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Research Article

GGE BIPLOT ANALYSIS OF PEARL MILLET EXPERIMENTAL HYBRIDS (*Pennisetum glaucum* (L.) R. Br.) FOR YIELD PERFORMANCE AND STABILITY ACROSS DIFFERENT ENVIRONMENTS IN INDIA

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Abstract: The study was conducted in A zone and B zone of millet growing parts of India at Alwar, Aurangabad, Jaipur and Jamnagar during 2019 rainy season. Hundred and forty four pearl millet hybrids were tested at different locations and promising hybrids were identified. The experiment was conducted using alpha lattice design with two replications. The analysis of variance (ANOVA) indicated that the mean grain yield ranged from 518.4 to 3779.2kg ha^{-1} for top cross hybrids MBL-11 X MOPT-24 (518.4 kg ha^{-1}) to 3779.2 kg ha^{-1} for MBL-4 X MOPT-26. Sixteen hybrids were found superior (3305.6 kg ha^{-1} to 3779.2 kg ha^{-1}) over best commercial check kaveri super boss (3297.0 kg ha^{-1}). GGE biplot analysis showed a total of 83.5% variation was showed for the tested pearl millet hybrids at different environments. The study result revealed that the most responsive of the corner hybrids were MBL-11 X MOPT-24, MBL-10 X MOPT-26, MBL-3 X MOPT-26 and MBL-13 X MIT-21. MBL-4 X MOPT-26 which was closer to the AEC x-axis arrow had the highest mean grain yield followed by MBL-14 X MOPT-26 and MBL-15 X MIT-21. Whereas, hybrids MBL-13 X MIT-21, MBL-6 X MIT-23 and MBL-8 X MIT-21 had the longest projection from the AEC x-axis were highly unstable. In terms of stability and performance hybrid MBL-4 X MOPT-26 was the highest followed by Hybrids MBL-6 X MIT-22, MBL-7 X MOPT-25 and MBL-12 X MOPT-27.

Keywords: *GGE biplot, Hybrids, Grain yield, Stability, Pennisetum glaucum*

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Introduction

If there were no GxE associated with the genotype x environment system relevant to a breeding objective, selection would be greatly simplified because the 'best' genotype in one environment would also be the 'best' genotype for all target environments [1]. The ultimate reason for differential stability among genotypes and for differential results from various test environments is non-repeatable GxE [2]. The study was carried out to interpret Genotype-Environment (G×E) interaction effects on pearl millet grain yield via AMMI analysis, find out stability and adaptation pattern of genotypes using graphical representation of GGE biplot, and determine the most suitable genotypes while combining a high level of grain yield with yield stability [3].

The main objectives of the study were to determine the magnitude and patterns of G×E interaction effects in pearl millet using GGE biplot methods of analysis, to display graphically the mean performance and stability of 140 pearl millet genotypes.

Materials and Methods

Hundred and forty pearl millet experimental hybrids (Single and top cross hybrids) including four standard checks (9444, HHB 67 Imp, GHB 538 and Kaveri Super Boss) were used as an experimental material. The study was performed in an alpha lattice design with two replications across four test locations during 2019 rainy season. The tested locations were Alwar, Aurangabad, Jaipur, and Jamnagar respectively. Sowing and other related agronomic practices were done as per recommendations. Data were collected from each location and treated separately [4].

Results and Discussion

Grain yield performance of 140 Pearl millet experimental hybrids along with checks were grown at different environments are described. The mean grain yield ranged from 518.4 to 3779.2kg ha^{-1} for top cross hybrids MBL-11 X MOPT-24 (518.4 kg ha^{-1}) to 3779.2 kg ha^{-1} for MBL-4 X MOPT-26. From the total pearl millet experimental hybrids seventy six hybrids showed above the mean average yield [5]. However, sixteen hybrids were found superior (3305.6 kg ha^{-1} to 3779.2 kg ha^{-1}) over best commercial check kaveri super boss (3297.0 kg ha^{-1}).

Combined analysis

The combined analysis of variance (ANOVA) for pearl millet genotypes that were evaluated at different locations has been described. The analysis of variance (ANOVA) revealed that the mean grain yield showed highly significant variation for the tested locations and the interaction of genotypes bythe environment [Table-1].

