The Pharma Innovation Journal 2022; 11(5): 1144-1151

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(5): 1144-1151

www.thepharmajournal.com
Received: 03-02-2022
Accepted: 12-04-2022

Stability analysis using alloplasmic isonuclear lines for yield and biofortified traits in pearl millet (*Pennisetum glaucum* (L.) R. Br.)

Kishan Gajera, Mungra KD, Paghadar PJ, Chovatiya SJ, Pansuriya YA and Sidapara MP

Kishan Gajera
Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Mungra KD
Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Paghadar PJ
Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Chovatiya SJ
Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Pansuriya YA
Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Sidapara MP
Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Corresponding Author:
Kishan Gajera
Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Abstract

Stability for grain yield performance and genotype x environment (G x E) interaction was studied in complete set of 64 genotypes [54 hybrids, six tester, three maintainer lines and one standard check (GHB 1129) were made by using line x tester mating design] of pearl millet evaluated in a randomized block design with three replications and three environments i.e. Kharif-2020 (DOS: 18th July, 2020), Summer-2021 (DOS: 11th February, 2021) and Summer-2021 (DOS: 21st February, 2021) designated as E_1, E_2 and E_3, respectively at the two different locations, i.e. at Instructional Farm, JAU, Junagadh and PMRS, Jamnagar during kharif-2020 and summer-2021, respectively. Among parents, J-2602 (57.16 g) and among crosses, $ICMA_4$ 11999 x J-2591, $ICMA_4$ 11999 x J-2597, $ICMA_5$ 11999 x J-2597, $ICMA_1$ 11999 x J-2597, $ICMA_5$ 11999 x J-2607 and $ICMA_5$ 11999 x J-2591 were having more grain yield per plant and had the least deviation from linear regression, but had significant regression coefficient (bi >1) and found to be highly responsive to better environments. while $ICMA_1$ 14666 x J-2565 and $ICMA_5$ 14666 x J-2565 had more grain yield per plant with non-significant deviation from regression, but had significant regression coefficient (bi < 1) showed above average response and high stability under unfavourable environments. The stable parents J-2482 were also showed stability for important yield components like ear head girth, total biomass per plant, Fe and Zn content. This indicated that stability of various component traits might be responsible for the observed stability of various hybrids for grain yield per plant. Hence, chances of selection of stable hybrids for yield could be enhanced by selecting for stability for yield components.

Keywords: L x T mating, genotype x environment interaction, Pearl millet, stability

Introduction

The pearl millet is an annual, tillering diploid (2n=14) crop plant, belongs to family Poaceae and supposed to be originated in Africa which thrives well in the arid and semi-arid tropical regions of Asia and Africa. The better nutritive value of pearl millet grains appear from its protein (9 to 15%), fat (5%) and mineral (2 to 7%) contents. It is also rich in vitamins A, thiamin and riboflavin contents and imparts substantial energy to the body with easy digestibility (Pal *et al.* 1996) [24]. Its contribution of micronutrients, especially iron [Fe] and zinc [Zn] is higher, varying from 30% to 50% of the intake of these micronutrients from cereals (Rao *et al.* 2006) [29]. India is the largest producer of this crop, as it occupies an area of 6.93 million ha with an average production of 8.61 million tones and productivity of 1243 kg/ha (Anon., 2019-20) [2]. In Gujarat, the cultivated area of pearl millet including *kharif* and summer season is an about 4.50 lakh hectare and production of 10.90 lakh metric tonnes with an average productivity of 2325 kg/ha (Anon., 2020) [3]. The major pearl millet growing states in India are Rajasthan, Gujarat, Maharashtra, Haryana, Uttar Pradesh and Karnataka, where it is grown both in *kharif* and summer seasons.

In plant breeding programme, many potential genotypes are evaluated under different environments (location and years) to test their adaptability before releasing a hybrid/variety for commercial cultivation. Genotype and its interaction with prevailing environment is the basic factor determining the final yield. The genotype x environment interaction is particularly important in the expression of quantitative characters, which are controlled by polygenic systems and are greatly modified by the environmental influences. Thus, in order to have unbiased estimates of various genetic components, it is imperative that the experiment should be repeated over different environments. Crop yield in which the plant breeder is most interested is dependent on the genotype, the environment and the interaction between genotype and environment. The result of the genotype x environment interaction is expressed as adaptability and stability of the genotype. When interaction between genotype and environment exists, ranking of genotype will be different under different environments. The stability of productivity is, therefore, very important. Hence, it is always desirable to study the stability of hybrids in respect of economically important characters. The knowledge of the nature and relative magnitude of the various types of G x E interaction is important in making decisions concerning the choice of breeding methods, selection programmes and testing procedures in crop plants (Baker, 1969) [4]. Phenotypically stable varieties are usually sought for commercial production of crop plants. In any breeding programme is necessary to screen and identify phenotypically stable genotypes, which could perform more or less uniformly under different environmental conditions. Considering this fact in mind, the present investigation was carried out to identify stable genotypes of pearl millet.

