant, flag leaf width, flag leaf length, lower raceme length, inflorescence width, inflorescence length and plant height were observed to record high GCV and hence could be considered as good selection indices under salinity.

Key words : Barnyard millet, *Echinochloa*, Salinity, stress tolerance index, GCV.

Introduction

One of the major challenges in global agriculture is to produce more from limited resources. It is estimated that world food production has to be increased to the tune of 70 percent to feed an additional 2.3 billion people in 2050 (FAO, 2009). But the production and productivity of crops are influenced by several biotic and abiotic stresses. Among the different abiotic stresses, soil salinity has a major detrimental role on crop production worldwide (Flowers, 2004 and Munns and Tester, 2008). The problem of salinity is more severe in arid and semi – arid tropics (Munns, 2005) where millets are the crop of choice. One of the best methods to alleviate the adverse effects of soil salinity without affecting the environment is to develop saline tolerant varieties of crops like millets. Among the different millets, Barnyard millet is widely cultivated in the states of Karnataka, Madhya Pradesh, Uttarakhand, Uttar Pradesh, Tamil Nadu and North Eastern states. This crop is adapted to soils with pH as low as 4.5 and salinity of 2,000–3,000 ppm (Farrell, 2011; Mitchell, 1989; Wanous,1990). Hence a study was formulated to screen barnyard millet germplasm for salinity tolerance.

Salinity stress is a complex trait causing cellular osmotic and ionic stresses which results in secondary stresses affecting whole plant co ordination (Chen et al, 2005). These responses are governed by several genes which are expressed during different stages crop ontogeny (Chen *et al.*,2005). Though selection based on yield components are important, it could be coupled with some

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more selection criteria for valid conclusion (Shannon & Noble 1990; Flowers & Yeo 1995). Considering the importance of early vigour in seedling germinating in problem soils and expression of yield component traits during maturity stage, a study was undertaken to investigate the response of barnyard millet germplasm subjected to different doses of salinity in laboratory condition and for native salinity under field condition.

Materials and Methods

A total of thirty-one barnyard millet germplasm lines obtained from Indian Institute of Millet Research, Hyderabad table 1 were used in the study along with two commercial checks (CO (KV) 2 and MDU 1). Germination stage salinity tolerance screening was done by top of paper method and the experiment was laid out in completely randomized design. Well filled seeds of the germplasm accessions were selected, surface sterilized for 5 min in 1% (v/v) sodium hypochlorite and rinsed twice in distilled water. Ten seeds of each genotypes were placed in the petri dishes with four NaCl concentrations *viz.*,0mM, 75 mM,100 mM and 150 mM. After seven days of germination observation on seedling growth parameters *viz.*, germination percentage, shoot length, leaf length, root length, total seedling length, fresh weight of the seedlings, dry weight of the seedlings were recorded. Based on the above parameters, stress tolerance indices like promptness index, shoot length stress tolerance index, root length stress tolerance index and seed vigour index I were calculated as per procedure suggested by ISTA, 2014. The pooled data was subjected to statistical analysis like ANOVA and genotypic correlation using TNAUSTAT software.

To study the performance in field conditions, the 31 accessions of barnyard millet were raised along with two commercial checks [CO (KV) 2 and MDU 1], in randomized block design with two replications, during *kharif*, 2019 at ADAC&RI experimental farm. The field was characterized by clay loam sodic soil with pH (9.07), EC (0.95dS/m) and ESP (43.69%). Each entry was raised in two rows plot per replication with spacing of 25 x 10 cm. All the recommended agronomic practices were followed for proper crop establishment and growth. Observations pertaining to 11 morphometric traits *viz.*, Days to fifty percent flowering, Plant height, inflorescence length, inflorescence width, lower raceme length, flag leaf length, flag leaf width, number of leaves on main tiller, number of productive tillers per plant, thousand grain weight and grain yield per plant, were recorded in three plants per accession per replication, as per the Descriptors of Barnyard millet (IPGRI, 1983) and the replication mean was subjected to statistical analyses using TNAUSTAT software.

