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RESEARCH ARTICLE Legume Research- An International Journal, Volume Issue : ()

AMMI and GGE Biplot Analysis of Seed Yield and Batter Quality Traits in Blackgram [*Vigna mungo* (L.) Hepper]

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10.18805/LR-4574

ABSTRACT

Background: Blackgram is an important pulse crop consumed in the form of fermented cuisines especially in south India. Yield being a complex trait, is highly influenced by environment. Studies on environmental influence on batter quality are rare. Hence, the current study was taken up to identity stable genotypes over environments with respect to yield and batter quality traits.

Methods: In the present study, 32 blackgram genotypes were evaluated for yield performance and batter quality traits during *kharif* 2019*, rabi* 2019-20 and *summer* 2020 at National Pulses Research Centre, Vamban. Pooled analysis of variance and stability analysis was performed by AMMI and GGE biplot.

Result: From stability analysis, it was evident that the genotypes, ACM BG 17-001, ACM BG 17-006 and ACM BG 18-010 expressed high mean value and stability for seed yield. In case of idly batter volume, the genotypes, ACM BG 17-001 was stable hence may be recommended for all season cultivation. The trait, vada batter volume was found to be with non-significant GxE interaction and hence do not interact with the environment. Among the environments under study, summer season was the most favourable environment for seed yield. However, for idly batter quality, *kharif* season was the most favourable environment.

Key words: AMMI, Batter volume, Blackgram, GGE biplot, Seed yield.

INTRODUCTION

Blackgram [*Vigna mungo* (L.) Hepper] is one of the important *kharif* pulse crops of India. The area under blackgram in India is 4.50 million hectares with a production of 3.23 million tonnes(Project Coordinator Report, 2018). It is an important pulse crop especially to south India as fermented food in the form of idli, dosa and vada. The speciality of blackgram in idly preparation is mainly due to the mucilaginous material present in it, which is almost absent in all other edible legumes. Yield, is an ultimate motive of any crop improvement programme. It is a complex trait influenced by many traits as well as the environment. Hence, there is a great need to identify the suitable genotypes/lines for their yield and yield components before practicing breeding. The genotype x environment interaction is an important parameter to be noted in plant breeding programmes to identify the stable genotypes that are widely adapted to the unique environment (Verma *et al*., 2008). G x E interaction also affects the genetic gains, recommendation and selection of cultivars with wider adaptability (Deitos *et al.,* 2006; Lal *et al.,* 2019). The knowledge about the influence of genotypes in battering quality is scarce. Genotypes play their role in contributing quality characters along with processing. Hence developing high yielding stable blackgram genotypes along with good battering quality becomes a need of the hour to enhance the area and production all over the country. By keeping in view, the above facts under consideration, the present study was taken up to evaluate the genotype x environment interaction of 32 blackgramgenotypes in three different seasons and to identify thestable genotypes suitable for cultivation.

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How to cite this article: Rajalakshmi, K., Manivannan, N., Anand, G., Vanniarajan, C. and Harish, S. (2021). AMMI and GGE Biplot Analysis of Seed Yield and Batter Quality Traits in Blackgram [*Vigna mungo* (L.) Hepper]. Legume Research. DOI: 10.18805/LR-4574.

Submitted: 28-12-2020 **Accepted:** 13-03-2021 **Online:** 17-04-2021

MATERIAL AND METHODS

The experiment was carried out during *kharif* 2019 (June-Sep) (E1), *rabi* 2019-20 (Nov-Jan) (E2) and *summer* 2020 (March-May) (E3) at National Pulses Research Centre, Vamban. A total of 32 genotypes were evaluated in randomized complete block design with two replications in each environment. The data on seed yield and batter quality were subjected to statistical analysis. The G X E interaction was studied as per AMMI model (Zobel *et al*., 1988) and GGE biplot (Yan, 1999 and Yan *et al*., 2001). Analyses were carried out using the software, PB tools (ver 1.3) developed by International Rice Research Institute, Philippines.

Vada batter preparation

Blackgram split dhals of each genotype were cleaned, sun dried for a day and stored in plastic containers. A quantity of 20 ml of blackgram split dhal of each genotype was measured in a measuring cylinder and used for the preparation of batter. Blackgram dhal was washed thrice in clean water to remove the husk and any adhering dirt and dust. The grains were soaked separately in clean water at normal room temperature for two hours. The soaked blackgram dhal was ground into a gelatinous paste using the grinder. Water was added based on the requirement for each genotype. After grinding, the batter volume was estimated by measuring cylinder (Veni *et al*., 2016).

