

Pattern of Genotype x Environment Interaction in Soybean

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Abstract: The genotype x environment interaction (GEI) is an important aspect of plant breeding program as it decides the general and specific adaptation of a variety to the varied environments. Higher magnitude of GEIs interactions were noted in soybean with their significant influence on yield. In the present study, 9 soybean genotypes were evaluated over 10 locations to investigate the structure of GEI using AMMI model. Among the variance components, environment had predominant role in deciding the genotypic performance, which could be attributed to diversity in the test environments. Significant GEI consisted of four principal component axes (PCA) with first two components explaining major portion of interaction. Wide variation was observed for yield among genotypes. JS 335, the popular variety ranked first with respect to performance over locations, but exhibited significant interaction with environments. Dharwad among environments had favorable conditions for the expression of genotypes. 10 locations have separated the biplot into 3 distinct groups in 3 quadrants which can be correlated with different rainfall and temperature regimes, which in turn could be associated with significant PCAs observed in the study.

Key words: Soybean, genotype x environment interaction, AMMI.

The genotype x environment interaction is an important aspect of both plant breeding program and the introduction of new crop cultivars (Freeman, 1985). High magnitude of GEIs were noted in soybean with significant influence on yield (Raut *et al.*, 1990; Taware *et al.*, 1991; Raut *et al.*, 1992; Basavaraja *et al.*, 1998). The total sum of squares for yield data could be partitioned into genotype main effect, the environment main effect and the GEI by ANOVA. Further, GEI is studied by regression analysis (Eberhart and Russell, 1966; Perkins and Jinks, 1968) or pattern analysis (Williams, 1976). Regression technique described the GEI based on regression co-efficient, while pattern analysis summarized the pattern of

responses based on principal component axis. But, these techniques failed in completely explaining the GEIs (Shorter, 1981) under field situations because of many confounding factors. Under such circumstances, application of additive main effects and multiplicative interaction (AMMI) analysis was more effective in explaining GEI over other methods of stability analysis (Zobel *et al.*, 1988). This model is a hybrid model involving both additive and multiplicative components of two-way data structure to form an integrated powerful least squares analysis (Freeman, 1985; Gauch, 1988). The AMMI model separates the additive variance from the multiplicative variance and then applies principal component analysis to the

interaction portion to extract a new set of co-ordinate axes, which explain in more detail the interaction pattern. The present investigation assessed the pattern of GEI in soybean under multilocation trials.

Materials and Methods

Nine soybean genotypes viz., DSb 1, DSb 3, DSb 5, DSb 6, DSb 7, DSb 8, KHSb 2, PK 1029 and JS 335 were grown in 6 row plots of 4 m length with a spacing of 30 x 10 cm in a randomized complete block design with three replications at 10 different locations of Northern Karnataka, during 2002 rainy season. The locations were Bidar (zone 1), Bheemarayanagudi, Raichur (zone 2), Arabhavi, Ugar Khurd, Bagalkot, Hagari (zone 3) and Dharwad, Sankeshwar, Nippani (zone 8). These zones were characterized by specific temperature and rainfall regimes. Bidar in zone 1 had good distribution of rainfall (Table 1) during the crop season with optimum temperature (maximum temperature around 30°C and minimum temperature around 20°C). In zone 2, Bheemarayangudi had less rainfall in the season while Raichur had very less rainfall in the month of July. Maximum temperature was >30°C and minimum temperature was around 24°C. Zone 3 had less rainfall with irregular pattern during the crop season. Maximum temperature was above 30°C and minimum temperature was around 22°C. Zone 8 had maximum temperature around 30°C and minimum temperature was around 20°C but rainfall was less than normal during July (14-61.2 mm) and September (6.6-40.3 mm) months as compared to average rainfall of 144 mm and 82 mm, respectively, in the zone.

Seeds were treated with 3 g captan kg⁻¹ seeds and rhizobium strain *Bradyrizobium*

japonicum @ 6 g kg⁻¹ seeds. The plots were kept free of weeds with two intercultivations at 20 and 40 days after sowing (DAS) and hand weeding at 60 DAS. Fertilizer was applied @ 20:80:40 kg ha⁻¹ NPK. The seed yield per plot was recorded and expressed as kg ha⁻¹ with appropriate conversion factor, which was used for statistical analysis. The data were subjected to Additive Main effects and Multiplicative Interaction (AMMI) analysis by IRRISTAT statistical package (IRRI, Manila, Philippines). Biplots (Bradu and Gabriel, 1978) were graphed with the same statistical package.