Result and Discussion

(i) Laboratory screening

The combined analysis of variance table 2 revealed significant genetic variability among the genotypes for all the nine physiological traits studied (Datta *et al.,* 2009, Nirmal Raj *et al*, 2019). Hence, it was possible to select superior genotypes at seedling stage for salinity tolerance. The pooled mean data for the three treatments for the ten best performing genotypes are presented in table 3.

Table 1: List of barnyard millet genotypes utilized for salinity screening.

Sl. No.	Name	Accession number	Source
1	BAR-111	IC473117	IIMR, Hyderabad
2	BAR-119	IC404344	IIMR, Hyderabad
3	BAR-120	IC404347	IIMR, Hyderabad
4	BAR-131	IC404370	IIMR, Hyderabad
5	BAR-154	IC404398	IIMR, Hyderabad
6	BAR-178	IC472680	IIMR, Hyderabad
7	BAR-191	IC473006	IIMR, Hyderabad
8	BAR-193	IC473027	IIMR, Hyderabad
9	BAR-208	IC473112	IIMR, Hyderabad
10	BAR-219	IC601269	IIMR, Hyderabad
11	BAR-220	IC601270	IIMR, Hyderabad
12	BAR-248	IC52691	IIMR, Hyderabad
13	BAR-264	IC472448	IIMR, Hyderabad
14	BAR-277	IC472851	IIMR, Hyderabad
15	BAR-308	IC472688	IIMR, Hyderabad
16	BAR-327	IC472962	IIMR, Hyderabad
17	BAR-388	IC472958	IIMR, Hyderabad
18	BAR-348	IC472805	IIMR, Hyderabad
19	BAR-365	IC472970	IIMR, Hyderabad
20	BAR-367	IC472989	IIMR, Hyderabad
21	BAR-371	IC473034	IIMR, Hyderabad
22	BAR-376	IC472716	IIMR, Hyderabad
23	BAR-383	IC472870	IIMR, Hyderabad
24	BAR-338	IC473103	IIMR, Hyderabad
25	BAR-198	IC473059	IIMR, Hyderabad
26	BAR-207	IC473109	IIMR, Hyderabad
27	BAR-241	IC41790	IIMR, Hyderabad
28	BAR-263	NC59228	IIMR, Hyderabad
29	BAR-270	IC472736	IIMR, Hyderabad
30	BAR-288	IC473039	IIMR, Hyderabad
31	BAR-1365	CB-VL-29	DPGR, TNAU, Coimbatore
32	CO-2		TNAU, Coimbatore
33	MDU-1		TNAU, Coimbatore

Table 2: Combined analysis of variance for twelve physiological traits of barnyard millet under laboratory condition.

Character	Genotype SS	Error SS
Degrees of freedom	33	33
Germination percentage	112.91**	16.38
Promptness index	1.21**	0.15
Shoot length	0.29**	0.07
Shoot length stress tolerance index	92.71**	36.36
Root length	0.80**	0.17
Root length stress tolerance index	435.72**	46.67
Leaf length	0.14**	0.05
Total seedling length	1.95**	0.38
Fresh weight	0.0002**	0.00
Dry weight	0.00**	0.00

Seed vigour index I 37304.08** 6669.01*Significant at 5% level; **Significant at 1% level.

It revealed that the commercial check MDU-1 outshined other genotypes for six physiological parameters *viz.*, germination percentage (100 %), promptness index (9.9), root length (6.6 cm), fresh weight (0.1 g), dry weight (0.01 g) and seed vigour index (1262.3) followed by BAR-119 which had significant mean performances for germination percentage (95 %), leaf length (3.7 cm) and seed vigour index (1187.2). Differential response of genotypes for salinity could be due to better osmotic adjustment (Oproi and Madosa, 2014), better portioning of ions into vacuoles (Genc, 2007) and / or potential to withstand specific toxicity of ions which may reduce germination percentage (Saboora and Kiarostami, 2006). Hence, these accessions could be selected in seedling stage for further salinity tolerance evaluation at maturity stage

Table 3: Mean performance for top ten barnyard millet genotypes for germination parameters.

