Website : www.asthafoundation.in
Frontiers in Crop Improvement
Vol 11 (1) : 21-26 (January-2023) Print ISSN : 2393-8234 Online ISSN : 2454-6011
Astha Foundation, Meerut (U.P.) India

Stability Analysis in Pearl Millet [*Pennisetum glaucum* (L.) R. Br.]

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Abstract

The study was conducted on thirty pearl millet genotypes to assess the G × E interaction and stability analysis. The experiment was laid out in randomized block design with two replications over three dates of sowing viz., 28th February, 14th March and 30th March during the summer of 2020. The analysis of variance for G × E interaction was significant for days to maturity, plant height, ear head girth, seed setting on main tiller, grain yield per plant, harvest index, test weight and protein content when tested against pooled error. The estimation of the environmental index (Ij), suggested that E_1 (Date of sowing 28th February 2020) was the most favourable environment. From the stability analysis based on Eberhart and Russell model, two genotypes out of thirty viz, GP-14 and J-2563 had higher grain yield per plant and seed setting on main tiller and these were suitable for favourable environmental conditions.

Key words : *G×E interaction, pearl millet, stability, yield.*

Introduction

Bajra *(Pennisetum glaucum* (L.) R. Br.) popularly known as "pearl millet", belongs to the *Gramineae* family. It is an annual tillering, cross-pollinated, diploid (2n=14) crop and is believed to have originated in northwestern Africa. Bajra is a coarse grain crop and is considered to be the poor man's staple nourishment. Pearl millet is the world's sixth and India's third most important cereal food crop after rice and wheat. In India, pearl millet occupies an area of 6.93 million hectares and production of 8.61 million tones with a productivity of 1243kg/ha. (1). It is the most important cereal crop in the drought-prone regions of Rajasthan, Haryana and Gujarat, valued for both grain and stover. The grains of Bajra are rich sources of iron (18-87ppm) and zinc (22-88ppm) (2). The breeding and crop improvement work in pearl millet in the earlier days was neglected. The improvement of this crop in India was initiated in 1920. The commercial hybrids of Bajra, developed in India with the production and extensive testing of single crosses with cytoplasmic male sterile line Tift 23 A. The Indian breeders announced the release of HB-1 hybrid pearl millet in 1965 (3).

The potential performance of improved genotypes under marginal conditions is always obscured by the effect of genotype by environment interaction leading to the selection of genotypes not suitable for particular environments (4) and subsequently leading to low yield. It is therefore important to assess genotype by environment interaction effect before releasing varieties (5, 6) Hence, it may be useful to determine the most suitable environment that may allow maximum expression of the genes controlling quantitative characters. The degree of genotype-environment interaction involved in the expression of a given character not only helps the plant breeder in planning future breeding programs but is also useful in determining the environments and number of tests to be conducted for the evaluation of breeding material. In a view of the above circumstance, a study was undertaken to identify the environmentally stable genotype of pearl millet for breeding and to select the most promising genotype for future breeding programmes.

Materials and Methods

The experimental material of the study comprised of 30 genotypes of pearl millet maintained at the Centre for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat. The experiment was laid out in randomized block design with two replications over three dates of sowing viz., 28th February (E_1), 14th March (E_2) and 30th March (E_3) during the summer of 2020. A spacing of 45 × 10-15 cm was maintained between the genotypes and recommended cultural practices were adopted to raise the crop. The observations were recorded on five randomly selected plants from each replication for ten traits viz., plant height (cm), number of effective tillers per plant, ear head length (cm), ear head girth (mm), seed setting on main tiller (%), dry fodder yield per plant (g), grain yield per plant (g),

Received : October-2022; Revised : November-2022; Accepted : November-2022

harvest index (%), test weight (g) and protein content (%), while two characters, namely, days to flowering and days to maturity were recorded on a plot basis. The recorded data after calculating the mean were subjected to analysis of variance. Stability analysis was carried out as per the method prescribed by (7) for grain yield and its contributing characters.

Results and Discussion

The varieties of crops never show similarity in their performance when tested under different environmental conditions. This is because of the presence of G×E interactions, which results in changes in relative ranking in terms of yield and component traits of different genotypes and also alters the magnitude of differences between genotypes from one environment to another. However, even with this refinement of technique, the interactions of genotypes with environments within the same year remain very large (8).

