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Stability of Selected High Yielding Genotypes Across Environments Represented by Dates of Sowing in Blackgram [*Vigna mungo* (L.) Hepper]

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Abstract

Blackgram is predominantly grown as a rainfed crop. Of late, onset of rainfall is erratic. Delayed rainfall is a common feature in Eastern Dry Zone of Karnataka. To optimize the productivity of blackgram, it is desirable to identify the genotypes suitable for late sowing conditions. Evaluation of 12 promising genotypes across environments representing three different dates of sowing during 2017, indicated significant genotype × environment interaction for seed yield plant^{-1} based on AMMI model. The genotypes, RU-16-10, IC-261182 and RU-16-11 with lowest estimate of AMMI stability value (ASV) and Stability index (SI) were identified as stable across three dates of sowing, while BG-2 and LBG-20 were found specifically adapted to August sowing for most of the QTs.

Keywords : AMMI stability value, Stability index and Genotype × Environment interaction

Black gram [*Vigna mungo* (L.) Hepper] is one of the most important legume crops of India in terms of area and production. It belongs to the family Fabaceae with 2n=22 and is believed to have originated in India. It contains about 25 per cent protein, 56 per cent carbohydrate, 2 per cent fat, 4 per cent minerals and 0.4 per cent vitamins. Its cultivation in India is about 3624 hectares with the production of 1945 tons and productivity of 0.5 t ha^{-1} (Pawar, 2001). In Karnataka, it is grown in an area of 91 hectare with a production of 25 tonnes and productivity of 275 t ha^{-1}. Blackgram is predominantly grown as a rainfed crop. Of late, onset of rainfall is erratic. Delayed rainfall is a common feature in Eastern Dry Zone of Karnataka. To optimize the productivity of blackgram, it is desirable to identify the genotypes suitable for late dates of sowing conditions and hence, the present study was undertaken.

Material and Methods

The material for the study consisted of twelve genotypes RU-16-10, LBG-20, BG-2, AKH-15, RU-13-101, IC-436545, IC-436547, RU-16-11, IC-436561, IC-261182, MBG-1045 and MBG-217 selected based on grain yield and three checks *viz.,* Rashmi, T-9 and DU-1. The seeds of twelve genotypes were sown in Randomized Complete Block Design (RCBD) with four replications in three monthly intervals *i.e.,* 8th August, 2017, 9th September, 2017 and 24th October, 2017. The experiment was conducted at K-block, UAS, GKVK, Bengaluru. Each genotype was sown in a single row of 2.25 m length with row-to-row spacing of 0.3m. After 10 days of sowing, seedlings of each genotype were thinned to maintain a spacing of 0.15m between the plants within a row. During the crop growth period, the recommended management practices were followed to raise a healthy crop. The data was recorded on five randomly selected plants in each replication on eleven quantitative traits (QTs) such as days to 50 per cent flowering, plant height (cm), primary branches plant^{-1}, clusters plant^{-1}, pods cluster^{-1}, pods plant^{-1}, pod length (cm), seeds pod^{-1}, pod weight plant^{-1}, seed yield plant^{-1} and 100 seed weight.

The QTs means of each genotype were also subjected to ANOVA following Additive Main Effect and Multiplicative Interaction (AMMI) model (Gauch and Zobel, 1988) to detect and characterize the patterns of GEI. GGE bi-plot methodology, which is a combination of AMMI bi-plot and GGE concepts (Yan *et al.,* 2000) was used for visual interpretation of patterns of GGE. To facilitate an objective method of identifying genotypes with specific/wide adaptation across different days of sowing, the AMMI stability value (ASV) was estimated (Purchase *et al.,* 2000).

RESULTS AND DISCUSSION

Detection of GEI

AMMI ANOVA: The *per cent* variance attributable to genotypes × dates of sowing interaction (GDSI) towards total variability of the genotypes was higher than that attributable to main effects of genotypes and dates of sowing for days to 50 per cent flowering, primary branches plant^{-1}, pod length and pod yield plant^{-1} and seed yield plant^{-1}. The main effects of genotypes contributed more towards total variability of the genotypes than those of dates of sowing and GDSI for days to maturity and 100 seed weight. The contribution of environments main effects towards total variability of the genotypes was higher than that of genotypes main effects and GDSI for the expression of plant height, clusters plant^{-1}, pods cluster^{-1} and pods plant^{-1} (Table 1).