Genotypes	Germination percentage (%)	Promptness index	Shoot length (cm)	Root length (cm)	Leaf length (cm)	Total seedling length (cm)	Fresh weight (g)	Dry weight (g)	Seed vigour index1
MDU-1 (c)	100**	9.9**	2.9	6.6*	3.2	12.6	0.1**	0.01*	1262.3**
BAR-119	95*	8.9	2.5	6.3	3.7*	12.9	0.1	0.01	1187.2*
BAR-193	95*	9.0*	3.1	5.9	3.3	12.3	0.1	0.01	1177.5*
BAR-219	83.7	8.1	2.9	7.2	3.3	13.4**	0.1	0.01	1161.0
BAR-264	88.7	8.3	3.3	6.6*	3.1	13.0*	0.1	0.009	1159.5
BAR-371	82.5	7.6	3.5*	6.7**	3.5	13.9**	0.1	0.012*	1153.7
BAR-277	93.7	8.8	2.9	5.9	3.3	12.1	0.1**	0.01	1131.6
BAR-388	91.2	8.6	3.5**	5.6	3.1	12.2	0.1	0.01	1124.3
BAR-178	93.7	9.2**	2.8	5.9	3.2	11.8	0.1**	0.01	1119.9
CO (KV) 2 (c)	87.5	8.5	3.1	5.2	2.8	11.1	0.1	0.011	968.6
GRAND MEAN	85.6	8.1	2.8	5.7	3.1	11.6	0.1	0.01	1001.2
CV	4.7	4.8	9.3	7.3	7.4	5.3	0.7	7.43	8.2
CD(5%)	8.1	0.9	0.5	0.8	0.5	1.2	0.002	0.0015	164.1
CD(1%)	10.8	1.0	0.7	1.1	0.6	1.6	0.002	0.002	218.9

*Significant at 5% level; **Significant at 1% level.

Table 4: Genotypic correlation of the nine physiological traits with seed vigour index.

	Germination percentage	Promptness index	Shoot length	Root length	Leaf length	Total seedling length	Fresh weight	Dry weight	Seed vigour index
Germination percentage	1	0.996**	0.139	0.375*	0.192	0.329	0.211	0.465*	0.793**
Promptness index		1	0.205	0.409*	0.204	0.377*	0.285	0.285	0.828**
Shoot length			1	0.320	0.379*	0.656**	0.223	0.233	0.507**
Root length				1	0.730**	0.909**	0.471**	0.517**	0.801**
Leaf length					1	0.830**	0.477**	0.372*	0.649*
Total seedling length						1	0.488**	0.494**	0.826**
Fresh weight							1	0.627**	0.420*
Dry weight								1	0.586**
Seed vigour index1									1

*Significant at 5% level; **Significant at 1% level.

Table 5: ANOVA for eleven quantitative traits of barn yard millet in field condition.

Character	Replication SS	Genotype SS	Error SS
Degrees of freedom	1	32	32
Days to fifty per cent flowering	0.186	16.696**	1.248
Plant height	0.255	375.913**	3.801
Inflorescence length	1.8	12.262**	0.488
Inflorescence width	0.026	0.742**	0.033
Lower raceme length	0.087*	0.651**	0.018
Flag leaf length	2.004*	33.128**	0.46
Flag leaf width	0.034	0.567**	0.016
Number of leaves on main tiller	4.909**	0.98**	0.253
Number of productive tillers	2.182*	1.91**	0.463
Thousand grain weight	0.067*	0.232**	0.013
Grain yield/plant	4.175**	103.61**	0.346

*Significant at 5% level; **Significant at 1% level.

Fig. 1: Seedling growth in different concentration of NaCl.

MDU1

BAR-308

To : 0mM, T1 : 75 mM, T3 : 100 mM and T4 : 150 mM

as response towards salinity at germination stage does not justify its tolerance in later stages (Munns, 2005). Similar results have been reported in sorghum (Roy *et al.*, 2018; Sagar *et al.*, 2019), foxtail millet (Ardie *et al.*, 2015) and finger millet (Shailaja and Thirumeni, 2007) under salinity.

Genotypic correlation revealed that the traits germination percentage, promptness index and total seedling length had highly significant positive correlation with seed vigour index. Hence, these traits could be reliable indicators for selection under varying saline concentrations (Table 4). None of the traits showed negative correlation with any of the character in pooled analysis. Root length recorded highly significant positive correlation of higher magnitude with seed vigour index than that of shoot and leaf length. All eight traits had significant positive correlation with seed vigour index indicating the importance of the traits taken for study during selection.

