

Application of AMMI for Grain Yield Stability Analysis in Large Speckled Bean Genotypes Grown in Midlands of Bale Zone

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Abstract: Genotypes–environment interaction was studied for grain yield of seventeen large speckled bean genotypes at Goro, Ginnir and Dellomena in the midlands of Bale zone for two consecutive years 2016 to 2017 main cropping season. Randomized complete block design with four replications was used for this study. Plot size of 6.4m² (4 rows at 40cm spacing and 4m long) was used at all the tested locations. Yield stability is one of the setbacks facing plant breeders in developing widely adapted varieties with superior yield. The present study was carried out to investigate the effect of genotype by environment (Gx_E) on the yield stability of speckled common bean using seventeen genotypes in six environments (Locations x years combination). The combined analysis of variance for mean grain yield revealed that highly significant variation for year, environment, genotypes, and Genotype by environment interaction. It revealed that 34.16% of the total variation was attributed to environment effect followed by genotypes 11.84%, and genotypes by environment interaction 2.97%. On the other hand the AMMI analysis for the grain yield revealed that 69.75% of the variation was due to environment effect followed by Genotypes (24.18) and GE (6.07%). AMMI 1 component explained 61.64% of the total interaction sum squares whereas AMMI 2 accounted for 38.36% of the variation. Of the tested genotypes G5 and G11 showed consistent stability across the testing environments showing slope value close to unity and deviation from regression near to zero with high mean grain yield. Therefore, these two genotypes were identified as candidate varieties to be verified in the coming cropping season for the possible releases in the midlands of bale zone and similar agro-ecologies.

Keywords: AMMI, Common Bean, GSI, Stability

1. Introduction

Common beans (*Phaseolus vulgaris* L.) are the most important grain legume in nearly all lowland and mid altitude areas of Ethiopia. It is produced primarily by smallholder farmers both for cash and consumption. In 2014, it was cultivated by 3.34 million smallholders on 340 thousand hectare of land which is about 20% of total farm land allocated for pulses [8].

The concepts of Gx_E and yield stability have been issues to the breeders and biometricians for a long of time. A significant Gx_E for a quantitative trait is known to reduce the usefulness of the genotype means over all locations or

environments for selecting and advancing superior genotypes to the next stage of selection [28]. If there were no Gx_E associated with the genotype environment system relevant to a breeding objective, selection would be greatly simplified because the ‘best’ genotype in one environment would also be the ‘best’ genotype for all target environments [6]. Furthermore, variety trials would be conducted at only one location to provide universal results [21]. Though the concept of stability is largely unclear in the plant breeding literature partly due to the myriad of definitions that have been used to represent this concept [6], it is a powerful tool to partition the G x E into mean squares responsible for its occurrence. High yield stability usually refers to a genotype’s ability to

perform consistently, whether at high or low yield levels, across a wide range of environments [1]. The ultimate reason for differential stability among genotypes and for differential results from various test environments is non-repeatable G x E [37]. Several biometrical methods had been developed and used to analyze GEI, stability, and adaptability. But currently, AMMI and GGE models were considered models of the first choice for multi-location trials data analysis and which genotype won where pattern discovery [19, 23, 27, 34, 38]. Therefore the present study was used to identify stable, high yielding genotypes tested over environments using the AMMI model.

2. Materials and Methods

Seventeen Speckled bean genotypes were evaluated for two consecutive years 2016 to 2017 at the three midland districts of bale zone (Ginir, Goro and Dellomena) during main cropping season using randomized complete block design with four replications at all the testing sites. The plot size used was 6.4m² (4 rows at 40cm spacing and 4m long). The two central rows were used as harvestable area to analysis the mean yield of the genotypes. Combined analysis

of variance least significant difference (LSD) multiple range test were done using Cropstat9 software. The AMMI analysis was performed using the model suggested by [11]. The stability parameters like regression coefficient (bi), deviation from regression were also calculated using Cropsta9 program. AMMI stability value (ASV) was computed by the model suggested by [31]:

$$ASV = \sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1)\right]^2 + [IPCA2]^2}$$

A =Where, $\frac{SSIPCA1}{SSIPCA2}$ is the weight given to the IPCA1 value by dividing the IPCA1 sum squares by the IPCA2 sum of squares. The larger the IPCA score, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller ASV scores indicate a more stable genotype across environments.