Materials and Methods

Experimental Materials

The experimental material for the present investigation comprised of nine lines (Three females with three different cytoplasmic source) *viz*., ICMA$_1$ 11999, ICMA$_4$ 11999, ICMA$_5$ 11999, ICMA$_1$ 14666, ICMA$_4$ 14666, ICMA$_5$ 14666, ICMA$_1$ 17777, ICMA$_4$ 17777 and ICMA$_5$ 17777 were obtained from ICRISAT Hyderabad and six tester (males) developed at PMRS, JAU, Jamnagar *viz*., J-2565, J-2591, J-2597, J-2602, J-2607 and J-2618 were obtained from Research Scientist (Pearl Millet), JAU, Jamnagar (Table 1). The check included in this experiment was GHB 1129 for micronutrient Fe and Zn.

Crossing programme

The crossing programme between the nine female and six male restorer lines was performed in the Pearl Millet Research Station, JAU, Jamnagar using line x tester mating design. The genotypes used as parental lines and their details are enlisted in Table 1. In present investigation, the advantage of cytoplasmic genetic male sterility was harnessed to obtain hybrid seeds. The inflorescences of CGMS lines to be used as a female. Six R-lines were crossed with nine A-lines to produce fifty-four hybrids. Hybrid and selfed seeds harvested and threshed separately to avoid contamination.

Experimental Details

The complete set of 64 genotypes comprising 54 hybrids, six tester, three maintainer lines and one standard check (GHB 1129) were evaluated in a randomized block design with three replications and three environments i.e. *Kharif*-2020 (DOS: 18st July, 2020), Summer-2021 (DOS: 11th February, 2021) and Summer-2021 (DOS: 21st February, 2021) designated as E_1, E_2 and E_3, respectively at the two different locations, i.e. at Instructional Farm, JAU, Junagadh and PMRS, Jamnagar during *kharif*-2020 and summer 2021, respectively. GHB 1129, a medium maturing bio-fortified hybrid for Zn and Fe released at state level for general cultivation in Gujarat was planted in trial in order to obtain information on superiority of hybrid over this hybrid as standard check. Each entry was accommodated in single row plot of 3 meter length with row to row and plant to plant distances of 60 and 12 cm, respectively. All the recommended agronomic practices and plant protection measures were followed in order to obtain a normal and healthy crop stand in the field.

Table 1: List of female, male parents and standard check used in the experiment

Sr No	Genotype	Pedigree	Source
Female parents/CGMS lines			
1	ICMA$_1$ 11999	ICMB 11999 BC to 81A (A_1) Cyto source	ICRISAT, Hyderabad
	ICMA$_4$ 11999	ICMB 11999 BC to 81A (A_4) Cyto source	ICRISAT, Hyderabad
	ICMA$_5$ 11999	ICMB 11999 BC to 81A (A_5) Cyto source	ICRISAT, Hyderabad
2	ICMA$_1$ 14666	ICMB 14666 BC to 06999A (A_1) cyto source	ICRISAT, Hyderabad
	ICMA$_4$ 14666	ICMB 14666 BC to 06999A (A_4) cyto source	ICRISAT, Hyderabad
	ICMA$_5$ 14666	ICMB 14666 BC to 02555A (A_5) cyto source	ICRISAT, Hyderabad
3	ICMA$_1$ 17777	ICMB 17777 BC to 81A (A_1) Cyto source	ICRISAT, Hyderabad
	ICMA$_4$ 17777	ICMB 17777 BC to 81A (A_4) Cyto source	ICRISAT, Hyderabad
	ICMA$_5$ 17777	ICMB 17777 BC to 81A (A_5) Cyto source	ICRISAT, Hyderabad
Male parents /Restorer inbreds			
1	J-2565	(J 834 X 700516)-1-4-4-2-4-B-2-2-B-B-B-1	JAU, Jamnagar
2	J-2591	{[((MC 94 S1-34-1-B x HHVBC)-16-2-1) x (IP 19626-4-2-3)]-B-28-3-4-3-1} x {RCB 2 S1-19-2-5-1-1-2-3-3-B}-B-5-P1-5	JAU, Jamnagar
3	J-2597	(MC 94 C2-S1-3-2-2-2-1-3-B-B x SDMV 90031 S1-3-3-2-2-2-2-2)-B-1-3-3	JAU, Jamnagar
4	J-2602	(MC 94 C2-S1-3-2-2-2-1-3-B-B x AIMP 92901 S1-488-2-1-1-4-B-B)-B-2-2-2	JAU, Jamnagar
5	J-2607	IP 12181 S1-1-4-1-B-5	JAU, Jamnagar
6	J-2618	ICMV 96490-S1-15-1-2-1-3-2-1	JAU, Jamnagar
Maintainer Lines			
1	ICMB	(DMR 133 x HTBC 48-B-1-1-1-5)-9-1-B-B-1	ICRISAT,

	11999		Hyderabad
2	ICMB 14666	[(ICMB 95111 x 9035/S92-B-3)-17-5-1-B-B-B x ICMB 99111]-3-2-1-2	ICRISAT, Hyderabad
3	ICMB 17777	[(ICMB 95111 x 9035/S92-B-3)-17-5-1-B-B-B x ICMB 99111]-3-2-4-B	ICRISAT, Hyderabad
Standard check hybrid			
1	GHB 1129	ICMA 99222 x J-2565	JAU, Jamnagar

Observations recorded

The observations were recorded on five randomly selected plants for 15 characters *viz*., days to 50% flowering, days to maturity, plant height (cm), number of effective tillers per plant, number of nodes on main stem, ear head length (cm), ear head diameter (cm), ear head weight (g), grain yield per plant (g), test weight (g), Fe content (ppm), Zn content (ppm), panicle index (%), total biomass per plant (g) and harvest index (%).