Idly batter preparation

Idli batter is a combination of cereal and pulse and it principally comprises of rice and blackgram. The ratio of rice and blackgram was 80ml rice/20 ml blackgram. Parboiled, milled rice of CR1009 variety was obtained from local market, Pudukkottai was used. Split dhal of blackgram genotypes was cleaned, sun dried for a day and stored in plastic containers. Parboiled rice and blackgram dhal were washed thrice in clean water to eliminate husk and any adhering dirt and dust. The grains were soaked in clean water at normal room temperature. The duration of soaking was four hours for rice and two hours for blackgram. The soaked rice and blackgram dhal of each genotype were ground separately in a grinder. The amount of water added was 1.5 to 2 times the dry weight of the ingredients. The rice was ground into the coarse batter. The blackgram was ground into a smooth gelatinous paste, when lifted by hand. The batter was mixed and 0.8 percent salt added. The *idli* batter was incubated at normal room temperature for fermentation for 12 hrs. The containers utilized for fermenting the batter were of sufficient capacity to hold the leavened batter. They were cleaned well to eliminate any contamination and kept closed to prevent the entry of any insects. The final batter volume was estimated by measuring the fermented rice and blackgram batter volume after gentle stirring (Veni *et al*., 2016).

RESULTS AND DISCUSSION

Data on each environment were analyzed separately. The results indicated that genotypes were found to be significant in all the three environments. Further, the data on all three locations were subjected in to pooled analysis of variance for seed yield and batter quality traits (Table 1). The results indicated that the traits seed yield (g) and idly batter quantity (ml) showed significant GxE interaction and hence the data were subjected to stability analysis. Manivannan *et al.* (2019) also reported similar results for seed yield in cowpea.

Stability analysis by AMMI model

AMMI biplot analysis is considered to be an efficient tool to explore G × E interactions graphically. The variance due to environment was significant for all the traits under study. The variance due to GxE interaction was significant for seed yield per plant (g) and idly batter (ml). The remaining character, vada batter volume depicted non-significant GxE interaction. This proves that the character, vada batter (ml) was not influenced by the environment and stable over environments. It can be interpreted that for evaluating genotypes for vada batter volume, it is not necessary to evaluate over different environments but a single environment analysis is sufficient. Hence, stability analysis was carried out for those traits with significant GxE interaction.

The analysis of variance for AMMI was presented in Table 2. The IPCA 1 and IPCA 2 were significant for both traits and the per cent explained by IPCA I and IPCA II for seed yield was 68.5% and 31.5% whereas it was 74.9% and 25.1% for idly batter volume respectively. The mean and IPCA scores for seed yield per plant (g) was presented in Table 3 and Fig 1 and 2. As per AMMI biplot 1 (Fig 1), checks, MDU 1 (G28) and VBN (Bg) 4 (G30) have high mean along with IPCA value around zero among the checks and hence stable. The genotypes, ACMBG 14-001 (G1), ACMBG16-011 (G2), ACMBG 16-015 (G3), ACM BG 17-001 (G6), ACM BG 17-006 (G11), ACM BG 18-007 (G19) and ACM BG 18-010 (G22) have high mean and IPCA value near zero and hence stable. With regard to the AMMI biplot 2 (Fig 2),

Table 1: Pooled ANOVA of various quantitative characters of blackgram.

Character	Genotype	Environment	GxE	Pooled error
	MSS			
Df	31	2	62	93
Seed yield per plant (g)	4.37**	32.69**	1.81**	1.86
Vada batter (ml)	59.45	1315.5**	49.36	25.69
Idly batter (ml)	622.45**	1113.50**	562.91**	131.2

*Significance at 5% level; **Significance at 1% level.

Table 2: ANOVA for stability (AMMI) for interactive traits.

Character	IPCA I		IPCA II	
	MS	% Explained	MS	% Explained
Seed yield per plant(g)	4.82**	68.5	2.36**	31.5
Idly batter (ml)	1632.84**	74.9	584.93**	25.1

*Significance at 5% level; **Significance at 1% level.

none of the high yielding checks is less interacting with the environment. The high yielding genotypes, ACMBG 17-001 (G6), ACM BG 17-006 (G11) and ACM BG 18-010 (G22) were nearer to the origin and hence less interacting with the environment. Considering both biplots, these three genotypes ACMBG 17-001 (G6), ACM BG 17-006 (G11) and ACM BG 18-010 (G22) can be recommended for cultivation in all seasons.

