International Journal of Statistics and Applied Mathematics 2023; SP-8(4): 657-661

ISSN: 2456-1452
Maths 2023; SP-8(4): 657-661

https://www.mathsjournal.com
Received: 13-05-2023
Accepted: 14-06-2023

Alok Shrivastava
Department of Agricultural Statistics, NM College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

SB Kanzariya
Department of Agricultural Statistics, NM College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

KG Modha
Department of Genetics and Plant Breeding, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

YA Garde
Department of Agricultural Statistics, NM College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Nitin Varshney
Department of Agricultural Statistics, NM College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

PK Parmar
Department of Meteorology, NM College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Corresponding Author:
Nitin Varshney
Department of Agricultural Statistics, NM College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Assessment of stability and genotype-by-environment interactions in the grain yield of pearl millet [*Pennisetum glaucum* (L.) R.Br.]

Alok Shrivastava, SB Kanzariya, KG Modha, YA Garde, Nitin Varshney and PK Parmar

Abstract
Genotype by environment interaction (GEI) markedly influences the success of breeding strategies in versatile crops. Genotype environment interaction and stability performance were investigated on grain yield of Pearl Millet [*Pennisetum glaucum* (L.) R.Br.] in four environments (E1, E2, E3 and E4) during Kharif season of the year 2020-21 using 23 genotypes along with one standard check. The main objective of this study is to quantify and evaluate the effects of genotypes, environments and their interactions for the grain yield of pearl millet genotypes and to identify stable and/or high-yielding genotypes. Secondary data has been collected from the Main Pearl millet research station, Jamnagar, Junagadh Agricultural University, Gujarat. Statistical analysis is performed by Randomized Complete Block Design (RCBD) with three replications under four different environments. It has been found from the results that GEI was significant ($p<0.01$) for yield. Additive main effect and multiplicative interaction (AMMI) analysis was performed to identify stable genotypes. Our results showed that based on the AMMI biplot graph, the genotype GHB 1231(G5) was recorded highest-yielding genotype and the most stable genotypes were GHB 1225 (G4) and GHB 1240 (G10).

Keywords: Pearl millet, Genotype × environment interaction (GEI), Stability, AMMI.

Introduction
Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is one of the world's hardiest warm-season cereal crops, grown in the tropical and sub-tropical regions of the world. India is the largest producer of millets in the world, harvesting about 11 million tons per year, nearly 36% of the world's output. Pearl millet, which accounts for about two-thirds of millet production in India, is grown in the drier areas of the country, mainly in the states of Rajasthan, Maharashtra, Gujarat, Uttar Pradesh, and Haryana. In India, pearl millet is the fourth most widely cultivated food crop after rice, wheat, and maize. It occupies an area of 6.93 million ha with an average production of 8.61 million tons and productivity of 1,243 kg ha^{-1} (Directorate of Millets Development, 2020). The widespread impression that pearl millet grain is essentially an animal feed, unpalatable to all but the desperately hungry, is wrong. The grain is actually a superior foodstuff, containing high quality protein with a good balance of amino acids. It has more oil than maize and is a "high-energy" cereal. Pearl millet is also a versatile foodstuff since it has neither the tannins nor the other compounds that reduce digestibility found in sorghum. Non-alcoholic beverages and snacks can be made and grain from certain cultivars is roasted whole and consumed directly. Moreover amongst all cereals (maize, sorghum, finger millet etc.) pearl millet is the most nutritious with high levels of protein (up to 12%) and energy (3600 Kcal kg^{-1}). It has a cheap source of protein, grain iron (Fe) and zinc (Zn) (ICRISAT Report, 2007) [12]. The crop also forms an excellent feed for livestock both as grain and forage and thus advantageous as a dual-purpose crop (Yadav *et al*., 2011) [9]. In addition, pearl millet is easy to grow and suffers less from diseases as compared to sorghum, maize, or other grains. Despite the several advantages, on-farm productivity of pearl millet in many areas of semi- arid tropics is low partly due to the effect of several abiotic (rusts, insect pest) and biotic (drought, low soil fertility etc.) constraints (Yadav *et al*., 1999) [10].