Statistical Analysis

The replication wise mean values of each genotype for various characters were used for statistical analysis. Following statistical procedures were used for analysis.

Analysis of genotype x environment interaction and stability parameters

The statistical analysis for genotype x environment interaction and phenotypic stability was carried out according to Eberhart and Russell (1966) [12] for grain yield and its components.

Results and Discussion

Analysis of variance for phenotypic stability

Analysis of variance for phenotypic stability as per Eberhart and Russel (1966) [12] revealed that the mean squares due to genotypes (G) were found highly significant for all the characters studied, when tested against pooled error and pooled deviation (**Table 2**). The mean squares due to environments (E) were found significant for all the characters except Zn content, when tested against pooled deviation as well as pooled error. The G x E interaction was found significant for all the characters except Zn content and total biomass per plant, when tested against error mean square. However, G x E interaction was significant for ear head diameter, Fe content, Zn content and total biomass per plant, when tested against pooled deviation.

The variance due to E + (G x E) was further partitioned into linear [Environment (linear) and G x E (linear)] and non-linear (pooled deviations) components. Mean square due to E + (G x E) component was significant for all the traits except Zn content, when tested against pooled error, while the same variance i.e. E + (G x E) was significant for all the traits except plant height, number of nodes on main stem and ear head length, when tested against pooled deviation. G x E (linear) component was significant for all the traits except number of nodes on main stem, ear head weight, grain yield per plant, test weight, Zn content and total biomass per plant, when tested against pooled error, while the same variance i.e. G x E (linear) was significant for ear head diameter, Fe content, Zn content, panicle index and total biomass per plant, when tested against pooled deviation. The mean squares due to environments (linear) was also noted significant difference for all the characters except Zn content when tested against both pooled error and pooled deviation. Mean squares due to pooled deviation was significant for all the characters except ear head diameter, Fe content, Zn content, total biomass per plant and harvest index when tested against pooled error.

Phenotypically stable varieties are usually sought for commercial production of crop plants. In any breeding programme is necessary to screen and identify phenotypically stable genotypes, which could perform more or less uniformly under different environmental conditions. Considering this fact in mind, the present investigation was carried out to identify stable genotypes of pearl millet. In the present study, the approach suggested by Eberhart and Russell (1966) [12] has been employed to understand the differential G x E interactions of parents and their hybrids and to assess the stability of the performance of different genotypes.

The stability of performance is one of the most desired characters of a genotype for wider adaptation. The stability parameters *viz*., mean performance (Xi), regression coefficient (bi) and deviation from linear regression (S^2di) for parents as well as hybrids were estimated for fifteen characters to assess the relative phenotypic stability of performance over environments.

Recently, interest has been focused on regression analysis. The regression approach was first proposed by Yates and Cochram (1938) [38] which was later modified by Finlay and Wilkinson (1963) [13] to interpret the varietal adaption to varying environments. Regression technique was slightly improved by adding one more parameters i.e. deviation from regression by Eberhart and Russel (1966) [12]. According to them, both linear (bi) and non-linear (S^2di) function should be considered while judging the phenotypic stability of genotype. Eberhat and Russell (1966) [12] defined a stable genotype as, which has a high mean yield (x), regression coefficient around unity (bi =1) and deviation from regression as small as possible (S^2di = 0). Later on, Breese (1969) [6] advocated that linear regression (bi) could simply be regarded as a measure of response of a particular genotype, whereas the deviation from regression (S^2di) as a measure of stability.

Table 2: Analysis of variance over the environment (Eberhart and Russel, 1966) for different characters in pearl millet

Sr. No.	Characters	Env	Genotypes (G)	G x E	E + (G x E)	E (L)	G x E (L)	Pooled dev.	Pooled error
		[2]	[69]	[138]	[140]	[1]	[69]	[70]	[414]
1.	Days to 50% flowering	158.35**++	07.36**++	01.97**	04.21**++	316.71**++	01.83**	02.08**	00.72
2.	Days to maturity	93.47**++	12.47**++	02.22**	03.52**++	186.95**++	02.49**	01.91**	00.87
3.	Plant height (cm)	288.50**++	630.09**++	50.48**	53.88**	577.01**++	47.68*	52.51**	29.34
4.	Number of effective tillers per plant	03.58**++	00.19**++	00.09**	00.14**+	07.17**++	00.08**	00.09**	00.02

5.	Number of nodes on main stem	07.28**++	01.41**++	00.22**	00.32**	14.57**++	00.13	00.32**	00.12
6.	Ear head length (cm)	07.41*+	18.32**++	01.92**	02.00**	14.82**++	01.99*	01.83*	01.26
7.	Ear head diameter (cm)	06.55**++	00.54**++	00.07**++	00.16**++	13.11**++	00.13**++	00.01	00.02
8.	Ear head weight (g)	42428.74**++	214.20**++	24.84**	630.61**++	84857.48**++	16.74	32.48**	15.86
9.	Grain yield per plant (g)	18458.94**++	196.00**++	16.62**	280.08**++	36917.89**++	12.86	20.09**	09.48
10.	Test weight (g)	17.3**++	01.64**++	00.18**	00.43**+	34.59**++	00.09	00.27**	00.11
11.	Fe content (ppm)	487.99**++	128.86*++	15.32**+	22.07**++	975.99**++	20.94**++	09.56	10.79
12.	Zn content (ppm)	04.995	55.31**++	04.24+	04.25+	09.99	05.47++	02.96	05.56
13.	Panicle index (%)	238.94**++	46.38**++	20.03**	23.16**+	477.89**++	25.49**++	14.36**	06.86
14.	Total biomass per plant (g)	60286.89**++	888.54**++	49.07++	909.61**++	120573.79**++	70.28++	27.45	67.93
15.	Harvest index (%)	2003.23**++	19.79**++	04.56**	33.12**++	4006.46**++	05.17*	03.91	03.26