For commercial crop plant production, phenotypically stable varieties are typically sought. Any breeding programme must screen for and identify phenotypically stable genotypes that can perform more or less uniformly under varying environmental conditions.

Analysis of variance : The analysis of variance for genotype x environment interactions in thirty genotypes for different characters, as per (7), is given in (Table-1). The mean sum square due to genotypes, environments, environment (linear) and genotype × environment (linear) was tested against pooled deviation. The pooled deviation was tested against pooled error too. Genotypes were found to be significant for days to flowering, days to maturity, plant height, ear head length, ear head girth, seed setting on main tiller, number of effective tillers per plant, harvest index, grain yield per plant, test weight and protein content. The mean square due to environment was highly significant for all the characters except ear head length. This indicated that the environment used was quite different from each other. The environment (linear) was highly significant for all the characters except ear head length. The G × E interaction was significant for days to maturity, plant height, ear head length, ear head girth, seed setting on main tiller, grain yield per plant, harvest index, test weight and protein content when tested against pooled error. This indicates that genotypes reacted differently in varied environments. The result is in agreement with earlier reports by (9, 10, 11, 12, 13). The G×E (linear) was observed significant for all the characters except for days to flowering, number of effective tillers per plant and dry fodder yield per plant. This reveals that a major portion of interaction was in linear in nature and prediction over environments for these characters would be possible. This result is in accordance with the findings of (12, 13). The variance due to pooled deviation was significant for all characters except days to maturity and seed setting on main tiller, which suggest the importance of a non-linear component for all the characters except days to maturity and seed setting on main tiller. If G×E (linear) and pooled deviation (non-linear) are significant for a character, then both components (linear and non-linear) appear to be important.

Environmental indices : The environment index reveals the favorability of an environment at a particular location. (14) pointed out that the estimates of the environment index can provide the basis for identifying the favorable environment for the expression of the maximum potential of the genotype. The positive and negative value of the environmental index indicates the favorable and unfavorable situations, respectively for each character (15). The estimation of the environmental index (Ij) given in (Table-2), suggests that E_1 (Date of sowing 28th February 2020) was a favorable environment for all characters except dry fodder yield per plant. The results are in agreement with (12, 13). The E_2 (Date of sowing 14th March 2020) was favorable for days to maturity, ear head length, ear head girth, and dry fodder yield per plant. The E_3 (Date of sowing 30th March 2020) was an unfavorable environment for all the characters except dry fodder yield per plant.

Stability parameters : A genotype's most desired quality for wider adaptation is performance stability. Each genotype's potential yield can be achieved using a specific set of agronomic techniques. Therefore, it is suggested that actual testing under diverse environments, including favourable and unfavourable ones, would be advantageous in order to identify stable genotypes. (7) suggested the ideal genotype as one which has a high mean ($\bar{X}$), unit regression co-efficient ($b_i = 1$) and the least deviation from regression ($S^2di = 0$). On the basis of stability parameters, genotypes with near-unity regression coefficients, higher mean values, and non-significant departures from linear regression were deemed appropriate and acceptable for favorable environmental conditions. While genotypes with a higher mean, a regression coefficient less than one, or negative and non-significant deviations from linear regression were considered responsive and suited for unfavorable environmental conditions. The stability parameters *viz.,* mean performance, regression coefficient ($b_i = 1$) and a mean square deviation from regression (S^2d_i) of 30 genotypes for eight characters having significant GxE interaction were computed to assess relative stability over a range of environments.

Table-1 : Analysis of variance (Mean square) for phenotypic stability for different characters in pearl millet.

Sources of variation	d.f.	DF	DM	PH	ET	EL	EG	SS	FY	GY	HI	TW	PC
Genotype (G)	29	38.81**	15.41**	419.48**	0.15*	18.78**	5.74**	12.42**	278.74	251.81**	145.18*	1.53**	2.86**
Environment (E)	2	3445.73**	46.28**	10207.90**	1.42**	9.40	50.16**	1383.24**	1486.00**	9860.67**	2176.00**	29.38**	13.22**
G × E	58	17.31	5.75**	256.60**	0.08	8.96	8.79**	4.38*	234.36	138.37**	113.78*	0.50*	1.85*
Environment (linear)	1	6891.47**	92.56**	20415.90**	2.85**	18.80*	100.32**	2766.48**	2972.10**	19721.30**	4352.00**	58.77**	26.45**
G × E (linear)	29	18.07	6.79**	406.75**	0.10	13.73	15.06**	4.97**	237.09	237.95**	160.37**	0.72**	2.69**
Pooled deviation	30	15.99**	4.55	102.90**	0.06**	4.04**	2.44**	3.66	223.90**	37.49**	64.95**	0.28*	0.97**
Pooled error	87	1.65	3.18	4.85	0.02	0.33	0.45	2.55	7.02	5.19	5.11	0.14	0.06

