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Research Article

Stability of promising greengram (*Vigna radiata* (L.) Wilczek) genotypes over seasons through AMMI analysis

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Abstract
Genotypes x environment interaction (GEI) effects are of special interest for plant breeders to identify stable genotypes. Present experiment was conducted for two years and two seasons from 2016-17 to 2017-18 at National Pulses Research Centre, TNAU, Vamban to assess the stability of 28 greengram genotypes for seed yield. In AMMI1 biplot for seed yield, the genotypes *viz*., VGG 16-003, VGG 16-016, VGG 16-054 and VGG 16-055 had IPCA 1 score close to zero with high main effects indicating that these genotypes were less influenced by environments and high yielders. VGG 16-054 and VGG 16-055 with high main effect and positive IPCA 1 score away from zero were identified as highly interacting genotypes with high yield. Genotypes *viz*., VGG 16-026, VGG 16-048, VGG 16-052, VGG 16-058, VBN (Gg) 3 and CO 8 were less interacting genotypes with high seed yield. These genotypes may be recommended for both the seasons *viz*., *Kharif* and *Rabi* seasons. Among environments, *Kharif* and *Rabi* seasons are highly interacting environments.

Introduction

Evaluation of genotypes for yield performance on a multi location, multi season frequently show genotype x environment (GE) interactions that complicate the selection and or recommendation of varieties . Greengram is an important grain legume crop grown in India and believed to be originated from India. In Tamil Nadu, greengram is cultivated in an area on 2.5 lakhs hectare with a production of 1.34 lakh tonnes and productivity of 536 kg/ha (AICRP-MULLaRP Annual Report, 2016-17). Adaptability is defined as the ability of a crop variety to perform well over diverse environments (Abheysiriwardena *et al*., 1991).

Varieties that show low G x E interaction and high yield are desirable for crop breeders and farmers, because it indicates that the environments have less effect on the performance of genotypes and their yield is largely due to the genetic composition (Linnemann *et al*., 1995). Several methods have been proposed for analyzing genotype × environment interaction (GEI) and the phenotypic stability of promising lines (Tarakanovas and Ruzgas, 2006). Two major groups of statistical methods have been proposed to analyze the G x E interaction are univariate and multivariate stability statistics (Lin *et al*., 1986). A combined analysis of variance can quantify the interactions and describe the main effects, but it is uninformative for explaining G x E interaction. Among multivariate methods, the additive main effect and multiplicative interaction analysis (AMMI) has been extensively applied in the statistical analysis of multi-environment cultivar trials.

The AMMI is a hybrid model involving both additive and multiplicative components of two way data structure. It separates the additive variance from the multiplicative variance and then applies principal component analysis (PCA) to the interaction portion to extract a new set of coordinate axes which explains the interaction pattern in more detail.. The effectiveness of AMMI procedure has been clearly demonstrated by various authors and more specifically by Zobel *et al.* (1988) in soybean, Crossa *et al.* (1990) in maize and Mahalingam *et al.* (2018) in greengram using multilocation trial data. The first example of using this model was provided by Zobel *et al.* (1988) who studied the interaction between the maturity of the genotypes and the day length of the locations in soybean Multi Evaluation Trial (MET). The objectives of the present study were to investigate the performance and consistency of newly evolved 28 greengram genotypes for seed yield (kg/ha) over different greengram growing seasons of Tamil Nadu, India using AMMI model.

Material and Methods

Twenty eight genotypes of greengram including two check varieties viz., CO 8 and VBN (Gg) 3 were evaluated in randomized block design (RBD) with two replications during *Kharif* 2016 and *Rabi* 2016-17, *Kharif* 2017 and *Rabi* 2017-18 at National Pulses Research Centre, Vamban, Tamil Nadu, India. All the genotypes were evaluated in a plot size of 12 m^2 with a spacing of 30 x 10 cm. Recommended package of practices were followed for raising good standing crop. The replicated data on seed yield (kg/ha) were analyzed as individual location-wise followed by pooled analysis. Further the data were subjected to stability analysis of AMMI model as per the standard method.

