



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

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## To cite this article:

Tadele Tadesse, Amanuel Tekalign, Gashaw Sefera, Belay Asmare. AMMI Analysis for Grain Yield Stability in Faba Bean Genotypes Evaluated in the Highlands of Bale, Southeastern Ethiopia. *Research & Development*. Vol. 2, No. 2, 2021, pp. 27-31.

doi: 10.11648/j.rd.20210202.11

**Received:** March 19, 2021; **Accepted:** May 19, 2021; **Published:** May 27, 2021

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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  $Y_{ij} = \mu + g_i + e_j + \sum_{n=1}^h \lambda_n \alpha_{ni} \cdot Y_{nij} + R_{ij}$  [2] where,

$Y_{ij}$  is the yield of the  $i^{\text{th}}$  genotype in the  $j^{\text{th}}$  environment,  $\mu$  is the grand mean,  $g_i$  is the mean of the  $i^{\text{th}}$  genotype minus the grand mean  $e_j$  is the mean of  $j^{\text{th}}$  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  $Y_{nij}$  are the principal and the principal component scores for the PCA axis  $n$  of the  $i^{\text{th}}$  genotype and  $j^{\text{th}}$  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, Slop, 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

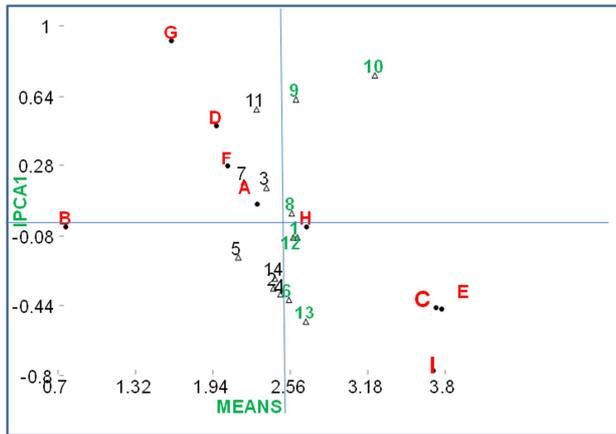
**3.4. AMMI Bi-plots**

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

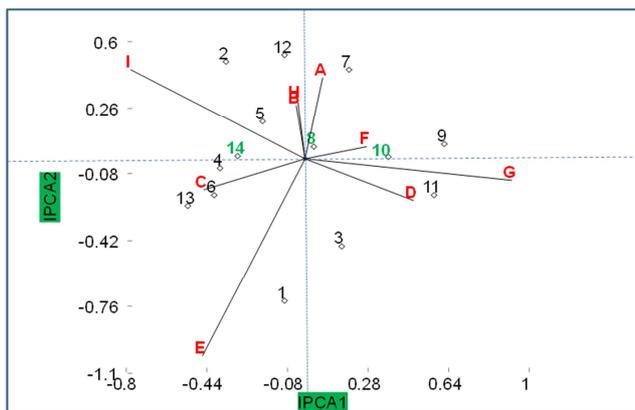
closet distance to the origin were less responsive to the changing environmental factors. In the present study, G8, G10 and G14, which are found close to the origin showed general stability, whereas, environment B, F, H and D showed less responsive to the changing environmental condition allow stability 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 BIPLLOT 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.

## Acknowledgements

The authors would like to thank Oromia Agricultural Research Institute for funding, and Sinana Agriculture Research Center, and pulse and oil crop research case team for data collection and trial management.

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