*and** : Significant at 5 and 1 per cent levels of significance, respectively.
DF: Days to flowering, DM: Days to maturity, PH: Plant height (cm), ET: Number of effective tillers per plant, EL: Ear head length (cm), EG: Ear head girth (mm), SS: Seed setting on main tiller (%), FY: Dry fodder yield per plant (g), GY: Grain yield per plant (g), HI: Harvest index (%), TW: Test weight (%) and PC%: Protein content (%).

Grain yield per plant : Stability parameters of thirty genotypes for grain yield per plant are presented in table-3. The deviation from regression (S^2d_i) was significant for thirteen genotypes (16110, 15388, 16317, 42063, 16088, 30566, 15776, GP-11, GP-33, GP-3, GP-46, J-2566 and 15298) and hence, these genotypes were unstable. Twelve genotypes (16110, 16317, 30566, 15776, GP-11, GP-33, GP-3, GP-46, GP-14, J-2566, J-2563 and 15298) recorded a higher mean value of grain yield per plant than the population mean (25.78). Out of these twelve genotypes, non-significant deviation from regression along with regression coefficient about unity was observed in two genotypes viz., GP-14 and J-2563 and thus they were responsive to a favorable environment. The genotype with a minimal variance for yield across the environments was considered stable (13, 16, 17, 18).

Stable genotypes for grain yield per plant along with stability for component traits are presented in table-4.

Seed setting on the main tiller : For seed setting on the main tiller, the deviation from regression (S^2d_i) was significant for five genotypes viz. 16110, GP-33, GP-3, J-2571 and 15298. Eleven genotypes (16110, 15388, 16317, 30566, GP-11, GP-33, GP-3, GP-46, GP-14, J-2512, and 15298) recorded a higher mean value than the population mean (81.63). The genotypes, 15388 R, 16317 R and GP-14 with significant unit regression ($b_i >1$) and non-significant S^2d_i was considered to perform well in favourable conditions. Whereas regression coefficient less than one ($b_i <1$) with high mean than general mean and non-significant deviation from regression were observed in genotypes, 30566 R, GP-11, GP-46 and J-2512. These genotypes would perform better in unfavourable environments.

Days to maturity : The deviation from regression (S^2d_i) was significant for six genotypes (16110, 42063, 15222, 15776, GP-33 and J-2566); hence, these genotypes were unstable. Thirteen genotypes (16110, 15388, 16317, 42063, 30566, 15776, GP-11, GP-33, GP-3, GP-46, GP-14 and 15298**)** exhibited a higher mean value than the general mean (86.35). The early maturity genotype, selection H-1 had non-significant unit regression (b_i) and non-significant S^2d_i indicating average stability over different environments. Whereas the genotypes, 30566 R, 15388 R and GP-3 that had significant unit regression (b_i <1) and non-significant $S^2d_{i,}$ are said to be low responsive and suitable for unfavorable environments, while genotypes, GP-14 and 15298 R with significant unit regression (b_i >1) and non-significant $S^2d_{i,}$ are said to be highly responsive and suitable for favorable environments. The genotypes GP-11 and GP-46 recorded non-

Table-2 : Estimates of the environmental index (I_j) for different characters under different environments expressed as deviation of grand mean.