(ii) Field screening

Analysis of variance for eleven quantitative characters revealed significant difference among the genotypes tested, suggesting inherent genetic difference among them, thus presenting sufficient scope for selection (Table 5). Mean performance of the genotypes revealed that the check variety MDU-1 had the maximum yield per plant (28.75g) under salinity and also recorded significant mean values for eight traits *viz.*, plant height, inflorescence length, inflorescence width, lower raceme length, flag leaf length, flag leaf width, number of productive tillers and thousand grain weight (Table 6). MDU-1 also showed significant mean value seed vigour index at seedling stage evaluation for salinity. Though check variety CO(KV)2 followed MDU-1 in terms of yield per plant (27.45g), the variety failed to exhibit seedling stage tolerance under salinity. From the thirty-one germplasm accessions, BAR 388 recorded highest yield per plant (26.75g) (Table 6) along with significant seed vigour index I table 3 which was followed by BAR 119 (23.25g) and BAR 193 (23.90g). The genotype BAR 308 recorded lowest values for vigour indices and recorded the least yield per plant at maturity. This indicates that unlike other cereals, barnyard millet tends to carry forward the tolerance at seedling stage till its maturity with some exceptions. Co-efficient of variation ranged from 2.99 (days to fifty percent flowering) to 12.55 (number of productive tillers per plant) indicating relatively low variability among the traits (Table 6). The overall variability of traits is low which may be attributed to the reduced cell division under higher stress (Schuppler *et al.*, 1998; Dhanalakshmi *et al.*, 2019).

Variability parameters such as, PCV, GCV, heritability and genetic advance as percentage of mean are the

Table 6: Mean performance of barnyard millet cultures for eleven quantitative traits.

