



Performance Evaluation of Faba bean (*Vicia faba* L.) Varieties in Buno Bedele zone of South-western Oromia, Ethiopia

Garoma Firdisa^{1*}, Mohammed Tesiso¹ and Gebeyehu Chala¹

Oromia Agricultural Research Institute, Bedele Agricultural Research Center, P.O.Box 167, Bedele, Ethiopia.

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*Corresponding Author

Garoma Firdisa

E-mail: garomafirdisa21@gmail.com

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ABSTRACT

A field experiment was carried out at Chora, Dabo Hana and Didesa districts in Buno Bedele zone of south western Oromia, Western Ethiopia, for two consecutive seasons (2021 to 2022 G.C) under rain fed conditions. The objective of the study was to evaluate and select best performing faba bean varieties. Twelve Faba bean varieties including the local check were evaluated in randomized complete block design (RCBD) in three replications. The data on days to 50% flowering, days to 90% maturity, plant height, number of pods per plant, number of seed per pod and grain yield were collected. The collected data were subjected to analysis of variances using R- software. Combined analysis of variance revealed that there was significant difference for all studied traits except days to 50% flowering number of pods per plant and number of seeds per pod, however, there were significant differences among varieties for all traits in each location. The highest grain yield was recorded from Walki (32.17 Qt ha⁻¹), followed by Hachalu (30.40 Qt ha⁻¹) while local check was the lowest yielder which is 16.74 Qt ha⁻¹. Regarding the plant height, Hachalu possessed the tallest among the others which is 154.20cm and local check was records the shortest in height which is 133.01cm. Regarding maturity Gabalcho variety was the early mature and Alloshe was the latest mature one. Highly significant and positive association of grain yield with plant height and number of pods per plant were found. AMMI model shows that environment accounted 39.90%, GXE 3.89%, genotype 11.26% of the total variation. The high percentage of environment is an indication that the major factor that influence yield performance of Faba bean is the environment. The first IPCAs is the most accurate model that could be predicted the stability of the genotype and explained by IPCA-I (2.95%) and IPCA-II (0.90%) of GEI. GGE- Biplot and mean yield results revealed that Walki and Hachalu varieties are the most stable varieties across test locations. Therefore, these two were recommended for the study area and similar agro-ecologies.

INTRODUCTION

Faba bean (*Vicia faba* L.) is also referred to as broad bean, horse bean or field bean (Sainte, 2011). Faba bean is produced throughout the world in different agro-ecological regions in which China followed by Ethiopia, Australia, United Kingdom, France and Egypt are the leading producers (FAOSTAT, 2018). Ethiopia is the leading producer of faba bean in Africa (Akibode and Maredia, 2011) and the crop is the leading pulse crops in the country (Temesgen and Aemiro, 2012). It is a major food and feed legume because of the high nutritional value of its seeds. In Ethiopia, it covers about covered 15.17 % of the grain crop area (1,863,445.42 ha) and 11.89% of the grain production (27,510,311.88 quintals) was drawn from the same crop. The production obtained from faba bean was 4.08% (about 9,439,641.70 quintals) of the grain production. In Oromia Faba bean production is 218,457.78 ha with 5,134,525.76 quintals and 23.50 Qt/ha average yield productivity (CSA, 2020). In Buno Bedele zone 2894.57 ha of total area was covered by Faba bean from which 63,929.52 Qt was obtained with average yield productivity 22.09 Qt/ha (CSA, 2020). Regardless of its importance, the national and regional average yield is low; 16.44 qt/ha and 15.68 qt/ha, respectively. Ethiopia is probably one of the primary centers of diversity for faba bean. Although the small seeded type of the Ethiopian faba bean is not well studied, there are some reports of tremendous diversity in protein content, chocolate spot and leaf rust resistance IBC (2008). Faba bean is grown in the country's high land and semi-high land regions with altitudes ranging from 1800-3000 meters above sea level. It is widely used for food and has high protein content (MOA, 2012). Pulses complement cereals as a source of protein and minerals as they provide 15-40% of protein (Monti and Grillo, 1983). Pulses have slowly digestible carbohydrates, high fiber and protein contents, and moderate energy. The amount of protein in pulses is about 17–35% on a dry weight basis (Mc Crory et al., 2010). Pulses can play a significant role in improving smallholders' food security as an affordable source of protein in fact; pulses make up around 15% of the average Ethiopian diet (IFPRI,

2010). This crop is very much important in the highlands and midlands of South western part of Oromia in Ethiopia since it fetches cash for the farming community and also serves as rotational crop which play great role in controlling disease epidemics in areas where cereal mono cropping is abundant. It plays a significant role in soil fertility restoration as a suitable rotation crop that fixes atmospheric Nitrogen. Nationally important cereal crops like wheat, tef and barley were used in crop rotation with Faba bean (MOA, 2012).