Dates of sowing environments significantly differentiated the genotypes for clusters plant^{-1}, pods cluster^{-1}, pods plant^{-1}, pod length, pod yield plant^{-1} and seed yield plant^{-1} as inferred from significant mean squares attributable to dates of sowing (Table 1). However, genotypes differed and interacted significantly with dates of sowing only for pod yield plant^{-1} and seed yield plant^{-1}. These results suggest the need for identifying the genotypes stable across dates of sowing or those that are specifically suitable for particular date of sowing considering that only seeds are marketable as consumable product. The patterns of interaction of genotypes with dates of sowing environments and those which are stable or otherwise were assessed only for seed yield plant^{-1} using both graphical (subjective) (GGE –bi-plot approach) and objective approaches based on AMMI stability value (ASV) and stability index (SI) parameters. Multi-environmental trials are widely used by plant breeders for evaluating the relative performance of genotypes over the target environment and to quantify adoptability and stability of genotypes (Jha *et al.,* 2013)

GGE bi-plot analysis of GEI patterns

Discriminating ability and representativeness of environments

Assessment of discriminating and representativeness of test environments is based on the length of environment (dates of sowing) vectors and the angle between the test environment vectors and average environment coordination (AEC) in the GGE bi-plot. The lines that connect the test environments points to the origin of GGE bi-plot is referred to as environment vectors. A single-arrowed line (ray) passing through the origin of the bi-plot and the average of the environments (in the present study, it is the average of three dates of sowing) is referred as AEC. The average environment is represented by the small circle at the end of the arrow of AEC (Yan and Tinker, 2006). Shorter the environment vectors, lower is the discriminating ability of the environment and longer the vector, higher is the discriminating ability of the environment. A test vector environment that has a smaller angle with AEC is more representative of test environments. A test environment vector that has a wider angle with AEC is least representative of test environments. The cosine of the angle between the vectors of two environments approximates the correlation between them. While acute angle between the vectors of test environments indicate positive correlation or similarity between them, obtuse and right angles indicate negative correlation/dissimilarity and no relationship, respectively between the test environments.

In the present study, August sowing environment was least discriminative but most representative as indicated by shortest length and closer angle of August environment vector. On the contrary October sowing environment was most discriminative and least representative as indicated by longest vector and obtuse angle of October sowing environment vector (Fig. 1). Bharatiya *et al.* (2017) arrived to the same conclusion in the multienvironment evaluation of soybean genotypes. Thus it is suggested to test germplasm accessions and/or breeding populations preferably during October sowing.

TABLE 1

AMMI ANOVA of blackgram genotypes evaluated over three environments representing dates of sowing for yield and its component traits

Sources of variation	Degrees of freedom	Days to 50% flowering		Primary branches $plant^{-1}$		Plant height		Clusters $plant^{-1}$	
		MSS	% Variation	MSS	% Variation	MSS	% Variation	MSS	% Variation
Genotypes (G)	14	12.86	10.97	0.11	06.75	06.9	02.28	03.9	02
Environments (E) (Dates of sowing)	02	04.82	01.02	0.07	00.55	1641.0 **	53.45	866.8 **	60.13
G×E	28	05.92	11.38	0.12	16.04	10.6	04.49	05.6	5.3
IPCA 1	15	07.98	07.89	0.14	09.30	15.3	03.48	08.2	4.26
IPCA 2	13	03.54	03.49	0.09	06.73	5.3	01.01	02.5	1.04
Error (e)	126	07.53		0.13		12.5		06.0	

Sources of variation	Degrees of freedom	Pods $cluster^{-1}$		Pods $plant^{-1}$		Seed yield $plant^{-1}$		100 seed weight $plant^{-1}$	
		MSS	% Variation	MSS	% Variation	MSS	% Variation	MSS	% Variation
Genotypes (G)	14	0.22	02.43	44.1	2.37	3.47 *	05.52	0.12	10.31
Environments (E)	02	51.15 **	80.41	7751.5 **	67.48	12.40 **	02.29	0.74	08.46
G×E	28	0.09	02.05	32.4	4.03	4.22 **	15.27	0.08	10.89
IPCA 1	15	0.09	01.09	38.5	2.57	4.79 **	08.49	0.09	06.74
IPCA 2	13	0.08	00.95	25.9	1.45	3.55 **	06.78	0.07	04.15
Error (e)	126	0.11		42.7	1.21		0.10		