The equation of AMMI model is as under :
$Y_{ger}=\mu+\alpha_g+\beta_e+\Sigma_n \lambda_n \gamma_{gn} \delta_{en}+\rho_{ge}+t_{ger}$
Where, Y_{ger} is the trait of genotype g in environment e : μ is the grand mean, α_g is the genotypes deviation from grand mean and the environment deviation, β_e, λ_n is the eigen value of PCA axis n; γ_{gn} and δ_{en} are the genotype and environment PCA scores for PCA axis, n : ρ_{ge} is the residual of AMMI model and t_{ger} is the random error. AMMI uses ordinary ANOVA to analyze main effects and principal components to analyze the non-additive (interaction) left over by the ANOVA model. PCA decomposes the interaction into PCA axes 1 to N and residual remains if all the axes are not used. The interaction between genotype and environment can be estimated by multiplying the score of the interaction principal component axis (IPCA) of genotype by an environment IPCA score.

Results and Discussion

Several statistical methods were developed for the analysis of genotypes by environment interactions (GEI) and phenotypic stability (Crossa *et al*., 1990). Regression 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 traditional 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 trial data structure.

Understanding of G x E interaction in plant species is of importance because it has implications for economic yield. In view of influence of environmental factors on crop growth, it is necessary to explore variation among genotypes (Anandan, 2011). In the present study, ANOVA on individual location indicated the presence of significant differences among genotypes. The significance of variance due to G x E in pooled analysis indicated the presence of genotype x environment interaction. Hence, the data were analyzed for AMMI analysis. AMMI analysis indicated significant differences among the genotypes, among seasons and also due to the interaction of genotypes x environment for seed yield (kg/ha). In the present investigation, the analysis of variance showed significance for PCA1, PCA2 and PCA3 (Table 1). Among these, PCA 1 alone recorded 83.20 percent of total sum of squares. Hence, IPCA1 alone may decide the G x E interaction within study.

Biplot analysis is probably the most powerful interpretive tool for AMMI models. Biplots are graphs where both genotype and environment mean are plotted on the same axes (X axis) so that their inter relationships can be visualized. There are two basic AMMI biplots, the AMMI1 biplot where the main effects (genotype mean and environment mean) and IPCA1 scores for both genotypes and environments are plotted against each other and the AMMI 2 biplot where scores for IPCA1 and IPCA2 are plotted. AMMI2 biplots do not show genotype or environment main effects and hence do not show adaptation (Table 2.).

Among the high yielding genotypes viz., VGG 16-003, VGG 16-005, VGG 16-016, VGG 16-054 and VGG 16-055 had IPCA 1 score close to zero indicating that these genotypes were less influenced by environments (Fig. 1.). Hence, the above said genotypes were stable and had general adaptability for both *Kharif* and *Rabi* seasons. The checks, VBN (Gg)3 and CO 8 were low yielders with moderate interaction with environments. Genotypes VGG 16-027, VGG 16-029, VGG 16-035 were high yielders with high interaction with environment. Hence, these genotypes are not stable. The genotypes VGG 16-028 and VGG 16-047 were high yielders and moderately interacting with environment. Hence, these genotypes can be recommended for all seasons. Among the environments, E 4 was high yielding environment. In general, *Kharif* seasons had relatively less interaction than *Rabi* seasons.

In AMMI 2 biplot, IPCA1 and IPCA 2 values were plotted (Fig. 2.). In this graph, sites with short spokes did not exert strong interactive forces. Those with long spokes exerted strong interaction. The points representing the environments E 1, E 2, E 3 and E 4 were connected to the origin. The environments, E 1, E 2 and E 4 had long spokes and hence exerted strong interaction. The E 3 (R*abi* 2016-17) had short spoke than E 1, E 2 and E 4 with the origin and hence it has less interactive effect. In case of genotypes viz., VGG 16-013, VGG 16-026, VGG 16-036, VGG 16-048, VGG 16-052, VGG 16-058, VBN (Gg) 3 and CO (Gg) 8 were very close to the centre of the origin. Genotypes nearer to the origin were nonsensitive to environmental interactive forces. Hence, these genotypes can be classified as stable and those distant from the origin were sensitive and had large interactions.

Based on the foregoing discussion, it can be concluded that the genotypes VGG 16-013, VGG 16-036, VGG 16-048, VGG 16-052, VGG 16-058, VBN (Gg) 3 and CO (Gg) 8 were less interacting genotypes with high seed yield. These genotypes may be recommended for both the seasons viz., *Kharif* and *Rabi* seasons.