Results and Discussion

The AMMI analysis of variance clearly indicated that, genotypes, environments and GEI components were significant accounting for 8, 75 and 17% of the treatment sum of squares (Table 2). This shows the predominant role of environment in deciding the genotypic performance, which can be attributed to the diversity in the test environments. Diversity is due to varying temperature regimes along with differing intensity of rainfall in different agro-climatic zones characterized by (Table 1). Significant GEI consisted of four principal component axes (IPCA) with first two components explaining two-third of the interaction. Residual sum of squares accounted for only a little portion (7%) of the interaction sum of squares with 28% of the degrees of freedom (Table 2).

Mean performance and first PCA score of genotypes and environments is presented in Table 3, while Fig. 1 presents a biplot of the AMMI results. The main effects (genotype and location means) are shown

Table 1. Distribution of rainfall (mm) at various loctions in different zones during 2002 rainy season

Months	Zone 1		Zone 2		Zone 3			Zone 8		
	Bidar	B'gudi	Rai- chur	Hagari	Bagal- kot	Ugar Khurd	Arabhavi	Nippani	Sank- eshwar	Dharward
June	153.8	66.7	62.6	29.6	73.4	62.8	75.2	221.3	162.3	59.5
July	179.1	73.2	39.4	10.2*	28.9	14.3	3.6	61.2*	55.9*	14.0*
August	203.2	93.3	103.8	37.3	100.6	79.4	85.6	199.1	146.0	49.0
Sept.	142.5	92.5	112.6	11.2*	6.0	12.0	6.6	40.3*	31.8*	6.6*
Oct.	130.9	139.9	180.4	87.4	127.6	103.9	83.8	100.6	182.7	103.6
Total	809.5	468.6	498.8	175.7	336.5	272.4	254.8	622.5	578.8	232.7

* Irrigation was provided to avoid wilting of the crop during flowering and pod maturation stages.

along the abscissa (X-axis) and first PCA component on ordinate (Y-axis). Biplot accounted for 89.5% of the sum of squares revealing the goodness revealing the goodness of fit of the model. The usual interpretation of such a biplot assay is that, if a genotype or an environment has a PCA score of nearly zero, it has small interaction effect and when a genotype and an environment have the same sign the PCA axis, their interaction is positive; if different, their interaction is negative.

Yield levels ranged from 88 kg to 3310 kg ha⁻¹ indicating wide variation observed

across environments (Table 3). JS 335 ranked first (2067 kg ha⁻¹) across locations which could be due to its inherent high yield potential and wide adaptability which is evident by its extensive cultivation from central zone to peninsular zone in India. Our results are in agreement with Basavaraja *et al.* (1995) who reported stable performance of JS 335 using Eberhart and Russell model. But JS 335 had high IPCA score (Table 3) due to its sensitivity to some environments in the present study and wide range of yield levels (641 to 3310 kg ha⁻¹) observed between locations. KHSb 2, a long duration variety gave the lowest yield across locations and

Table 2. AMMI analysis of variance for seed yield in soybean

Source of variation	df	Mean sum of squares	Percentage of sum of squares
Genotype	8	448268**	8.08
Environment	9	3686120**	74.75
G x E	72	105860**	17.17
PCA 1	16	184285*	38.69***
PCA 2	14	153141**	28.13
PCA 3	12	90050 ^{NS}	14.18
PCA 4	10	89702*	11.77
Residual	20	27590	7.24
Error	159	13022	-
Total	89	4986880	100.0

*, ** Significant at 5% and 1% level of probability, respectively, *** percentage of G x E interaction sum of squares.