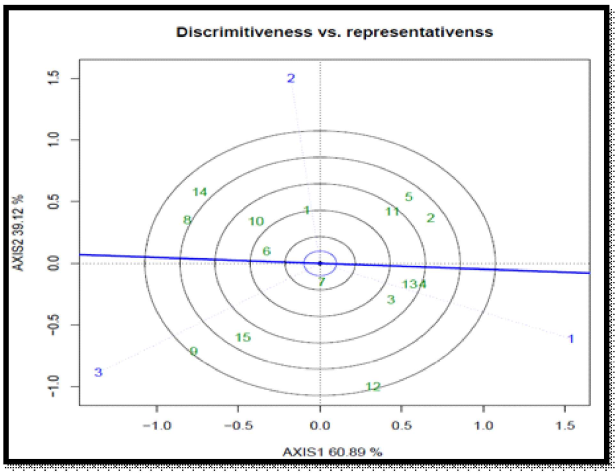

Fig. 1: Discriminative vs. Representativeness view of GGE bi-plot for seed yield plant^{-1}

G1	IC-436561	G2	IC-261182
G3	AKH-15	G4	LBG-20
G5	RU-16-11	G6	MBG-1045
G7	MBG-217	G8	RU-13-101
G9	IC-436545	G10	IC-436547
G11	RU-16-10	G12	BG-2
G13	Rashmi	G14	T-9
G15	DU-1		

Ranking genotypes relative to ideal genotype

An ideal genotype should have both high mean performance and high stability across dates of sowing. An ideal genotype (center of concentric circles) is the point on AEC (highly stable) in the GGE bi-plot in the positive direction and has a vector length equal to the longest vector of the genotypes on the positive side of AEC. Using the ideal genotype as the center, concentric circles are drawn to help visualize the distance between each genotype and ideal genotype. The genotypes located closer to the "ideal genotype" are more desirable than others. Obviously those that are away from 'ideal genotype' are more undesirable.

In the present study, the genotypes Rashmi followed by LBG-20 were located at the center of concentric circles for seed yield plant^{-1} (Fig.2) and hence regarded as ideal genotypes. These are stable across three dates of sowing. The genotypes, AKH-15, IC-261182, RU-16-11 and RU-16-10 were located closer to ideal

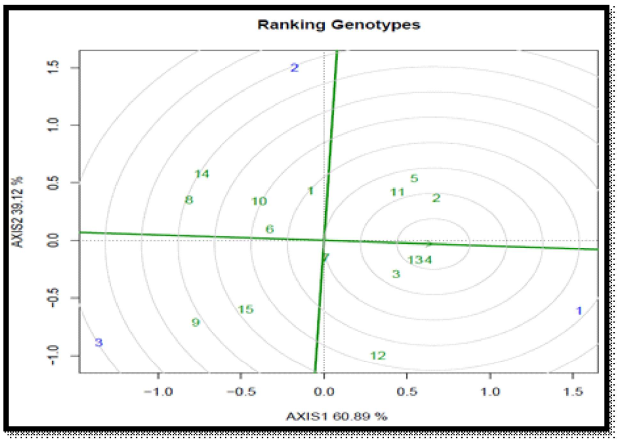

Fig. 2: Average environment co-ordination view of GGE bi-plot based on environment- focused scaling for comparision of genotypes with the ideal genotype for seed yield plant^{-}

E1 August sowing, E2 September sowing, E3 October sowing

genotypes for seed yield plant^{-1}. Except Rashmi all these ideal/non ideal genotypes are germplasm accession. Hence, these five germplasm accessions along with Rashmi could be preferentially used in breeding blackgram for developing varieties stable across different dates of sowing.

