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Stability and Adaptability Study for Seed Yield of Improved Faba Bean Varieties in the Highlands of Oromia Region, Ethiopia

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***Abstract*— *Yield of a variety is the most complex trait and influenced by several factors. G x E interaction significantly influenced grain yield of faba bean suggested the presence of differentially adapted faba bean genotypes. The reliability of genotype performance across different environmental conditions is an important consideration in plant breeding. Thirteen faba bean genotypes were evaluated at five faba bean growing areas of Oromia highlands during 2017/18 main cropping season with the objective of determining the magnitude and nature of G x E interaction for grain yield of faba bean varieties and to identify stable high yielding variety(s) under wide production for the tested environments and similar agro-ecologies. Combined analysis for grain yield revealed highly significant ($P \leq 0.01$) difference among varieties, locations and variety by location interaction. Walki (3.35 tons ha-1) was the highest yielding variety followed by Tumsa (3.10 tons ha-1), Gebelcho (3.08 tons ha-1) and Dosha (3.00 tons ha-1)with yield advantages of 24.07%, 14.80%, 14.07% and 11.11% compared to the grand mean, respectively. Stability analysis models used in the present study such as regression coefficient (bi) and deviation from regression (S^2di) variance (Wi) ecovalence, coefficient of determination (r^2i), cultivar superiority measure (Pi), stability variance (α^2i) and coefficient of variation revealed that Gebelcho, Shallo and Walki varieties were the most adapted across environment and accompanied with high mean grain yield. Conversely, varieties Holeta-2 and Mosisa were the most unstable. Overall, Dosha and Tumsa had specific adaptation to environments Bore and Alleyo, respectively, Alloshe at Uraga. Walki was also adapted to Gedo and Anna Sorra. Furthermore, Gebelcho Shallo and Walki had general adaptability hence can be recommended for wider production in the tested locations and similar agro-ecologies of the region*.

***Keywords*— *Adaptability; Seed yield; Stability; Stability variance; Vicia faba*.

I. INTRODUCTION

Faba bean (*Vicia faba* L.) is one of the earliest domesticated food legumes in the world (Singh *et al*., 2013). It is believed that faba bean was introduced to Ethiopia soon after its domestication around 5000 B.C. (Asfaw *et al*., 1994) and the country is now considered as one of the secondary centers of genetic diversity (Bond, 1976; Hailu *et al*., 1991). Accordingly, it grown in mid altitudes and highland regions of Ethiopia between 1800-3000 meters above sea level (ICARDA, 2006; Musa and Gemechu, 2006); where it required chilling temperature with the annual rain fall of 700-1000 mm (Musa and Gemechu, 2006).

Faba bean is one of the major pulses grown in the highlands of Ethiopia (Musa and Gemechu, 2006). Ethiopia is the second largest faba bean producing country in the world next to People's Republic of China and the first in Africa followed by Egypt and Morocco (Saxena, 1991; Haciseferogullari *et al*., 2003; Musa and Gemechu, 2006). Pulses grown in 2016/17 covered 12.33% (1,549,911.86 hectares) of the grain crop area and 9.69 (about 28,146,331.73 quintals) of the grain production was drawn from the same crops. From this area, faba bean took up 3.40% (about 427,696.80 ha) of the grain crop area. Among pulses, faba bean accounted for 3.02% (about 8,780,108.79 quintals) (CSA, 2017). The productivity of the crop under smallholder farmers is not more than 1.89 tons ha^{-1} (CSA, 2015), despite the availability of high yielding varieties (> 2.0 tons ha^{-1}) (MOA, 2011).

Ethiopia is a country of great environmental variation (EMA, 1988). Where environmental differences are great, it may be expected that the interaction of genotypes with environment will also be great. As a result, one cultivar may have the highest yield in one environment, while a second cultivar may excel in others. This necessitated the study of genotype by environment interaction to know the magnitude of the interactions in the selection of genotypes across several environments besides calculating the average performance of the genotypes under evaluation. G x E interaction of faba bean have been formerly studied by several researchers (Gemechu and Musa, 2002; Musa and Gemechu, 2004; Gemechu *et al*., 2006; Abdelmula and Abuanja, 2007; Karadavut *et al*., 2010; Fekadu *et al*., 2012; Tamene *et al*., 2015).