The mean and IPCA scores for idly batter volume was presented in Table 3 and Fig 3 and 4. Based on AMMI biplot 1 (Fig 3), the checks, VBN 8 (G32) alone had high mean and IPCA value nearer to zero and hence stable over environments. Among the genotypes, ACMBG16-025 (G5), ACMBG 17-001 (G6), ACM BG 17-004 (G9) and ACM BG 17-005 has the relatively high idly batter volume than check VBN 8 and with IPCA value nearer to zero and hence less interacting with environments. With regard to AMMI biplot 2 (Fig 4), E1 has the longest spoke considering that it is highly responsive. E2 is the most favourable environment. Based on biplot 2, among the high yielding genotypes ACM BG17-001 (G6) was considered as stable as they are nearer to the origin. Considering both biplot 1 and 2, genotype ACM BG 17-001 (G6) was considered as stable for idly batter volume and can be recommended for all seasons.

Table 3: Mean and IPCA scores of the genotypes and environments for seed yield per plant (g) and idly batter volume (ml).

Code	Genotype	Seed yield per plant (g)			Idly batter volume (ml)		
		Mean	IPCA1	IPCA2	Mean	IPCA1	IPCA2
G1	ACM BG 14-001	8.04*	-0.59	-0.08	204.67*	-2.83	3.12
G2	ACM BG 16-011	6.75*	0.82	-0.94	190.33	0.52	0.44
G3	ACM BG 16-015	8.04*	-0.83	-0.27	186.33	0.24	0.19
G4	ACM BG 16-017	6.04	0.38	0.77	187.83	1.21	1.40
G5	ACM BG 16-025	6.07	-0.27	0.19	194.17	0.12	-3.38
G6	ACM BG 17-001	6.87*	-0.37	-0.18	197.17	-0.17	-0.34
G7	ACM BG 17-002	6.08	-1.10	-0.39	196.17	-3.23	0.52
G8	ACM BG 17-003	4.28	-0.27	0.05	208.50*	-3.80	3.09
G9	ACM BG 17-004	4.52	-0.16	-0.74	189.33	-0.04	0.69
G10	ACM BG 17-005	5.17	0.28	0.39	200.00	0.24	0.52
G11	ACM BG 17-006	6.44*	0.16	-0.25	186.83	-4.89	-4.08
G12	ACM BG 17-007	4.47	-0.31	0.28	160.17	-0.44	-2.37
G13	ACM BG 18-001	4.01	0.32	0.20	174.17	1.50	-0.21
G14	ACM BG 18-002	3.04	0.10	0.10	146.67	-1.98	-1.18
G15	ACM BG 18-003	3.98	0.44	-0.20	161.83	-3.78	-1.55
G16	ACM BG 18-004	5.67	0.79	0.59	182.50	2.88	1.49
G17	ACM BG 18-005	6.16	0.23	0.35	176.50	-1.28	-0.81
G18	ACM BG 18-006	5.18	0.14	-0.11	194.17	1.22	0.43
G19	ACM BG 18-007	6.64*	-0.20	-0.47	174.00	0.80	-0.48
G20	ACM BG 18-008	6.17	-0.45	-0.12	188.67	-0.87	0.86
G21	ACM BG 18-009	4.57	0.93	0.04	196.83	-3.24	0.99
G22	ACM BG 18-010	6.47*	0.21	-0.13	178.50	1.78	-1.30
G23	ACM BG 19-001	5.84	-0.23	0.84	183.50	2.19	0.92
G24	ACM BG 19-002	5.54	0.08	0.26	171.67	-0.30	-2.43
G25	ADT 5	4.75	-0.17	-0.56	183.50	3.16	0.61
G26	ADT 6	3.58	-0.50	0.44	196.33	0.80	0.19
G27	CO 5	5.18	-1.15	0.42	179.67	-0.03	-0.03
G28	MDU 1	6.26*	0.06	-0.68	197.83	1.49	0.13
G29	KKM 1	5.72	0.38	-0.31	167.50	3.45	-1.04
G30	VBN (Bg) 4	6.97*	0.77	-0.35	182.00	-0.04	2.55
G31	VBN 6	4.57	-0.28	0.42	155.83	5.12	-1.87
G32	VBN 8	4.65	0.76	0.42	188.00	0.23	2.93
EI	*Kharif* 2019	4.41	1.85	1.29	187.92	0.05	-7.90
EII	*Rabi* 2019-20	6.31	-2.28	0.67	177.03	8.96	3.98
EIII	*Summer* 2020	5.94	0.43	-1.96	186.41	-9.02	3.92
	Mean	5.55			183.78		
	SE	0.79			6.61		
	CD (5%)	1.56			13.09		