S. No.	Genotypes	Days to fifty percent flowering	Plant height (cm)	Inflores-cence length (cm)	Inflores-cence width (cm)	Lower raceme length (cm)	Flag leaf length (cm)	Flag leaf width (cm)	Number of leaves on main main	Number of productive tillers per plant	Thousand grain weight (g)	Grain yield per plant (g)
1	CO (KV)2	41.50	54.25	11.75	2.55*	1.95	16.25**	1.80*	6.00	5.50	2.55**	27.45**
2	MDU 1	44.25	79.85**	15.65**	3.10**	2.95**	23.50**	2.75**	6.00	7.50**	3.20**	28.75**
3	BAR – 111	35.00*	40.15	7.90	1.70	1.20	10.25	1.30	5.50	5.00	2.05	8.85
4	BAR – 119	40.25	73.80**	12.10	1.55	1.70	20.15**	2.30**	6.00	6.00	2.65**	23.25**
5	BAR – 120	41.25	79.10**	17.05**	2.25	2.40**	19.75**	2.20**	6.00	5.50	2.05	12.55
6	BAR – 131	44.25	59.10**	10.65	2.80**	2.15	17.05**	1.60	5.50	7.00*	2.40	16.60**
7	BAR – 154	42.50	65.80**	12.45	1.90	2.75**	16.10**	1.65	7.50**	3.50	2.30	12.95
8	BAR – 178	35.75	49.20	10.30	1.50	1.75	11.45	1.35	5.50	6.50	2.15	4.80
9	BAR – 191	34.50*	47.20	8.90	1.75	1.75	12.70	1.25	5.00	5.50	2.30	9.20
10	BAR – 193	37.00	71.55**	12.05	2.95**	2.05	19.40**	2.20**	4.50	6.00	2.25	23.90**
11	BAR – 198	34.00**	39.15	11.15	1.55	1.35	10.80	1.00	5.50	4.50	1.65	3.65
12	BAR – 207	36.25	47.75	8.80	1.70	1.60	12.05	1.10	5.00	6.50	1.95	4.30
13	BAR – 208	35.25	45.95	9.10	2.05	1.95	11.35	0.95	5.00	6.50	2.20	4.05
14	BAR – 219	37.50	53.50	10.25	1.35	2.45**	12.80	0.90	5.50	5.00	2.60**	9.05
15	BAR – 220	33.75**	55.25	12.90*	1.85	2.35**	12.35	1.35	5.50	5.50	2.45*	14.35
16	BAR – 241	40.25	46.55	9.05	2.15	1.60	12.85	1.30	5.00	5.50	2.20	13.40
17	BAR – 248	36.75	51.90	10.75	1.80	2.90**	11.80	1.10	5.00	6.00	2.30	7.15
18	BAR – 263	34.50*	66.85**	12.45	2.65**	2.25	15.70*	1.50	6.00	4.50	1.85	18.80**
19	BAR – 264	38.50	32.20	7.85	1.50	0.95	8.85	1.00	4.50	5.00	2.25	23.35**
20	BAR – 270	36.00	37.40	10.50	1.80	1.75	10.35	1.55	5.50	4.50	2.15	14.45
21	BAR – 277	36.25	61.75**	16.00**	3.60**	1.50	16.95**	2.50**	6.00	5.00	2.20	14.55
22	BAR – 288	36.75	62.25**	12.50*	1.60	1.35	9.25	1.25	5.00	6.50	1.95	8.55
23	BAR – 308	34.50*	31.90	7.85	2.25	0.80	8.70	0.95	5.00	3.50	1.75	3.00
24	BAR – 327	35.00*	49.15	9.40	1.70	1.50	11.75	1.25	4.50	4.50	2.20	9.25
25	BAR – 338	36.75	35.55	8.45	1.50	1.10	9.90	1.50	4.00	4.00	1.65	14.05
26	BAR – 348	35.25*	44.70	9.30	2.40	1.95	12.55	1.15	5.00	6.50	2.25	12.15
27	BAR - 365	34.00**	39.55	9.60	1.20	0.95	10.55	1.20	5.50	5.00	2.10	14.05
28	BAR - 367	36.00	52.20	10.30	1.30	2.70**	14.55	1.25	6.00	6.00	2.40	12.60
29	BAR - 371	37.50	73.20**	14.85**	2.85**	1.90	22.50**	2.50**	7.00**	5.50	2.05	11.15
30	BAR - 376	36.75	46.40	10.80	1.85	1.30	11.50	1.15	5.50	4.50	1.70	10.05
31	BAR - 383	37.75	45.30	9.35	2.20	1.85	12.75	1.15	5.00	4.50	2.05	9.65
32	BAR - 388	39.50	76.10**	15.45**	3.25**	2.45**	21.00**	2.55**	6.00	6.50	3.00**	26.75**
33	BAR - 1365	37.75	48.60	10.10	2.00	1.65	14.10	1.30	5.50	5.50	2.25	22.35**
Grand mean		37.36	53.43	11.08	2.07	1.84	13.99	1.51	5.45	5.42	2.21	13.61
CV		2.99	3.65	6.30	8.77	7.26	4.85	8.28	9.22	12.55	5.10	4.32
CD (0.05)		2.25	3.92	1.40	0.36	0.27	1.36	0.25	1.01	1.37	0.23	1.18
CD (0.01)		2.99	5.22	1.87	0.49	0.36	1.82	0.34	1.35	1.82	0.30	1.58

*Significant at 5% level; **Significant at 1% level

fundamental criterion for identifying key traits that can be effectively employed during selection and breeding programmes. Both PCV and GCV were in range with each other for all the traits except, number of leaves on main tiller and number of productive tillers (Table 7). This suggests that the two traits are more influenced by environment than the genotype, whereas the other traits are expressed by the contribution of both environment and genotype (Anuradha *et al.*, 2017). High PCV and GCV values (>20) were observed for grain yield per plant, flag leaf width, flag leaf length, lower raceme length,

Table 7: Genetic variability parameters for eleven quantitative traits.

S.No.	Characters	Coefficient of variation (%)		Heritability (h^2)	Genetic advance as percent of mean
		PCV	GCV		
1	Days to fifty percent flowering	8.02	7.44	86.09	14.22
2	Plant height (cm)	25.79	25.53	98.00	52.06
3	Inflorescence length (cm)	22.79	21.90	92.35	43.36
4	Inflorescence width (cm)	30.13	28.83	91.53	56.82
5	Lower raceme length (cm)	31.38	30.53	94.65	61.18
6	Flag leaf length (cm)	29.30	28.90	97.26	58.70
7	Flag leaf width (cm)	35.71	34.74	94.62	69.62
8	Number of leaves on main tiller	14.39	11.06	58.99	17.49
9	Number of productive tillers	20.08	15.68	60.97	25.22
10	Thousand grain weight (g)	15.80	14.96	89.58	29.16
11	Grain yield/plant (g)	52.99	52.81	99.33	108.43

Table 8: D^2 clustering pattern of the barnyard millet genotypes.