Genotype Selection Index (GSI) also calculated by the formula suggested by [18]. Here it is calculated by taking the rank of mean grain yield of genotypes (RY_i) across environments and rank of AMMI stability value (RASV_i).

$$GSI_i = RASV_i + RY_i$$

Table 1. Lists of seventeen speckled bean genotypes used in the study.

Genotype Code	Genotypes	Genotype Code	Genotypes
G1	DAB- 359	G10	DAB- 368
G2	DAB- 378	G11	DAB- 437
G3	DAB- 376	G12	DAB- 360
G4	DAB- 457	G13	DAB- 459
G5	DAB- 410	G14	DAB- 430
G6	DAB- 369	G15	Brown Speckled
G7	DAB- 375	G16	Cranscope
G8	DAB- 439	G17	Dame
G9	DAB- 417		

3. Result and Discussion

The combined analysis of variance revealed that highly significant variation among the genotypes, environments and their interaction for mean grain yield at (P< 0.01%). Similar findings were reported by [3, 24, 35] for common bean varieties performance and their growing environments in Ethiopia. Furthermore, [2, 7, 10, 29-30, 33, 36] in previous studies, which found significant differences associated with the effects of genotypes, environments, and GE interactions when evaluating common bean genotypes in multi-environment trials in Brazil. The significant interactions of genotypes x environments (locations and years) suggest that grain yield of genotypes varied across the tested environments. Significant differences for genotypes, environments and GE interaction indicated the effect of environments in the GE interaction, genetic variability among the entries and possibility of selection for stable genotypes. [9] reported that GE interaction with location is more important than GE interaction with year. As GE interaction was significant, therefore we can further proceed

and estimate phenotypic stability [17]. Of the total variation observed, 34.16% was due to the environment followed by genotypes (11.84%), and GEI (10.63%) of the total sum squares (Table 2). The significant GL, GY, LY, and GLY were also indicated that the relative performance of lines at different locations and years was not similar.

Table 2. Combined ANOVA for 17 speckled bean genotypes.

Source of Variation	DF	Sums of Squares	Mean Squares	% explained
Year (Y)	1	14.4604	14.4604**	8.33
Location (L)	2	59.2928	29.6464**	34.16
Replication	3	1.37958	0.459861*	0.79
Genotype (G)	16	20.5561	1.28476**	11.84
Y X L	2	18.4517	9.22587**	10.63
L X G	32	5.16107	0.161283**	2.97
Y x L X G	48	11.0747	0.230722**	6.38
Residue	303	43.1778	0.142501**	24.88
Total	407	173.554		

Table 3 describes the mean grain yield, stability parameters like slop (bi), deviation from regression (S²di), the IPCA scores, ASV and GSI of the speckled bean genotypes. Purchase [31] developed the AMMI stability

value (ASV) based on the AMMI model's IPCA1 and IPCA2 (interaction principal components axes 1 and 2, respectively) scores for each genotype. Considering the ASV value, genotypes G16, G14, G7, G3, G13, G9, G2 and G5 showed the least ASV indication stability of these genotypes across the testing environments (Table 3). Since ASV only consider the IPCA score without taking into account the mean grain yield of the genotypes, stable genotypes identified using ASV may gave lower yield. Stability per se should however not be the only parameter for selection, because the most stable genotypes would not necessarily give the best yield performance [25-26] hence there is a need for approaches that incorporate both mean yield and stability in a single

index, that is why various authors introduced different selection criteria for simultaneous selection of yield and stability [4-5, 12-13, 16, 23 and 32].

Therefore, in order to solve this problem a new approach known as genotype selection index (GSI) was recommended by [16]. Using AMMI stability value and mean yield, GSI incorporates both mean yield and stability in a single criterion. Low value of this parameter shows desirable genotypes with high mean yield and stability [15]. Based on this Genotypes Selection Index (GSI), G3, G5, G4 and G11 were considered as the most stable genotypes with higher grain yield (Table 3).