Sr. No.	Characters	Environments		
		E_1	E_2	E_3
1.	Days to flowering	12.37	-5.73	-6.63
2.	Days to maturity	1.08	0.19	-1.37
3.	Plant height (cm)	21.28	-10.02	-11.27
4.	Number of effective tillers per plant	0.24	-0.18	-0.07
5.	Ear head length (cm)	0.35	0.29	-0.65
6.	Ear head girth (mm)	1.25	0.06	-1.33
7.	Seed setting on main tiller (%)	7.05	-0.57	-6.49
8.	Dry fodder yield per plant (g)	-7.58	6.33	1.26
9.	Grain yield per plant (g)	20.55	-6.78	-13.75
10.	Harvest index (%)	9.76	-5.9	-3.87
11.	Test weight (g)	1.12	-0.37	-0.75
12.	Protein content (%)	0.7	-0.62	-0.07

Table-3 : Stability parameters of thirty genotypes for grain yield per plant in pearl millet.

Sr. No.	Genotypes	Grain yield per plant (g)		
		Mean	b_i	S^2d_i
1.	16110	30.66	1.168**	52.207**
2.	Selection H-1	17.50	0.652**	2.692
3.	30275	22.33	0.829**	1.88
4.	15851	22.16	0.828**	0.469
5.	15388	18.66	-0.051	46.919**
6.	16317	30.33	0.679*	62.453**
7.	42063	14.16	0.312	31.162**
8.	16088	23.50	1.328**	16.797*
9.	15167	25.50	1.194**	-3.498
10.	30566	31.00	0.814**	17.296*
11.	15222	22.00	0.886**	-1.787
12.	15776	39.16	2.432**	224.222**
13.	GP-49	18.00	0.677**	-3.251
14.	GP-5	20.00	0.938**	-1.369
15.	GP-11	25.83	1.12**	13.967*
16.	GP-33	28.33	0.942**	130.422**
17.	GP-37	24.50	1.11**	-1.958
18.	GP-3	42.83	1.08*	164.183**
19.	GP-46	51.66	1.56**	115.399**
20.	GP-14	42.33	2.46**	-2.829
21.	J-2566	37.83	2.391**	93.338**
22.	J-2503	16.83	0.297**	4.488
23.	J-2571	15.66	0.146	1.197
24.	J-2495	14.33	0.552**	0.688
25.	J-2563	26.16	1.402**	8.27
26.	J-2512	23.33	0.678**	-0.824
27.	J-2496	22.00	0.959**	0.209
28.	15298	27.00	1.127**	49.976**
29.	J-2559	20.33	0.709**	-3.063
30.	GP-38	19.66	0.782**	-0.416
	Mean	25.78		
	S.Em. ±	1.67		

*and** : Significant at 5 and 1 per cent levels of significance, respectively.

Table-4 : Stable genotypes for grain yield per plant along with stability for component traits.

Genotypes	Stability parameter	Grain yield per plant (g)	Seed setting on main tiller (%)	Days to maturity	Plant height (cm)	Test weight (g)	Ear head girth (mm)	Harvest index (%)	Protein Content (%)
GP-14	mean	42.33	83.15	86.99	133.04	7.96	23.71	31.04	5.99
	b_i	2.46**	1.463**	4.341**	2.877**	1.734**	2.709**	-0.226	0.987
	S^2d_i	-2.829	0.343	-1.825	112.873**	0.083	2.914**	64.972**	1.371**
J-2563	mean	26.16	80.63	85.66	112.91	7.43	22.50	13.57	5.78
	b_i	1.402**	1.182**	0.978**	1.628**	1.242**	0.337**	0.731*	3.928**
	S^2d_i	8.27	-1.716	-2.02	0.834	-0.093	-0.312	13.205*	0.399**

*and**: Significant at 5 and 1 per cent levels of significance, respectively.

significant unit regression (b_i) and non-significant S^2d_i, indicating average stability over different environments.

Plant height : For fifteen genotypes (16110, 16317, 15167, 15776, GP-33, GP-37, GP-3, GP-46, GP-14, J-2503, J-2571, J-2512, J-2496, 15298 and J-2559), the deviation from regression (S^2d_i) was significant; hence these genotypes were unstable. Thirteen genotypes (16110, 15388, 16317, 16088, 30566, 15776, GP-11, GP-37, GP-3, GP-46, GP-14, J-2566 and 15298) recorded a higher mean value of plant height than the population mean (115.54). The genotypes, 15388 R and GP-11 had significant unit regression (b_i <1) and non-significant S^2d_i which are said to be low responsive and fit for unfavorable environments whereas the genotypes, 16088 R, 30566 R and J-2566 with significant unit regression (b_i >1) and non-significant $S^2d_{i,}$ are said to be highly responsive and fit for favorable environments.

