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Research Article

Diversity and stability studies in barnyard millet (*Echinochloa frumentacea* (Roxb). Link.) germplasm for grain yield and its contributing traits

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Abstract
Nutritionally, Barnyard millet is an important crop, it is probably originated in central Asia and spread from central Asia to Europe and America. Climate change will alert an extra constrains as many parts of the country are becoming drier with increasingly severe weather patterns. Developing better barnyard millet cultivars is always placing as an important strategy in crop improvement. This study was focused to evaluate the phenotypic diversity and stability of barnyard millet germplasm for yield and its attributing traits. Diversity as revealed by D^2 analysis indicated that the trait grain yield had contributed maximum towards the diversity followed by days to maturity. The accessions M5P1, M36P1 and M37P1 exhibited the highest mean values for grain yield per plant, but no significance difference was found comparing checks. Stability analysis revealed that none of the accessions were showed stable performance, indicated that influence of environmental factors played a major role.

Keywords
Barnyard millet, diversity, stability, environments

INTRODUCTION

Barnyard millet (*Echinochloa frumentacea* (Roxb). Link.) is one among the group of crops called small millets. It can be grown with little use of water and it is alternate to water-guzzing crops. It has also been utilized for the reclamation of sodicity, arsenic and cadmium problem soils as it grows well under soil salinity condition and mitigates the cadmium stress; and increase the biosynthesis in plants Sherif and Ali (2007); Abe *et al.* (2011). It is also cultivated at hills under double cut production system with better yield Bandyopadhyay, (2009). The grains of barnyard millet contains of 6.2 g of protein, 9.8 g of crude fibre, 2.2 g of fat, 4.4 g of ash, 65.5 g of carbohydrate, 300 Kcal of energy, 0.30 mg of thiamin and 0.09 mg of riboflavin Muthamilarasan *et. al,* (2016) and the grains are consumed just like rice Ruiz-Santaella *et al* (2006). The nutrient – rich grain is making a quick come back in the Indian Agrarian landscape after decades of long neglect. In 2016, the area under the cultivation of barnyard millet in India, figured about 1, 46000 ha with its production of about 1, 51000 tons Bhat *et al.* (2018).

In Tamil Nadu, it is being practiced as rainfed agriculture and spread across districts like Ramanathapuram, Madurai, Virudhunagar, Theni, Salem, Namakkal, Villupuram, Dindigul, Coimbatore and Erode districts Nirmalakumari *et al.*(2009). The awareness of using small millets is catching up fast in the urban centres due to its fair source of protein, which is highly digestible and is an excellent source of dietary fibre with good amounts of soluble and insoluble fractions Hadimani and Malleshi (1993); Veena *et al.* (2005). Although barnyard millet like any other millet is nutritionally superior to cereals, yet its utilization is unexplored. Thus, it leads to highly demandable millet and occupies its need to increase the area under cultivation and productivity. This study aims to evaluate the barnyard millet accessions including of some early maturing germplasm for genetic diversity and stability of yield and early maturity across three different environments, to identify stable and high yielding accessions for their utilization in barnyard millet improvement.

MATERIALS AND METHODS

Forty germplasm of barnyard millet were used in this study (Table 1). These germplasm were obtained from the Genebank, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India; Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai; Department of Millets, Tamil Nadu Agricultural University (TNAU),

Table 1. Details of genotypes used for the study

Sl.No	Genotypes	Origin/Parentage	Source
1	ACM 110		
2	ACM 161		
3	ACM 295	India	
4	ACM 331		Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai
5	ACM 333		
6	ACM-15-343	A cross derivative from ACM cultures	
7	ACM-15-353	A cross derivative from ACM cultures	
8	GECH 10		All India Co-ordinated Small Millets Improvement Project, Bengaluru.
9	GECH 15		
10	IEc – 52		
11	IEc - 167		
12	IEc – 568		
13	IEc – 166		
14	IEc – 672		
15	IEc – 82		
16	IEc – 109		
17	IEc – 107	India	ICRISAT, Hyderabad
18	IEc – 108		
19	IEc – 386		
20	IEc – 385		
21	IEc – 356		
22	IEc – 350		
23	IEc – 391		
24	IEc – 71		
25	IEc – 296		
26	IEc – 396		
27	T 5	India	Department of Millets, Tamil Nadu Agricultural University, Coimbatore.
28	M1	Gamma ray - 900 Gy	
29	M2	EMS - 70mM + Gamma ray 700 Gy	
30	M3	EMS - 60 mM	
31	M5	EMS - 70mM + Gamma ray 800 Gy	Mutant lines of Co (Kv)-2
32	M12	Gamma ray - 800 Gy	Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai
33	M18	EMS - 70 mM	
34	M27	Gamma ray - 900 Gy	
35	M28	Gamma ray - 900 Gy	
36	M36	EMS - 70mM + Gamma ray 900 Gy	
37	M37	EMS - 70mM + Gamma ray 900 Gy	
38	M38	EMS - 60 mM	
39	MDU – 1	India	Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai
40	Co (KV)- 2		Department of Millets, Tamil Nadu Agricultural University, Coimbatore.