*,** = Significant at 5% and 1% levels of probability, respectively against pooled error
+,++ = Significant at 5% and 1% levels of probability, respectively against pooled deviation
Value in parenthesis [ ] shows the degree of freedom for different source of variation

It is always justified to breed for genotypes with only high yield potential because of the times the yield potential cannot be expressed. Therefore, a much higher priority should be given to improve yield stability (Ceccarelli, 1989) [7] Stability is genetically controlled characters (Bradshaw, 1965 [5] and Scott, 1967 [30]) therefore, one can breed also for stability. Stability for yield may be dependent upon stability of different yield components. Hence, information on the relative stability for different yield components is essential to understand diverse mechanism contributing to yield stability. Stability in performance is one of the most desirable properties of a genotype for its wide adaptability.

Environmental index

The estimates of environmental index worked-out for different traits are presented in Table 3. E_1 was observed to be favorable for plant height (1.22), number of nodes on main stem (0.20) and panicle index (2.13), while E_2 was found to be congenial for all the traits except ear head length (-0.30) and panicle index (-1.04), whereas E_3 was favorable for days to 50% flowering (-1.40), ear head length (0.34), ear head weight (10.66), grain yield per plant (6.90), test weight (0.08) and total biomass per plant (27.34).

Table 3: Estimates of environmental index for various characters under different environments in pearl millet

Sr. No.	Characters	Environmental Index		
		E_1	E_2	E_3
1.	Days to 50% flowering	1.58	-0.18	-1.40
2.	Days to maturity	0.74	-1.33	0.58
3.	Plant height (cm)	1.22	1.12	-2.34
4.	Number of effective tillers per plant	-0.05	0.24	-0.19
5.	Number of nodes on main stem	0.20	0.16	-0.37
6.	Ear head length (cm)	-0.03	-0.30	0.33
7.	Ear head diameter (cm)	-0.19	0.35	-0.16
8.	Ear head weight (g)	-28.15	17.49	10.66
9.	Grain yield per plant (g)	-18.55	11.64	6.90
10.	Test weight (g)	-0.53	0.45	0.07
11.	Fe content (ppm)	-2.28	2.89	-0.61
12.	Zn content (ppm)	-0.24	0.28	-0.03
13.	Panicle index (%)	2.13	-1.04	-1.08
14.	Total biomass per plant (g)	-31.00	3.66	27.34
15.	Harvest index (%)	-4.49	5.91	-1.42

Estimation of Stability parameters

The stability of performance is one of the most desired characteristics of a genotype for wider adaptation. In present study linear regression is regarded as measure of responsiveness and deviation from regression as measure of stability of a particular genotype. The genotypes with higher *per se* performance with non- significant S^2d_i were classified on the basis of regression coefficient (b_i). The genotypes with $b_i < 1$ (significantly less than 1) were identified for adverse/poor environmental conditions, $b_i > 1$ (significantly higher than 1) for favourable/good environmental conditions and $b_i = 1$ for average environmental conditions. A genotype is considered to be stable in performance if it has high mean performance, unit regression coefficient (b_i=1) and least deviation from regression ($S^2d_i = 0$). Stability parameters *viz.*, mean performance (X_i), regression coefficient (b_i) and deviation from linear regression (S^2d_i) for parents as well as hybrids were estimated for fifteen characters to assess the relative phenotypic stability of performance over environments and the results for grain yield per plant is presented in Table 4.

The perusal of stability parameters for grain yield per plant and other 14 characters revealed that none of genotypes was stable for all the characters which indicated that any generalization pertaining to stability of genotypes for all the traits was not possible. For grain yield per plant, six parents and 44 crosses expressed their stability across the environments. Among them $ICMA_4$ 11999 x J-2591, $ICMA_4$ 11999 x J-2597, $ICMA_5$ 11999 x J-2597, $ICMA_1$ 14666 x J-2565, $ICMA_1$ 11999 x J-2597, $ICMA_5$ 11999 x J-2607, $ICMA_5$ 14666 x J-2565 and $ICMA_5$ 11999 x J-2591 were found as an eight top stable crosses due to their high grain yield per plant, regression coefficient (b_i) and non-significant deviation from linear regression (S^2d_i). The crosses, $ICMA_4$ 11999 x J-2591, $ICMA_4$ 11999 x J-2597, $ICMA_5$ 11999 x J-2597, $ICMA_1$ 11999 x J-2597, $ICMA_5$ 11999 x J-2607 and

ICMA$_5$ 11999 x J-2591 were having more grain yield per plant and had the least deviation from linear regression, but had significant regression coefficient (bi >1) and thus, found to be highly responsive to better environments. while ICMA$_1$ 14666 x J-2565 and ICMA$_5$ 14666 x J-2565 had more grain yield per plant with non-significant deviation from regression, but had significant regression coefficient (b_i < 1) showed above average response and high stability under unfavourable environments.