The economical approach to control these constraints is through resistance breeding (Singh, 1990) [7] and selecting genotypes adapted to low input and drought-prone environments (Vadez *et al.*; 2012, Yadav *et al.*, 1996) [8, 11]. Unfortunately, the potential performance of improved genotypes under marginal conditions is always affected by the effect of genotype by environment interaction (GE) (Yan. 2012). These lead to selection of genotypes not suitable for particular environments and subsequently leading to low yield. It is therefore important to assess GE effect before releasing varieties. For successful selection, it is necessary to study the nature of the association of characters with other relevant traits. Hence several methods have been adopted to assess GE in pearl millet breeding [16].

Millet varieties are difficult to adapt to their production conditions due to the existence of significant GEI in the variety generation process. GEI has a significant influence on millets, despite its drought resilience, making it difficult and costly to choose and recommend new millet varieties for various situations.

The techniques for dividing GEI into a component due to each genotype determine how much each genotype contributes to GEI. A yield trial's stability should be taken into consideration (Rao and Prabhakaran, 2005) [6]. AMMI biplot analysis is recognized to be a useful method for diagnosing GEI behaviours graphically. This model splits the overall GEI impact of each genotype into interaction effects related to individual environments, in addition to providing an estimate of the total GEI effect of each genotype.

Materials and Methods

General Information

The secondary data was collected from Main Pearl millet research station, Jamnagar, Junagadh Agricultural University in *kharif* season of the year 2018-2019 with 23 genotypes in Randomized Block Design (RBD) with three replications across 4 environments *viz.* Amreli (E1), Anand (E2), Dhari (E3) and Talaja (E4). Observations were recorded on six characters *viz.*, grain yield, fodder yield, days to maturity, ear head length, effective tillers per plant and plant height.

Table 1: List of pearl millet genotypes utilized in the study

Serial no.	Code	Genotypes
1	G1	GHB 1129
2	G2	GHB 1203
3	G3	GHB 1214
4	G4	GHB 1225
5	G5	GHB 1231
6	G6	GHB 1232
7	G7	GHB 1234
8	G8	GHB 1237
9	G9	GHB 1239
10	G10	GHB 1240
11	G11	GHB 1241
12	G12	GHB 1242
13	G13	GHB 1245
14	G14	GHB 1247
15	G15	GDBH 1
16	G16	GHB 538
17	G17	GHB 558
18	G18	GHB 732
19	G19	GHB 744
20	G20	GHB 905
21	G21	86M11
22	G22	9444
23	G23	Dhanshakti (C)

AMMI model

The AMMI (Additive Main Effect and Multiplicative Interaction) model combines ANOVA for the genotypes and environments' main effects with principal component analysis of the G×E interaction (GEI). AMMI partitions the overall variation into genotype main effects, environment main effects and GEI.

Table 2: Analysis of variance (ANOVA) of the AMMI model for stability analysis

Source	DF
Treatment	(ge-1)
Replication	(r-1)
Error	(ge-1), (r-1)
Genotype	(g-1)
Environment	(e-1)
G × E	(g-1)(e-1)
IPCA1	(g+e-1-2n)
IPCA2	(g+e-1-2n)
Residual	(g-1), (e-1)-2 (g+e-4)
Total	(ger-1)

Where,

r = number of replications

g = number of genotypes

e = number of environments

n = number of axes.

Results and discussion

Descriptive Statistical Analysis

The coefficient of variation for all environments were mentioned in Table 3. Environment Dhari (E3) has the highest 20.87% coefficient of variation while the lowest coefficient of variation, 12.43% has been found for the environment Anand (E2). It was discovered that E3 had the greatest variation in pearl millet grain yield per plant. The genotypic, phenotypic and environmental variance was found highest in Dhari (E3) among all the environments. In general, the phenotypic coefficient of variation (PCV) was somewhat higher than the genotypic coefficient of variation (GCV) demonstrating the importance of the environment in character expression. These findings were similar to studies by Bhusan *et al.* (2013) [2], Kumar *et al.* (2014) [4].