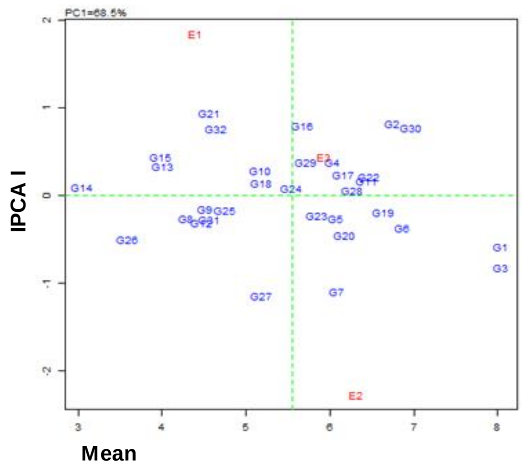

Fig 1: AMMI Biplot 1 for seed yield per plant (g).

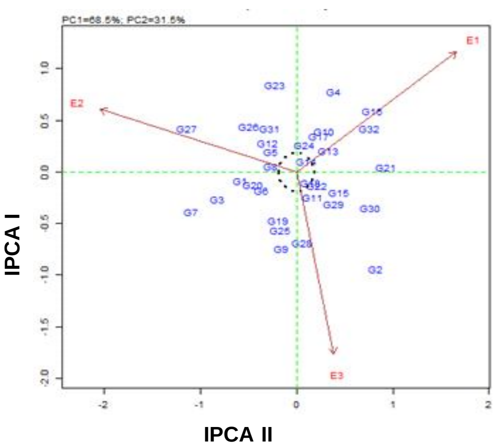

Fig 2: AMMI Biplot 2 for seed yield per plant (g).

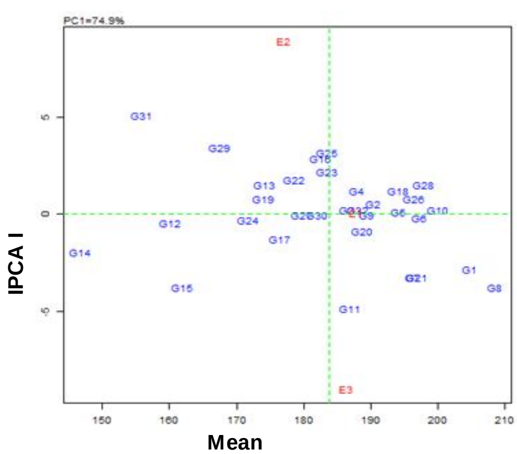

Fig 3: AMMI Biplot 1 for idly batter volume (ml).

Stability analysis by GGE Biplot

The GGE-Biplot of Yan *et al.* (2001) was utilized for evaluating G x E interaction and stability of the genotypes under study. The GGE-Biplot approach is preferred to AMMI since only G and GxE are important and E is not important and therefore only these components must be simultaneously considered by Yan *et al.* (2007). Moreover, GGE biplot best interprets GxE interaction pattern and gives an obvious view of which variety performs best in which environments and thus facilitates mega-environment identification than AMMI (Gurmu *et al*. 2012).

GGE Biplot analysis for seed yield per plant (g)

Relationship among test environment

From Fig 5, E1 and E3, as well as E2 and E3, are correlated whereas E1 and E3 are not correlated. E2 is the discriminating environment followed by E3 and E1. Distance between the environmental vectors indicates that E1 and E3 are in one group and E2 is in another group. Hence, among the seasons, *kharif* (E1) and summer (E3) seasons have similar performances in case of GxE interaction and hence any one season alone may be studied for future trials.

Representativeness of environment

From Fig 6, E3 is the most representative since it forms a smaller (acute) angle with average environment axis (AEA). E2 is the least representative environment but discriminative and hence *rabi* season can be used to select specifically adapted genotypes and cull unstable genotypes.