In general, parents found stable for grain yield per plant also depicted their stability of performance across the environments for one or more yield attributing traits. The highest yielding stable parent, J-2602 (57.16 g) was found to be stable for number of nodes per plant and ear head diameter. J-2607 was one of the parents of the stable hybrids (ICMA$_5$ 11999 x J-2607) for grain yield per plant. Its utilization in hybrid breeding would be useful in improvement of R-line breeding.

The eight stable hybrids for grain yield per plant are listed in **Table 5** along with their grain yield per plant and various component traits for which they showed stability. The perusal of the data revealed that the best three stable hybrids for grain yield per plant were ICMA$_4$ 11999 x J-2591 (77.62 g), ICMA$_4$ 11999 x J-2597 (76.32 g) and ICMA$_5$ 11999 x J-2597 (76.20 g). Among these, first ranked stable hybrid, ICMA$_4$ 11999 x J-2591 was found to be stable for days to maturity, number of nodes on main stem, ear head length, ear head weight, test weight, Fe content, Zn content, panicle index, total biomass per plant and harvest index.

In general, most of the hybrids identified as stable for grain yield per plant also showed stability for one or more component traits like days to 50% flowering, days to maturity, plant height, number of effective tillers per plant, number of nodes on main stem, ear head length, ear head diameter, ear head weight, test weight, Fe content, Zn content, panicle index, total biomass per plant and harvest index. This indicated that stability of various component traits might be responsible for the observed stability of various hybrids for grain yield per plant. Hence, chances of selection of stable hybrids for yield could be enhanced by selecting for stability for yield components. Grafius (1959) [14] also observed that stability of grain yield might be due to the stability of various yield components.

The stability parameters for component traits revealed that none of the parents and hybrids (genotypes) was stable for all the traits. The stability parameters for component traits revealed that 42 and 48 genotypes turned out to be stable each for days to flowering and days to maturity, respectively with low mean values (negative values were considered desirable for these traits), different regression coefficient values and non-significant deviations from linear regression. As many as 58, 39, 49, 59, 61 52 and 51 genotypes were found to be stable for plant height, number of effective tillers per plant, number of nodes on main stem, ear head length, ear head diameter, ear head weight and grain yield per plant, respectively with high mean, non-significant deviations from linear regression. Total of 60, 61, 63, 52, 63 and 59 genotypes turned out to be stable across the environments for test weight, Fe content, Zn content, panicle index, total biomass per plant and harvest index, respectively by recording high mean values for these traits with non-significant deviations from linear regression.

Traits wise result of genotypes showing specific adaptation to favourable (better management condition) and unfavourable (poor management condition) environments revealed that 12 and 10 genotypes for days to flowering, 10 and 38 genotypes for days to maturity, 16 and 9 genotypes for plant height, 14 and 1 genotypes for number of effective tillers per plant, 17 and 7 genotypes for number of nodes on main stem, 17 and 15 genotypes for ear head length, 21 and 8 genotypes for ear head diameter, 12 and 4 genotypes for ear head weight, 10 and 14 genotypes for grain yield per plant, 9 and 21 genotypes for test weight, 11 and 16 genotypes for Fe content, 23 and 13 genotypes for Zn content, 27 and 10 genotypes for panicle index, and 15 and 5 genotypes for total biomass per plant and 9 and 9 genotypes for harvest index, were found to be highly responsive to favourable and unfavourable environments, respectively.

The potential yield of each genotype can be realized under a particular set of agronomical practices. Hence, it is suggested that in order to identify stable genotypes, actual testing under variable environments including favourable and unfavourable would be advantageous. During selection, the attention should be paid to the phenotypic stability of characters directly related to grain yield per plant *viz*., number of effective tillers per plant, ear head length, ear head girth, ear head weight, grain yield per plant and test weight in pearl millet.

Among nine stable hybrids, best three stable hybrids for grain yield per plant were ICMA$_4$ 11999 x J-2591 (77.62 g), ICMA$_4$ 11999 x J-2597 (76.32 g) and ICMA$_5$ 11999 x J-2597 (76.20 g). Several research workers have also reported stability parameters for grain yeid and its componets *viz*., Singh and Gupta (1978) [33], Chaudhary *et al.* (1981) [8], Gupta *et al.* (1983) [16], Pethani and Kapoor (1985) [26], Gupta and Ndoye (1991) [37], Suryavanshi *et al.* (1991) [34], Chavan and Nerkar (1994) [9], Karale *et al.* (1997) [18], Yadav *et al.* (1997) [37], Prajapati *et al.* (1998) [27], Monyo *et al.* (2000) [23], Anarase *et al.* (2001) [1], Hanif *et al.* (2001) [17], Raiger and Prabhakaran (2001) [28], Shindhe *et al.* (2002) [31], Chikurte *et al.* (2003) [10], Kumar and Sahib (2003) [20], Umaretiya (2006) [35], Wedajo (2014) [36], Singh and Singh (2016) [32], Dadarwal *et al*. (2018) [11], Lagat *et al*. (2018) [22], Katariya *et al*. (2019) [25], Pawar *et al*. (2019) [25] and Kumar *et al*. (2020) [21].

