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Yield Stability Analysis of Mungbean (*Vigna radiata* L. Wilczek) Hybrids Using AMMI Method

Nitesh, S.D.*, Manoj Katiyar, Sarvendra Kumar, Mahak Singh, Lokendra Singh, Bajpai, V.P., Anjani Kumar Singh, Amar and Yashwanth, R.D.

Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

*Corresponding author: mail@niteshgpb.in (**ORCID ID:** 0000-0002-4938-6069)

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ABSTRACT

Genotype × Environment interaction (GEI) effects are of special interest to identify stable genotypes plant breeders. The present experiment was conducted in three growing seasons viz., *Kharif* 2019, spring-summer 2020, and summer 2021 at Research Farm, C.S. Azad University of Agriculture and Technology, Kanpur, to assess the stability of 48 F_1 hybrids along with 19 homozygous *mung* bean parents for seed yield per plant. AMMI1 biplot for seed yield per plant, the hybrids *viz.,* PDM139 × KM2355, IPM147 × KM2355, KM2241 × MH1142 and PM1125 × MH1142, similarly IPM 147-1, KM2241 and KM2255 parents had IPCA1 score close to zero with high main effects indicating that these hybrids were less influenced by environments and high yielders. PDM139 × PM1126, IPM147 × PM1126, KM2241 × KM2355 and KM2352 × MH1142, and parents KM2328, SML1811, KM2360, and IPM147, were found to be high yielders with high interaction with the environment. Among environments, *Kharif* and *Summer* seasons are highly interacting environments. Finally, the hybrids *viz* PM1125 × MH1142 and PDM139 × KM2355 were found less interacting hybrids with high seed yield per plant. These hybrids may be recommended and used in other crop improvement programs for all three growing seasons of *mung* bean.

HIGHLIGHTS

- Mungbean is an important grain legume crop widely cultivated in all growing seasons.
- Identification of stable and high-yielding hybrids through AMMI analysis, to enhance the production and productivity of green gram crop.

Keywords: Mungbean, AMMI, yield stability, seasons

Mung bean is a popular grain legume crop in India, with its origins in the Indian subcontinent. The ability of a genotype to adapt to a variety of environmental conditions is a prerequisite in today's world (Abeysiriwardena *et al.* 1991). The genotype-environment (GE) interaction is the most extensively used statistical methodology for evaluating hybrids for yield performance across many environments to identify stable hybrids. Genotypes with little GE interaction and high yield are attractive for crop breeders and farmers because they suggest that the environment has little effect on genotype performance and that the genetic component contributes significantly to yield (Linnemann *et al.* 1995). Several strategies for evaluating genotype-environment interaction (GEI) and selecting phenotypically stable promising lines have been proposed (Tarakanovas and Ruzgas 2006). Two prominent well-known and widely used statistical methods have been proposed to analyze the GE interaction-univariate and multivariate stability statistics (Lin *et al.* 1986). A combined analysis of variance can quantify the interaction and identify the significant effects, but it can't explain the G E

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interaction. As a result, the additive main effect and multiplicative interaction analysis (AMMI) has been widely used in multi-environment stability analysis among multivariate methods.

AMMI is a two-way data structure hybrid model with additive and multiplicative components. It separates additive and multiplicative variance, then uses principal component analysis (PCA) to extract a new set of coordinate axes to uncover the genotype-environment interaction pattern. The effectiveness of the AMMI model has been established in numerous research employing multi-environment trials, such as Zobel *et al.* (1998) in soybean, Crossa *et al.* (1990) in maize, Kumar *et al.* (2017) in chickpea, and Mahalingam *et al.* (2018) in mung bean. The purpose of this study was to use the AMMI model to assess the performance and consistency of forty homozygous mung bean hybrids in terms of seed output per plant over various mung bean growing seasons in Uttar Pradesh, India.

MATERIALS AND METHODS

Forty-eight hybrids and nineteen parents of mung bean were evaluated in a randomized block design (RBD) with two replication during *Kharif* 2018, *spring-summer* 2019 and *summer* 2020 at Research farm, C.S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India. Hybrids and parents were evaluated in the plot in three lines with a spacing of 30 × 10 cm. All the recommended package of practices was followed for raising the healthy crop. Individual location-wise analysis of replicated data on seed yield per plant was followed by a pooled analysis. AMMI analysis was conducted using R software package *amiability* (Ajay *et al.* 2019). The data was also submitted to an AMMI model stability study using the conventional procedure.