Multi-location yield trials facilitate quantification of the environment and the G x E interaction effects. However, a fact not generally recognized is that, in addition, every yield trial by analyzing processes that determine yield can inexpensively quantify the genetic, physiological and environmental controls that results in yield differences among cultivars, seasons and locations (Tarakanovas and Rusgas, 2006). Various methods of G x E interaction analysis exist, including parametric and non-parametric approaches. The most widely used parametric methods is the joint regression including regression coefficient (bi) variance of deviation from regression (S^2di) (Farshadfar and Sutka ,2006; Pourdad and Mohammadi , 2008).

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The aim of this study was to determine the magnitude and nature of G x E interaction for grain yield of faba bean varieties and to identify stable high yielding variety(s) under wide production for the tested environments and similar agro-ecologies of Oromia highlands, Ethiopia.

II. Materials and Method

2.1. Description of Study Sites

The field experiments were conducted during the 2017/18 main cropping seasons from July to January at five locations representing highland agro-ecologies of Oromia region. The locations were Gedo, Bore, Alleyo, Anna Sorra and Uraga.

2.2. Plant Materials and Field Management

Thirteen (13) faba bean varieties released from federal and regional research centers were obtained from Holeta Agricultural Research Center (HARC) and Sinana Agricultural Research Center (SARC). Randomized Completely Block Design (RCBD) with three replications was used. Each variety were sown in 4 rows; 4m length with 40cm inter-row spacing and 10cm between plants and fertilizer rate 19/38/7 $N/P_2O_5/S$ Kg ha^{-1} was applied at planting time.

TABLE 1. Descriptions of the study locations

Location	Code	Altitude (m.a.s.l)	Rainfall (mm)	Soil type	Global Position	
					Latitude	Longitude
Gedo	E1	2240	1186.4	Clay loam	9^0 02' N	37^0 25' E
Bore	E2	2736	1550	Nitosols	6^0 24' N	38^0 35' E
Alleyo	E3	2692	NA	Nitosols	6^0 19' N	38^0 39' E
Anna Sorra	E4	2451	NA	Nitosols	6^0 10' N	38^0 42' E
Uraga	E5	2385	1204	Clay loam	6^0 05' N	38^0 35' E

Sources: Yazachew and Kassahun, 2011; Geleta, 2015; Demissie, 2016.

TABLE 2. Description of tested varieties

Variety	Code	Pedigree	Methods of development	Seed size	Year of release	Adaptation area (m.a.s.l)	Breeder/ Maintainer
Shallo	G1	EH011-22-1	Introduction	Small	2000	2300 - 2800	SARC
Mosisa	G2	EH99047-1	Introduction	Medium	2013	2300 - 2800	SARC
Alloshe	G3	EH03043-1	Introduction	Large	2017	2300 - 2800	SARC
Walki	G4	Bulga-70 x ILB4615	Hybridization	Medium	2008	1800 - 2800	HARC
Gebelcho	G5	Tesfa x ILB4726	Hybridization	Large	2006	1800 - 3000	HARC
Tumsa	G6	Tesfa x ILB 4726	Hybridization	Large	2010	2050 - 2800	HARC
Obsie	G7	CS20DK x ILB 4427	Hybridization	Large	2007	1800 - 3000	HARC
Dosha	G8	Coll 155/00-3	Collection	Medium	2009	1900 - 2800	HARC
Bulga70	G9	Coll 111/77	Collection	Small	1995	2300 - 3000	HARC
Hachalu	G10	EH960091-1	Introduction	Large	2010	1900 - 2800	HARC
Holeta-2	G11	BP1802-1-2	Introduction	Small	2000	2300 - 3000	HARC
Gora	G12	EH91026-8-2 x BPL44-1	Hybridization	Large	2012	1900 - 2800	HARC
Didia	G13	-	Hybridization	Large	2014	1800 - 2800	HARC

Sources: Crop variety register

2.3. Statistical Analysis

The analysis of variance (ANOVA) for each location was done. Variance homogeneity was tested and combined analysis of variance was performed using the linear mixed model (PROC ANOVA) procedure to partition the total variation into components due to genotype (G), environment (E) and G x E interaction effects. Genotype was treated as a fixed effect and environment as a random effect. Comparison of varietal means was done using Duncan's Multiple Range Test (DMRT) at the 5% probability level.