Table 3. Mean yield First and second IPCA and various yield-stability statistics investigated in small red common bean.

Genotype code	Mean yield (t/ha)	RYi	bi	MS-DEV (S ² di)	IPCA1	IPCA2	ASV	RASV	GSI
G1	1.45	8	0.66	0.67	-0.27	-0.12	0.45	15	23
G2	1.09	15	0.77	0.01	-0.17	-0.18	0.33	7	22
G3	1.57	4	1.19	0.34	0.15	0.06	0.24	4	8
G4	1.62	3	1.01	0.05	0.13	-0.28	0.35	8	11
G5	1.78	1	1.26	0.02	0.24	-0.16	0.35	8	9
G6	0.98	17	0.65	0.79	-0.28	-0.11	0.46	16	33
G7	1.2	13	0.91	0.51	-0.07	-0.06	0.13	3	16
G8	1.54	6	0.87	0.05	-0.15	0.28	0.37	10	16
G9	1.38	11	1.16	0.03	0.10	0.26	0.30	6	17
G10	1.36	10	1.40	0.89	0.34	-0.04	0.55	17	27
G11	1.65	2	0.84	0.01	-0.23	0.07	0.37	10	12
G12	1.42	9	0.91	0.06	-0.12	0.32	0.37	10	19
G13	1.51	7	0.84	0.02	-0.10	-0.24	0.29	5	12
G14	1.06	16	0.92	0.21	-0.07	0.04	0.12	2	18
G15	1.55	5	1.31	0.53	0.25	0.25	0.41	14	19
G16	1.22	12	1.02	0.56	0.01	0.06	0.06	1	13
G17	1.17	14	1.29	0.89	0.24	0.04	0.39	13	27

AMMI Analysis

The AMMI model combines the analysis of variance for the genotype and environment main effects with principal components analysis of the G × E interaction [20-21]. The grain yield data were subjected to combined analysis of variance and AMMI analysis which is a combination of analysis of variance and multiplication effect analysis. Briefly, analysis of variance is used to partition variance into three components: genotype deviations from the grand mean, environment deviations from the grand mean, and GE deviations from the grand mean. Subsequently, multiplication

effect analysis is used to partition GE deviations into different interaction principal component axes (IPCA), which can be tested for statistical significance through ANOVA. In this study, the analysis of variance for AMMI model revealed significant difference for genotypes, environment and GEI interaction. Accordingly, 69.75% of the total variation was attributed to environment followed by genotypes (24.18%) and GEI (6.07%) of the total sum squares. The AMMI model analysis had partitioned the GEI into the first two significant IPCAs with contributions of IPCA1 (61.64%) and IPCA2 (38.36%) (Table 4).

Table 4. Analysis of Variance for the AMMI Model.

SOURCE	D. F.	S. S.	M. S.	% TSS
Genotype	16	2.56952	0.160595**	24.18
LOCATIONS	2	7.4116	3.7058**	69.75
G X E	32	0.645134	0.02016**	6.07
AMMI COMPONENT 1	17	0.397688	0.023393**	61.64
AMMI COMPONENT 2	15	0.247446	0.016496**	38.36
TOTAL	50	10.6262		

AMMI biplots were recently preferred biplots to visualize adaptability and stability of genotypes over test environments [19-22]. In AMMI1 biplot, the genotypes with IPCA1 scores close to zero express general adaptation and the larger scores depict more specific adaptation in combination with environments of the same sign IPCA1

scores ([14]. Furthermore, the relative magnitude and direction of genotypes along the abscissa and ordinate axis in biplot is also important to understand the response pattern of genotypes across environments and to differentiate high yielding and adaptable genotypes [34]. In Figure 1 where IPCA was plotted against mean grain yield,

the vertical line passing through the origin is the grand mean. Accordingly, G12, G1, G13, G8, G15, G3, G4, G11 and G5 were above mean grain yield above the grand mean. Environment Goro, gave the highest mean grain yield compared to the other sites since it is found in the right side of the figure 1. On the other hand those genotypes and environment which was found in the left side of the vertical line gave mean grain yield below the grand mean. Genotypes G6, G14 and G2 were more specifically adapted to Dellomena site whereas G7 and G16 were adapted to the other site, Ginir. G3, G4, G15 and G5 also more yield at Goro sites than the other sites.

