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Short Communication

Study on genotype x environment interactions and AMMI analysis for agronomic traits in mungbean (*Vigna radiata* L. Wilczek.) under rainfed conditions

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Abstract

In the present study, 23 genotypes of mungbean were evaluated for stability performance under different environments continuously for three years during *kharif* 2016 (E_1), 2017 (E_2) and 2018 (E_3) under rainfed conditions. Genotype Pusa Vishal exhibited regression coefficient equal to unity with non-significant deviation from regression coefficient and hence showed wider adaptability under poor or good environments. Genotype EC520016 showed earliness in maturity with wider adaptability. Environmental indices indicated that environment E_2 and E_3 were most favourable for yield and majority of yield attributing traits, whereas E_3 alone was important for seed yield/plant and number of seeds/ pod. Based on AMMI models, Pusa Vishal, PD139, IPM2-3, IPM2057 and PML2-14 showed higher IPCA scores coupled with high population mean in E_3. AMMI2 analysis indicated ML2056, and K851 with high IPCA1 in E_3 whereas IPM99-125, BM63 and PM2-14 with high IPCA2 in the same environment. Genotypes which positioned very close to centre point and are least effected by G x E interactions while those presented away from the point of centre are more affected by G x E interactions and hence not stable. Identified genotypes may be utilized in improvement programme of *Vigna radiata* for targeted environments.

Key words: AMMI analysis, GEI, principal components, stability, agronomical traits, mungbean

Mungbean [*Vigna radiata* (L.) Wilczek.], a short duration legume crop, is an important pulse crop of *kharif* season. The area of mungbean has doubled in the last two decades with an annual rate of 2.5% in Jammu region due to its short duration (60 days) which makes it suitable for various cropping systems. However, the production of mungbean fall short to meet the consumer demand and hence India imports. Therefore, there is a great need to increase production and productivity of mungbean in the country by more intensive interventions (http://agropedia.iitk.ac.in). The production of mungbean is about 84.1 thousand quintals and the productivity is 3.17 q/ha in the state of Jammu and Kashmir (Jeelani and Choure 2015) but there is a need to identify the high yielding with wider adaptability and stability in varieties for rainfed areas. The productivity in mungbean is very low due to moisture stress conditions and fluctuations prevailing not only in the state of Jammu and Kashmir but entire country affecting the productivity and production. Variable sowing dates also lead to epiphytic conditions of pest and diseases. Increase in yield is expected by adopting strategic breeding programme (Singh et al. 2009). The major constraint to develop the high yielding varieties of *Vigna radiata* (L.) Wilczek are low inherited yield potential, lack of genetic variability, lack of suitable ideotype, poor harvest index and susceptibility to biotic and abiotic factors (Souframanien and Gopalkrishnan 2004). G x E interactions play a great role in realizing the yield of a genotype from given conditions of environment. A phenotype usually gets

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changed when a genotype is grown over varying environments (Comstock and Moll 1963). Also the process of identification of a stable genotypes is difficult because of G × E interactions. This has been largely due to the problem of defining and measuring phenotypic stability. Various attempts were made to characterize the behaviors of genotypes in response to varying environments. Statistical approach of Finlay and Wilkinson (1963) has proved considerably useful to measure the phenotypic stability in the performance of genotype. They considered linear regression slope (bi) as a measure of stability. This regression analysis proposed by Finlay and Wilkinson (1963) was improved upon by Eberhart and Russell (1966). They introduced one more parameter, deviation from regression (S^2di) which accounts for unpredictable irregularities in the response of genotypes to varying environments. The G x E interaction is a challenging issue for plant breeders in developing improved varieties. Keeping in view of the above-mentioned strategic points a set of diverse varieties were evaluated to find out the stable genotypes under rainfed conditions for Jammu and Kashmir region.