Coimbatore, India and All India Coordinated Small Millets Improvement Project, Bengaluru, India, and two local checks namely MDU 1 and CO (Kv) 2 were included. These checks were released as varieties by Agricultural College and Research Institute (AC&RI), Madurai in 2015 (MDU 1) and Tamil Nadu Agricultural University, Coimbatore in 2009 (CO (Kv) 2). The experiments were laid in randomized complete block design (RCBD) with two replications at three different environments. At Idukki, a hills region of Kerala state, considered as E1, at AC&RI, Madurai (E2), a plain region and at Theni, a valley region considered as E3. The meteorological data of the distinguished environments is furnished in the Table 2.

Table 2. Meteorological data of the three environments

Location	Latitude	Longitude	Average Rainfall	Average Temperature	Date of sowing
Idukki	10.01^{0}N	77.34^{0}E	1082 mm	21.9^{0}C	07 th January 2019
Madurai	9.95^{0}N	78.01^{0}E	857 mm	28.8^{0}C	09th January 2019
Theni	9.93^{0}N	77.47^{0}E	791 mm	27.2^{0}C	11th January 2019

All these experiments were conducted during the summer season 2019 and sowing was carried out with two days gap in each location **(Table 2)**.The data on seventeen yield and its contributing traits on five randomly selected plants in each accession and in each replication were recorded following the barnyard millet descriptors (Bioversity International. 1983). The traits such as plant height, days to first flowering, days to maturity, the number of nodes, node length, the number of basal tillers, stem diameter, flag leaf length, flag leaf width, inflorescence length, inflorescence width, length of lower racemes, length of peduncle, the number of racemes, thousand grain weight, single ear head weight and grain yield per plant were considered for data collection. All the inputs practices were followed on time with proper pest management as per the package of practices recommended by TNAU, Coimbatore.

The data over quantitative traits were analyzed for each environment individually and combined of all three environments using Residual Maximum Likelihood (REML) (Patterson, 1971 #248)Patterson and Thompson, (1971) in GenStat 19th edition (http://www.genstat.co.uk) giving consideration to accessions as random and environment as fixed. Wald statistic was utilized for environment significance. The components of variance due to genotype (σ^2_g), genotype × environment (σ^2_{ge}) and standard errors (SE) were calculated for individual and pooled data. Best Linear Unbiased Predictors (BLUPs) Schonfeld and Werner, (1986) were obtained for all the quantitative traits for each accession for individual environment and for pooled data. The BLUPs obtained from combined of three environments were used for Mahalonobis's generalized distance (D2) estimation to measure the genetic divergence among the accessions and clustering was done following Tocher's method Radhakrishna Rao (1952). Stability analysis was performed using the PBTools software PBTools, (2014).

Table 3. Estimation of variance components for individual and pooled of three environments using REML approach

Variables	**E1**	**E2**	**E3**	**Pooled**	
	σ^2g	**σ^2g**	**σ^2g**	**σ^2g**	**σ^2ge**
Days to flowering	213.69**	193.40**	213.39**	191.18**	15.65**
Days to maturity	281.90**	205.99**	292.77**	252.00**	8.21**
Grain yield per plant (g)	340.31**	245.49**	70.44**	172.26**	46.41**
Length of flag leaf (cm)	28.92**	23.57**	21.69**	15.87**	8.87**
Length of lower racemes	0.24**	0.62**	0.40**	0.16**	0.26**
Length of inflorescence	16.05**	13.20**	13.65**	10.60**	3.66**
Length of nodes	6.61**	3.91**	4.90**	1.20	3.92**
Length of peduncle	18.71**	4.66**	2.66**	1.09	7.59**
Number of tillers	15.48**	4.48**	7.08**	1.42	7.60**
Number of nodes	2.07**	1.23**	2.01**	0.84**	0.93**
Number of racemes	145.89**	143.75**	143.37**	130.31**	13.98**
Plant height	1198.72**	827.25**	211.16**	450.23**	294.88**
Stem diameter	1.42**	1.07**	0.56**	0.84**	0.18**
Single ear head weight	19.64**	8.87**	4.02**	7.89**	2.96**
Thousand grain weight	0.09**	0.40**	0.11**	0.01	0.19**
Width of flag leaf	0.29**	0.50**	0.31**	0.26**	0.11**
Width of inflorescence	0.65**	0.57**	0.52**	0.41**	0.17**