Conclusion

From the foregoing discussion, it is clear that, parent J-2602 was found to be stable for grain yield per plant and some of the important yield components should be given due importance while formulating breeding programme aiming to develop high yielding and stable hybrids in pearl millet. The best stable cross combinations for grain yield per plant and important yield components were ICMA$_4$ 11999 x J-2591, ICMA$_4$ 11999 x J-2597 and ICMA$_5$ 11999 x J-2597. Thus, due importance to be given to this parent while formulating R- line breeding programme aiming to develop high yielding and stable hybrids in pearl millet.

Table 4: Stability parameters of different genotypes for grain yield per plant (g) in pearl millet

Sr. No.	Genotypes	Grain yield per plant (g)			
		Mean	b_i	$+SE_{bi}$	S^2d_i
Parents					
1.	ICMB 11999	56.56	0.96**	0.16	3.34
2.	ICMB 14666	50.49	0.85**+	0.07	-7.01
3.	ICMB 17777	52.74	0.72**	0.22	15.77
4.	J-2565	51.13	0.91*	0.39	70.93**
5.	J-2591	49.15	1.08**	0.29	35.48*
6.	J-2597	55.46	0.84**	0.21	13.20
7.	J-2602	57.16	1.27**++	0.01	-9.43
8.	J-2607	48.20	0.71**	0.19	8.83
9.	J-2618	54.08	0.80**	0.27	28.63*
Hybrids					
10.	$ICMA_1$ 11999 x J-2565	71.88	1.24**	0.37	63.64**
11.	$ICMA_1$ 11999 x J-2591	73.36	1.10**++	0.01	-9.47
12.	$ICMA_1$ 11999 x J-2597	74.89	1.02**	0.11	-3.07
13.	$ICMA_1$ 11999 x J-2602	71.48	1.29**	0.22	15.71
14.	$ICMA_1$ 11999 x J-2607	73.71	1.28**+	0.13	-0.78
15.	$ICMA_1$ 11999 x J-2618	71.54	1.11**++	0.01	-9.45
16.	$ICMA_4$ 11999 x J-2565	70.01	1.13**	0.23	19.24
17.	$ICMA_4$ 11999 x J-2591	77.62	1.20**++	0.05	-8.38
18.	$ICMA_4$ 11999 x J-2597	76.32	1.07**	0.07	-6.71
19.	$ICMA_4$ 11999 x J-2602	69.03	1.26**	0.23	17.94
20.	$ICMA_4$ 11999 x J-2607	73.36	1.29**	0.27	29.09*
21.	$ICMA_4$ 11999 x J-2618	70.96	1.00**	0.03	-8.96
22.	$ICMA_5$ 11999 x J-2565	71.09	1.11**	0.37	64.17**
23.	$ICMA_5$ 11999 x J-2591	74.00	1.07**	0.15	2.98
24.	$ICMA_5$ 11999 x J-2597	76.20	1.09**+	0.04	-8.53
25.	$ICMA_5$ 11999 x J-2602	70.80	1.22**	0.17	5.75
26.	$ICMA_5$ 11999 x J-2607	74.49	1.23**	0.33	47.15*
27.	$ICMA_5$ 11999 x J-2618	73.38	1.06**++	0.02	-9.24
28.	$ICMA_1$ 14666 x J-2565	75.53	0.96**	0.22	16.68
29.	$ICMA_1$ 14666 x J-2591	67.28	1.06**	0.24	20.51
30.	$ICMA_1$ 14666 x J-2597	69.63	0.84**	0.25	22.28
31.	$ICMA_1$ 14666 x J-2602	69.63	0.97**	0.11	-3.29
32.	$ICMA_1$ 14666 x J-2607	67.62	0.97**	0.14	0.87
33.	$ICMA_1$ 14666 x J-2618	70.21	1.06**	0.20	11.31
34.	$ICMA_4$ 14666 x J-2565	73.85	0.86**	0.21	14.60
35.	$ICMA_4$ 14666 x J-2591	62.17	0.97**	0.04	-8.67

Table 4: Contd…

Sr. No.	Genotypes	Grain yield per plant (g)			
		Mean	b_i	$+SE_{bi}$	S^2d_i
36.	$ICMA_4$ 14666 x J-2597	68.26	0.82**	0.19	9.21
37.	$ICMA_4$ 14666 x J-2602	69.64	1.04**	0.03	-8.86
38.	$ICMA_4$ 14666 x J-2607	68.65	0.96**	0.18	7.46
39.	$ICMA_4$ 14666 x J-2618	73.11	1.05**	0.23	19.23
40.	$ICMA_5$ 14666 x J-2565	74.44	0.88**	0.19	10.51
41.	$ICMA_5$ 14666 x J-2591	61.85	0.95**	0.03	-9.11
42.	$ICMA_5$ 14666 x J-2597	66.38	0.74*	0.30	37.27*
43.	$ICMA_5$ 14666 x J-2602	69.19	1.01**++	0.00	-9.48
44.	$ICMA_5$ 14666 x J-2607	68.86	0.97**	0.13	-0.85
45.	$ICMA_5$ 14666 x J-2618	72.01	1.05**	0.16	4.27
46.	$ICMA_1$ 17777 x J-2565	71.27	0.95**	0.05	-8.26
47.	$ICMA_1$ 17777 x J-2591	69.93	0.82**++	0.01	-9.48
48.	$ICMA_1$ 17777 x J-2597	66.50	1.21**	0.27	29.21*
49.	$ICMA_1$ 17777 x J-2602	68.91	1.00**	0.20	11.46
50.	$ICMA_1$ 17777 x J-2607	68.10	0.78**++	0.01	-9.39
51.	$ICMA_1$ 17777 x J-2618	72.84	1.03**	0.06	-7.53
52.	$ICMA_4$ 17777 x J-2565	70.87	0.84**	0.14	0.13
53.	$ICMA_4$ 17777 x J-2591	68.08	0.92**	0.17	5.89
54.	$ICMA_4$ 17777 x J-2597	66.60	1.27**	0.29	35.66*
55.	$ICMA_4$ 17777 x J-2602	67.81	0.97**	0.22	14.98
56.	$ICMA_4$ 17777 x J-2607	66.97	0.91**	0.17	5.46