Ideal test environments and mega environments identification

The centre of the concentric circles is a point on the AEA at the distance of the longest environmental vector from the origin in the positive direction (Fig 6). E3 is the closest to

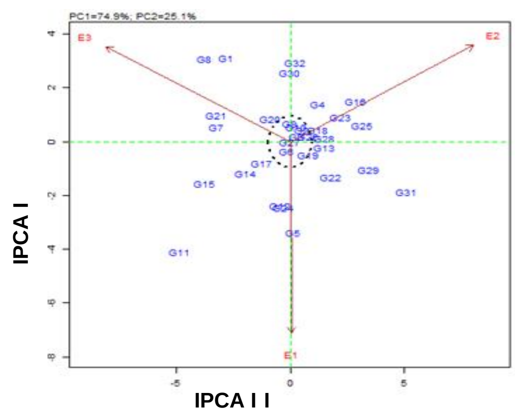

Fig 4: AMMI Biplot 2 for idly batter volume (ml)

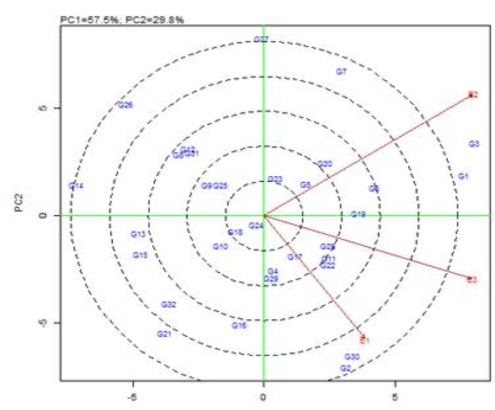

Fig 5: Environment view for seed yield per plant.

this point and therefore it is the ideal test environment for selecting genotypes adapted to all environments. E2 is the poorest environment. E1 and E3 form a mega environment and E2 form a separate mega environment.

Genotype evaluation based on GGE biplot

Based on Fig 7, the genotypes *viz*., ACMBG 14-001 (G1), ACMBG 16-011 (G2), ACMBG 16-015 (G3), ACMBG 16-017 (G4), ACMBG 17-001 (G6), ACMBG 17-005 (G10), ACMBG 17-006 (G11), ACMBG 18-004 (G16), ACMBG 18-005 (G17), ACMBG 18-007 (G19), ACMBG 18-009 (G21), ACMBG 18-010 (G22), MDU 1 (G28), KKM 1 (G29), VBN(Bg) 4 (G30) and VBN 8 (G32) were above average performers in E1. The genotypes ACMBG 16-025 (G5) and ACMBG 18-006 (G18) were near average performer and other genotypes are poorer than an average performer in E1. Genotypes *viz*., ACMBG 14-001 (G1), ACMBG 16-015 (G3), ACMBG 16-025 (G5), ACMBG 17-001 (G6), ACMBG 17-002 (G7), ACMBG 17-006 (G11), ACMBG 18-005 (G17), ACMBG 18-007 (G19), ACMBG 18-008 (G20), ACMBG 18-010 (G22), CO 5 (G27), MDU 1 (G28) and VBN(Bg) 4 (G30) were above average performers in E2. Genotype ACMBG 16-011 (G2) was identified to be near average performer while other genotypes are poorer than average in E2. Genotypes *viz*.,ACMBG 14-001 (G1), ACMBG 16-011 (G2), ACMBG 16-015 (G3), ACMBG 16-017 (G4), ACMBG 16-025 (G5), ACMBG 17-001 (G6), ACMBG 17-006 (G11), ACMBG 18-004 (G16), ACMBG 18-005 (G17), ACMBG 18-007 (G19), ACMBG 18-008 (G20), ACMBG 18-010 (G22), MDU 1 (G28), KKM 1 (G29) and VBN(Bg) 4 (G30) were above average performers in E3. Genotype ACMBG 17-002 (G7) was near average performer and other genotypes are poorer than an average performer in E3.

Mean performance and stability of the genotype

The single arrowed line is the Average Environment Coordination abscissa (AEC) (Fig 8). It points to higher mean yield across environments. The double arrowed line is the AEC coordinate representing greater variation in either direction. The genotypes *viz*., ACMBG 16-017 (G4), ACM BG 17-001 (G6), ACM BG 17-006 (G11), ACMBG 18-005 (G17), ACM BG 18-007 (G19), ACM BG 18-010 (G22), ACMBG 19-001(G23) and KKM 1 (G29) were with high mean and less variation over environments whereas other genotypes had a greater variation with the environment.