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Table 1. Analysis of variance for seed yield (kg/ha) in greengram

Source	acumulated value	Df	Sum of squares	Mean sum of squares
IPC1	83.20	29	6661468.20	229705.80*
IPC2	92.70	27	762547.20	28242.49*
IPC3	99.90	25	578336.50	23133.46*
IPC4	99.90	23	0.00	0.00

Table 2. Performance of greengram genotypes and their IPCA score for seed yield (kg/ha)

Sl. No	Genotype	Seed yield (kg/ha)	IPCA 1	IPCA 2	IPCA 3
1	VGG 16-003	909	-0.254	-4.339	3.435
2	VGG 16-005	892	-1.234	-4.556	-1.078
3	VGG 16-006	852	3.762	-8.242	-2.312
4	VGG 16-007	715	13.320	-1.305	-3.288
5	VGG 16-008	762	13.736	3.854	-8.218
6	VGG 16-013	846	-2.449	-0.055	2.280
7	VGG 16-016	894	1.338	5.156	-3.759
8	VGG 16-026	784	2.744	0.202	-1.285
9	VGG 16-027	1125	-11.341	-2.717	-1.856
10	VGG 16-028	1013	-4.095	-9.678	-1.122
11	VGG 16-029	1035	-10.428	7.342	3.927
12	VGG 16-030	704	13.432	0.099	7.236
13	VGG 16-035	1020	-18.322	-6.965	1.933
14	VGG 16-036	958	-3.188	3.715	-3.060
15	VGG 16-044	754	12.915	1.025	2.158
16	VGG 16-045	918	-9.407	5.315	-1.736
17	VGG 16-046	937	-8.836	1.488	-5.005
18	VGG 16-047	1027	-5.974	-4.124	5.356
19	VGG 16-048	923	-4.318	0.062	-1.234
20	VGG 16-049	793	7.479	-3.747	0.678
21	VGG 16-050	802	10.533	-2.336	3.165
22	VGG 16-052	893	-3.302	-0.790	4.768
23	VGG 16-053	889	-6.945	7.842	-8.393
24	VGG 16-054	965	0.892	6.220	5.913
25	VGG 16-055	935	0.224	8.735	10.306
26	VGG 16-058	961	4.131	-1.383	-2.357
27	VBN (Gg) 3	795	2.461	-1.438	-3.676
28	CO 8	783	3.128	0.620	-2.775
Environments					
	Kharif 16 (E1)	756	14.712	-9.790	-16.002
	Kharif 17 (E2)	759	5.706	21.213	-1.355
	Rabi16-17 (E3)	732	15.940	-7.502	16.716
	Rabi17-18 (E4)	1308	-36.358	-3.921	0.641