The experimental materials comprised with 23 genotypes of mungbean namely, Pusa Vishal, ML818, PD139, IPM2-3, SML668, IPM99-125, Pusa0672, IPM2057, PM2-14, IPR57, IPM95-31, ML2056, PM5, MH521, Ganga 8, IPM2-3-2, BM63, EC520016, MH9-8-1, V1133, MG331, K851 and LG460 were received from the ICAR-Indian Institute of Pulses Research, Kanpur. The experiments were conducted at the experimental farm of SKUAST at Rakhdhiansar, Jammu in randomized block design with three replications during *kharif* 2016, 2017 and 2018 under rainfed conditions. Each genotype was sown in eight rows with row length of 4m and spacing 30 x 10 cm^2. All the recommended package and practices were involved for getting good healthy crop along with recommended plant protection measures. Fifteen random plants were selected from each genotypes in each replication and in each year to record the data for seed yield and its attributing traits *viz.,* days to 50% flowering, number of primary branches/plant, plant height, pod length, number of seeds/pod, 1000 seed weight (TSW), days to maturity and seed yield/plant.

Pooled mean data of all the traits under study of each year were subjected to analysis of variance and stability parameters using statistical package Indostat 9.3 version. The stability of each genotype for each trait was calculated by regression of the mean of individual genotypes in environmental index and deviation from regression coefficient from unity as per methodology of Eberhart and Russel (1966) model. To analyze the GEI, additive mean effect and multiplicative interaction effects (AMMI) model was used and this statistical model is a combination of customary analysis of variance and principal component analysis using the GGE biplot technique proposed by Yan and Kang (2003).

Stability parameters

Homogeneity of variance were tested against homogenous error for each trait studied using Bartlett's test and allow for pooled analysis of variance of eight traits including seed yield and its components over three environments, indicated significant differences among varieties for all the traits. Variance due to environments and environment (linear) showed significant differences for all the traits studied except number of primary branches per plant indicating that the environments were linear in this investigation. GEI further subdivided into linear (bi) and non-linear (S^2di) components. The significance of linear component of GEI was recorded for all the traits except number of primary branches per plant. Significant non-linear components (pooled deviation) were recorded for plant height, number of primary branches per plant and pod length.

The results of present study are presented in Table 1. For days to 50% flowering, the genotypes, ML818, IPM2-3 and IPR57 showed minimum regression coefficient (S^2di) and therefore, these genotypes having above average stability and are recommended for low environments only. Genotypes Pusa Vishal, SML668, IPM2057, PM2-14 and MH521 showed minimum mean value than population mean with regression coefficient approaches to unity and least non-significant deviation from regression coefficient (S^2di) and hence, showed poor adaptability in all the environments. Genotype EC520016 showed higher mean value thus selected as a stable genotype with wider adaptability. For plant height Genotypes Pusa Vishal, SML668, Pusa 0672, IPM2057, IPM95-31, ML2056, Ganga 8, MH9-8-1, V1133 and LG 460 showed lesser with coefficient (S^2di) and therefore, recommended for unfavourable environment only. ML818 showed regression coefficient approaches to unity and at par with mean value (population) for plant height, hence recommended for wider adaptability. Nomarato et al. (2009) also reported a similar type of regression coefficients and mean values in their studies.

Table 1. Estimates of mean (i), regression coefficient (bi) and deviation from regression (S^2di) for yield and its component traits in mungbean genotypes

