

# AMMI Analysis for Grain Yield Stability in Faba Bean Genotypes Evaluated in the Highlands of Bale, Southeastern Ethiopia

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**Abstract:** Genotype by environment interactions are studied to gain a better understanding of various phenomena. Among which yield stability can be highly determined by evaluating genotypes across different testing sites. This study was conducted to determine the effect of genotype  $\times$  environment interaction (GEI) on grain yield, and to assess yield stability of faba bean genotypes. For this purpose, fourteen faba bean genotypes were evaluated using randomized complete block design with four replications at Sinana, Agarfa and Goba for three years (2017 to 2019) in the highlands of Bale, Southeastern Ethiopia. In this study it was revealed significant variation for the main effects, Genotypes, Environments and their interaction effect at  $P < 0.01\%$ . Genotype's mean grain yield ranged from 2.14t/ha (EK05024-3) to 3.24t/ha (EK06007-2). The analysis of variance for AMMI also revealed significant variation for genotypes, environment and genotypes by environment interaction. Of the total sum of variation observed in grain yield environment, genotype and GEI contributed 86.15%, 5.67% and 8.15%, respectively. Using stability parameters ASV and Genotype Selection Index (GSI), genotype G1, G8, G12 and G14 showed general stability over the testing environments, whereas G3, G4, and G10 showed moderate stability since they have the second lowest GSI. But of all these genotypes, G10 gave the largest mean grain yield with a yield advantage of 21% compared to the checks used in this study. Therefore, G10, because of its yielding potential and moderate stability over the testing environments, it was selected as candidate genotype to be verified for possible release in the highlands of Bale, Southeastern Ethiopia and similar agro-ecologies.

**Keywords:** AMMI, Faba Bean, Genotype X Environment Interaction, GSI

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## 1. Introduction

Among pulse crops produced in Ethiopia, Faba bean leading in terms of area coverage and total production [10]. Faba bean is mainly produced in an elevation of 1800 to 3000 m.a.s.l. [12]. As faba bean has wider adaptation in different agro-ecologies, their response differently to the testing environments mainly described as genotype  $\times$  environment interaction (GEI). Genotype's wider or specific adaptation has determined by the genotype environment interaction. This differential phenotypic response of genotypes to environmental changes cannot be explained by the genotype and the environment main effect, unless and

otherwise it is considered along with  $G \times E$  interaction effects [11]. Several methods helped to quantify  $G \times E$  interaction, all of which are based on evaluation of genotypes under multiple environments. Different methods were used to explain  $G \times E$  interaction facilitate the decision to recommend variety have been extensively reviewed by different authorities, Crossa J *et al.*, Ferreira DF. *et al.*, Hussein MA. *et al.*, and Zobel RW *et al.*, [3, 7, 9, 17]. Not all methods are equally effective in analyzing the multi-environment data structure in breeding programs [13, 17]. Additive main effects and multiplicative interaction (AMMI) is the most powerful statistical package used to analyze the stability analysis to clearly indicate the interaction. Thus the

present study was initiated with the objective to identify high yielding and stable faba bean genotypes that were tolerant/resistant to major faba bean diseases, chocolate spot, Aschochyta blight and rust in the study areas, in the highlands of Bale, Southeastern Ethiopia.

## 2. Materials and Methods

Including two standard checks, and one local cultivar a total of fourteen faba bean genotypes (Table 1) were evaluated using randomized complete block design with four replications at three locations Sinana, Goba and Agarfa for three consecutive years 2017 to 2019 cropping season in the highlands of Bale. Plot of 6.4m<sup>2</sup> (4 rows at 40cm spacing and 4m long) was used at all the testing sites. The recommended seeding rate of 200kg/ha, and NPS fertilizer at a rate of 100kg/ha was used at all the locations. Analysis of variance of grain yield for each environment was done using the CropStat, ver. 7.2 computer programs.