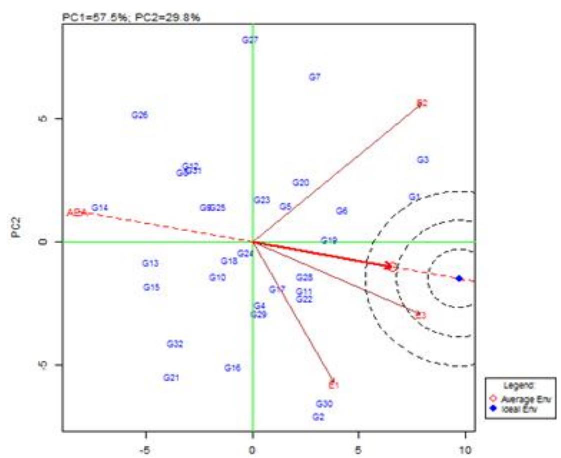

Fig 6: Environment view for seed yield per plant.

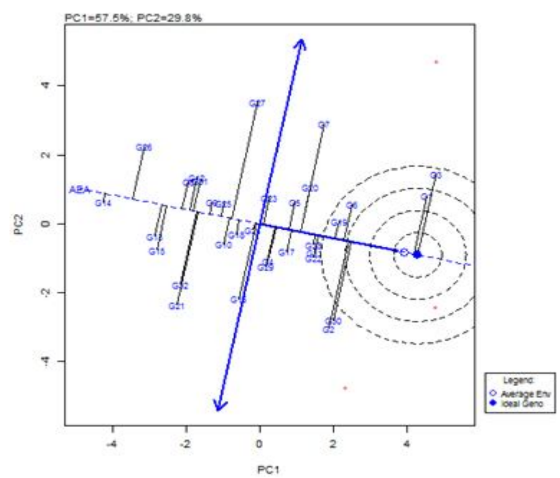

Fig 8: Genotypic view for seed yield per plant.

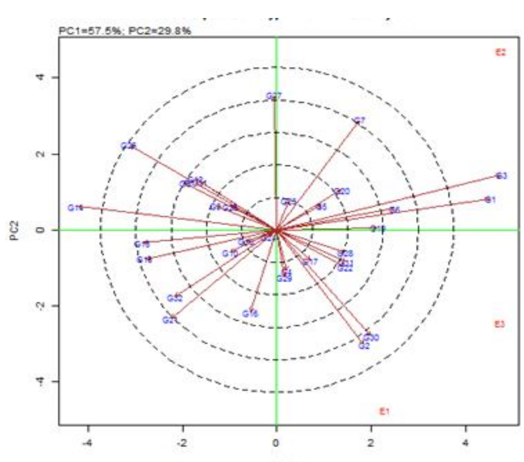

Fig 7: Genotypic view for seed yield per plant.

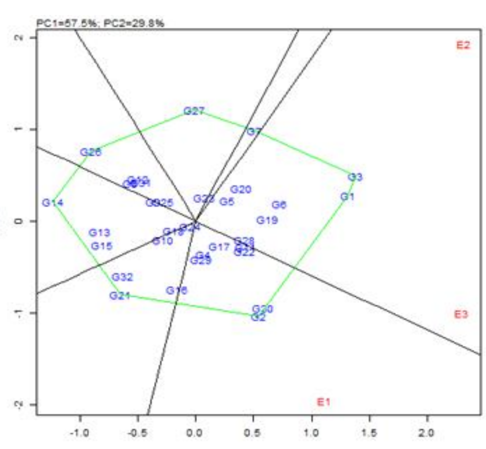

Fig 9: which won where biplot for seed yield per plant.

What-won-where biplot

The genotype on the vertices of the polygon indicates that they are either best or poorest performers in one or more environments (Fig 9). The genotypes; ACM BG 14-011 (G1), ACM BG 16-011 (G2), ACM BG 16-015 (G3) and VBN (Bg) 4 (G30) perform best in E1 and E3 whereas ACM BG 16-015 (G3), ACM BG 17-002 (G7) and CO 5 (G27) perform the best in E2.

GGE Biplot analysis for idly batter volume (ml)

Relationship among test environment

From Fig 10, E1 and E3 are correlated whereas E1 and E2, as well as E2 and E3, are less correlated. E3 is the discriminating environment followed by E3 and E1. Distance between the environmental vectors indicates that E1 and E3 are in one group and E2 is in another group. Hence, E1 or E3 may be used along with E2 for future trials. Thus *kharif* or *summer* and *rabi* season may be utilized for future trials.