Test weight : In case of test weight, the deviation from regression (S^2d_i) was significant for five genotypes (30275, 42063, 15776, J-2496 and 15298); hence these genotypes were unstable. Twelve genotypes (Selection H-1, 15388, 16317, 30566, 15776, GP-33, GP-3, GP-46, GP-14, J-2566, J-2563 and 15298) had a higher mean of test weight than the population mean (7.40). The genotype, GP-3 exhibited significant unit regression (b_i <1) and non-significant S^2d_i and is said to be low responsive and suitable for unfavorable environments. Whereas the genotypes, Selection H-1, GP-33, GP-14, J-2566 and J-2563 with significant unit regression (b_i > 1) and non-significant S^2d_i, are said to be highly responsive and fit for favorable environments and the genotypes, 15388 R, 16317 R, 30566 R and GP-46 recorded non-significant unit regression (b_i) and non-significant S^2d_i indicating their average stability over different environments.

Ear head girth : Twelve genotypes (16317, 30566, 15222, 15776, GP-11, GP-33, GP-3, GP-46, GP-14, J-2503, J-2571 and J-2512) had a higher mean of ear head girth than the population's mean (22.72). The genotypes, 30566 R and J-2571 with significant unit regression (b_i < 1) and non-significant S^2d_i are said to be low responsive and fit for unfavorable environments, while the genotypes, 15222 R, GP-3, and J-2503 with non-significant unit regression (b_i) and non-significant S^2d_i indicated average stability over different environments. The deviation from regression (S^2d_i) was significant for thirteen genotypes (16317, 16088, 15776, GP-11, GP-33, GP-46, GP-14, J-2566, J-2495, J-2512, J-2496, 15298 and J-2559); hence these genotypes were unstable.

Harvest index : The deviation from regression (S^2d_i) was significant for eighteen genotypes (16110, Selection H-1, 15851, 16317, 30566, 15776, GP-49, GP-11, GP-33, GP-46, GP-14, J-2566, J-2571, J-2495, J-2563, J-2496, 15298 and GP-38), and hence these genotypes were unstable. Fifteen genotypes (16110, Selection H-1, 30275, 15388, 16317, 42063, 16088, 30566, GP-3, GP-46, GP-14, J-2566, J-2495, J-2496 and J-2559) recorded a higher mean value of harvest index than the population mean (25.46). The genotypes, 15388 R and GP-3 with significant unit regression (b_i < 1) and non-significant S^2d_i are said to be low responsive and suitable for unfavorable environments. A significant unit regression (b_i >1) and non-significant S^2d_i were recorded by genotypes 30275 R, 42063 R, 16088 R and J-2559 and these are said to be highly responsive and fit for favorable environments.

Protein Content : For protein content, twenty-five genotypes had a significant deviation from regression (S^2d_i); hence, these genotypes were unstable except five genotypes (15851, 15388, 15167, GP-49 and GP-3). Eighteen genotypes (16110, 15388, 16317, 16088, GP-5, GP-11, GP-33, GP-3, GP-46, GP-14, J-2566, J-2503, J-2571, J-2495, J-2563, J-2512, 15298 and J-2559) recorded a higher mean value of protein content than the population mean (5.35). The genotypes, 15388 R and GP-3 with a significant unit regression (b_i <1) and non-significant S^2d_i, are said to be low responsive and suitable for unfavorable environments.

Conclusions

It is critical to identify stable genotypes under different growing seasons, which will be very useful to plant breeders in improving the crop. In the analysis of variance, G × E interaction was significant for days to maturity, plant height, ear head girth, seed setting on main tiller, grain yield per plant, harvest index, test weight and protein content when tested against pooled error. Environments (Linear) also showed highly significant differences for all the characters under study. It reveals the wide difference between environments. The estimation of the environmental index (Ij), suggests that E_1 (Date of sowing 28th February 2020) was the most favorable environment. According to Eberhart and Russell stability model, out of thirty, two genotype viz, GP-14 (for grain yield per plant, days to maturity, seed setting on main tiller and test weight) and J-2563 (for grain yield per plant and seed setting on main tiller) were responsive to favorable environment. Stable genotypes can be utilized for future breeding programs.

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