Stability analysis: The additive main effect and multiplicative interaction (AMMI) analysis was performed using the model suggested as  $Y_{ij} = \mu + g_i + e_j + \sum_{n=1}^h \lambda_n \alpha_{ni} \cdot Y_{nj} + R_{ij}$  [2] where,

$Y_{ij}$  is the yield of the  $i^{th}$  genotype in the  $j^{th}$  environment,  $\mu$  is the grand mean,  $g_i$  is the mean of the  $i^{th}$  genotype minus the grand mean  $e_j$  is the mean of  $j^{th}$  environment minus the grand mean,  $\lambda_n$  is the square root of the eigen value of the principal component Analysis (PCA) axis,  $\alpha_{ni}$  and  $Y_{nj}$  are the principal and the principal component scores for the PCA axis  $n$  of the  $i^{th}$  genotype and  $j^{th}$  environment, respectively and  $R_{ij}$  is the residual. The Genotype by environment Interaction bi-plot was plotted for the 14 Faba bean genotypes tested at 9 environments. The regression of yield for each variety on yield means for each environment was computed with the CropStat 7.2 program.

The AMMI Stability Value (ASV) is analyzed by the method suggested as below [14]:

$$ASV = \sqrt{\left[ \frac{SS_{IPCA1}}{SS_{IPCA2}} (IPCA1score) \right]^2 + [IPCA2]^2}$$

**Table 2.** Combined analysis of variance for faba bean genotypes tested at three locations for three consecutive years.

Source of Variation	Degree freedom	Sum Squares	Mean Squares	% explained of TSS
YEAR (Y)	2	15.8116	7.90582**	
Location (L)	2	124.791	62.3954**	18.07
Replication	3	1.44178	0.480593	
Genotype (G)	13	32.9046	2.53112**	4.76
Y X L	4	358.95	89.7374**	
L X G	26	13.5915	0.52275**	1.97
Y X L X G	78	33.8156	0.433533*	
RESIDUAL	375	109.348	0.291594	
TOTAL	503	690.653		

Where \*,\*\*=indicates significant and highly significant at  $P < 0.01$  level of probability, respectively

### 3.2. AMMI Analysis

The ANOVA for AMMI analysis revealed highly significant variation of environments, GEI, and genotypes

Where,  $\frac{SS_{IPCA1}}{SS_{IPCA2}}$ , 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. The smaller IPCA score indicates a more stable genotype across environments.

Genotype Selection Index (GSI): is calculated for each genotype by the method suggested as  $GSI_i = RY_i + RASV_i$  [6].

**Table 1.** Genotype code and the name of 14 faba bean genotypes.

SN	Genotypes Code	Genotypes	Environments Code
1	G1	Shallo x EH98143-1-2-1-0	A=Sinana 2017
2	G2	Shallo x EH00100-2-1-3-0	B=Agarfa 2017
3	G3	Shallo x EH00097-2-1-2-0	C=Goba 2017
4	G4	Shallo x EH00098-7-1-2-0	D=Sinana 2018
5	G5	EK 05024-3	E=Agarfa 2018
6	G6	Shallo x EH 99019-5-2-2-0	F=Goba 2018
7	G7	Shallo x EH00102-5-5-1-0	G=Sinana 2019
8	G8	Shallo x EH00100-2-2-4-0	H=Agarfa 2019
9	G9	EK 06027-2	I=Goba 2019
10	G10	EK 06007-2	
11	G11	EK 06007-4	
12	G12	Mosisa (Satndard.check)	
13	G13	Shallo (Satndard.check)	
14	G14	Local check	

## 3. Result and Discussion

### 3.1. The Analysis of Variance

The combined analysis of variance for grain yield revealed highly significant variation for environments, genotypes and Genotypes by environment interaction at  $P < 0.01\%$  (Table 2). The same significant interaction of environment, genotypes and GEI in their study was reported by [1, 8, 10, 16]. The significant of GEI for grain yield indicates the genotypes responded differently to the tested environments. Of the total SS variation for grain yield, 18.07% was accounted by environments followed by genotypes (4.76%) and their interaction (1.97%). From this it is concluded that the environments were more diverse for the variation obtained in grain yield by the tested genotypes.