The method of Eberhart and Russell (1966) was used to calculate the regression coefficient (bi) and deviation from regression (S^2di). It was calculated by regressing mean grain yield of individual genotypes/environments on environmental/genotypic index.

$$Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}$$

where; Y_{ij} = Mean of i^{th} genotype in j^{th} environment. μ_i = the grand mean, β_i = the regression coefficient of the i^{th} genotype on environmental index, I_j = the environmental index obtained by the difference between the mean of each environment and the grand mean.

$$b_i = \frac{\sum Y_{ij} I_j}{\sum I_j^2}$$

where, $\Sigma Y_{ij}I_j$ = the sum of products of the i^{th}observation in the j^{th} environment and the environmental index, and ΣI_j^2 = the sum of squares of environmental index.

Therefore, the performance of each variety could be predicted by using the estimates of the parameters, $\hat{Y}_{ij} = x_i + b_i I_i$ where xiis the estimate of μ. The second stability parameter is themean square deviation from linear regression and could be estimated first by squaring the deviation $\delta_{ij} = (Y_{ij} - ý_{ij})$ to provide an estimate of another stability parameter (S^2di)that couldbe calculated as:

$$S_{di}^2 = \left[\frac{\sum \delta_{ij}^2}{n-2}\right] - \frac{S_e^2}{r}$$

where; Se^2/r = the estimate of the pooled error or the variance of a genotype mean at the j^{th} location, and n = number of locations, r = number of replications.

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Ecovalence (Wi) suggested by Wricke (1962) measure was also computed to further describe stability.

$$W_i = \sum [X_{ij} - \bar{X}i - \bar{X}j + \bar{X}]^2$$

where, X_{ij} = the mean performance of genotype i in the j^{th} environment, X_i and X_j = the marginal means of genotype i and environment j respectively, and X = the overall mean. Thus, genotypes with a low W_i value are stable.

Pinthus (1973) proposed to use the coefficient of determination (r^2i) instead of deviation mean squares to estimate stability of genotypes, because r^2i is strongly related to S^2di (Becker, 1981).

Coefficient of determination: $r2i = \frac{s2di}{s2xi}$

The application of r^2i and bi has the advantage that both statistics are dependent of units of measurement.

Lin and Binns (1988a) defined the superiority measure (Pi) of the i^{th} test cultivar as the MS of distance between the i^{th} test cultivar and the maximum response as

$$P_i = \frac{n(\bar{X}_L - \bar{M})^2 + \sum_j (X_{ij} - \bar{X}_L - M_j + \bar{M})^2}{2n}$$

where, X_{ij} is the average response of the i^{th} genotype in the j^{th} environment, X_i is the mean deviation of genotype i, M_j is the genotype with maximum response among all genotypes in the j^{th} location, and n is the number of locations. The first term of the equation represents the genotype sum of squares and the second part the G x E sum of squares. The smaller the value of Pi, the less is the distance to the genotype with maximum yield and the better the genotype. A pair wise G x E interaction mean square between the maximum and each genotype is also calculated.

Shukla (1972) defined the stability variance of genotype i as its variance across environments after the main effects of environmental means have been removed. Since the genotype main effect is constant, the stability variance is thus based on the residual (GE_{ij}+ e_{ij}) matrix in a two-way classification. The stability statistic is termed "stability variance" (S^2i) and is estimated as follows

The mean Coefficient of variability analysis introduced by Francis (1977) was designed to aid in studies on the physiological basis of yield stability. He introduced a simple graphical approach to assess performance and stability concurrently. It was found to characterize genotypes in groups rather than individually (Francis and Kannenberg, 1978).