The equation of AMMI model is as under:

$$Y_{ger} = \mu + \alpha_g + \beta_e + \sum_n \lambda_n \gamma_{gn} \delta_{en} \rho_{ge} \tau_{ger}$$

Where, Y_{ger} represents seed yield per genotype g in season e; μ is the grand mean of seed yield per plant, α_g represent the deviation of hybrids from the grand mean; β_e similarly represent deviation of the environment from grand mean, λ_n represent PCA n-axis eigenvalue; γ_{gn} and are the PCA scores of genotype and environment for PCA axis n. ρ_{ge} is the AMMI model's residual and τ_{ger} represent random error. AMMI uses ordinary ANOVA to assess main effects, while principal component analysis is used to analyze non-additive (interaction) effects leftover by the ANOVA model. If all axes are not used, PCA decomposes the interaction into PCA axes 1 to n, leaving residuals. The interaction between genotype and environment may be inferred by multiplying the genotype's interaction principal component axis (IPAC) score by the environmental IPCA score.

RESULTS AND DISCUSSION

Among the many statistical methods adopted for analysis of hybrids by environment interaction (GEI) and phenotypic stability (Crossa *et al.* 1990). Regression based technique was widely used (Eberhart and Russell 1966; Perkins and Jinks 1968) due to its simplicity and the fact that the information on adaptive response was easily applicable to locations (Annicchiarico 1997). Zobel *et al.* (1988) compared the tradition statistical models such as analysis of variance (ANOVA), principal component analysis (PCA) and linear regression with AMMI analysis and showed that traditional analysis was not always effective in the interpretation of the multi-environment trait data structure.

Table 1: Analysis of variance for seed yield per plant (g) in mung bean

Source	Accumulated Value	DF	Sum of Squares	Mean sum of square
Env	—	2	22.54	11.272*
Rep(Env)	—	3	1.86	0.620
Gen	—	66	2195.12	33.259***
Env:Gen	—	132	217.94	2.4283***
PCA1	89.80	67	195.71	2.9210***
PCA2	100.0	65	22.23	0.3419
Residues	—	198	134.62	0.680

Understanding of G×E interaction in plant species is of importance because it has implications for economic yield. In present study, ANOVA on individual location indicated the presence of significant difference among hybrids. The significant of variance due to G×E in pooled analysis indicated the presence of genotype × environment interaction. Hence, the data were analyzed for further AMMI analysis. AMMI analysis indicated significant differences among the hybrids, among seasons, and also genotype × environment interaction for seed yield per plant. In the present investigation, the

Table 2: Performance of mung bean hybrids and their IPC score for seed yield per plant