Representativeness of environment

From Fig 11, E1 is the most representative since it forms a smaller (acute) angle with average environment axis (AEA). E2 is the least representative environment but discriminative and hence can be used to select specifically adapted genotypes and cull unstable genotypes.

Ideal test environments and mega environments identification

From Fig 11, E1 and E3 are the closest to the point AEA and therefore these are ideal test environments for selecting genotypes adapted to all environments. E2 is the poorest environment. E1 and E3 form a mega environment and E2 form a separate mega environment.

Genotype evaluation based on GGE biplot

From Fig 12, the genotypes; ACMBG 14-001 (G1), ACMBG 16-011 (G2), ACMBG 16-017 (G4), ACMBG 17-001 (G6), ACMBG 17-002 (G7), ACMBG 17-003 (G8), ACMBG 17-004 (G9), ACMBG 17-005 (G10), ACMBG 17-006 (G11), ACMBG 18-003 (G15), ACMBG 18-006 (G18), ADT 6 (G26) and MDU 1 (G28) were above average performers in E1. Hence these genotypes can be recommended to grow in *kharif* season for obtaining higher idly batter volume. The genotype, ACM BG 18-005 (G17) was near average performer and other genotypes are poorer than an average

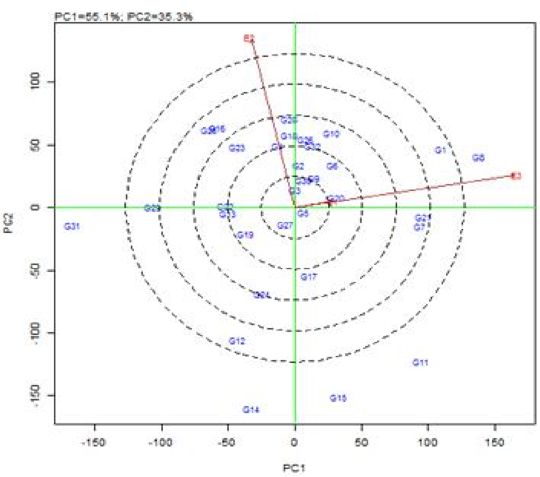

Fig 10: Environment view for idly batter volume.

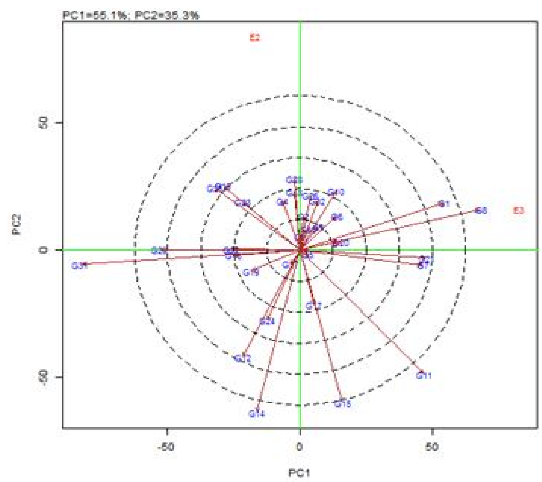

Fig 12: Genotypic view for idly batter volume.

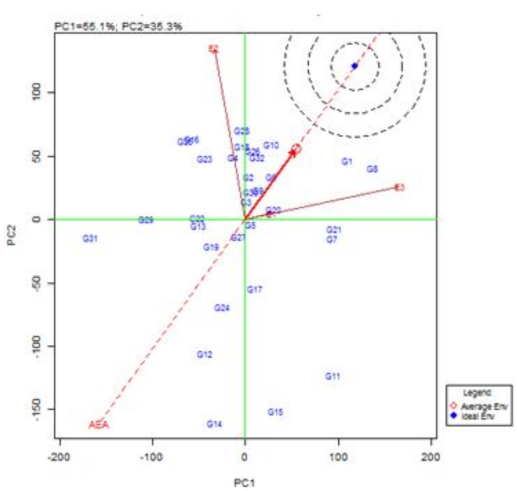

Fig 11: Environment view for idly batter volume.