III. Results and Discussion

3.1. Analysis of Variance and Estimates of Variance Components

According to the results of combined ANOVA for grain yield the environments, genotypes, G x E interaction, error and replication within locations contributed 53.12%, 13.50%, 18.31%, 13.46% and 1.61%, respectively (Table 3) of the total sum of squares. The environmental main effect accounted higher from the total variation in grain yield. This indicated the test environments were highly variable and large differences among the test environments on the yield performance of faba bean varieties. The previous report on faba bean in Ethiopia also indicated that the environmental effect accounted for the largest part of the total variation (Mulusew *et al*., 2008; Tamene *et al*., 2015). On the other hand, genotype and G x E interaction effects accounted lower from the total variation in grain yield. This study clearly showed that the environments were distinct, and the genotypes responded differently to the different environments in terms of grain yield. The G x E interaction effects were also observed to be cross-over type for grain yield. Previous reports also showed that tremendous levels of G x E interaction effects exist in faba bean in the different environments in Ethiopia (Gemechu and Musa, 2002; Musa and Gemechu, 2004; Gemechu *et al*., 2006; Tamene *et al*., 2015).

TABLE 3. Combined analysis of variance for grain yield (tons ha^{-1}) of 13 faba bean varieties across five locations during 2017/18 main cropping season

Sources	Degrees of freedom(DF)	Sum of squares(SS)	Mean squares(MS)	SS%
Total	194	245.66		
Environments	4	130.50	32.62**	53.12
Block (Environments)	10	3.96	0.396	1.61
Genotype	12	33.16	2.76**	13.50
Genotype x Environment	48	44.97	0.94**	18.31
Pooled Error	120	33.07	0.28	13.46
Mean = 2.70				
CV (%) = 19.46				
R^2 = 86.54				

Keys: ** = highly significant at the level of 1% probability, ns = non-significant; CV = coefficient of variability, R^2 = R-squared.

The genotype (δ^2g), location (δ^2l) and their interaction (δ^2gl) variance component accounted the total variation of 8.55%, 56.54% and 15.09%, respectively (Table 4). The remaining 19.82% was accounted by the error variance (δ^2e). The δ^2g less than δ^2gl of the total variation, indicating that the genotypes were less consistent over locations. Higher environmental variance component revealed that environmental effects were much greater than the genotypic effects. This further shows that care should be taken when conducting multi-environment trials for faba bean in selecting representative testing sites in the recommendation domain.

TABLE 4. Estimates of variance components for grain yield

Variance Components	Estimates	Total Variation (%)
Environment	0.813	56.54
Genotype	0.123	8.55
Genotype x Environment	0.217	15.09
Error	0.285	19.82

The mean performance of thirteen faba bean varieties for grain yield for each environments and over environments

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presented in Table 5. The highest mean grain yield of 5.46 tons ha^{-1} was recorded from Dosha at Bore and the least was 0.30 tons ha^{-1} recorded from Mosisa variety at Anna Sorra. The significant interaction suggests that grain yield of varieties varied across the testing environments from 3.35 tons ha^{-1} to 1.90 tons ha^{-1}, which recorded by varieties Walki and Holeta-2 respectively. On average, the highest (3.82 tons ha^{-1}) and the lowest (1.62 tons ha^{-1}) environment mean grain yield were observed at Bore and Anna Sorra, respectively (Table 5).