Note: σ^2g, genotypic variance component; σ^2ge Genotype x environment variance component

RESULTS AND DISCUSSION

The REML analysis indicated that the genotypic variance component (σ^2_g) was significant for all the traits in all three environments studied, and in the combined environment indicating the presence of considerable variability for all the traits except the traits like length of nodes, length of peduncle, the number of tillers and thousand grain weight which showed non-significance (Table 3). The variance component due to genotypic and environment interaction (σ^2_{ge}) was significant for all the traits under combined of three environments, indicating that significant influence of environment on the expression of traits.

Mean performance of barnyard millet accessions for various quantitative traits in different growing environments (Table 4) indicated that the trait plant height significantly differed in all three environments (75.86 cm in E3 to 148.47 cm in E1), while days to maturity was similar in all three environments (96.3.4 days E2 to 99.65 days in E3), and pooled of three environments (97.66 days) (Table 3). Grain yield was significantly differed between E1 (40.29 g) and E3 (23.34g) and E2 (35.99 g) and pooled of three environments (33.20 g) exhibited almost equal data on yield (33.20 g). Similarly, the traits like flag leaf length, inflorescence length, node length, length of peduncle and single ear head weight were varied significantly from E1 to E3 (Table 3), which indicated that the agro-climatically conditions, soil types and other meteorological parameters in the phenotypic expressions. The E2 and pooled data positioned in between values to both E1 and E3 for majority of the traits.

Based on the mean performance, there are 12 accessions such as IEc 71, IEc 82, IEc 107, IEc 108, IEc 109, IEc 296, IEc 350, IEc 356, IEc 385, IEc 386, IEc 391 and IEc 396 matured early (64 – 84 days) and dwarf stature in plant height (54-116 cm) comparing to all other accessions. However, these accessions were expressed low to moderate yield (3.16 – 27.36 g) than the checks. Therefore, these traits can be considered as useful in the breeding program for developing the early maturing genotypes through hybridization breeding methods. Considering the grain yield per plant among the 40 accessions, three accessions like M5P1 (52.6 g), M36P1 (52.93g) and M37P1 (50.86 g) recorded high grain yield than checks (MDU 1- 48.07 g and CO (Kv) 2 – 49.90 g), but no significance difference.

Table 4. Mean performance of barnyard millet accessions at different environments, and pooled of three environments

Trait	E1	E2	E3	Pooled
Days to flowering	63.74^{ab}	60.42^{b}	65.58^{a}	63.24^{ab}
Days to maturity	97.00^{a}	96.34^{a}	99.65^{a}	97.66^{a}
Grain yield per plant (g)	40.29^{a}	35.99^{ab}	23.34^{b}	33.20^{ab}
Length of flag leaf (cm)	29.03^{ab}	29.04^{ab}	17.68^{b}	25.25^{a}
Length of lower racemes	3.73^{a}	3.03^{ab}	2.15^{b}	2.97^{ab}
Length of inflorescence	20.26^{a}	17.28^{ab}	15.27^{b}	17.60^{ab}
Length of nodes	16.86^{a}	11.82^{ab}	8.71^{b}	12.46^{ab}
Length of peduncle	15.17^{a}	10.77^{ab}	6.33^{b}	10.76^{ab}
Number of tillers	16.44^{a}	12.55^{b}	13.16^{ab}	14.05^{ab}
Number of nodes	6.53^{ab}	7.51^{a}	5.91^{b}	6.65^{ab}
Number of racemes	43.17^{ab}	48.90^{a}	37.43^{b}	43.17^{ab}
Plant height	148.47^{a}	135.86^{ab}	75.86^{b}	120.07^{ab}
Stem diameter	2.77^{ab}	3.12^{a}	1.95^{b}	2.61^{ab}
Single ear head weight	9.83^{a}	9.68^{a}	4.06^{b}	7.86^{c}
Thousand grain weight	3.39^{b}	4.33^{a}	3.44^{b}	3.72^{b}
Width of flag leaf	2.76^{a}	2.77^{a}	2.07^{a}	2.54^{a}
Width of inflorescence	3.66^{a}	3.07^{a}	2.54^{b}	3.09^{a}