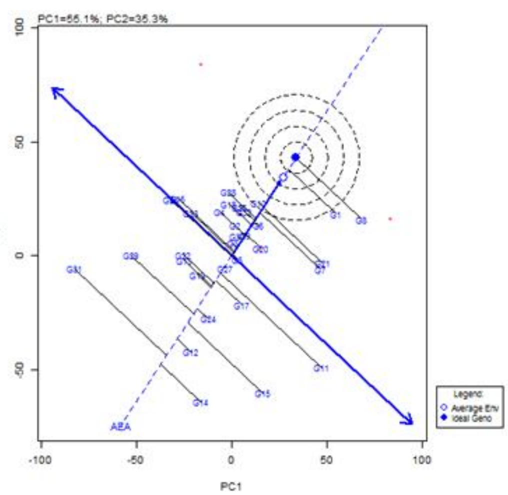

Fig 13: Genotypic view for idly batter volume.

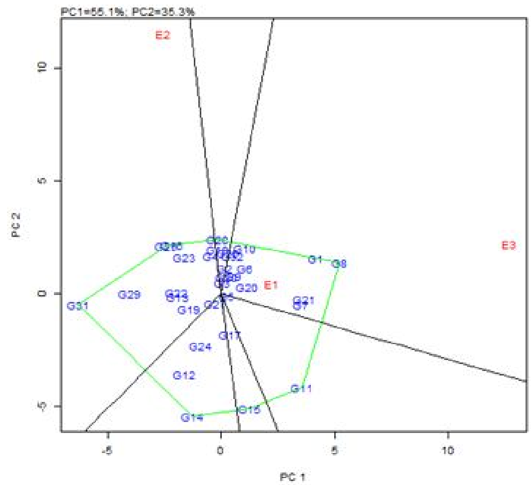

Fig 14: Which won where biplot for idly batter volume.

performer in E1. Genotypes *viz*., ACMBG 14-001 (G1), ACMBG 16-017 (G4), ACMBG 17-001 (G6), ACMBG 17-005 (G10), ACMBG 18-006 (G18), ACMBG 18-008 (G20), ACMBG 19-001(G23), ADT 5 (G25), ADT 6 (G26), MDU 1 (G28), KKM 1 (G29) and VBN 6 (G31) were above average performers in E2. These genotypes can be recommended to be grown during *rabi* season for obtaining high idly batter volume. Genotypes ACMBG 17-003 (G8) and ACMBG 18-007 (G19) were identified to be near average performer while other genotypes are poorer than average. Genotypes *viz*., ACMBG 14-001 (G1), ACMBG 16-011 (G2), ACMBG 17-001 (G6), ACMBG 17-002 (G7), ACMBG 17-003 (G8), ACMBG 17-005 (G10), ACMBG 17-006 (G11), ACMBG 18-003 (G15), ACMBG 18-008 (G20), ADT 6 (G26), MDU 1 (G28) and VBN 8 (G32) were above average performers in E3. These genotypes can be recommended to grow during the *summer* season for obtaining high idly batter volume. Genotypes ACMBG 16-017 (G4) and ACMBG 18-005 (G17) were near average performer and other genotypes are poorer than an average performer in E3.

Mean performance and stability of the genotype

From Fig 13, the genotypes *viz*., ACMBG 16-015(G3), ACM BG 17-001 (G6), ACMBG 17-004 (G9), ACM BG 17-005 (G10), ADT 6 (G26) and VBN 8 (G32) were with high mean and hence less variation over environments for idly batter volume.

What-won-where biplot

From Fig 14, E1 and E3 form a mega environment whereas E2 forms a separate mega environment. The genotypeACM BG 17-003 (G8) performs well in E1 and E3 for idly batter volume. These genotypes perform the best when raised during *kharif* or *summer* season. ACM BG 18-008 (G20), ADT 5 (G25), MDU 1 (G28) and VBN 6 (G31) perform the best in E2 *i.e.*, they tend to obtain higher idly batter volume when grown during *rabi* season.

CONCLUSION

The genotypes, ACM BG 17-001, ACM BG 17-006 and ACM BG 18-010 for seed yield (g) and genotype ACMBG 17-001 for idly batter volume (ml) were found to be stable. Hence these genotypes can be recommended for all season cultivation for stable performance. With regard to the idly batter, E1 (*kharif* 2019) was found to be the most favourable environment since it is representative. The genotypes grown during *kharif* season tend to have higher idly batter volume than other seasons. This is the first ever report on the GxE interaction study on idly batter volume in blackgram.

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