Generally, it was a crop of manifold merits in the farming communities of highland and midland of Ethiopia. Genotypes exhibit fluctuating yields when grown in different environments of agro-climatic zones. This complication demonstrates the superiority of a particular genotype. Multi-environment yield trials are crucial to identify adaptable high yielding cultivars and discover sites that best represent the target environment (Dabessa, et al., 2016. Yazici, et. al., 2017). Poor response of genotypes to different environmental condition is the result of genotype and genotype by environment interaction (GEI). Evaluating released varieties on different environmental conditions which were released from different institution/ research centers/ is the good approach in selecting the best variety/ies which solve the limitation of improved seed distribution. Therefore, the objective of this study was to evaluate improved soybean varieties that give best yield in the study area and similar agro ecology.

2. MATERIALS AND METHODS

2.1 Description of the study Area

The field experiment was conducted during the 2021 – 2022 main cropping seasons for two years at three districts of Buno Bedele Zone, South Western Oromia where is Faba bean is widely grown. The locations were Chora, Dabo Hana and Didesa districts. The detailed agro-ecological conditions of the locations are presented in Table 1.

Table 1 Agro-ecological features of the experimental Locations

Locations	Altitude (m.a.s.l)	Average Rainfall (mm)	Soil Type	Geographical Coordinates		Average. Temp. (°C)	
				Latitude N	Longitude E	Max.	Min.
Chora	2000	1440	Nitosols	8°19'60.00"	36°14'60.00"	25.5	12.5
Dabo Hana	1990	1945	Nitosols	8°55'60 20"	36°26' 19.00"	25.8	12.9
Didessa	2340	1000	Nitosols	8°04'60.00"	36°39'59.99"	28	13

Source: Zonal website

2.2 Materials

Eleven (11) Faba bean varieties were brought from HARC (EIAR) and SARC (OARI) with one local check from the farmers total 12 varieties were evaluated as experimental materials.

Table 2 Description of Faba bean varieties used in the experiment

Varieties	Altitude ranges (m.a.s.l)	Year of Release	Source
Alloshe	1800-2600	2017	SARC/OARI
Dagaga	1800-2600	2002	HARC/EIAR
Dosha	1800-2600	2009	HARC/EIAR
Gabalcho	1800-2600	2006	HARC/EIAR
Hachalu	1800-2600	2010	HARC/EIAR
Mosisa	1800-2600	2013	SARC/OARI
Moti	1800-2600	2006	HARC/EIAR
Moyibon	1800-2600	2019	SARC/OARI
Obse	1800-2600	2007	HARC/EIAR
Tosha	1800-2600	2019	SARC/OARI
Walki	1800-2600	2008	HARC/EIAR
Local	1800-2600	NA	Farmer

Note: SARC = Sinana Agricultural Research Center, HARC = Holeta Agricultural Research Center, EIAR = Ethiopian Institute of Agricultural Research Institute, OARI= Oromia Agricultural Research Institute (Ekule et al., 2022)

2.3 Experimental Layout

These materials were randomly assigned to the experimental block and the experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The spacing between blocks and plots was 1m and 0.5m, respectively. The gross size of each plot was 6m² (2.5m X 2.4m) having six rows with a row-to-row spacing of 40cm. Planting was done by keeping the distance between plants to the spacing of 10cm. NPS fertilizer was applied at the rate of 100kg ha⁻¹ at the time of planting. All other recommended agronomic management practices were applied properly

2.4 Data collection

Days to 50% seed emergence: Days to emergence was recorded as number of days from planting to the time when 50% of the seedlings in plots through visual observation.

Days to 50% flowering: this was determined by counting the number of days from planting to the time when first flowers appeared in 50% of the plants in a plot.

Days to physiological maturity: it was determined as the number of days from planting to the time when 90% of the plants started senescence of leaves and pods started to turn black.

Plant height (cm): it was measured at physiological maturity from the base to the tip of a plant randomly in harvestable rows using meter tape and averaged on a plant basis.

Number of pods per plant: it was recorded based on five pre-tagged plants in each net plot area at harvest and the average was taken as number of pods per plant

Number of seeds per pod: the total number of seeds in the pods of five plants was counted and divided by the total number of pods to find the number of seeds per pod.

Grain yield (kg ha⁻¹): Plants harvested from the four central rows and for aboveground dry biomass were threshed to determine grain yield, and the grain yield was adjusted to the moisture content of 10%.

Disease Data (Scoring scale): Disease data of important Faba bean diseases like chocolate spot, Aschochyta blight and Rust were collected based on 1-9 scale following Little and Hills (1978); where 1 stands for immune, 2 for highly resistant, 3 for resistant, 4 for moderately resistant, 5 and 6 for moderately susceptible, 7 for susceptible, and 8 and 9 highly susceptible.