‡Means with the same letter within row are not significantly different at $P \leq 0.05$

D^2 statistics is a very useful statistical measure in multivariate analysis and it is an important biometric tool for plant breeders to utilize its applications in the field of classification and clustering Mahalanobis, (1936). The D^2 analysis resulted in six major clusters and the cluster I had the maximum number of fifteen accessions, followed by cluster IV that had 12 accessions. Cluster VI had 7 accessions; and Cluster II, III and Cluster IV had two accessions each. Interestingly, all the early maturing accessions were fallen into the Cluster V which indicated that these accessions are closely diverged.

The mean values of various traits of pooled environments based on D^2 values are presented in **Table 5**. Cluster V had the accessions which recorded low mean values for many traits, like dwarf plant height (89.54 cm), early flowering (4.53 days), early maturity (74.40 days), the number of nudes (5.19), stem diameter length (1.30 cm), flag leaf length (19.81 cm), flag leaf width (1.82 cm), inflorescence length (13.40 cm), width of inflorescence (2.23 cm), length of lower racemes (2.60 cm), the number of racemes (27.69), thousand grain weight (3.54 g), single ear head weight (3.86 g) and grain yield per plant (16.40 g), whereas, it had high mean values for peduncle length (12.00 cm). All Clusters except Cluster V, contained a high mean value for plant height (> 130 cm – 138.09 cm). Cluster I, II and VI had accessions that had high mean value for days to first flowering (late flowering - > 71 – 73 days) and all Clusters except Cluster V also had a high mean value for days to maturity (107-110 days). Similarly, the high mean value for the number of nodes was observed for Clusters I, II, III, IV and VI, except Cluster V. Almost all the Clusters had contained maximum mean values for length of nodes. Cluster III contained the accessions that had the low mean value for the number of tillers (11.97). The accessions with higher mean value for the traits such as, stem diameter (> 3- 3.63 cm), flag leaf length (26.46 – 30.44 cm), flag leaf width (2.72-3.36 cm), inflorescence length (17.86-21.62 cm), width of inflorescence (2.23-3.71 cm), length of lower racemes (2.92-3.49 cm), the number of racemes (48.44 - 54.32), thousand grain weight (> 3 – 3.94 g), single ear head weight (9.95 – 11.68 g) and grain yield per plant (45 – 51.51 g) for all the Clusters except Cluster V. Cluster I had accessions which had a medium mean values for single ear head weight (8.73 g) and grain yield per plant (35.10 g). The accessions contained high mean values (Clusters I, II, III, IV and VI) for grain yield per plant had taken long days to harvest (lately matured), indicating that the late maturing accessions are high yielding Arunachalam and Vanniarajan (2012).

Table 5. Mean values of various traits based on pooled of three environments

Cluster Number	PH	DF	DM	NN	LON	NBT	SD	LFL	WFL	LOI	WOI	LLR	LOP	NOR	TGW	SEW	GY_P
C I	130.21	72.56	107.63	7.08	12.29	14.37	3.03	26.46	2.72	19.07	3.31	2.92	9.94	48.44	3.82	8.73	35.10
C II	136.65	72.75	107.05	7.10	13.31	14.29	3.29	30.44	2.97	21.62	3.61	3.38	9.70	50.98	3.70	9.95	44.24
C III	132.73	69.85	109.35	7.92	12.81	11.97	3.63	28.46	3.36	18.78	3.71	3.13	9.30	54.32	3.68	11.68	49.86
C IV	132.82	67.80	108.70	7.73	11.66	13.52	3.62	28.61	2.98	17.86	3.59	3.21	10.27	51.93	3.94	11.31	51.51
C V	89.54	43.53	74.40	5.19	11.82	13.49	1.30	19.81	1.82	13.40	2.23	2.60	12.00	27.69	3.54	3.86	16.40
C VI	138.09	71.33	107.27	7.43	13.89	15.08	3.22	28.47	2.88	20.11	3.59	3.49	10.92	50.44	3.81	10.17	45.00