Table 3: Descriptive statistics for various genotypes of pearl millet at different environments for grain yield (t/ha)

	Amreli (E1)	Anand (E2)	Dhari (E3)	Talaja (E4)
Descriptive statistics				
Mean	3.04	3.11	2.69	1.59
Standard Dev.	0.38	0.39	0.56	0.21
CV%	12.57	12.43	20.87	13.02
S.Em	0.22	0.22	0.33	0.12
CD (0.01)	0.84	0.85	1.24	0.46
Genetic parameters				
GCV	10.96	10.27	17.73	21.25
PCV	16.68	16.12	27.39	24.93
h_b^2	43.23	40.55	41.92	72.7
GA	0.45	0.42	0.64	0.59
GAM %	14.85	13.47	23.65	37.33

AMMI Score and Biplot Interpretation

The mean sum square for the environment, genotype and G × E interaction were 11.40, 0.30 and 0.16 respectively (Table 4). The first and the second interaction PCA were highly significant (p<0.01), capturing (53.6%) and (24.5%) of the total variation in the GEI SS, respectively (Table 5). These findings were in conformity with those of Akcura *et al.* (2005) [1], Pabale *et al.* (2010) [5].

Table 4: Analysis of variance (ANOVA) for the AMMI model for grain yield

Source	DF	SS	MS
Genotype	22	6.61	0.30**
Environment	3	34.21	11.40**
G × E	66	10.42	0.16**
AMMI 1	24	5.58	0.23**
AMMI 2	22	2.55	0.12**
Total	137	59.37	

*, **Significant at 5% and 1%

According to Fig. 1, the genotypes or environments placed left-hand side of the vertical line possess less yield as compared to average yield and genotypes and environments placed right-hand side of the vertical line possess higher yield than average yield.

The genotypes G5, G4, G1, G6, G22, G18, G12, G9, G2 and G19 possess high grain yield than average yield in decreasing order. The genotypes G8, G11, G3, G14, G16, G21, G13, G17 and G23 possess low grain yield than average yield in decreasing order. The genotype G5 was recorded as the highest-yielding genotype in E2 which is also the highest-yielding and stable environment among all the environments because it is placed near the horizontal line.

Table 5: PCA scores for genotypes and environments

AMMI scores for genotypes			
Code	**Genotypes**	**IPCA1**	**IPCA2**
G1	GHB 1129	0.31	0.51
G2	GHB 1203	0.19	0.08
G3	GHB 1214	-0.35	0.19
G4	GHB 1225	-0.05	-0.01
G5	GHB 1231	-0.27	-0.14
G6	GHB 1232	-0.34	-0.15
G7	GHB 1234	-0.17	-0.03
G8	GHB 1237	0.38	-0.05
G9	GHB 1239	-0.23	0.06
G10	GHB 1240	0.04	-0.04
G11	GHB 1241	0.08	-0.28
G12	GHB 1242	-0.01	-0.22
G13	GHB 1245	-0.54	0.32
G14	GHB 1247	-0.41	0.01
G15	GDBH 1	-0.23	-0.02
G16	GHB 538	0.41	0.5
G17	GHB 558	0.19	-0.06
G18	GHB 732	-0.27	-0.49
G19	GHB 744	-0.11	0.49
G20	GHB 905	-0.16	-0.21
G21	86M11	0.67	-0.46
G22	9444	0.29	-0.08
G23	Dhanshakti (C)	0.58	0.08
AMMI scores for environments			
E1	Amreli	0.87	-0.7
E2	Anand	-0.18	-0.25
E3	Dhari	-1.16	-0.07
E4	Talaja	0.47	1.02

In Fig. 2, The origin of the graph which lies at zero on the x-axis and y-axis represented the most stable genotypes as compared to another genotype. Here, G4 and G10 were the most stable genotypes in all the environments. According to this figure, G10, G21 and G17 had related to E1 whereas G20 adapted to E2. While G15, G7 and G14 were favourable in E3 and G1 adapted in E4. The genotypes G19, G18, G13 and G16 had performed poorly because these genotypes were far from their origin. The above data implies that the genotypes G5, G4 and environment E2 were recommended for a higher yield with higher stability, whereas G4 and G10 were recommended for higher stability of yield across all environments.