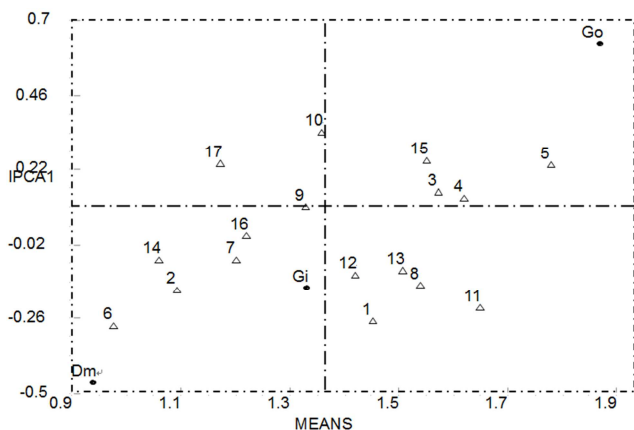


Figure 1. Biplot analysis of GEI based on AMMI 1 for IPCA 1 score and mean grain yield of genotypes and environments.

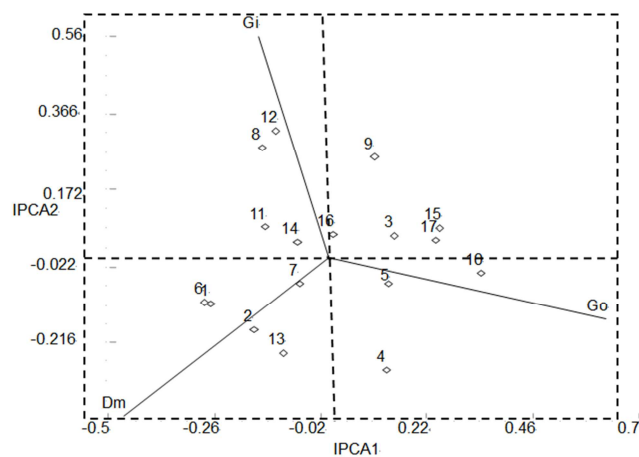


Figure 2. Biplot analysis of GEI based on AMMI 2 model for the first two IPCA scores.

The AMMI2 biplot (Figure 2) explained 100% of the GE interaction, making it a useful test for interaction. It was observed that most of the genotypes and environments were dispersed around the biplot. Genotypes farther from the centre of biplot show specific adaptation. In order to estimate specific adaptation and study their stability, biplot diagram was used. [26] in a study of genotype \times environment interaction in durum wheat revealed that those genotypes which are far from the centre of biplot, have high $G \times E$ interaction and those genotypes that nearest to centre of biplot, have high stability. Thus, here in this study G7, G5,

G3, G11, G14 and G16 were more stable than the other genotypes since they were found near to the origin and have general adaptability. However, G7, G14 and G16 though they were stable, they gave grain yield below the grand mean. The other genotypes showed specific to the certain environments. For instance, G1, G2, G6 and G13 were more adapted to Dellomena whereas G4, G10, G15 and G17 were specifically adapted to site Goro. G8 and G12 were more favorable to site Ginir.

4. Conclusion

The results indicated that the yield performance of speckled bean genotypes was highly influenced by GE interaction effects; the magnitude of environment effect was about 2.88 times that of genotype effect. When the stability parameters like slope (bi), deviation from regression, ASV, GSI and mean grain yield take into consideration, out of the tested genotypes G5 and G11 were found to be more stable with high mean grain yield. Therefore, these two genotypes were identified as candidate genotypes to be verified for the possible release in the coming cropping season

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