Table-1 Combined analysis of ANOVA for pearl millet hybrids evaluated at different locations for grain yield

Source of variation	d.f.	SS	MS	v.r.	F pr.
Environment	3	791200000	263700000**	724.28	<.001
Treatment	118	467200000	3960000**	10.87	<.001
Treatment x Environment	348	252800000	726400**	1.99	<.001
Residual	459	167100000	364100		

GGE biplot analysis

The environment and genotype effects were highly significant in the Additive Main Effect and Multiplicative Interaction (AMMI) model, implying that environments are varied and genotypes performed differently in each environment offering a great scope for selecting better adaptive hybrids [10, 11].

The combined analysis of variance showed significant differences among genotypes, environments and Genotype by Environment (G x E) interaction for all morphological characters under study [12]. The GGE biplot analysis showed that PCA1 and PCA2 described for 45.9% and 37.5% of GGE sum of squares respectively for grain yield of pearl millet hybrids [Table-2], elucidating a total of 83.50% variationas indicated in [Fig-1].

Table-2 Analysis of variance for the AMMI model of the 144pearl millet hybrids in the 4 environments for grain yield

Source	df	Sum of squares	Explained %	Mean squares
Environments(E)	3	1111613464		370537821.4**
Genotypes (G)	143	352596701.8		2465711.2**
G x E	429	245661417.2		572637.3**
IPCA 1	145	112806835.6	45.91	777978.1**
IPCA 2	143	92216032.13	37.53	644867.3**
IPCA 3	141	40638549.44	16.54	288217
Residuals	576	183872801.7		

*** Significant at P<0.01*

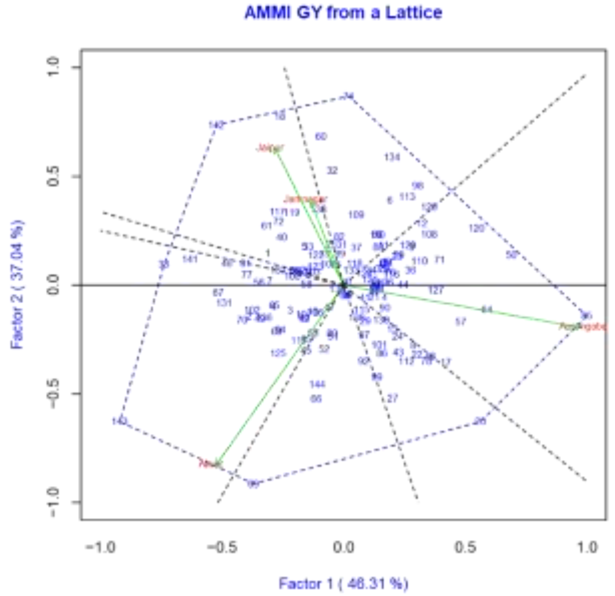

Fig-1 GGE biplot analysis of 144 pearl millet hybrids evaluated across different environments during 2019 rainy season.

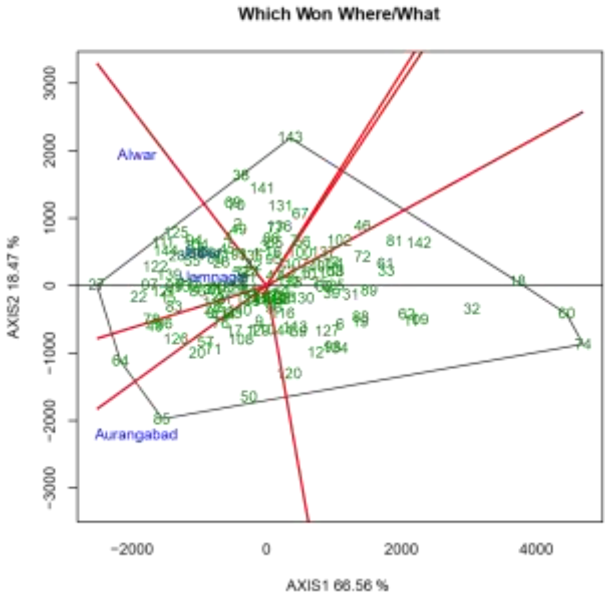

Fig-2 The “which-won-where” view of the GGEbiplot based on the G × E data

The GGE biplot analysis for pearl millet hybrids grown indifferent environments are presented in [Fig-1]. The most responsive of the corner hybrids were MBL-11 X MOPT-24, MBL-10 X MOPT-26, MBL-3 X MOPT-26 and MBL-13 X MIT-21.[6].