S. No.	Cluster	No. of genotypes	Name of genotypes
1	Cluster 1	10	BAR 191, BAR 327, BAR 383, BAR 348, BAR 376, BAR 111, BAR 219, BAR 288, BAR 241, BAR 367
2	Cluster 2	5	BAR 207, BAR 208, BAR 178, BAR 198, BAR 308
3	Cluster 3	4	BAR 338, BAR 365, BAR 270, BAR 220
4	Cluster 4	2	MDU 1, BAR 388
5	Cluster 5	2	BAR 119, BAR 193
6	Cluster 6	2	BAR 131, BAR 154
7	Cluster 7	1	BAR 248
8	Cluster 8	2	BAR 264, BAR 1365
9	Cluster 9	2	BAR 120, BAR 371
10	Cluster 10	1	BAR 263
11	Cluster 11	1	BAR 277
12	Cluster 12	1	CO(KV)2

inflorescence width, inflorescence length and plant height which indicated the consistent nature of these traits (Dhanalakshmi *et al.,* 2019). Thus selection based on these traits will be effective in crop improvement (Subramanian *et al.,* 2019). Similar observations were made by Dhanalakshmi *et al.* (2019) in barnyard millet under sodicity.

High heritability coupled with genetic advance as percent of mean was observed in grain yield per plant, flag leaf width, flag leaf length, lower raceme length, inflorescence width, inflorescence length and plant height (Table 8). Selection based on these traits will be more fruitful due to the preponderance of additive gene action, as heritability and genetic advance is a measure of the heritable element (Subramanian *et al.,* 2019). Similar results were obtained by Sood *et al.* (2015) in barnyard millet and Yadav *et al.* (2017) in rice under stressed condition.

Diversity analysis gives valuable information on the available genetic diversity between the genotypes which will aid plant breeder to select elite germplasm for crossing to exploit heterosis and also to create variability (Govindaraj *et al.,* 2015; Manimekalai *et al.,* 2018). Out of the eleven yield components studied, yield per plant contributed the maximum (75.00%) towards divergence which was followed by plant height (9.47%), lower raceme length (7.20%) and flag leaf length (4.55%) (Fig. 2). Based on D^2 analysis the thirty-three genotypes were grouped into twelve distinct clusters of which cluster I was the largest with 10 genotypes followed by cluster II with 5 genotypes and cluster III with 4 genotypes. Clusters VII, X, XI and XII were mono-clusters and five clusters were with two genotypes each. The genotypes MDU-1 and BAR-388 that were identified as saline tolerant at both seedling and maturity stage were grouped together under cluster IV. The genotypes BAR 119 and BAR 193, which also had desirable mean value at both stages, were also grouped together (Table 4).

Maximum intra cluster distance was recorded by cluster IX (14.39) indicating larger diversity among the genotypes within the cluster. Minimum intra cluster distance was recorded by cluster IV (8.31) indicating lesser diversity within the cluster. Cluster II and IV recorded the maximum inter cluster distance (81.65), whereas cluster VI and X recorded the minimum inter cluster distance (17.25) (Table 9). Hybridization among genotypes with high diversity could result in myriad of segregants which could be exploited in breeding programmes (Nirosha *et al.,* 2016, Manimekalai, *et al.,*2018).

Cluster mean values are given in Table 10. Cluster IV recorded higher cluster mean values for six traits *viz.,* plant height, flag leaf length, flag leaf width, number of productive tillers, thousand grain weight and yield per plant. For breeding genotypes with reduced days to maturity, the genotype from cluster X can be utilized as it recorded least days to fifty percent flowering (34.50 days).

Table 9: Intra and Inter cluster distance of the barnyard millet genotypes.