57.	$ICMA_4$ 17777 x J-2618	73.68	0.99**	0.01	-9.44
58.	$ICMA_5$ 17777 x J-2565	73.67	1.01**	0.19	9.02
59.	$ICMA_5$ 17777 x J-2591	67.40	0.90**	0.27	28.98*
60.	$ICMA_5$ 17777 x J-2597	65.65	1.22**	0.44	94.85**
61.	$ICMA_5$ 17777 x J-2602	67.35	1.07**	0.29	33.83*
62.	$ICMA_5$ 17777 x J-2607	68.19	0.80**+	0.10	-4.03
63.	$ICMA_5$ 17777 x J-2618	72.53	1.05**	0.09	-5.64
Check					
64.	GHB 1129	54.08	0.83**	0.18	8.45
Mean		67.78	1.00	-	-

*, ** Significant at 5 and 1 percent levels, respectively as tested as $b_i/SE(b_i)$
+, ++ Significant deviation of bi from unity at 5 and 1 percent levels, respectively as tested as $1-b_i/SE(b_i)$

Table 5: The most widely adapted hybrids identified on the basis of grain yield per plant along with their stability for component traits in pearl millet

Sr. No.	Crosses	Mean (gm)	Stable yield attributes
1	$ICMA_4$ 11999 x J-2591	77.62	DM, NN, EL, EW, TW, FE, ZN, PI, TB, HI
2	$ICMA_4$ 11999 x J-2597	76.32	DF, NE, NN, ED, EW, TW, FE, ZN, PI, TB, HI
3	$ICMA_5$ 11999 x J-2597	76.20	DM, NE, NN, EL, ED, TW, FE, ZN, PI, TB, HI
4	$ICMA_1$ 14666 x J-2565	75.53	NE, NN, EL, ED, EW, ZN, PI, TB, HI
5	$ICMA_1$ 11999 x J-2597	74.89	DF, NE, NN, TW, FE, ZN, PI, TB, HI
6	$ICMA_5$ 11999 x J-2607	74.49	DF, NN, EL, TW, FE, ZN, PI, TB, HI
7	$ICMA_5$ 14666 x J-2565	74.44	DF, NE, EL, ED, EW, TW, FE, ZN, PI, TB,
8	$ICMA_5$ 11999 x J-2591	74.00	DF, DM, NN, EL, ED, TW, FE, ZN, PI, TB, HI

DF: Days to 50% flowering
DM: Days to maturity
PH: Plant height
NE: Number of effective tillers per plant
NN: Number of nodes on main stem
EL: Ear head length
ED: Ear head diameter
EW: Ear head weight
GY: Grain yield per plant
TW: Test weight
FE: Fe content
ZN: Zn content
PI: Panicle index
TB: Total biomass per plant
HI: Harvest index