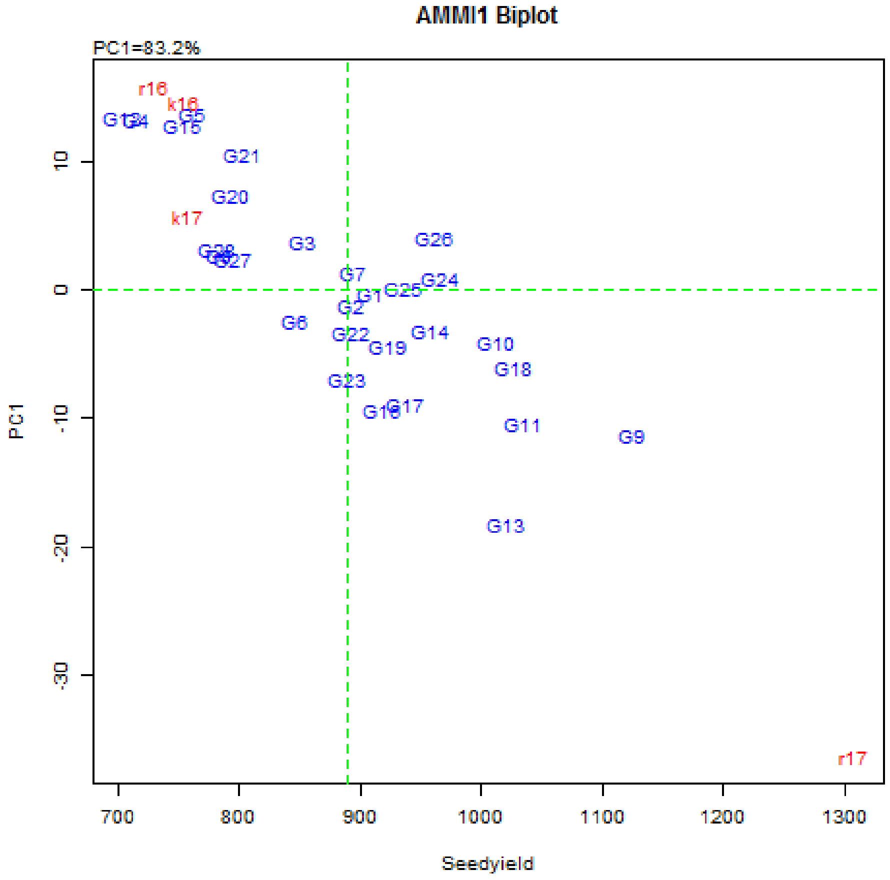

Fig. 1. AMMI 1 biplot for seed yield in greengram

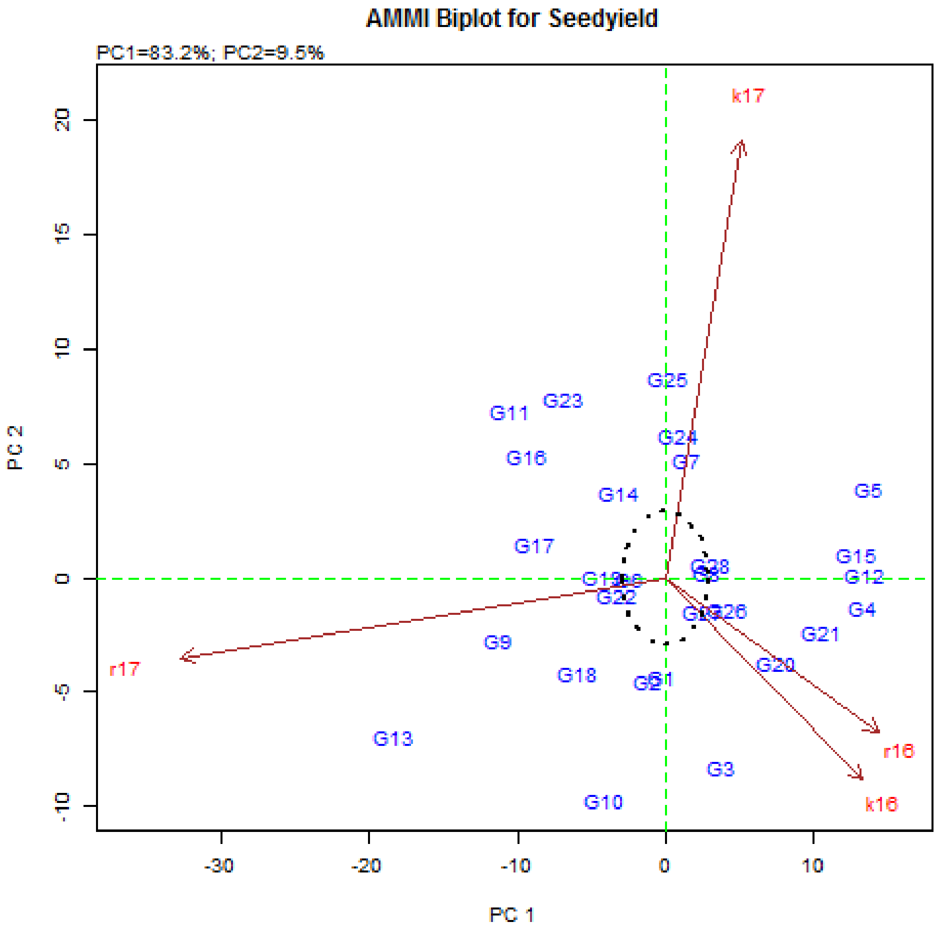

Fig. 2. AMMI 2 biplot for seed yield (kg/ha) in greengram