Cluster number	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	151.60 (12.31)	551.75 (23.49)	311.56 (17.65)	3820.70 (61.81)	2239.90 (47.33)	397.81 (19.95)	320.09 (17.89)	1540.10 (39.24)	786.05 (28.04)	883.60 (29.73)	810.70 (28.47)	2802.72 (52.94)
II		106.87 (10.34)	1218.26 (34.90)	6667.27 (81.65)	4489.18 (67.00)	1402.76 (37.45)	358.55 (18.94)	3445.25 (58.70)	1572.79 (39.66)	2388.62 (48.87)	1870.63 (43.25)	5358.29 (73.20)
III			151.86 (12.32)	2751.51 (52.45)	1448.12 (38.05)	333.64 (18.27)	794.23 (28.18)	733.74 (27.09)	928.77 (30.48)	492.98 (22.20)	650.04 (25.50)	1713.81 (41.40)
IV				68.98 (8.31)	335.20 (18.31)	2155.66 (46.43)	5153.66 (71.79)	1295.15 (35.99)	2584.17 (50.83)	1284.14 (35.83)	1923.92 (43.86)	380.92 (19.52)
V					101.90 (10.09)	1079.80 (32.86)	3402.56 (58.33)	630.96 (25.12)	1441.88 (37.97)	464.47 (21.55)	955.73 (30.91)	288.50 (16.99)
VI						138.91 (11.79)	830.41 (28.82)	924.30 (30.40)	407.51 (20.19)	297.64 (17.25)	377.98 (19.44)	1569.65 (39.62)
VII							(0)	2594.60 (50.94)	1213.83 (34.84)	1580.20 (39.75)	1563.18 (39.54)	4139.26 (64.34)
VIII								174.33 (13.20)	1889.37 (43.47)	542.87 (23.30)	1166.14 (34.15)	389.55 (19.74)
IX									207.21 (14.39)	652.50 (25.54)	306.59 (17.51)	2418.75 (49.18)
X										(0)	392.13 (19.80)	842.21 (29.02)
XI											(0)	1579.83 (39.75)
XII												(0)

Values in parenthesis indicate intra cluster distance.

Table 10: Cluster mean values for eleven quantitative traits of barnyard millet.

Cluster Number	Days to flowering (50%)	Plant height (cm)	Inflores-cence length (cm)	Inflores-cence width (cm)	Lower raceme length (cm)	Flag leaf length (cm)	Flag leaf width (cm)	Numbe of leaves on main tillers	Number of productive tillers per plant	Thousand grain weight (g)	Grain yield per plant (g)
I	36.48	48.74	9.78	1.80	1.77	12.10	1.20	5.20	5.35	2.17	10.28
II	35.15	42.79	9.44	1.81	1.49	10.87	1.07	5.20	5.50	1.94	3.96
III	35.13	41.94	10.36	1.59	1.54	10.79	1.40	5.13	4.75	2.09	14.23
IV	41.88	77.98	15.55	3.18	2.70	22.25	2.65	6.00	7.00	3.10	27.75
V	38.63	72.68	12.08	2.25	1.88	19.78	2.25	5.25	6.00	2.45	23.58
VI	43.38	62.45	11.55	2.35	2.45	16.58	1.63	6.50	5.25	2.35	14.78
VII	36.75	51.90	10.75	1.80	2.90	11.80	1.10	5.00	6.00	2.30	7.15
VIII	38.13	40.40	8.98	1.75	1.30	11.48	1.15	5.00	5.25	2.25	22.85
IX	39.38	76.15	15.95	2.55	2.15	21.13	2.35	6.50	5.50	2.05	11.85
X	34.50	66.85	12.45	2.65	2.25	15.70	1.50	6.00	4.50	1.85	18.80
XI	36.25	61.75	16.00	3.60	1.50	16.95	2.50	6.00	5.00	2.20	14.55
XII	41.50	54.25	11.75	2.55	1.95	16.25	1.80	6.00	5.50	2.55	27.45

Hence, outstandingly performing genotypes present in these clusters could be utilized as potential parents for crop improvement in barnyard millet under salinity.