Genotypes	Days to flowering				Plant height (cm)				PBR			
	Mean	bi	R^2	S^2di	Mean	bi	R^2	S^2di	Mean	bi	R^2	S^2di
Pusa Vishal	45.89	0.99	0.98	-0.18	48.03	2.49**	1.00	-0.40	2.27	5.07	0.74	0.81***
ML818	47.44	1.23	0.95	0.78	57.55	1.02	0.99	0.30	3.60	0.53	0.61	0.00
PD139	46.33	0.84	1.00	-0.62	53.71	0.64*	1.00	-0.38	3.11	0.91	0.60	0.03
IPM2-3	47.44	1.60	0.97	0.96	58.62	-0.07*	0.52	-0.19	3.64	0.98	0.72	0.02
SML668	45.56	0.90	0.99	-0.45	55.17	2.59*	1.00	-0.33	2.88	3.86	0.73	0.48***
IPM99-125	50.33	2.05	1.00	-0.46	59.50	2.00	0.98	4.09 **	3.89	2.50	0.32	1.23***
Pusa 0672	46.44	0.87	0.99	-0.53	51.70	2.16	0.99	1.38 *	3.10	2.66	0.81	0.14 **
IPM2057	46.22	0.99	1.00	-0.58	46.55	2.17*	1.00	-0.32	4.69	12.98	0.71	6.40***
PM2-14	46.56	0.81	1.00	-0.60	55.36	1.82**	1.00	-0.39	3.34	0.52	0.43	0.01
IPR57	46.56	1.54	0.99	-0.02	43.96	-0.15**	1.00	-0.40	3.04	-0.45	0.59	-0.01
IPM95-31	45.22	0.43*	1.00	-0.61	55.47	1.13	1.00	-0.39	3.01	0.58	0.25	0.07 *
ML2056	49.44	1.33	0.99	-0.38	49.50	1.61	1.00	0.03	3.78	-2.84	0.55	0.61 ***
PM5	44.00	0.56*	1.00	-0.61	60.40	-0.76**	1.00	-0.39	3.00	-0.99	0.84	0.00
MH521	48.89	1.55	1.00	-0.53	62.10	-1.09*	0.98	0.57	4.08	-1.43	0.64	0.08*
Ganga 8	51.56	0.18	0.12	3.74 **	52.22	1.60*	1.00	-0.33	2.63	3.18	0.78	0.25 ***
IPM2-3-2	46.33	0.39	0.62	1.18	61.16	-1.28**	1.00	-0.39	4.07	3.39	0.67	0.51 ***
BM63	46.22	0.43*	1.00	-0.61	68.67	-1.38**	1.00	-0.40	2.54	3.40	0.74	0.37 ***
EC520016	48.78	1.06	0.98	-0.08	65.27	-0.54**	1.00	-0.40	4.29	-2.27	0.75	0.14 **
MH9-8-1	46.56	0.99	1.00	-0.58	54.32	1.49*	1.00	-0.38	3.47	-0.99	0.84	0.00
V1133	53.11	0.68	1.00	-0.60	52.83	2.47	0.99	2.09 *	5.06	-2.09	0.10	3.81***
MG331	47.67	1.31	1.00	-0.57	55.95	1.47	1.00	0.05	4.62	2.18	0.05	8.34 ***
K851	49.00	0.85	0.93	0.41	56.09	1.75	0.98	3.53**	3.99	-0.66	0.37	0.05
LG460	48.11	1.44	0.99	-0.18	45.05	1.86*	1.00	-0.36	3.30	-1.22	0.94	-0.01
Pop. mean	47.55	1.00	-	-	55.18	1.00	-	-	3.54	1.00	-	3.54
SE(m)	0.53	-	-	-	0.58	-	-	-	0.72	-	-	0.72
SE (bi)	0.17	-	-	-	0.12	-	-	-	3.33	-	-	3.33