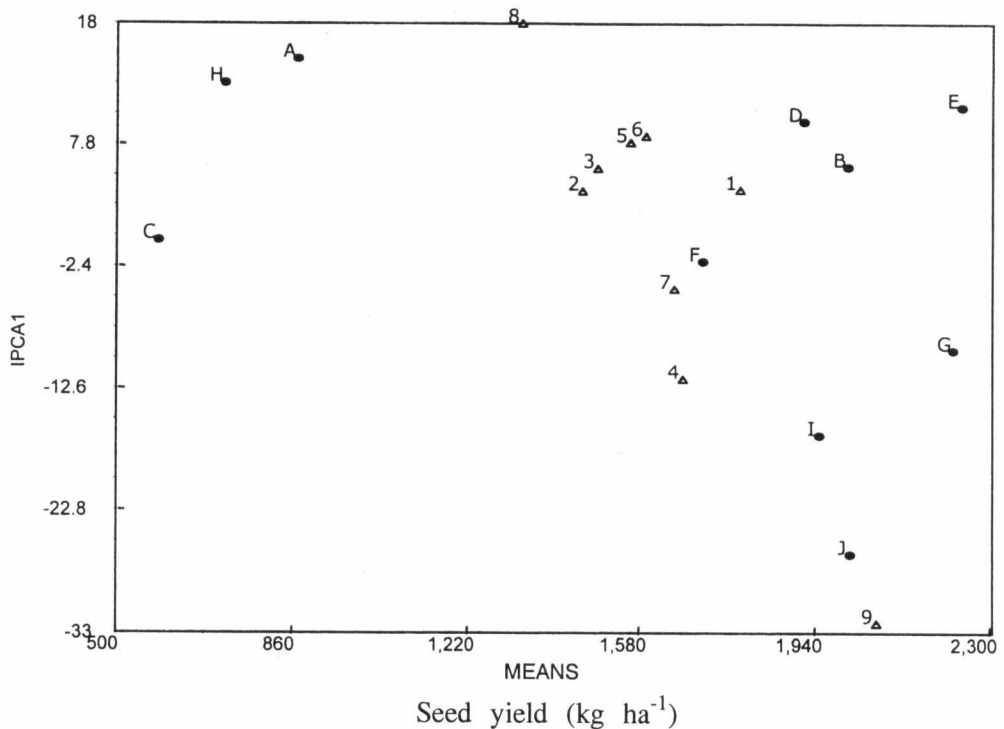


Fig. 1. AMMI 1 biplot of main effects and interactions for seed yield in soybean (1. DSb 1, 2. DSb 3, 3. DSb 5, 4. DSb 6, 5. DSb 7, 6. DSb 8, 7. PK 1029, 8. KHsb 2, 9. JS 335, A. Arabhavi, B. Bidar, C. Bhemarayanagudi, D. Bagalkot, E. Dwarwad, F. Hagari, G. Nippani, H. Raichur, I. Sankeshwar, J. Ugarkhurd).

exhibited high interaction effect with the environments. Genotypes, PK 1029 and DSb 1 provided above average yields with near zero PCA score and hence their ranking is more reliable in all the environments. DSb 6 had above average yield and was moderately influenced by GEI effect. DSb 5, 7 and 8 with below average yields had moderate GEI effects.

Dharwad presented an excellent environment for all genotypes to express their yield potential, but it showed high interaction effects. Bhemarayangudi was the most unfavorable environment, wherein 6 of the 9 genotypes had low yields, but had

near zero PCA score indicating very less interaction effect with the genotypes. Hagari had potential for average yield levels with near zero PCA score indicating low interaction effect on the genotypes. Raichur and Arabhavi had very low yields with high interaction effect. Environments grouped together in the biplot have similar yielding potential and/or similar interaction effect with the genotypes. Locations in zone 2 have low mean yields due to high temperatures and low rainfall in that zone.

Nippani, Sankeshwar and Ugar Khurd were favorable locations for DSb 6 and JS 335 since these locations and genotypes