Sl. No	Hybrids	GYP	IPCA-1	IPCA-2
1×17	KM 2241 × PM 1126	8.6100	-0.4372	-0.2580
1×18	KM 2241 × KM 2355	11.9767	-0.4479	0.1506
1×19	KM 2241 × MH 1142	9.3067	-0.0726	0.1373
2×17	KM 2352 × PM 1126	10.4133	-0.5043	-0.1053
2×18	KM 2352 × KM 2355	9.0600	-0.4907	0.0263
2×19	KM 2352 × MH 1142	11.7683	-0.4666	-0.0192
3×17	PDM 139 × PM 1126	14.4967	-0.4099	-0.2063
3×18	PDM 139 × KM 2355	8.7283	-0.1027	-0.0095
3×19	PDM 139 × MH 1142	10.1983	-0.4448	-0.1136
4×17	PM 1125 × PM 1126	8.4733	-0.4328	-0.1822
4×18	PM 1125 × KM 2355	8.7650	-0.4987	-0.0151
4×19	PM 1125 × MH 1142	8.7867	-0.0603	-0.0710
5×17	KM 2342 × PM 1126	9.2200	-0.5498	-0.0911
5×18	KM 2342 × KM 2355	8.9233	-0.4728	-0.1556
5×19	KM 2342 × MH 1142	8.7517	-0.4739	-0.0563
6×17	KM 2328 × PM 1126	8.3200	0.1550	0.3755
6×18	KM 2328 × KM 2355	10.4433	-0.4572	-0.1389
6×19	KM 2328 × MH 1142	10.7933	-0.4565	-0.2264
7×17	SML 1811 × PM 1126	9.9850	-0.4693	0.1554
7×18	SML 1811 × KM 2355	10.2450	-0.4420	0.0094
7×19	SML 1811 × MH 1142	8.7050	-0.3674	-0.0342
8×17	IPM 147 × PM 1126	14.3300	-0.4574	-0.1330
8×18	IPM 147 × KM 2355	8.0817	-0.0958	0.1452
8×19	IPM 147 × MH 1142	8.1150	0.2703	-0.0298
9×17	IPM 147-1 × PM 1126	10.4583	-0.4669	-0.1411
9×18	IPM 147-1 × KM 2355	9.5700	-0.4412	-0.1479
9×19	IPM 147-1 × MH 1142	10.7583	-0.4477	-0.0389
10×17	KM 2360 × PM 1126	7.8217	-0.1918	0.0877
10×18	KM 2360 × KM 2355	8.7900	-0.1345	0.1584
10×19	KM 2360 × MH 1142	9.6767	-0.4398	-0.0974
11×17	KM 2348 × PM 1126	5.2800	0.5389	-0.3708
11×18	KM 2348 × KM 2355	5.0550	0.5022	-0.4226
11×19	KM 2348 × MH 1142	5.5500	0.2105	0.2019
12×17	IPM 02-3 × PM 1126	5.2350	0.2030	0.1427
12×18	IPM 02-3 × KM 2355	5.8117	0.2832	0.2034
12×19	IPM 02-3 × MH 1142	6.6783	0.1956	0.1615
13×17	PUSA 1671 × PM 1126	5.3567	0.4197	-0.0310
13×18	PUSA 1671 × KM 2355	5.3100	0.2192	0.1697
13×19	PUSA 1671 × MH 1142	4.7183	0.6059	-0.3398
14×17	KM 2368 × PM 1126	5.1717	0.4160	-0.0606
14×18	KM 2368 × KM 2355	5.9633	0.2106	0.2239
14×19	KM 2368 × MH 1142	5.6483	0.2429	0.2638
15×17	KM 2362 × PM 1126	5.7717	0.2275	0.2272
15×18	KM 2362 × KM 2355	5.4450	0.4322	-0.2173
15×19	KM 2362 × MH 1142	4.8850	0.4303	-0.3419
16×17	KM 2364 × PM 1126	4.9133	0.1754	0.2865
16×18	KM 2364 × KM 2355	5.0667	0.2446	0.3165
16×19	KM 2364 × MH 1142	5.1550	0.5972	-0.3855

Sl. No	Parents	GYP	IPCA-1	IPCA-2
P-1	KM2241	6.2933	0.1539	0.4889
P-2	KM 2352	8.7117	0.1959	0.3613
P-3	PDM 139	7.5083	0.2273	0.2192
P-4	PM 1125	8.1133	0.2019	0.2281
P-5	KM 2342	7.4767	0.2446	0.3025
P-6	KM 2328	8.4117	-0.5532	-0.1325
P-7	SML 1811	8.7467	-0.4281	-0.0404
P-8	IPM 147	8.4750	0.2703	0.2597
P-9	IPM 147-1	7.9117	-0.0955	0.0196
P-10	KM 2360	8.3150	0.2689	0.1453
P-11	KM 2348	4.5383	0.5768	-0.3604
P-12	IPM 02-3	4.8417	0.5672	-0.3406
P-13	PUSA 1671	5.5600	0.2827	0.2850
P-14	KM 2368	4.8833	0.5641	-0.4936
P-15	KM 2362	5.0133	0.5148	-0.1556
P-16	KM 2364	4.8883	0.5172	-0.2404
P-17	PM 1126	7.6783	0.2075	0.1626
P-18	KM 2355	5.5217	0.1708	-0.0449
P-19	MH 1142	6.6533	0.2649	0.3332
E1	*Kharif* 2019	7.4756	0.7036	1.4337
E2	Spring Summer 2020	7.7581	1.7871	-1.0706
E3	Summer 2020	8.0556	-2.4907	-0.3631

analysis of variance showed significance for IPCA1 and IPCA2. Among these IPCA1 along recorded for 89.80 percent of the total variance. Hence IPCA1 alone may decide the G×E interaction within the study.

The most potent interpretative technique for AMMI models is biplot analysis. Biplots are graphed in which the genotype and environment mean are presented on the same axes (X-axis) to make the interrelationship between the two easier to see. The AMMI1 biplot depicts the significant effects (genotype mean, and environment mean) and IPCA1 scores for hybrids, parents, and environments against each other, while the AMMI2 biplot plots IPCA1 and IPCA2 scores. AMMI2 biplots do not exhibit the main effects of genotype or environment so do not show adaptation (Table 2).