(Table 3). This analysis also revealed about 86.15% of the total sum square of variation for grain yield was due to the environments, whereas 8.18% was due to genotype by environment interaction, and 5.67% was because of the

genotypes. This revealed as the testing sites were more diverse for the variation in grain yield observed by the genotype. High percent of variation due to the environment was also reported by Tadele Tadesse *et al.*, and Tamene *et al.*, [15, 16] on faba bean; [4] on Triticale. Since the AMMI model revealed the significance of the GEI, The first two AMMI components showed significant variation at  $P < 0.01\%$ , and explained a total variation of 40.42% was accounted for

AMMI 1, followed by 22.93 for AMMI 2, 13.04 for AMMI 3 and 10.97 for AMMI 4, respectively. The first two AMMI components in total showed 63.35% of the total variation indicating the two AMMI components well fit and confirm the use of AMMI model. [3, 17] describes the interaction sum of square highly predicted by the first two AMMI components.

**Table 3.** Analysis of Variance of AMMI model for grain yield of faba bean genotypes.

Sources	DF.	SS	MS	TSS explained %
Genotypes	13	8.226	0.633	5.67
Environment	8	124.888	15.611	86.15
G X E	104	11.852	0.114	8.18
AMMI 1	20	4.791	0.240**	40.42
AMMI 2	18	2.717	0.151**	22.93
AMMI 3	16	1.546	0.097	13.04
AMMI 4	14	1.3	0.093	10.97
GXE RESIDUAL	36	1.498	0.633	
TOTAL	125	144.97		

### 3.3. Stability Analysis

The analysis using AMMI stability value indicated that G8, G5, G14, G3, G12 and G7 had low ASV is indicating stable performance over the studied areas. Though all these aforementioned genotypes showed stable performance, they gave a mean grain yield lower than the highest yielding check, Shallo (2.68t/ha) (Table 4). Stability is not the only parameter for selection of high yielding genotypes as the

most stable genotypes would not necessarily give the best yield performance. Therefore, the use of GSI which consider both mean grain yield and ASV, is important to identify genotypes that can perform in a stable manner with higher yield. Accordingly, genotypes G8, G1, G12 and G14 showed the lower GSI value indicating general stability. G3, G4, G10 and G13, on the other hand, gave the second lowest GSI value indicating moderate stability. In general, G10 gave the highest mean grain yield with moderate stability.

**Table 4.** Mean grain yield, Slope, deviation from regression IPCA values, ASV and GSI for grain yield of Faba bean.

SN	Genotypes	Mean	Rank Yi	Slope (bi)	MS-DEV (S <sup>2</sup> di)	IPCA1	IPCA2	ASV	Rank ASV	GSI
1	Shallo x EH98143-1-2-1-0	2.61	3	1.15	0.14	-0.09	-0.73	0.75	9	12
2	Shallo x EH00100-2-1-3-0	2.43	10	1.07	0.13	-0.35	0.49	0.79	10	20
3	Shallo x EH00097-2-1-2-0	2.36	11	0.96	0.13	0.16	-0.45	0.53	3	14
4	Shallo x EH00098-7-1-2-0	2.49	8	1.12	0.09	-0.38	-0.05	0.67	7	15
5	EK 05024-3	2.14	14	1	0.07	-0.19	0.19	0.39	2	16
6	Shallo x EH 99019-5-2-2-0	2.55	7	1.18	0.06	-0.41	-0.19	0.74	8	15
7	Shallo x EH00102-5-5-1-0	2.19	13	0.84	0.04	0.2	0.45	0.57	6	19
8	Shallo x EH00100-2-2-4-0	2.58	5	1.01	0.02	0.04	0.06	0.09	1	6
9	EK 06027-2	2.6	4	0.84	0.18	0.62	0.07	1.1	13	17
10	EK 06007-2	3.24	1	0.96	0.1	0.75	0.03	1.32	14	15
11	EK 06007-4	2.29	12	0.84	0.12	0.57	-0.19	1.03	12	24
12	Mosisa	2.58	5	0.97	0.13	-0.09	0.53	0.56	5	10
13	Shallo	2.68	2	1.25	0.05	-0.52	-0.24	0.96	11	13
14	Local check	2.44	9	1.11	0.02	-0.3	0.01	0.53	3	12

Where YRi=rank for grain yield, bi=regression coefficient, MS-DEV=deviation the regression, IPCA=Interaction principal component, ASV=AMMI Stability Value, GSI=Genotype selection Index