TABLE 5. The mean values of grain yield (tons ha^{-1}) of 13 faba bean varieties at individual environment during 2017/18 main cropping season

No	Variety	Test Environments					GM	Rank
		Gedo	Bore	Alleyo	Anna Sorra	Uraga		
1	Shallo	2.64	4.34^{b}	2.00^{b-e}	1.66^{c-f}	3.72^{a-c}	2.87^{b-e}	6
2	Mosisa	2.41	3.12^{c-e}	2.14^{b-d}	0.30^{g}	3.98^{ab}	2.39^{f}	11
3	Alloshe	2.26	3.68^{b-e}	2.71^{ab}	1.82^{b-e}	4.29^{a}	2.95^{b-e}	5
4	Walki	2.94	4.45^{ab}	2.59^{a-d}	2.92^{a}	3.86^{a-c}	3.35^{a}	1
5	Gebelcho	2.54	4.36^{b}	2.65^{a-c}	2.08^{a-d}	3.75^{a-c}	3.08^{a-c}	3
6	Tumsa	2.41	4.68^{ab}	3.39^{a}	1.26^{d-f}	3.75^{a-c}	3.10^{ab}	2
7	Obsie	2.46	4.19^{bc}	2.50^{b-d}	1.13^{e-g}	2.36^{e}	2.53^{ef}	10
8	Dosha	1.82	5.46^{a}	2.61^{a-d}	1.32^{d-f}	3.77^{a-c}	3.00^{a-d}	4
9	Bulga70	1.71	2.99^{de}	1.25^{e}	0.92^{fg}	2.98^{de}	1.97^{g}	12
10	Hachalu	2.19	3.72^{b-e}	2.08^{b-e}	2.62^{ab}	2.72^{de}	2.67^{c-f}	7
11	Holeta-2	1.64	1.83^{f}	1.80^{de}	0.79^{fg}	3.38^{b-d}	1.90^{g}	13
12	Gora	2.23	2.90^{ef}	2.53^{b-d}	2.22^{a-c}	3.18^{cd}	2.61^{d-f}	9
13	Didia	2.04	3.99^{b-d}	1.85^{c-e}	2.07^{a-d}	3.35^{b-d}	2.66^{c-f}	8
	EM	2.25	3.83	2.32	1.62	3.47	2.70	
	CV(%)	31.87	16.77	21.21	31.68	12.50	19.46	

GM = genotypic means, EM = environmental means, EMS = error mean square, CV = coefficient of variation. Values with the same letters in a column are not significantly different.

3.2. Stability Analysis

3.2.1. Eberhart & Russell's Regression Analysis

The highly significance of mean square for G x E interaction ($P \leq 0.01$) on grain yield was observed Table (3). This allowed the partitioning of G x E interaction effects in environment linear, G x E (linear) interaction effects (sum squares due to regression, bi) and unexplained deviation from linear regression (pooled deviation mean squares, S^2di). Besides, the analysis of variance for linear regression in Table (5) revealed that highly significant differences ($P \leq 0.01$) between varieties. The G x E (linear) interaction was highly significant, indicating that the stability parameter "bi" estimated by linear response to change in environment was not the same for the varieties (Table 6). Pooled deviation mean square was also highly significant, indicating that the differences in linear response among varieties across environments did not account for the interactions. Therefore, the fluctuation in performance of varieties grown in various environments was not fully predictable (partially unpredictable). Similar result was obtained in bean genotypes tested (Firew, 2003; Setegn and Habtu, 2003) in different part of Ethiopia and (Ferreira *et al*., 2006) in Brazil.

TABLE 6. Analysis of variance for linear regressions on faba bean varieties mean yield on environmental mean yield

Sources	Degrees of freedom	Sum of squares	Mean squares
Varieties	12	11.159	0.929**
Env.+ (G x E)	52	58.632	1.127**
Env. in linear	1	43.643	43.643**
G x E (linear)	12	5.084	0.424**
Pooled deviation	39	9.906	0.254**
Residual	130	13.483	0.104