Note: DF – Days to Flowering, **DM** – Days to Maturity, **GY_P** – Grain Yield per Plant, **LFL** – Length of Flag Leaf, **LLR** - Length of Inflorescence; **LON** – Length of Node; **LOP** – Length of Peduncle; **NBT** – Number of Basal Tillers; **NN** – Number of Nodes; **NOR** – Number of Racemes; **PH** – Plant Height; **SD** – Stem Diameter; **SEW** – Single Ear head Weight; **TGW** – Thousand Grain Weight; **WFL** – Width of Flag Leaf; **WOI** – Width of Inflorescence

The distances of inter and intra cluster are presented in Table 6. The inter cluster distance was peak between cluster III and V (D= 120.698) and the maximum intra-cluster distance was recorded in cluster V (D=47.218). This implicit that these clusters have the accessions with greater genetic divergence Patil and Kale (2013). With reference to the traits contributions to the genetic divergence (Table 7), the most important trait grain yield per plant (51.92 %) showed its maximum contribution to genetic divergence. The days to maturity (23.72%) stood up with second place for its contribution, followed by stem diameter (6.54 %), thousand grain weight (6.03 %), and single ear head weight (4.49%). This clearly indicated that the selection of accessions from the genetically diverged groups by the plant breeders, must classify the resources on the basis of traits performance such as grain yield per plant, days to maturity, stem diameter, thousand grain weight and single ear head weight as they implied with greater contribution towards divergence.

Table 6. Inter and Intra D square cluster distances of barnyard millet accessions based on pooled of three environments

	C I	C II	C III	C IV	C V	C VI
C I	23.98	22.865	27.795	29.266	120.853	28.507
C II		13.157	21.15	25.277	124.487	22.322
C III			13.794	16.364	127.492	24.968
C IV				13.954	120.698	26.138
C V					47.218	120.932
C VI						28.233

Relative contribution of each trait towards the genetic diversity is presented in Table 7. The rank was allotted to individual traits based on its contribution to the total genetic divergence. The major contribution was expressed by grain yield per plant (51.92 %), followed by days to maturity (23.72 %). These two traits covered 75.64 % altogether to the total divergence. Stem diameter (6.54 %) and thousand grain weight (6.03 %) had contributed almost equally to the genetic divergence, followed by single ear head weight (4.49 %) and inflorescence width (3.72

Table 7. Contribution of each character to divergence, based on pooled of three environments

Sl.No	Trait	No. of first rank	% contribution
1	Days to flowering	0	0.00
2	Days to maturity	185	23.72
3	length of flag leaf	0	0.00
4	Length of lower racemes	6	0.77
5	Length of inflorescence	2	0.26
6	Length of nodes	2	0.26
7	Length of peduncle	0	0.00
8	Number of basal tillers	0	0.00
9	Number of nodes	1	0.13
10	Number of racemes	2	0.26
11	Plant height	1	0.13
12	Stem diameter	51	6.54
13	Single ear head weight	35	4.49
14	Thousand grain weight	47	6.03
15	Width of flag leaf	14	1.79
16	Width of inflorescence	29	3.72
17	Grain yield per plant	405	51.92
	TOTAL		100.00