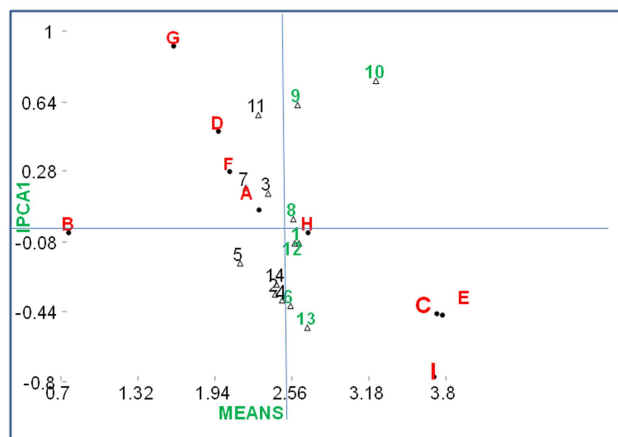
### 3.4. AMMI Bi-plots

The AMMI1 bi-plot was constructed from the first Interaction principal component value and mean grain yield, indicates that genotype and environments found at the right side of the perpendicular line passing through the origin, gave a mean grain yield greater than the grand mean (2.51t/ha). Accordingly, genotypes G1, G6, G8, G9, G10, G12 and G13; whereas environments C, E, H and I gave mean grain above

the grand mean. The rest genotypes and environments gave a mean grain yield below the grand mean (Figure 1).

The second bi-plot graph (Figure 2) which is constructed by the use of the two interaction principle components also indicates that genotypes found closer to the origin showed stable performance over the testing environments. [5] Clearly indicates as those genotypes found close to the origin showed general adaptability than those found at far distance away from the origin likewise those environments found in the

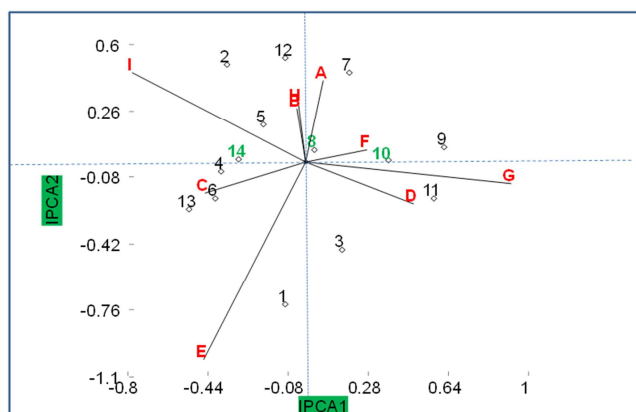
closest distance to the origin were less responsive to the changing environmental factors. In the present study, G8, G10 and G14, which are found close to the origin showed general stability, whereas, environment B, F, H and D showed less responsive to the changing environmental condition allow stability for the genotypes tested in it (Figure 2).



VARIATE: T/HA DATA FILE: MSFBRV MODEL FIT: 95.1% OF TABLE SS

**Figure 1.** Bi-plot interaction based on AMMI 1 and the mean grain yield.

#### INTERACTION BILOT FOR THE AMMI2 MODEL



VARIATE: T/HA DATA FILE: MSFBRV MODEL FIT: 63.3% OF GXE SS

**Figure 2.** Interaction bi-plot for the AMMI 2.

## 4. Conclusion

The field trial conducted at Sinana, Goba and Agarfa for three years cropping season revealed that the yield and yield component of faba bean genotypes was highly affected by the environmental factor which allow to have different performance over the tested sites. Furthermore, the adaptability and stability of a genotype are useful parameters for recommending cultivars for known cropping conditions. From the present study it was concluded that G10 which gave the highest mean grain yield than the rest of the genotypes with yield advantage of 21% over the checks, and showed moderate stability over the testing sites, is identified as candidate genotypes to be verified in the coming cropping season for possible release after being evaluated by the

National Variety Releasing Committee.