Key: ** = highly significant at the level of 1% probability

According to Eberhart and Russell's (1966) a stable genotype should have regression coefficients (bi=1) closer to one and deviation from regression ($S^2di \sim 0$) nearly equal to zero. But, stability alone is not sufficient and thus should be accompanied by high grain yield. Based on these parameters, varieties Gebelcho and Alloshe had relatively high grain yield performance, regression coefficient closer to unity could be considered as stable and adaptable to wider environments. Gebelcho and Shallo had deviation from regression($S^2di=0$) closer to zero and high grain yield performance selected as most stable varieties (Table 7). Similar results were reported by Tamene *et al*. (2015) and Tadele *et al*. (2017). However, varieties Dosha and Tumsa had coefficient of regression greater than unity, i.e. below average stability, and deviation from regression (S^2di) different from zero with high mean grain yield. So these varieties were best fit for specific adaptation in the favorable environments. Conversely, variety Bulga70 had regression coefficient closer to unity (1.025) and deviation from regression very close to zero (0.07), but it's the lowest in mean grain yield, that it's stable to unfavorable environments (Table 7). These results are in lines with Firew (2003) in common bean; Adane (2008) in linseed; Yasin and Hussen (2013) in field pea.

3.2.2. Wricke's (Wi) Ecovalence Analysis

Wricke's ecovalence was determined for each of the 13 faba bean varieties evaluated at five environments (Table 7). The most stable varieties according to the ecovalence method of Wricke's (1962) were Gebelcho, Shallo and Bulga70 while Dosha, Mosisa and Holeta-2 were unstable.

3.2.3. Coefficient of Determination (r^2i)

Coefficient of determination (r^2i) represents the predictability of estimated response of the varieties Table (7). The values ranged from 0.49 to 0.99 which indicated that 49% to 99% of the variation in the mean seed yield was explained by varietal response across the testing environments. Based on coefficient of determination varieties Gebelcho, Shallo and

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Alloshe were the most stable and have general adaptation when they compared with the other varieties. But variety Bulga70 was yielded below average.

TABLE 7. Mean yield, regression coefficients (bi), deviation from regression (S^2di), Wricke's (Wi) ecovalence and coefficient of determination (r^2_i) values for 13 faba bean varieties tested in five locations

Variety	Code	Means (t ha^{-1})	Rank	Bi	Rank	S^2di	Rank	Wi	Rank	r^2i	Rank
Shallo	G1	2.87	6	1.207	6	0.10	4	0.432	3	**0.94**	**2**
Mosisa	G2	2.39	11	1.302	8	0.60	13	2.107	12	0.76	8
Alloshe	G3	2.95	5	1.033	4	0.19	7	0.563	5	0.87	4
Walki	G4	3.35	1	0.767	7	0.15	5	0.617	6	0.82	6
Gebelcho	G5	3.08	3	1.027	2	0.02	1	0.049	1	**0.99**	**1**
Tumsa	G6	3.10	2	1.328	10	0.32	10	1.317	8	0.86	5
Obsie	G7	2.53	10	0.979	1	0.52	11	1.551	9	0.68	9
Dosha	G8	3.00	4	1.743	13	0.28	9	2.694	13	0.92	3
Bulga70	G9	1.97	12	1.026	5	0.07	3	0.215	2	**0.94**	**2**
Hachalu	G10	2.67	7	0.512	11	0.27	8	1.618	10	0.52	10
Holeta-2	G11	1.90	13	0.692	9	0.59	12	2.052	11	0.49	11
Gora	G12	2.61	9	0.414	12	0.05	2	1.289	7	0.80	7
Didia	G13	2.66	8	0.969	3	0.16	6	0.487	4	**0.87**	**4**

3.2.4. Lin and Binns Cultivar Superiority Measure (Pi)

The smaller the value of the Pi, the less is the distance to the genotype with maximum mean yield and the better the genotype (Alberts, 2004). The genotypes with the lowest (Pi) values are considered the most stable. According to this method, the most stable variety ranked first for Pi and for mean yield was Walki followed by Gebelcho ranked third for mean grain yield. Others with low Pi values and high ranking for mean yields were Tumsa and Dosha. The ranks of the Pi measure is more an indication of performance and not really an indication of stability (Alberts, 2004). However, the most unstable varieties according to this analysis were Holeta-2 and Bulga70, which are also very low yielding varieties (Table 8).

3.2.5. Stability Variance ($\alpha^2 i$)

In this method the values are estimates of a genotypes variance across environments. The variety Gebelcho with the smallest value was the most stable and was followed by Bulga70 and Shallo (Table 8). The varieties with the most poorest stability according to this procedure were Dosha, Mosisa and Holeta-2.