Table 8. Stability analysis through GGE biplot for 40 accessions

Sl. No	Traits	Closer ideal genotypes	Nature of stability	Proximal ideal genotypes	**Nature of stability**
1	Days to flowering	M28P1 (G33)	Stable	ACM-15-353 (G39), M37P1(G35), M36P1(G34), M27P1 (G32), M18P1 (G31), M12P1 (G30), M3P2 (G28), M1P1 (G26), IEc350 (G21), ACM 161 (G1), T5 (G2), ACM 110 (G3), IEc52 (G4), GECH 10 (G5), ACM 333 (G11), GECH15 (G12), IEc672 (G13), IEc356 (G20)	Stable/ Partially stable
				MDU 1 (G 37) , ACM-15-343 (G38)	Partially stable
2	Days to maturity	M28P1 (G 33)	Stable	ACM 161 (G1), T5 (G2), ACM 110 (G3), IEc52 (G4), GECH 10 (G5), IEc167(G6), ACM 331(G7), ACM 295 (G8), IEc568 (G9), IEc166 (G10), ACM 333 (G11), GECH15 (G12), M1P1(G26), M2P1(G27),M3P2(G28),M5P1(G29), M12P1 (G30), M18P1 (G31), M27P1 (G32), M36P1 (G34), M37P1 (G35), M38P1 (G36), ACM 15-343 (G38), ACM-15-353 (G39).	Stable/ Partially stable
3	Grain yield per yield	None	None	ACM 110 (G3), GECH 10 (G5), M38P1 (G36), M5P1(29), IEc52 (G4), MDU 1(G37), M37P1 (G35), M27P1(32), IEc568 (G9), T5 (G2), IEc296 (G 24)	Partially stable
4	Length of inflorescence	M18P1 (G31), M27P1 (G32)	Stable	ACM 331 (G7), M1P1(G26), M3P2 (G28)	Stable
				M5P1 (G29), ACM 295 (G8), ACM-15-353 (G39), MDU 1 (G37), M2P1 (G27)	Partially stable
5	Number of basal tillers	IEc71 (G23)	Stable	IEc672 (G13)	Stable
				IEc166 (G10), IEc296 (G24), GECH 10 (G5).	Partially stable
6	Plant height	CO (Kv) 2 (G40)	Stable	ACM 161 (G1), T5 (G2), IEc167 (G6), ACM 331 (G7), ACM 295 (G8), ACM 333 (G11), M5P1 (G29), M12P1 (G30), M18P1 (G31), M27P1 (G32), M28P1(G33), M36P1(G34), M37P1(G35), M38P1(G36), MDU 1(G37), ACM-15-343 (G38), ACM-15-353 (G 39)	Partially stable
7	Thousand grain weight	IEc52 (G4)	Partially stable	IEc108 (G 17), M3P2 (G 28)	Partially stable

%). The other traits like days to flowering, flag leaf length, length of lower raceme, length of nodes, inflorescence length, node length, peduncle length, the number of basal tillers, the number of nodes, the number of racemes, plant height and width of flag leaf contributed very less or zero participation to the genetic divergence. Therefore, the selection of accessions through best contributed traits would be effective in breeding programs.