The which-won-where biplot [Fig-2] showed different winning genotypes in different environments. Pearl millet hybrid MBL-4 X MOPT-26 won in most of the environments during year 2019. In [Fig-1-4] hybrid MBL-4 X MOPT-26 was favorable at Alwar, Jaipur and Jamnagar. This elucidated that Hybrid MBL-4 X MOPT-26 had broader favorable environments as compared toother pearl millet hybrids [9].

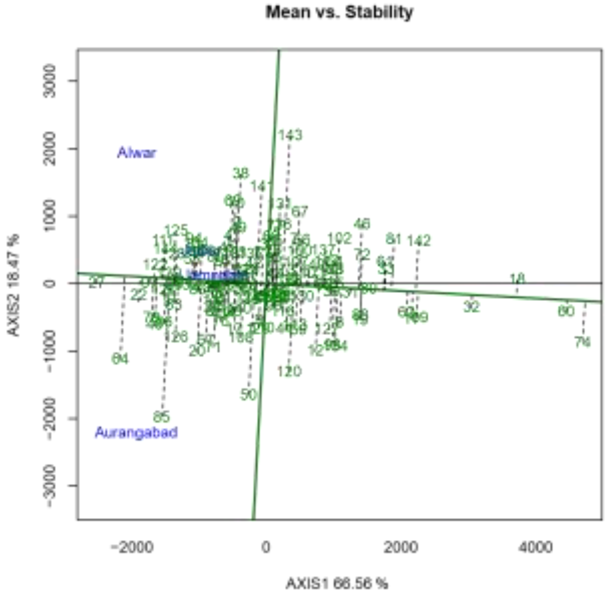

Fig-3 Mean performance and stability of pearl millet hybrids

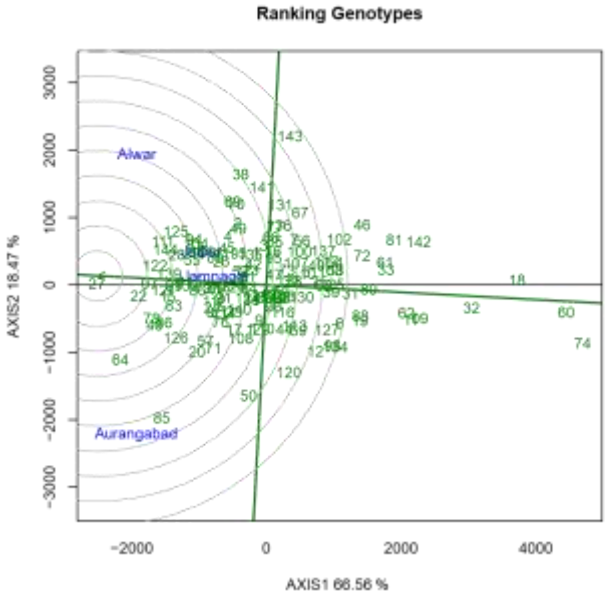

Fig-4 GGE biplot of ideal hybrid and comparison of the hybrids with the ideal hybrids

The average performance and stability of pearl millet hybrids were indicated in [Fig-3]. Hybrids were arranged in ranking along the average environment coordinate or average environment axis (AEC x-axis) with an arrow indicating the highest value based on their mean performance across different environments. As indicated in [Fig-3] MBL-4 X MOPT-26 which was closer to the AEC x-axis arrow had the highest mean grain yield followed by MBL-14 X MOPT-26 and MBL-15 X MIT-21 this reveals that top cross hybrid is the ideal hybrid because of high mean yield and stable compared to other hybrids [8]; whereas, hybrids MBL-3 X MOPT-24, MBL-5 X MOPT-24 and MBL-9 X MOPT-24 invisible hybrids which were located further away from the AEC x-axis arrow had the poorest yields [7]. Four checks were found to be significantly low yielders than the test hybrids across India, indicating the potential of genetic improvement through top cross hybrids [8]. Pearl millet hybrids MBL-13 X MIT-21, MBL-6 X MIT-23 and MBL-8 X MIT-21with the longest projection from the AEC x-axis were highly unstable. Similarly, MBL-14 X MOPT-26 and MBL-15 X MIT-21 where some other invisible hybrids were highly stable.