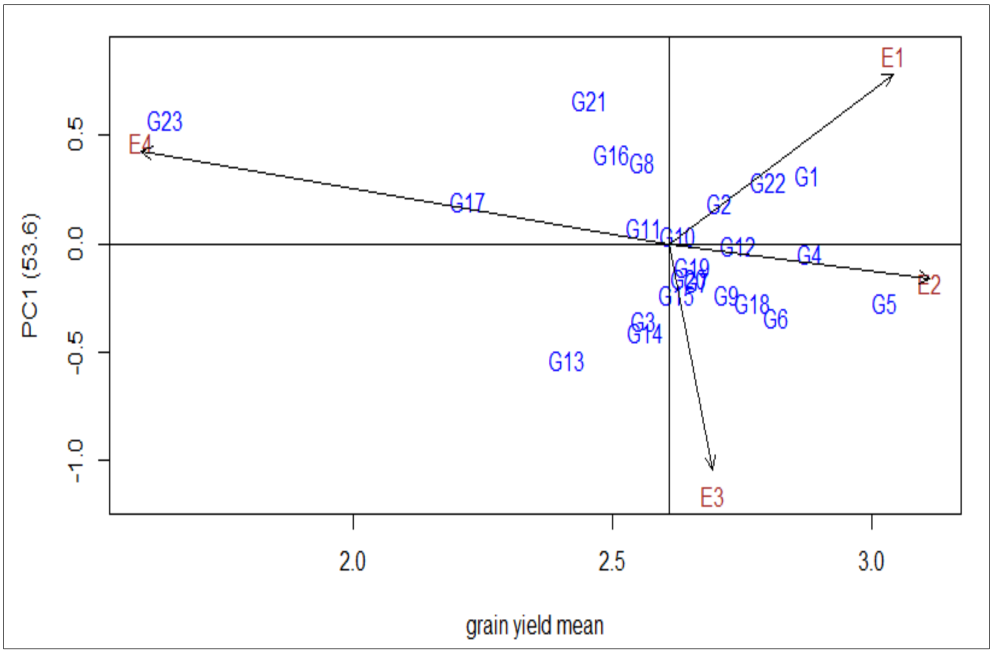

Fig. 1: AMMI 1 (Mean vs PC1) biplot for the pearl millet grain yield

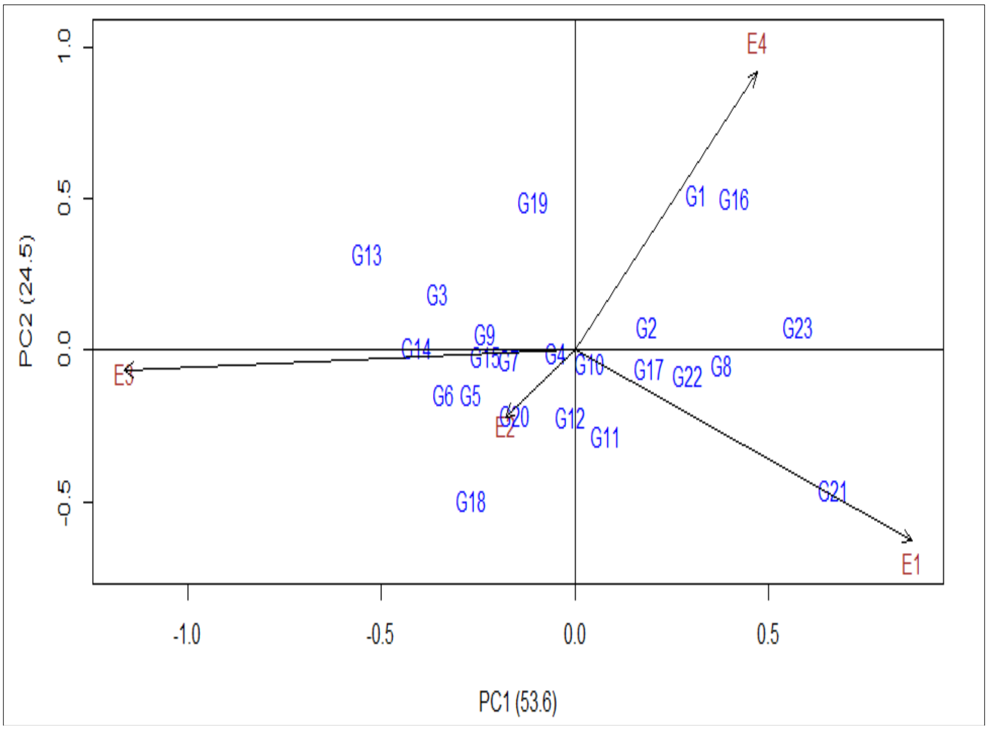

Fig 2: AMMI 2 (PC1 vs PC2) biplot for the pearl millet grain yield

Conclusion

The current study concluded that the genotype GHB 1231 (G5) and environment Anand (E2) was recommended for the higher yield and higher stability, whereas the genotypes GHB 732 (C) (G18), GHB 1239 (G9) and GHB 1242 (G12) genotypes had average yield but excellent stability according to AMMI 1 biplot. The genotypes G10 and G4 were found the most stable genotypes among all environments.

Acknowledgement

The authors are thankful to Navsari Agricultural University, Navsari for providing facilities.

Competing Interests

The authors have declared that no competing interests exist.

References

1. Akcura M, Kaya Y, Taner S. Genotype-environment interaction and phenotypic stability analysis for grain yield of durum wheat in the central Anatolian region. Turkish Journal of Agriculture and Forestry. 2005;29(5):369-375.
2. Bhushan B, Bharti S, Ojha A, Pandey M, Gourav SS, Tyagi BS, *et al*. Genetic variability, correlation coefficient and path analysis of some quantitative traits in bread wheat. J wheat res. 2013;5(1):21-26.
3. Bassi JA, Kabura BH. Performance of pearl millet [*Pennisetum glaucum* (L.) R. Br.] Varieties intercropped with cowpea varieties as affected by planting dates in Nigerian Sudan savanna. Int. J Agric. Nutr. 2020;2(1):29-35. DOI: 10.33545/26646064.2020.v2.i1a.28