TABLE 8. Varietal performance measure (Pi), Shukla's stability variance (α^2i) and coefficient of variability (CV) values for 13 faba bean varieties tested at five locations

Variety	Code	Means (t ha^{-1})	Rank	Pi	Rank	α^2i	Rank	CV(%)
Shallo	**G1**	**2.87**	**6**	0.516	5	**0.099**	**3**	39.545
Mosisa	G2	2.39	11	1.426	11	0.591	12	57.21
Alloshe	G3	2.95	5	0.529	6	0.138	5	34.43
Walki	G4	3.35	1	0.183	1	0.156	6	23.12
Gebelcho	**G5**	**3.08**	**3**	0.289	2	**-0.014**	**1**	30.74
Tumsa	G6	3.10	2	0.392	3	0.358	8	42.28
Obsie	G7	2.53	10	0.954	10	0.429	9	43.16
Dosha	G8	3.00	4	0.468	4	0.766	13	55.39
Bulga70	**G9**	**1.97**	**12**	1.785	12	**0.035**	**2**	49.06
Hachalu	G10	2.67	7	0.784	8	0.453	10	24.37
Holeta-2	G11	1.90	13	2.242	13	0.578	11	49.35
Gora	G12	2.61	9	0.947	9	0.354	7	16.17
Didia	**G13**	**2.66**	**8**	0.691	7	**0.117**	**4**	35.80

3.2.6. Coefficient of Variability (CV)

The mean CV analysis introduced by Francis (1977) was designed to aid in studies on the physiological basis of yield stability. He introduced a simple graphical approach to assess performance and stability concurrently. It measures the performance and CV for each genotype over all environments and the mean yield plotted against the CV. High yield and small variation group of genotypes appear the most desirable using any approach. The stable genotype is the one that provides a high yield performance and consistent low CV. According to this definition varieties Gebelcho, Walki and Alloshe fall into the high yield and low variation group and can be considered the good performance and most stable (Figure 1).

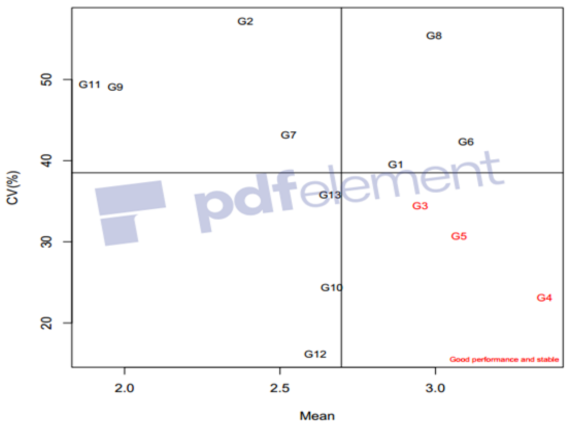

Figure 1. Mean yield (tons ha^{-1}) plotted against CV (%) from data on 13 faba bean varieties over five locations.

Comparison and Correlations of Stability Measures

The Overall Ranking of Tested Varieties Using Stability Models

TABLE 9. Ranking of 13 faba bean varieties for grain yield based on the stability parameters