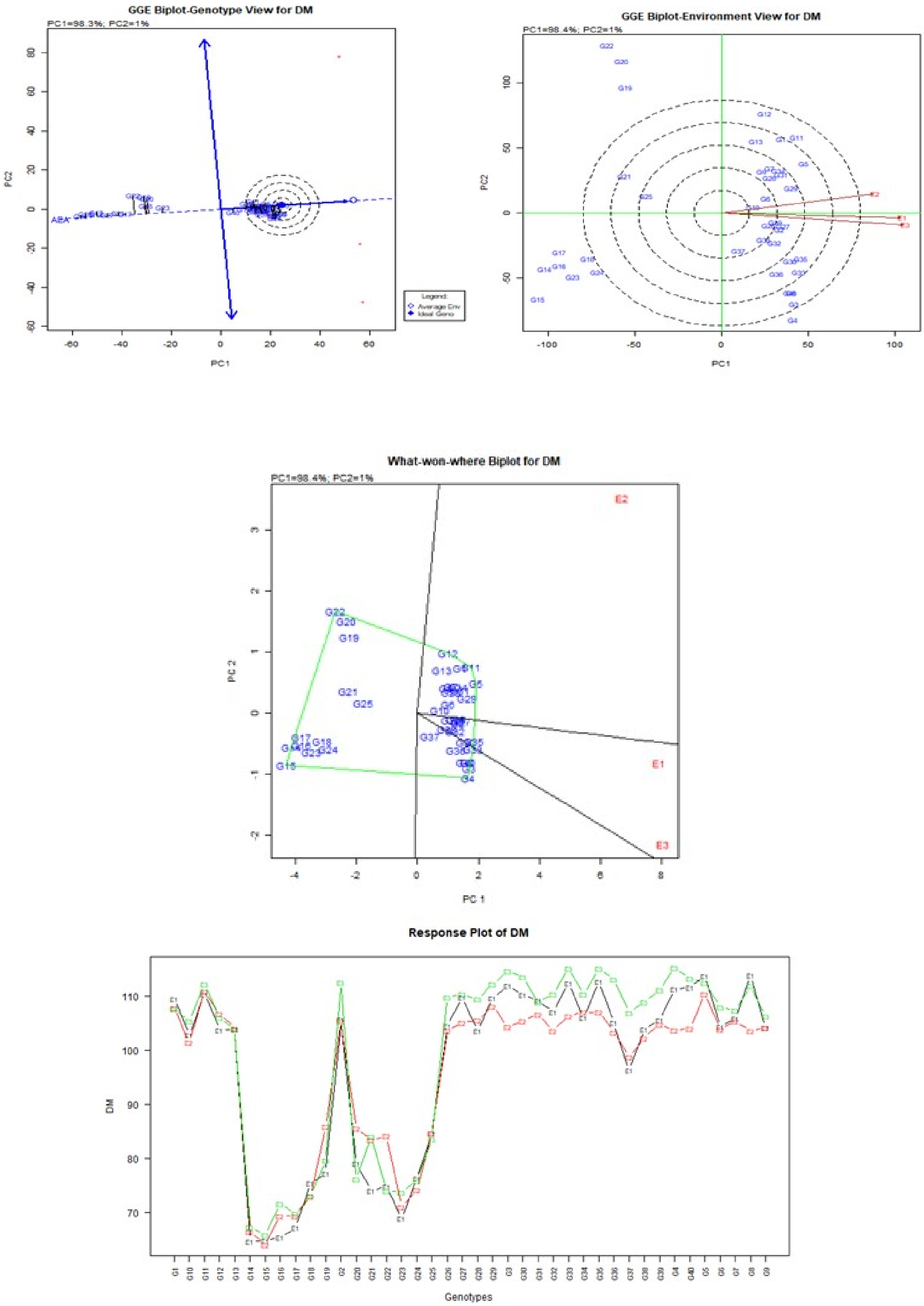

Fig.1. Biplots for days to maturity

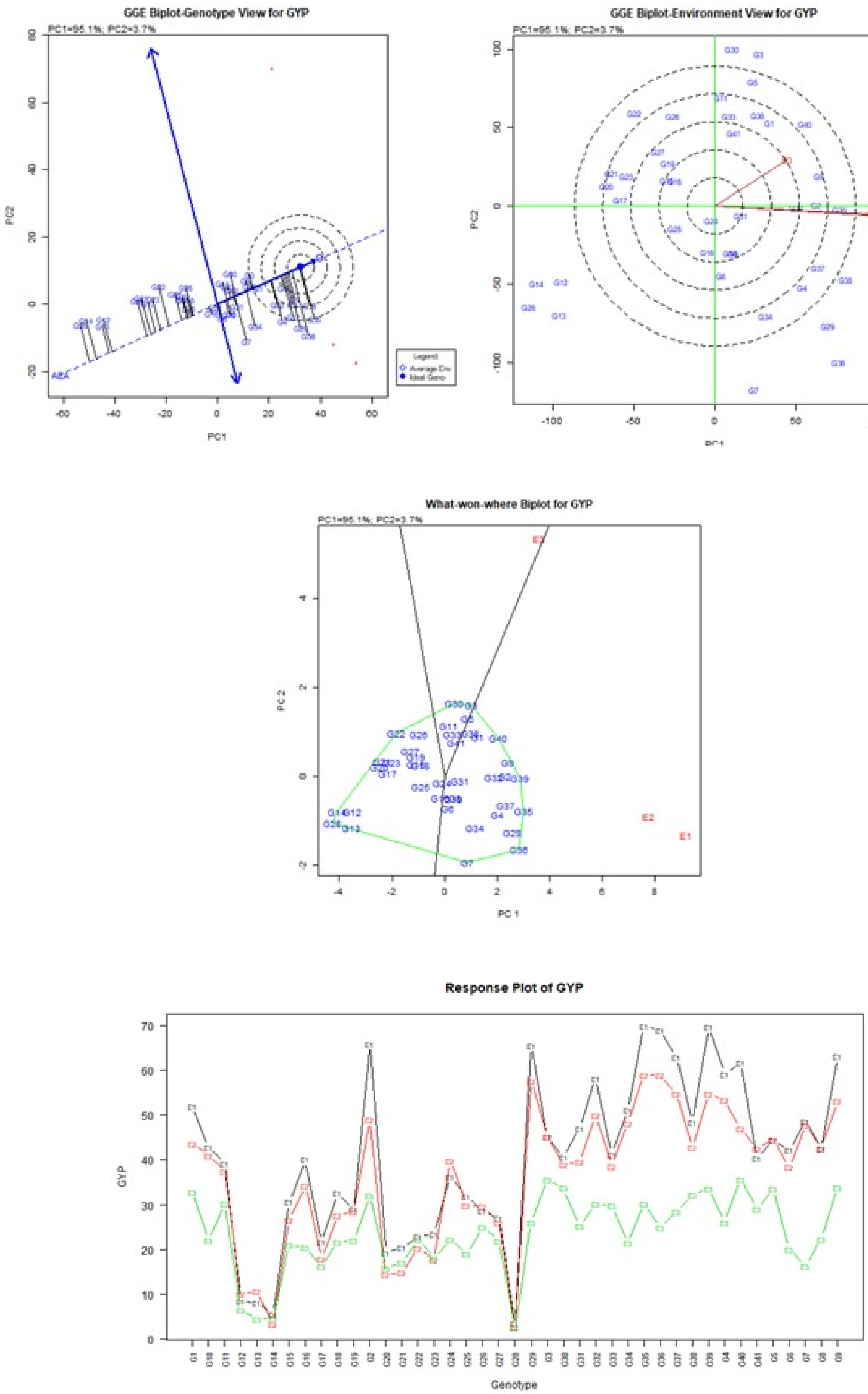

Fig. 2. Biplots for grain yield per plant

The stability analysis for maturity and grain yield are depicted in Fig. 1 and 2, for duration of maturity and grain yield, respectively and **Table 8** illustrates stability analysis through GGE biplot for better understanding of the traits. From the table, it is evident that there are few accessions were positioned as closer ideal genotypes for the traits like days to flowering (M28P1), days to maturity (M28P1), length of inflorescence (M18P1 and M27P1), the number of basal tillers (IEc 71), plant height (CO (Kv) 2) and thousand grain weight (IEc 52). All the traits except thousand grain weight (partially stable) were exhibited stable performance, whereas, the trait, grain yield per plant did not identify as stable performer. About 24 accessions were proximal to ideal accession for days to maturity, while 11 accessions were proximal for grain yield per plant including MDU 1, M5P1, M36P1 and M37P1, which are exhibited partially stable performance. Hence, the accessions like MDU 1, M5P1, M36P1 and M37P1 are identified as better stable performer for grain yield that could be recommended for utilizing crop improvement program.

Table 9. What-won-where bi-plot for 40 accessions in three environments

Sl. No	Character	E1	E2	E3
1	Days to flowering	M28P1 (G 33)	M5P1 (G 29)	M37P1 (G 35)
2	Days to maturity	M37P1 (G35), M27P1 (G 32)	GECH 10 (G5), ACM 333 (G 11), GECH15 (G 12)	IEc52 (G 4), ACM 110 (G 3), M27P1 (G 32) M37P1(G 35)
3	Grain yield per plant	M38P1(G36), ACM 331 (G 7), M5P1 (G 29)	M37P1 (G 35), ACM-15-353 (G 39), CO (Kv) 2 (G 40), IEc568 (G 9)	ACM 110 (G 3), M12P1 (G 30)
4	Length of inflorescence	ACM 295 (G 8), IEc568 (G 9), GECH 10 (G 5)	M18P1 (G 31), M27P1 (G 32)	MDU 1 (G 37)