PDM139 × KM2355, IPM147 × KM2355, KM2241 × MH1142 and PM1125 × MH1142 were among the hybrids with IPCA 1 scores close to zero, indicating that the environment less influenced these hybrids. Similarly, parents, IPM 147-1, KM2241, and KM2255 had IPCA 1 scores close to zero (Fig. 1).

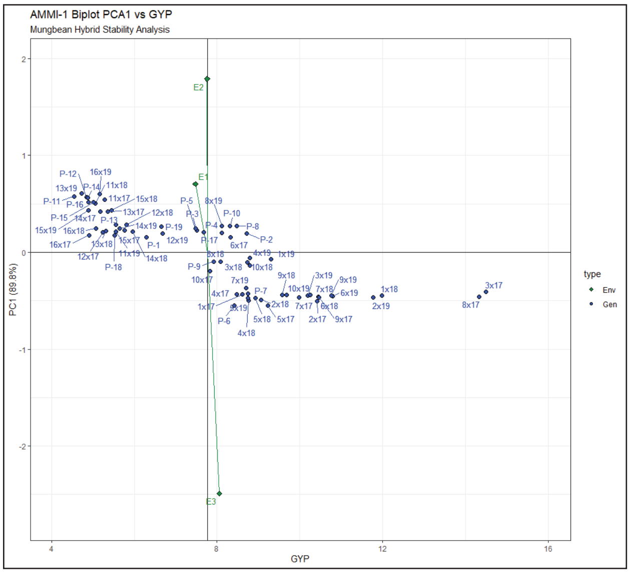

Fig. 1: AMMI 1 Biplot for seed yield per plant

As a result, the aforementioned stable hybrids were adaptable to all three seasons, namely Kharif, Spring Summer, and Summer. PDM139 × PM1126, IPM147 × PM1126, KM2241 × KM2355, and KM2352 × MH1142 hybrids, as well as their parents KM2328, SML1811, KM2360, and IPM147, were shown to be high yielders with high environmental interaction. As a result, these hybrids and parents were discovered to be unstable. The hybrids KM2241 × MH1142, KM2360 × KM2355, PM11125 × MH1142, and PDM139 × KM2355 produced good yields while interacting with the environment in a controlled way. As a result, these hybrids are suitable for all growing seasons. Summer was the highest yielding season, whereas the spring *Kharif* season had little contact with the growing seasons.

In AMMI 2 biplot, IPCA1 and IPCA2 values were plotted (Fig. 2.). This graph shows that sites with short spokes do not exert strong interactive forces, while those with longer spokes exert strong interaction. All the three seasons – E1, E2, and E3 had long spokes and exerted strong interaction. Among the three environments – E1 (*Kharif* season) had short spoke with the origin, which has a less interactive effect. Hybrids PDM139 × KM2355, PM1125 × MH1142 KM2360 × PM1126 and IPM147 × MH1142 and parent IPM147-1 and KM2355 were very close to the center of the origin. These hybrids and parents nearer to the origin were non-sensitive to environmental interaction forces. Hence, these hybrids can be classified as stable, and those distant from the origin were sensitive and had significant interactions.

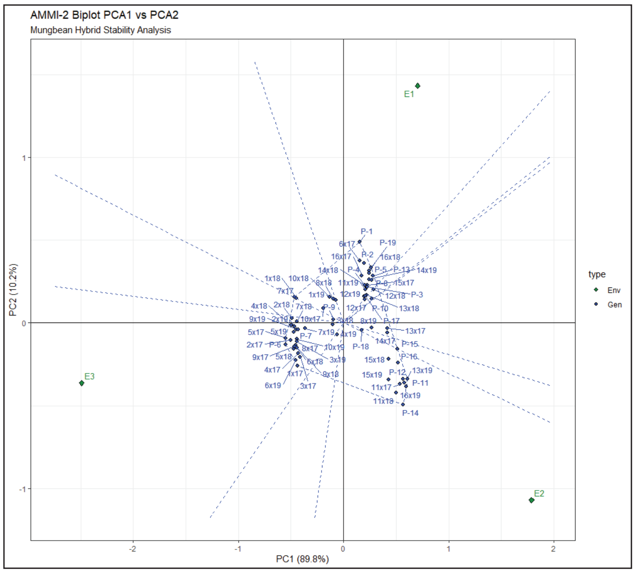

Fig. 2: AMMI 2 Biplot of seed yield per plant

Based on the preceding discussion, it can be concluded that hybrids PM1125 × MH1142 and PDM139 × KM2355 were found less interacting with high seed yield per plant. These hybrids may be recommended for growing in all three seasons' viz., *Kharif, sprin- summer* and *summer.*

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