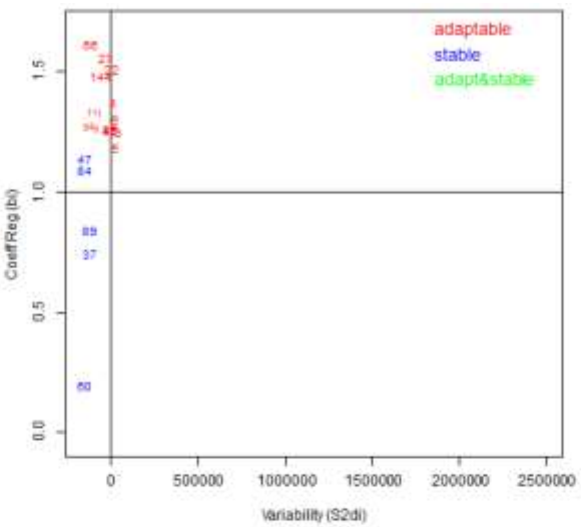

Fig-5 Highly stable and adaptable genotypes across the environments

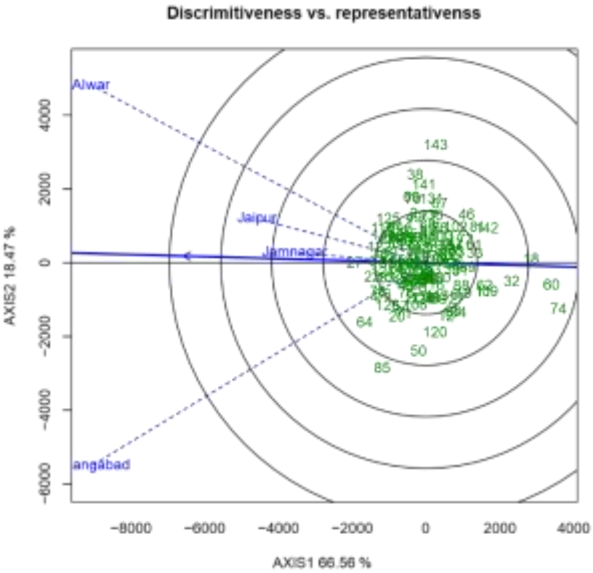

Fig-6 Ranking environments based on discriminating ability and representativeness for grain yield data

However, from breeding point of view stable and better performance genotypes are highly recommended for further production viz., MBL-6 X MIT-22, MBL-7 X MOPT-25, MBL-9 X MOPT-24, MBL-12 X MOPT-27 and MBL-13 X MOPT-25 [Fig-5]. Based on this, Hybrid of MBL-4 X MOPT-26 had better performance and stable as compared to others. So that in terms of stability and better performance hybrid MBL-4 X MOPT-26 is a recommended hybrid followed by hybrid MBL-7 X MOPT-25 and hybrid MBL-12 X MOPT-27 as indicated [Fig-5].

Conclusion

In GGE analysis identification of ideal hybrid is one of the basic elements to identify the hybrid among the tested hybrids that have been evaluated at different environments. Hence, MBL-4 X MOPT-26 is the ideal hybrid followed by MBL-6 X MIT-22 and MBL-12 X MOPT-27 because there is smaller distance from the hybrids to the virtual ideal hybrid as indicated [Fig-4]. Jamnagar and Jaipur were closest to this point and therefore, best, whereas Alwar and Aurangabad were poorest for selecting hybrids adapted to the whole region. [Fig-6] was based on a "Tester-centered (G + GE)" table, without any scaling and it is column metric preserving.

Application of research: Stable hybrids could be used directly for commercial use or transgressive segregants with good buffering capacity could be developed from these stable or adaptable hybrids.

Research Category: Genetic and plant breeding

Abbreviations: MBL- Millet B lines, MIT- Millet Inbred lines
MOPT- Millet open pollinated variety as tester
AEC - Average-environment coordination, AEA - Average-environment-axis
ATC - Average tester coordinate, MET - Multiple environment trials
AMMI - additive main effects and multiplicative interaction

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Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Research Farms, International Crops Research Institute for The Semi-Arid Tropics, Patancheru, Telangana, India

Cultivar / Variety / Breed name: Pearl Millet (*Pennisetum glaucum* (L.) R. Br.)

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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