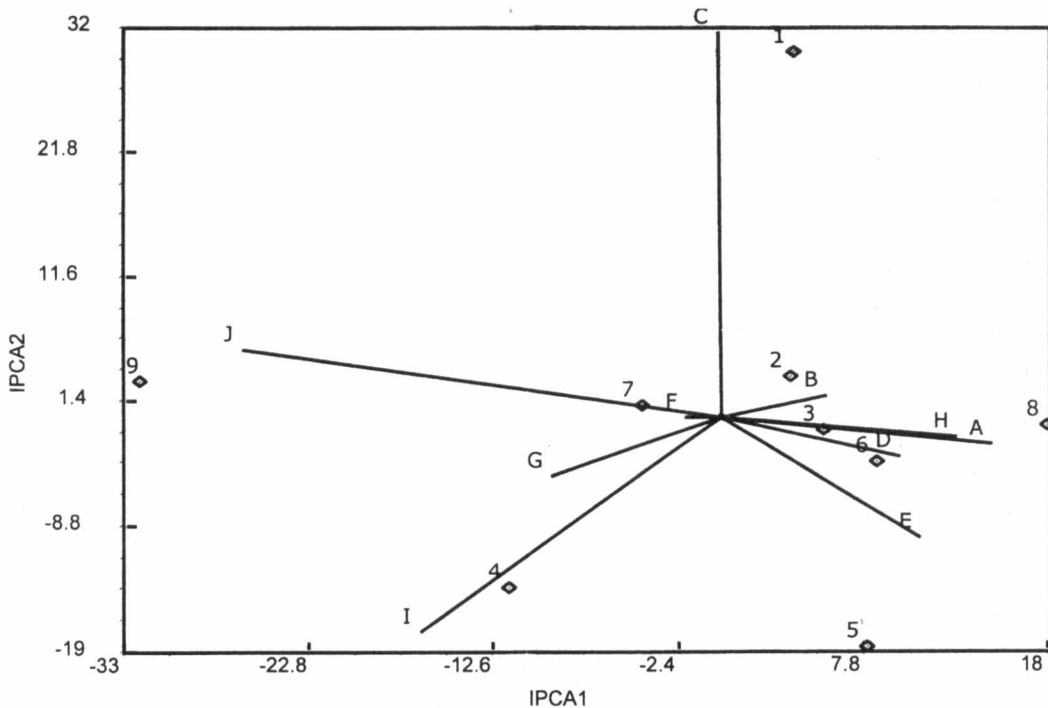


Fig. 2. Interaction biplot for the AMMI 2 model for seed yield in soybean (1. DSb 1, 2. DSb 3, 3. DSb 5, 4. DSb 6, 5. DSb 7, 6. DSb 8, 7. PK 1029, 8. KHsb 2, 9. JS 335, A. Arabhavi, B. Bidar, C. Bheemarayanagudi, D. Bagalkot, E. Dwarwad, F. Hagari, G. Nippani, H. Raichur, I. Sankeshwar, J. Ugarkhurd.

have same sign on the first PCA axis. DSb 3, 5, 7 and 8 had positive interaction with Bidar, Dharwad and Bagalkot as they have similar PCA score.

It is interesting to note that the locations have separated in the biplot into three distinct groups in three quadrants (Fig. 1). These groups have different rainfall and temperature regimes, which could be associated with significant PCAs in the study. Further detailed climatological observations revealed exact reasons for the large GEI in soybean yield trials. Earlier, Zobel *et al.* (1988) suggested day length/maturity relationships as responsible

for significant first PCA axis in soybean yield trials.

The biplot of first two PCA axes is represented in Fig. 2, which together accounted for 66.8% of the interaction SS. Since the GEI effect is determined by the product of corresponding PCA scores, genotypes or environments with a small GEI will have small scores and be close to the center of the axes. Genotypes occurring close together on the plot tend to have similar yields in all environments, while genotypes far apart may either differ in mean yield or show a different pattern of response over the environments. Further,

direction of the genotypes from the center relative to each other indicates correlations between them (Kempton, 1984).

Bheemarayangudi among locations and DSb 1 among genotypes, which have near zero IPCA score on first axis had high interaction score with second axis. Hagari among environments and PK 1029 among genotypes fell close to the center of the axis and hence had small GEI effect with both PCA axes. The genotypes DSb 3, 5 and 8 had positive correlation in their GEI effects. JS 335 and KHSb 2 fell far away from the center of axis differing both in yield potential and GEI effect. Ugar Khurd, Nippani and Sankeshwar were grouped together from rest of the locations since these locations had sufficient rainfall and/or irrigation facility. Thus AMMI analysis carried out in the present study gave greater insight into the magnitude and nature of GEI.

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