5	Number of basal tillers	IEc71 (G 23), ACM-15-343 (G 38)	GECH 10 (G 5)	GECH 10 (G 5)
6	Plant height	ACM 295 (G 8), IEc167 (G 6), IEc568 (G 9)	M18P1 (G 31), M2P1 (G 27), CO (Kv) 2	CO (Kv) 2 (G 40), M2P1 (G 27), M18P1 (G 31
7	Thousand grain weight	M36P1 (G 34)	IEc52 (G 4), M3P2 (G 28)	M36P1 (G 34)

The biplot provides information on relative performance of genotypes between the environments and helps to divide the target environment into multiple mega environments. The accessions pertaining for its favorable environment were furnished in Table 9. On the basis of environment, some accessions respond well to a specific environment. Considering the yield, ACM 331, M5P1 and M38P1 were most suitable to E1 for grain yield per plant, while the accessions like ACM-15-353, CO (Kv) 2, IEc 568 and M37P1 suited for E2. In E3, ACM 110 and M12P1 were found to be most suitable. From the stability analysis, it is found that, none of the accessions were stable in all three environments for grain yield per plant which indicated that the influence of environmental factors played a major role.

From the experiment results, it is evident that there is existence of genetic diversity of morphological and agronomic characters in the barnyard millet germplasm. We could identified some of the early maturing genotypes (64-80 days) irrespective of good grain yield, which could be efficiently used in breeding programmes for improvement of this crop. The stability analysis indicated that, none of the accessions were stable in all three environments for grain yield per plant due to the influence of environmental factors. Thus, the differentiation of germplasm based on morphologically similar and presumably genetically similar groups is helpful for selecting parents for crossing.

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