In the present study, based on consistant performance in the lab and field experiments, MDU 1 and BAR 119 were identified to be superior in terms of tolerance both at seedling and maturity stage. None of the accessions outperformed the check variety MDU -1 whereas, the check variety CO(KV)2 failed to withstand salinity at seedling stage. For selection, traits such as grain yield

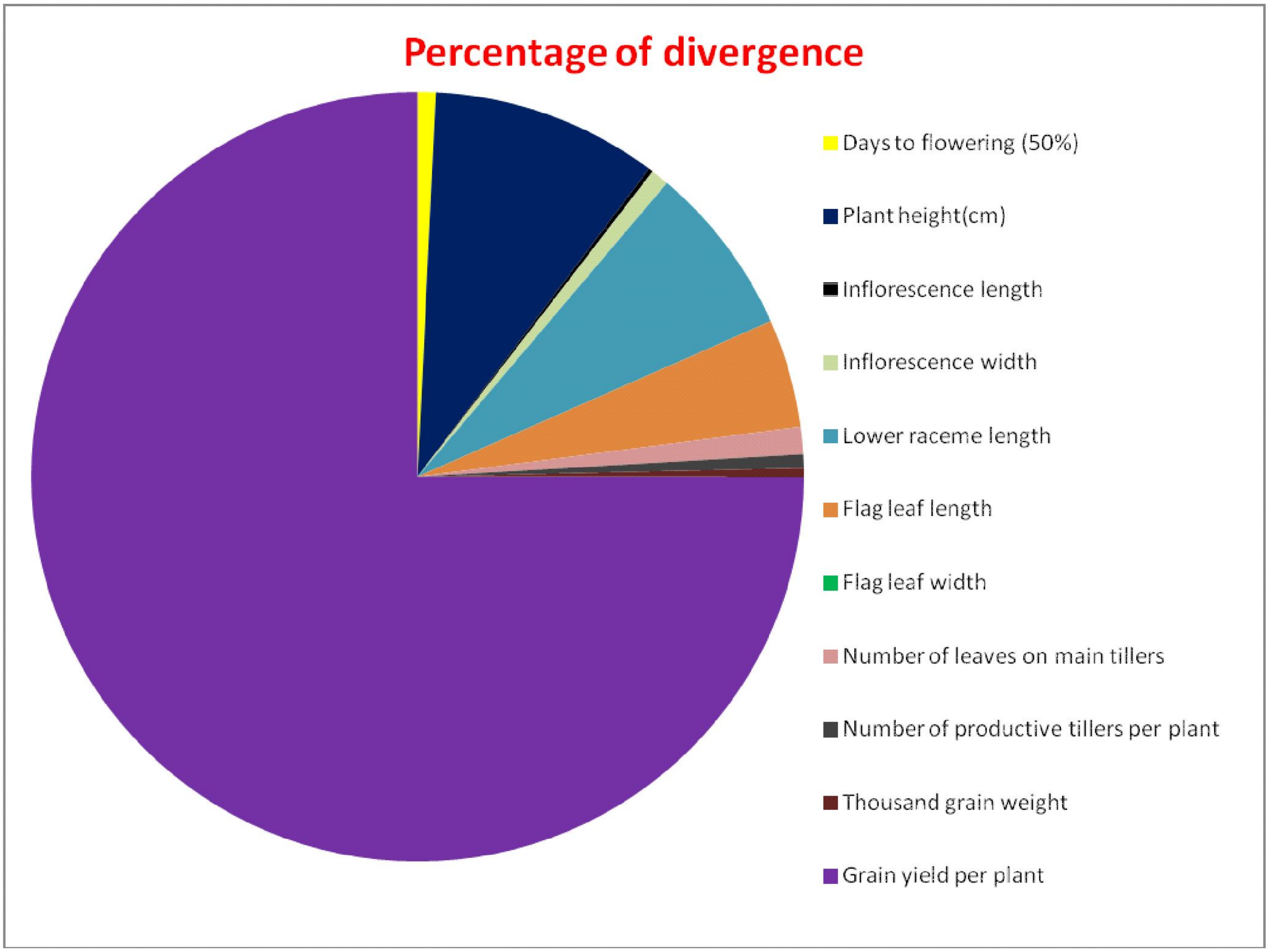

Fig. 2: Percentage of contribution of traits.

per plant, flag leaf width, flag leaf length, lower raceme length, inflorescence width, inflorescence length and plant height could be employed as selection indices under salinity stress.

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