References

1. Anarase SA, Ugale SD, Moholkar ND. Phenotypic stability of yield and yield components in pearl millet. J. Maharashtra Agric. Univ. 2001;7(3):250-252.
2. Anonymous. Directorate of Millets Development, 2020, Project Coordinator Review, 2020. (https://aicrp.icar.gov.in) accessed on 26 February, 2021.
3. Anonymous. Gujarat Agricultural Statistics at a Glance 2019-20, Directorate of Agriculture, Gujarat State Gandhinagar, 2020. (http:// dag.gujarat.gov.in) accessed on 26 February, 2021.
4. Baker RJ. Issues in diallel analysis. Crop Sci. 1969;18:533-536.
5. Bradshaw AD. Evolutionary significance of plasticity in plants. Adv. Genet. 1965;13:115-155.
6. Breese EL. The measurement and significance of genotype-environment interactions in grasses. Heredity. 1969;24:27-44.
7. Ceccarelli S. Wide adaptation, How wide? Euphytica. 1989;40:197-205.
8. Chaudhary BS, Subarao GV, Saxena MB, Manga VK. Note on phenotypic stability in population vs. hybrids of pearl millet. Ind. J. Agric. Sci. 1981;51:457.
9. Chavan AA, Nerkar YS. Heterosis and combining ability studies for grain yield and its components in pearl millet. J. Maharashtra Agric. Univ. 1994;19(1):58-61.
10. Chikurte KN, Desale JS, Anarse SA. Genotype x environment interaction for yield and yield components in pearl millet. J. Maharashtra Agric. Univ. 2003;28(1):30-33.
11. Dadarwal M, Gupta PC, Kajala IS. Phenotypic stability studies in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Ind. J. Agric. Res. 2018;52(3):278-283.
12. Eberhart SA, Russel WA. Stability parameters for comparing varieties. Crop Sci. 1966;6(1):36-40.
13. Finlay KW, Wilkinson GN. The analysis of adaptation in a plant breeding programme. Aus. J. Agric. Res. 1963;14(1):742-754.
14. Grafius JE. Heterosis in barley. Agron. J. 1959;40(1):58-53.
15. Gupta SC, Ndoye AT. Yield stability analysis of promising pearl millet genotypes in Senegal. Maydica. 1991;36(1):83-86.
16. Gupta SC, Ndoye AT, Andrews DJ. Variety traits of millet in senegal. Agro. Tro. 1983;38(1):229-233.
17. Hanif M, Fateh J, Javed HI, Malik HN, Hussain M. Stability analysis of millet varieties across diverse environments in Pakistan. Sarhad J Agric. 2001;3(2):243-249.
18. Karale MU, Ugale SD, Suryawanshi YB, Patil BD. Heterosis in line x tester crosses in pearl millet. Ind. J of Agric. Res. 1997;31(1):39-42.
19. Katariya HM, Khanpara MD, Vora Z, Parmar R, Patel JB, Kulkarni GU *et al*. Stability analysis in pearl millet (*Pennisetum glaucum* (L.) R. Br.). Int. J. Chem. Stu. 2019;7(2):242-251.
20. Kumar MH, Sahib KH. Phenotypic stability for grain and fodder yields in pearl millet. J. Res. Angaru. 2003;31(4):39-42.
21. Kumar R, Sudhir S, Prem S, Kumar A. Genetic analysis of grain yield and its attributes using diverse systems of male sterile lines and pollinators in direct sown and ratooned pearl millet. Int. J. Curr. Micro. App. Sci. 2020;9(2):486-499.
22. Lagat N, Kimurt P, Kiplagat O, Towett BK, Jeptanui L, Gatongi I *et al*. Evaluation of Genotype x Environment Interaction and Stability of Grain Yield and Related Yield Components in Pearl Millet (*Pennisetum glaucum*

(L.) R. Br.). J. Exp. Agric. Int. 2018;21(1):1-18.
23. Monyo ES, Mgonja MA, Chandari S, Chinhema E. Relative stability of selected pearl millet varieties from southern africa. Afri. Crop Sci. Conf. Proc. 2000;6(1):90-92.
24. Pal M, Deka J, Rai RK. Fundamentals of Cereals Crop Production. Tata McGraw Hill Publishing Company Limited, New Delhi, 1996.
25. Pawar VY, Magar NM, Awari VR, Kute NS, Patil HT, Deshmukh GP *et al*. Genotype x environment interactions for grain yield in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. J. Pharmacogn. Phytochem. 2019;8(3):2156-2159.
26. Pethani KV, Kapoor RL. Phenotypic stability for grain yield in pearl millet. Ind. J. Genet. 1985;45(1):362-367.
27. Prajapati BH, Patel NM, Khokhar AN. Genotype x environment interaction and stability analysis in pearl millet (*Pennisetum americanum* L.). Guj. Agric. Univ. Res. L. 1998;24(1):62-66.
28. Raiger HL, Prabhakaran VT. A study on the performance of a few parametric stability measures using pearl millet data. Ind. J. Genet. 2001;61(1):7-11.
29. Rao PP, Birthal PS, Reddy BV, Rai KN, Ramesh S. Diagnostics of sorghum and pearl millet grains-based nutrition in India. Int. Sorghum and Millets Newsletter. 2006;47:93-96.
30. Scott GE. Selecting for stability of yield in maize. Amer. Breeders Assoc. Rept. In Heterosis, (Ed. J.W. Gowen). Iowa State College Press. Amer, Iowa, USA. 1967;4:296-301.
31. Shindhe GC, Bhingarde MT, Khaimar MT, Methetre SS. AMMI analysis for stability of grain yield pearl millet [*Pennisetum typhoides* L.]. Ind. J. Genet. Pl. Breed. 2002;62(3):215-217.
32. Singh OV, Singh AK. Assessment of G x E interaction in pearl millet [*Pennisetum glaucum* (L.) R. Br.] germplasm in hot-arid climate of Rajasthan. Ind. J. Agric. Res. 2016;50(1):92-95.
33. Singh S, Gupta PK. Phenotypic stability in pearl millet. Ind. J. Genet. 1978;38:444-451.
34. Suryavanshi YB, Ugale SD, Patil RB. Phenotypic stability of yield and yield components in pearl millet. J. Maharashtra. Agric. Univ. 1991;16(2):218-221.
35. Umaretiya SV. Line x tester studies on heterosis, gene action and phenotypic stability in pearl millet [*Pennisetum glaucum* (L.) R. Br.], (Unpublished) Thesis, J. A. U., Junagadh, 2006.
36. Wedajo G. Evaluation of pearl millet [*Pennisetum glaucum* L.] Genotypes for yield and yield stability in south omo and west hararghe. J Bio. Agric. Healthcare. 2014;4(8):143-148.
37. Yadav R, Yadav HP, Chandra B. Stability analysis for grain yield in pearl millet. Agric. Sci. Digest. 1997;17(3):175-177.
38. Yates F, Cochran WG. The analysis of group of experiments. J Agric. Sci. 1938;28(1):556-580.