Contd………

Genotypes	Pod length				Seeds/Pod				Days to maturity			
	Mean	bi	R^2	S^2di	Mean	bi	R^2	S^2di	Mean	bi	R^2	S^2di
Pusa Vishal	8.23	3.36	0.96	0.04	11.33	0.35	0.82	-0.03	71.33	0.76	1.00	0.23
ML818	8.12	2.08	0.96	0.01	10.85	1.99	0.99	-0.03	73.89	0.86	1.00	-0.40
PD139	6.71	-0.34	0.71	-0.01	11.44	0.35	0.95	-0.04	72.44	0.94	1.00	-0.38
IPM2-3	8.01	4.66	0.97	0.06*	12.46	-0.13	0.08	0.04	72.44	0.79**	1.00	0.48
SML668	7.62	-0.23	0.28	0.00	11.97	1.03	1.00	-0.04	72.22	0.89	1.00	-0.33
IPM99-125	7.25	-1.020*	0.98	-0.01	11.84	1.87**	1.00	0.04	73.56	0.98	1.00	-0.47
Pusa 0672	8.28	3.35	0.98	0.00	12.67	-0.26	0.19	0.09	74.11	1.08	1.00	-0.47
IPM2057	7.21	0.21	0.42	-0.01	12.36	0.22	0.56	-0.03	73.11	1.00	1.00	-0.37
PM2-14	7.57	-0.01	0.00	0.17**	11.58	0.73	0.94	-0.03	73.67	0.85*	1.00	-0.46
IPR57	7.38	1.61	0.99	-0.02	11.63	-1.16	0.97	-0.03	72.67	1.07	1.00	-0.35
IPM95-31	7.61	0.70	0.73	0.00	11.98	0.77*	1.00	-0.04	73.89	1.146*	1.00	-0.48
ML2056	8.12	1.18	0.99	-0.02	12.34	1.42	0.98	-0.02	74.11	1.05	1.00	-0.48
PM5	8.66	3.41	0.94	0.07*	11.80	1.61	0.93	0.04	73.22	1.06	1.00	-0.37
MH521	8.13	1.89	0.95	0.00	12.12	1.78	1.00	-0.04	72.11	1.00	1.00	-0.37
Ganga 8	6.58	-2.37	0.94	0.02	10.82	1.84*	1.00	-0.04	72.37	1.04	1.00	-0.37
IPM2-3-2	7.31	1.04	0.83	0.01	10.72	1.48*	1.00	-0.04	73.99	1.18	1.00	0.98
BM63	6.71	-0.96**	1.00	-0.02	11.68	0.57	0.54	0.08	73.79	1.03	0.98	4.61**
EC520016	7.53	-0.11	0.06	0.01	12.72	0.32	0.92	-0.04	75.56	1.26**	1.00	-0.49
MH9-8-1	8.11	2.550*	1.00	-0.02	11.81	1.01	1.00	-0.04	73.66	1.07	1.00	0.27
V1133	6.79	-1.20	0.63	0.08 *	11.67	1.26	0.98	-0.03	73.78	0.88	1.00	0.28
MG331	7.50	0.34**	1.00	-0.02	11.52	1.71	0.76	0.39**	74.83	1.09	1.00	0.73
K851	7.09	1.22	0.97	-0.01	10.27	3.16*	1.00	-0.04	74.11	0.91	0.99	1.61 *
LG460	7.71	1.64	0.83	0.05	11.86	1.08	0.91	0.01	73.34	1.07	1.00	-0.47
Pop. mean	7.58	1.00	-	-	11.71	1.00	-	-	73.40	1.00	-	-
SE(m)	0.13	-	-	-	0.15	-	-	-	0.53	-	-	-
SE (bi)	0.54	-	-	-	0.32	-	-	-	0.05	-	-	-

Contd……

Genotypes	1000 seed weight				Seed yield/plant			
	Mean	bi	R^2	S²di	Mean	bi	R^2	S²di
Pusa Vishal	52.31	2.87	0.55	0.05	9.59	1.09	0.94	-0.03
ML818	53.57	2.13	0.90	0.06	5.52	3.82	0.98	-0.02
PD139	22.52	1.81	0.72	-0.05	8.28	0.78	0.99	-0.03
IPM2-3	51.47	1.80	0.86	-0.06	8.48	-2.82**	1.00	-0.03
SML668	46.29	2.41	0.88	-0.06	5.41	1.13	0.71	-0.01
IPM99-125	46.22	1.61	0.56	-0.03	9.44	2.263*	1.00	-0.03
Pusa 0672	59.81	1.27	0.62	-0.05	6.52	1.14	0.75	0.01
IPM2057	39.44	2.42	0.96	-0.07	7.59	0.88	0.87	-0.02
PM2-14	60.67	-2.21	0.27	0.17	11.65	-1.69	0.97	-0.03
IPR57	61.20	1.81	0.58	0.03	5.52	1.56	0.82	-0.01
IPM95-31	49.95	1.06	0.84	-0.07	6.60	1.17	0.83	0.02
ML2056	54.40	1.48	0.72	0.05	6.54	0.29	0.07	0.02
PM5	39.56	3.65	0.76	0.01	6.40	1.53	0.86	-0.01
MH521	52.18	1.81	0.93	-0.07	5.52	2.15	0.90	-0.01
Ganga 8	48.64	2.21	1.00	0.07	5.85	2.69	0.99	-0.03
IPM2-3-2	45.69	1.23	0.52	-0.04	6.57	1.83	0.97	-0.02
BM63	51.51	2.51	0.93	-0.06	5.52	2.15	1.00	-0.03
EC520016	55.62	1.05	0.60	-0.06	6.39	0.26	0.03	0.05
MH9-8-1	59.95	-12.37	0.90	0.26*	5.53	1.30	0.90	-0.02
V1133	57.51	0.79	0.27	-0.04	5.82	1.84	0.99	-0.03
MG331	49.65	1.11	0.29	-0.02	6.67	0.28	0.09	0.00
K851	53.78	-0.55	0.02	0.20	5.69	0.81	0.24	0.05
LG460	49.74	3.10	0.49	0.12	6.29	-1.46	0.80	-0.01
Pop. mean	50.51	1.00	-	-	6.84	1.00	-	-
SE(m)	0.18	-	-	-	0.09	-	-	-
SE (bi)	1.91	-	-	-	0.67	-	-	-