2.5 Statistical Analysis

Analysis of variance was done using R- software. Mean separations were estimated using Least Significant Difference (LSD) for the comparison among the experimental varieties at 0.05 probability level. Combined analysis of variance for both years and seasons was done to test the response of varieties to both environment and seasons after testing the homogeneity of the variance.

2.5.1 Stability Analysis

Additive Main Effect and Multiplicative Interaction (AMMI) model, Genotype Main Effect and Genotype x Environment Interaction Effect (GGE), and biplot

analysis were used to determine the effects of GEI on yields. These analyses were performed using R software (Pacheco et al., 2015).

2.5.1.1 AMMI Model

Additive Main Effect and Multiplicative Interaction (AMMI) is one of most widely used model to explain G×E interaction of multi-environment genotype trial and categorizing the genotypes into narrow or wider adaptation (Crossa *et al.*, 1990). The AMMI analysis uses analysis of variance (ANOVA) followed by a principal component analysis applied to the sums of squares allocated by the ANOVA to the GEI (Kempton, 1984).

The AMMI Model Equation is:

$$\bar{Y}_{ijk} = \mu + G_i + E_j + \sum_k \lambda_k \alpha_{ik} \beta_{jk} + P_{ij}$$

Where: $\bar{Y}_{ijk}$ = the yield of the *i*th genotype in the *j*th environment, G_i = the mean of the *i*th genotype minus the grand mean, E_j = the mean of the *j*th environment minus the grand mean, λ_k = the square root of the Eigen value of the *k*th IPCA axis, α_{ik} and β_{jk} = the principal component scores for IPCA axis *k* of the *i*th genotypes and the *j*th environment, P_{ij} = the deviation from the model

2.5.1.2 GGE- Biplot

The GGE concept was used to visually analyze the METs data. This methodology uses a biplot to show the factors (G and GE) that are important in genotype evaluation and that are also the source of variation in GEI analysis of METs data (Yan and Hunt, 2001). The GGE-biplot shows the first two principal components derived from subjecting environment centered yield data (yield variation due to GGE) to singular value decomposition (Yan W. *et al.*, 2000).

3. RESULT AND DISCUSSION

3.1 Analysis of Variance

Combined analyses of data from Dabo Hana district, Didesa district and Chora district showed significant varietal differences ($p \leq 0.01$) in yield Qt/ha (Table 3).

The varieties were evaluated based on their yield performance and other agronomic traits. The varieties revealed significant variation for grain yield. Even though, the location effect revealed that highly significant variation ($p \leq 0.01$), loc*variety showed a non-significant difference for grain yield. Concerning year*variety, the grain yield showed a significant variation ($p \leq 0.05$). This indicates that the varieties responded differently to the tested locations and year for yield or the varieties respond genotype by interaction for grain yield. So, this combined analysis indicates that we could do more stability analysis.

Table 3 Combined mean ANOVA of 12 Faba bean varieties for grain yield in Qt ha⁻¹ in 2022-2023 main cropping season

SOV	DF	SS	MSS	F value	Pr(>F)
Treatment	11	4062.30	369.30	6.45	4.441e-09 ***
Location	2	14406.60	7203.30	125.73	< 2.2e-16 ***
Year	1	2250.00	2250.00	39.27	2.373e-09 ***
Trt*Loc	22	1400.10	63.60	1.11	0.06794ns
Trt*Year	11	1212.60	110.20	1.92	0.03843 *
Loc*Year	2	1.00	1.00	0.018	0.04355*
Trt*Loc*Year	22	408.80	37.20	0.65	0.03527*
Residuals	192	10999.60	57.30		

Note: Trt = Treatment, Loc = Location, * = significant at 0.05, ** = significant at 0.01, *** = highly significant at 0.001 probability level

Mean Performance of Grain Yield and other traits

Grain Yield (Qt/ha)

The combined analysis revealed that Faba bean varieties were significant for grain yield ($p \leq 0.001$) (Table 4). The highest seed yield (32.17 qt ha⁻¹) was observed from variety Walki followed by Hachalu (30.40 Qt ha⁻¹) and the lowest seed yield (16.74 qt ha⁻¹) was obtained from Local check, and similar results were reported by Ashenafi and Mekuria (2015) at Sinana and Agarfa areas. On the other hand this result disagrees with the finding of Gereziher *et al* (2018), which reported that significant differences were observed in seed yield of

Faba bean varieties and accordingly, Dosha shows that 38.91 Qt ha⁻¹). Similarly, Yirga and Zinabu (2019) reported that variety Dosha was highest in terms of mean yield (2197.9kg/ha).

Crop yield is one of the most important agronomic traits since it is related to cost effectiveness and food security (Gelin *et al.*, 2004). As a result, the varieties such Walki, and Hachalu preferred, due their association with high yield.