Mean performance *vs.* stability patterns

The mean performance and stability could be visualized based on the environment of genotypes in relation to AEC using AEC view of GGE bi-plot. The single arrowed AEC points to higher mean performance of the genotypes across environments (dates of sowing). The genotypes with their points located towards arrow of AEC are considered to exhibit high mean performance. On the contrary, the genotypes with their points located opposite to AEC arrow are considered to exhibit lower performance. Further, the relative lengths of projections of the genotypes from AEC are indicative of their relative stability shorter the length of the projections of genotypes from AEC, greater is the stability of the genotypes. Greater the absolute length of the projections of genotypes, greater would be their poor stability.

In the present study, the genotypes such as Rashmi, LBG-20, IC-261182, RU-16-11 and RU-16-10 were

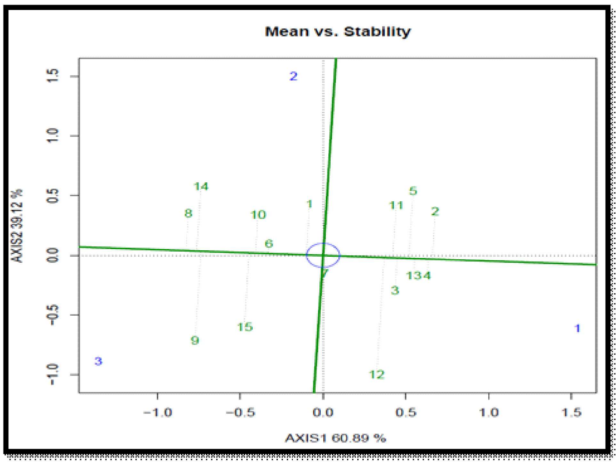

Fig. 3 : Average environment co-ordination view of GGE bi-plot based on environment focused scaling for the mean performance vs. stability for seed yield plant^{-1}

G1	IC-436561	G2	IC-261182
G3	AKH-15	G4	LBG-20
G5	RU-16-11	G6	MBG-1045
G7	MBG-217	G8	RU-13-101
G9	IC-436545	G10	IC-436547
G11	RU-16-10	G12	BG-2
G13	RASHMI	G14	T-9
G15	DU-1		

identified as stable ones with high mean seed yield plant^{-1} as indicated by least projections from AEC (Fig. 3). These genotypes should be first-look choice by breeders for use in breeding high yielding and stable blackgram varieties.

'Which–won–where' patterns

One of the features of GGE bi-plot is its ability to display "which-won-where" pattern of genotypes. This feature is shown by polygon view of the GGE bi-plot. A polygon is drawn on the genotypes that are farthest from the bi-plot origin so that all other genotypes fall within the polygon. The perpendicular lines starting from GGE bi-plot origin are drawn to each side of the polygon. The perpendicular lines are equality lines between adjacent genotypes on the polygon.

The genotypes located on the vertices of the polygon perform either the best or poorest in one or more environments (dates of sowing). The equality lines divide the bi-plot into sectors. The vertex genotype in each sector is the winning genotype at environments whose markers (points) fall into the respective sector based on previous study. Environments within the same sector share the same winning genotype, and environments in different sectors have different winning genotypes. Thus polygon view of a GGE bi-plot indicates presence or absence of cross-over GEI.

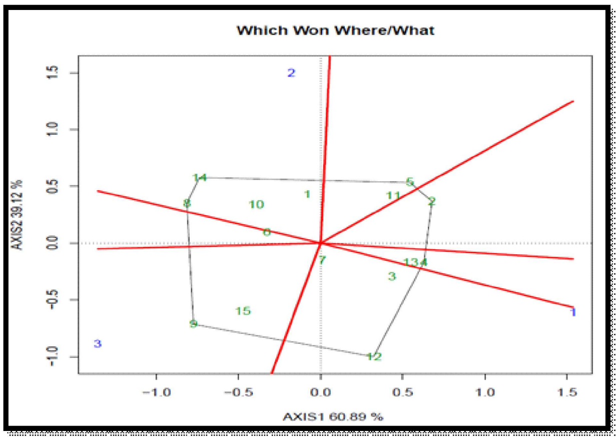

Fig. 4 : Polygon view of GGE bi-plot on the symmetrical scaling for 'which won where' pattern of genotypes and environments for seed yield plant^{-1}

E 1 - August sowing; E 2 - September sowing; E 3 : October sowing

In the present study, the genotypes, LBG-20, BG-2, IC-261182, RU-16-11, T-9, RU-13-101 and IC-436545 were found located at the vertices of the polygon of GGE bi-plot for seed yield plant^{-1}. In general, different genotypes won in different dates of sowing environments for seed yield plant^{-1}. The genotypes, LBG-20, BG-2, IC-261182, RU-16-11 and IC-436545 were the best ones for August and October sowing dates, respectively. On the other hand, T-9 and RU-13-101 were identified as most suitable for September sowing (Fig.4).