Genotypes, ML818, IPM2-3, ML2056, MH521, MG331, V1133 and K851 showed higher no. of primary branches/plant with minimum S2di and therefore recommended for unfavourable environment only. IPM2-3 showed S2di approaching to unity (0.98) with minimum non-significant deviation and displayed above average stability in performance hence, recommended for wider adaptability. Genotypes, SML668 and IPM95-31 showed higher pod length with less b<1 and minimum S2di could be recommended for unfavourable environment. Genotypes Pusa Vishal, ML818, Pusa 0672, ML2056, MH521, MH9-8-1 and LG460 showed more length with minimum S2di and indicated below average stability and therefore may be adaptable to specific favourable environment only. Based on these parameters IPM2-3-2 is suitable for general cultivation.

Genotypes, ML2056, PM5 and MH521 showed higher no. of seeds/pod with mean regression coefficient, may be recommended for favourable environment while Pusa 0672, IPM2057 and EC520016 exhibiting minimum S2di may be suitable for unfavourable environment. SML668, MH9-8-1 and LG560 with higher mean value are of wider adaptability. Genotypes Pusa Vishal, ML818, IPM2-3, Pusa 0672, IPR57, ML2056 and BM63 showed high TSW with minimum S2di may be recommended for specific favourable environment. IPM95-31 and EC520016 showed at par mean value with population mean and regression coefficient equal to unity (b=1) and therefore, selected as widely adaptable genotypes. Genotype EC510016 showed higher mean value than population mean with regression coefficient equals to unity (b=1) hence, recommended for general cultivation. IPM2057, IPR57, MH521,Ganga 8and LG460 showed early maturity with equals to minimum coefficient and therefore, they are suitable for general cultivation whereas, Pusa 0672, ML2056, BM63, MH9-8-1 and MG331 showed higher mean value and the genotypes, IPM2057, PM5 and LG460 also showed mean with regression coefficient equal to unity (b=1) displaying wider adaptability. Paul et al. (2018) and

Thangavel et al. (2011) studied g x e interactions in mungbean and reported similar findings for different yield traits, while Paul et al. (2018) supported the present findings on different genetic parameters studying chickpea genotypes under heat stress.

Genotypes, PD139, IPM2057and PM2-14 showed high seed yield /plant with minimum S2di and therefore, suitable for unfavourable environment while Pusa Vishal showed higher mean value thus selected for wider adaptability in both, good and poor environments. From the present study, it was concluded that Pusa Vishal exhibiting regression coefficient equal to unity with non-significant deviation from regression coefficient and hence showed wider adaptability under poor or good environments. This genotype is recommended for commercial cultivation under diverse environments. Genotype EC520016 showed earliness in maturity with wider adaptability and it may be utilised for the development of early maturing improved varieties. Similar results on stability of genotypes with respect to yield and its related traits were reported by Singh et al. (2014) and Win et al. (2018) in mungbean, whereas, the results of Namorato et al. (2009) on G x E interactions, multivariate analysis and stability parameters corroborated the present findings. Paul et al. (2018) working on chickpea and Bocianowski et al. (2019) studying rapeseed also observed similar G x E interactions and Win et al. (2018), Thangavel et al. (2011) also supported the present findings. Environmental indices indicated that environment E_2 and E_3 were most favourable for yield and majority of yield attributing traits whereas E_3 alone was important for seed yield/plant and number of seeds per pod. Hence, the selected genotypes may be utilized in mungbean improvement programme at targeted environments with true type of breeding lines.

Authors' contribution

Conceptualization of research (SK, JPS, AK); Designing of the experiments (SK, JPS, HKC, AK); Contribution of experimental materials (HKC, JPS, SK); Execution of field/lab experiments and data collection (SK, JPS, AK, APS); Analysis of data and interpretation (SK, JPS, RS, RG, MS, AKS); Preparation of manuscript (SK, JPS, AK, HKC).

Declaration

The authors declare no conflict of interest.

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