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## References

- [1] Cathrine K., Jens Nørgaard K. Winnie F. Jens S., Frederick L. Luc Janss, and Andersen S. U. (2019). Evaluation of yield, yield stability and yield-protein trade-off in commercial faba bean cultivars <https://doi.org/10.1101/843862>.
- [2] Crossa J. Statistical analyses of multi-location trials. *Adv. Agron.* 1990; 44: 55-85.
- [3] Crossa, J., Fox P. N., Pfeiffer, W. H., Rajaram, S., and Gauch, H. G. 1991 AMMI adjustment for statistical analysis of an interactional wheat yield trial. *Theor. App Genet*, 81: 27-37.
- [4] Dagnachew L., Kassahun T., and Girma M., 2014. Genotype by environment interaction and grain yield stability analysis for advanced triticale (x. *Triticosecale* wittmack) geno-types in western oromia, ethiopia. *Ethiop. J. Sci.*, 37 (1): 63–68, 2014.
- [5] Ebdon, J., and Gauch, H. 2002. Additive Main Effect and Multiplicative Interaction Analysis of National Turfgrass Performance Trials. I. Interpretation of Genotype × Environment Interaction. *Crop Sci.*, 42 (2): 489-496.
- [6] Farshadfar, E. 2008. Incorporation of AMMI stability value and grain yield in a single non-parametric index (GSI) in bread wheat. *Pak J Biol Sci*, 11 (4): 1791-1796.
- [7] Ferreira DF, Demetrio CGB, Manly BFJ, Machado ADA, Vencovsky R. Statistical model in agriculture: Biometrical methods for evaluating phenotypic stability in plant breeding. *Cerne Lavras*. 2006; 12: 373-388.
- [8] Getahun Mitiku and Abere Mnalku. 2019. Faba Bean (*Vicia faba* L.) Yield and Yield Components as Influenced by Inoculation with Indigenous Rhizobial Isolates under Acidic Soil Condition of the Central Highlands of Ethiopia. *Ethiop. J. Agric. Sci.* 29 (3) 49-61.
- [9] Hussein MA, Bjornstad A, Aastveit AH. SASG x ESTAB: A SAS program for computing genotype x environment stability statistics. *Agron. J.* 2000; 92: 454-459.
- [10] Mesfin T, Wassu M, Mussa J. (2019). Genetic Variability on Grain Yield and Related Agronomic Traits of Faba Bean (*Vicia faba* L.) Genotypes under Soil Acidity Stress in the Central Highlands of Ethiopia. *Chemical and Biomolecular Engineering*, 4 (4): 52-58. doi: 10.11648/j.cbe.20190404.12.
- [11] Mohammadi R, Armion M, Shabani A, (2007). Daryaei A. Identification of stability and adaptability in advanced durum genotypes using AMMI analysis. *Asian J. Plant Sci.* 6: 1261-1268.
- [12] Mussa J, Gemechu K. (2006). *Vicia faba* L. In: Brink, M. and Belay, G. (eds.). *Plant Resources of Tropical Africa 1: Cereals and Pulses*. Wageningen, Netherlands/Backhuys: PROTA Foundation.

- [13] Navabi A, Yang RC, Helm, J, Spaner DM. 2006. Can spring wheat growing mega-environments in the northern great-plains be dissected for representative locations or niche-adapted genotypes *Crop Sci.* 2006; 46: 1107-1116.
- [14] Purchase, J. L., Hatting H., and Vandenventer, C. S. 2000. Genotype x environment interaction of winter wheat in South Africa: II. Stability analysis of yield performance. *South Afr J Plant Soil*, 17: 101-107.
- [15] Tadele Tadesse, Behailu Mulugeta, Gashaw Sefera, Amanuel Tekalign. 2017. Genotypes by Environment Interaction of Faba Bean (*Vicia faba L.*) Grain Yield in the Highland of Bale Zone, Southeastern Ethiopia. *Plant*. Vol. 5, No. 1, 2017, pp. 13-17. doi: 10.11648/j.plant.20170501.13.
- [16] Tamene, T., Gemechu K., Tadesse S., and Mussa J. (2015). Yield stability and relationships among stability parameters in faba bean (*Vicia faba L.*) genotypes. *The crop Journal* 3: 258 – 268.
- [17] Zobel RW, Wright MJ, Gauch HG. Statistical analysis of a yield trial. *Agron. J.* 1988; 80: 388-393.