AMMI Stability Value (ASV)

The estimate of ASV is a useful parameter for objective assessment of stability of the genotypes. Lower the magnitude of ASV, higher is the stability of the genotypes. In the present study, lower magnitude

TABLE 2

Estimates of IPC scores and parameters to assess stability (ASV & YSI) of blackgram genotypes

Genotypes	Mean	Rank	ASV	Rank	SI	Rank
RU-16-10	09.43	1	0.19	1	2	1
IC-261182	09.84	2	0.36	2	4	2
RU-16-11	10.30	3	0.38	3	6	3
MBG-1045	10.31	4	0.42	4	8	4
IC-436547	10.39	5	0.56	5	10	5
AKH-15	10.52	6	0.64	6	12	6
IC-436545	10.52	7	0.68	7	14	7
MBG-217	10.57	8	0.73	8	16	8
BG-2	10.65	9	0.75	9	18	9
IC-436561	10.98	11	0.78	11	22	11
RU-13-101	11.06	12	0.83	12	24	12
LBG-20	11.27	14	1.03	14	28	14
Checks						
RASHMI	10.88	10	0.77	10	20	10
T-9	11.13	13	0.99	13	26	13
DU-1	11.44	15	1.04	15	30	15
SE m±	1.04					
CD @ P = 0.05	2.88					

of the estimates of ASV suggested stability of RU-16-10, IC-261182 and RU-16-11 across three dates of sowing for seed yield plant^{-1} (Table 2).

Stability Index (SI)

The estimate of SI is another useful parameter for objective assessment of stability of the genotypes based on both mean yield and stability. Low magnitude of SI indicates high stability. In the present study, lower magnitude of estimates of SI suggested stability of RU-16-10, IC-261182 and RU-16-11 across three dates of sowing for seed yield plant^{-1} (Table 2). Thus both ASV and SI parameters suggested stability of RU-16-10, IC-261182 and RU-16-11 across three dates of sowing.

However, the relatively high yielders such as Rashmi, MBG-1045 and DU-1 were not stable across different sowing date environments. Such negative relationship between performance levels and stability/adaptability could be attributed to the possible involvement of different sets of genes controlling *per se* performance and stability and trade-offs between performance and stability. The genotypes, RU-16-10, IC-261182 and RU-16-11 with a fairly high seed yield plant^{-1} and reasonably good stability based on both GGE bi-plot assessment and on ASV and SI parameters could be extensively used in breeding blackgram varieties with high stability and high productivity. Such stable varieties are expected to contribute to sustainable blackgram production. Also, breeding varieties with high yield and high stability is essential to increase economic returns to the farmers and hence maintain competitiveness of blackgram with other crops.

From the above results, it could be concluded that the accessions such as MBG-217, MBG-1041 & BG-2 with fewer days to 50 per cent flowering, MBG-1041 & AKH-15 with more pods plant^{-1} and MBG-217, BG-2, RU-16-10, MBG-1041 & AKH-15 with high seed yield plant^{-1} as compared to the check variety Rashmi are useful in breeding short duration cultivars with higher productivity. The AMMI analysis of variance indicated significant variability attributable to genotype × dates of sowing interaction for seed yield plant^{-1}.

The genotypes, RU-16-10, IC-261182 and RU-16-11 with lowest estimate of ASV and SI were identified as stable across three dates of sowing, while BG-2 and LBG-20 were found specifically adapted to August sowing for most of the QTs.

The stability of RU-16-10, IC-261182, RU-16-11, BG-2 and LBG-20 across different dates of sowing needs confirmation through multi location and multiyear trials. Those with confirmed stability are suggested for extensive use in breeding, high yielding stable blackgram varieties.

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