Variety	GYLD (t ha^{-1})	R	bi	R	S^2di	R	Wi	R	r^2i	R	Pi	R	α^2i	R	CV	OR
Shallo	2.87	6	1.207	6	0.10	4	0.432	3	**0.94**	2	0.516	5	**0.099**	**3**	39.55	2
Mosisa	2.39	11	1.302	8	0.60	13	2.107	12	0.76	8	1.426	11	0.591	12	57.21	10
Alloshe	2.95	5	1.033	4	0.19	7	0.563	5	0.87	4	0.529	6	0.138	5	34.43	4
Walki	3.35	1	0.767	7	0.15	5	0.617	6	0.82	6	0.183	1	0.156	6	23.12	3
Gebelcho	3.08	3	1.027	2	0.02	1	0.049	1	**0.99**	1	0.289	2	**-0.014**	**1**	30.74	1
Tumsa	3.10	2	1.328	10	0.32	10	1.317	8	0.86	5	0.392	3	0.358	8	42.28	6
Obsie	2.53	10	0.979	1	0.52	11	1.551	9	0.68	9	0.954	10	0.429	9	43.16	8
Dosha	3.00	4	1.743	13	0.28	9	2.694	13	0.92	3	0.468	4	0.766	13	55.39	8
Bulga70	1.97	12	1.026	5	0.07	3	0.215	2	**0.94**	2	1.785	12	**0.035**	**2**	49.06	5
Hachalu	2.67	7	0.512	11	0.27	8	1.618	10	0.52	10	0.784	8	0.453	10	24.37	9
Holeta-2	1.89	13	0.692	9	0.59	12	2.052	11	0.49	11	2.242	13	0.578	11	49.35	11
Gora	2.61	9	0.414	12	0.05	2	1.289	7	0.80	7	0.947	9	0.354	7	16.17	7
Didia	2.66	8	0.969	3	0.16	6	0.487	4	**0.87**	4	0.691	7	**0.117**	**4**	35.80	4
Mean	2.70															

GYLD = grain yield, ASV = AMMI stability value, GSI = genotype selection index, bi = coefficient of regression, S^2di = deviation from regression, Wi = Wrick's (1962) ecovalence, r^2 = coefficient of determination, Pi = cultivar superiority measure, α^2i = stability variance, CV = coefficient of variation, R = rank and OR = overall rank.

Correlations of Stability Parameters

According to Steel and Torrie (1980) coefficient of rank correlation the comparison of mean seed yield was highly significantly positively correlated (P<0.01) with Pi but non-significantly negatively correlated with all other parameters.

High significance (P<0.01) for Spearman's rank correlation coefficients were noted between deviation from regression, ecovalence variance and stability variance procedure. The procedures of Shukla and Wricke had a total correspondence (r =1.000). This indicates that these two procedures were equivalent for ranking purposes which correspond with previous findings (Wricke and Weber, 1980; Purchase, 1997).

TABLE 10. Correlation coefficient among the stability measures including grain yield

	GYLD	bi	S^2di	Wi	r^2i	Pi	α^2i	CV
GYLD	1							
bi	0.251	1						
S^2di	-0.414	0.151	1					
Wi	-0.213	0.231	0.734**	1				
r^2i	0.460	0.544*	-0.668*	-0.541*	1			
Pi	-0.971**	-0.239	0.505	0.295	-0.514	1		
α^2i	-0.213	0.226	0.732**	0.999**	-0.545*	0.295	1	
CV	-0.424	0.735**	0.596*	0.453	0.038	0.460	0.448	1

*,** = significant at level of 5% and 1% probability respectively, ns = non significant. GYLD = grain yield; ASV = AMMI stability value; GSI = genotype selection index; bi = regression coefficient; S^2di = deviation from regression; Wi = Wricke's (1962) ecovalence; r^2i = coefficient of determination, Pi = cultivar superiority measure, α^2i = stability variance, CV= coefficient of variation.

IV. Conclusion and Recommendation

Various methods, including the regression model (Eberhart and Russells, 1966), Ecovalence (Wricke's, 1962), coefficient of determination (Pinthus, 1973), cultivar superiority measure (Lin and Binns, 1988), stability variance (Shukla, 1972) and Coefficient of variability (Francis, 1977) were used for the present study.

Evaluation of varieties for adaptation is a fast truck strategic approach to develop and promote agricultural technology. Based on the specific and wider adaptability the tested varieties were selected. Generally, from this study Gebelcho, Shallo and Walki were most stable better yielding performance, above the grand mean and recommended for wider production in the tested environments and similar agro-ecologies of the region. Whereas varieties, Dosha and Tumsa were selected as they had high specific adaptation to environments of Bore and Alleyo, respectively. While Alloshe and Mosisa for Uraga

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