4. Kumar R, Harish S, Dalal MS, Malik V, Devvart Chugh LK, Garg P, *et al*. Studies on variability, correlation and path analysis in pearl millet [*Pennisetum glaucum* (L.) R. Br.] Genotypes. Forage Res. 2014;40(3):163-167.
5. Pabale SS, Pandya HR, Mehta DR. Additive Main Effects and Multiplicative Interaction (AMMI) analysis for grain yield of pearl millet in Gujarat. Int. J. Appl. Agric. Sci. 2010;5(4):541-547.
6. Rao AR, Prabhakaran VT. Use of AMMI in simultaneous selection of genotypes for yield and stability. J. Indian Soc. Agric. Stat. 2005;59(1):76-82.
7. Singh SD. Sources of resistance to downy mildew and rust in pearl millet. Plant disease. 1990;74(11):871-4.
8. Vadez V, Hash T, Bidinger FR, Kholova J. Phenotyping pearl millet for adaptation to drought. Frontiers of Physiology. 2012;3:1-12.
9. Yadav OP, Rai KN, Khairwal IS, Rajpurohit BS, Mahala RS. Breeding pearl millet for the arid zone of northwestern India: Constraints, Opportunities and approaches. All India Coordinated Pearl Millet Improvement Project, Jodhpur, India; c2011.
10. Yadav MS, Duhan JC. Effect of fungicidal seed treatment by seed dresser on storage life and survival of smut spores of pearl millet. Crop Research. 1999;18:124-126.
11. Yadav OP. Pearl millet breeding: achievements and challenges. Plant Breeding Abstracts. 1996;66:157-163.
12. ICRISAT. Production Trends in pearl millet production: International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India; c2007.