Days to Maturity (Days)

Analysis of variance revealed that days to 50% maturity had significant ($P < 0.05$) effect. Gabalcho variety is

matured early (105.32days) compared to others and Alloshe variety is the latest in maturity (121.11days). However, no significant difference was observed with Moti (106.41), Moyibon, Obse, Dosha and Tosha (Table 4). The result disagrees with the finding of Ashenafi and Mekuria (2015) and Tafere et al. (2012) who reported that Moti was the early maturing genotype; whereas Gebelcho was late maturing variety. Early maturing varieties are the most adaptable varieties and have advantage over the late maturing varieties in areas where rain starts late and withdraws early.

Plant Height (cm)

The highest plant height (154.20cm) was recorded in Hachalu followed by Mosisa (150.35cm) (Table 4). This result is in disagreement with that of Tafere et al. (2012) who reported Dosha was the tallest in plant height. It may be due to the fact that plant height is highly affected by the genetic make of the varieties and the environment. Moreover, Talal and Munqez (2013) reported that plant height was significantly affected by faba bean accessions.

Disease Reaction

The three fungal diseases, chocolate spot (*Botrytis fabae*), ascochyta blight (*Ascochyta fabae*) and rust (*Uromyces viciae-fabae*) can lead to very significant loss in yield and seed quality if susceptible varieties are cultivated and disease is not managed effectively with regular application of fungicides Hanounik, and Robertson. (1989). Chocolate spot (*Botrytis fabae*) is a serious disease of faba beans in wet seasons and can cause serious yield loss. The leaf symptoms are small, brown spots that merge and produce large, black blotches if high humidity prevails, Lane and Gladders (2000). Chocolate spot and rust severity scores (1-9 scale) were recorded following Little and Hills (1978), for all tested varieties of faba bean in three locations. Almost all of the varieties tested across three locations exhibited immune to moderately susceptible (2-5) reactions to important diseases indicating that they could be used as a source of gene for resistance in breeding programs Table 4.

Table 4: Combined mean performance of different Faba bean varieties for yield and yield related traits across years and locations.

Varieties	DTF (days)	DTM (days)	PLH (cm)	NP/PL	NS/P	GY(Qt/ha)	YAd. %	CS
Alloshe	43.14	121.10 ^a	149.3 ^{ab}	16.47	3.06 ^{abc}	30.25 ^{ab}	80.70	3r
Dagaga	42.95	115.10 ^{bc}	148.8 ^{ab}	18.73	3.09 ^{abc}	28.25 ^{abc}	68.75	4mr
Dosha	40.86	118.56 ^{ab}	149.9 ^{ab}	15.03	3.10 ^{ab}	28.13 ^{abc}	68.04	4mr
Gabalcho	40.57	105.32 ^d	143.8 ^{abc}	16.32	2.87 ^{bc}	23.13 ^c	38.17	4mr
Hachalu	40.86	111.21 ^c	154.2 ^a	18.87	3.15 ^{ab}	30.40 ^{ab}	81.60	5ms
Mosisa	40.57	119.54 ^{ab}	150.3 ^{ab}	17.87	3.05 ^{abc}	29.82 ^{ab}	78.14	3r
Moti	39.43	118.12 ^{ab}	148.4 ^{ab}	15.16	3.04 ^{abc}	27.16 ^{abc}	62.25	4mr
Moyibon	39.57	118.20 ^{ab}	143.9 ^{abc}	14.44	2.94 ^{bc}	24.84 ^{bc}	48.39	4mr
Obse	40.25	118.10 ^{ab}	141.1 ^{bc}	14.83	3.10 ^{ab}	23.95 ^c	43.07	4mr
Tosha	42.14	117.90 ^{ab}	145.6 ^{ab}	17.85	3.04 ^{ab}	26.90 ^{abc}	60.69	4mr
Walki	41.32	115.84 ^{bc}	143.4 ^{abc}	19.71	3.29 ^a	32.17 ^a	92.17	3r
Local	42.05	119.11 ^{ab}	133.0 ^c	15.36	2.75 ^c	16.74 ^d	-	5ms
GM	42	116.55	145.98	16.45	3.04	26.81		
LSD (0.05)	4.2	4.61	12.34	2.58	3.02	5.64		
CV %	29.5	26.5	21.92	29.8	20.01	29.60		
P-value	NS	**	*	NS	*	**		

****Note:** DTF= Days to Flowering, DTM= Days to Maturity, PLH= Plant height (cm), NP/PL= Number of pod per Plant, NS/P= Number of seed per Pod, GY=Grain Yield, YAd=Yield Advantage, Over local check, CS= Chocolate Spot, GM= Grand mean, LSD= Least significant different, CV= Coefficient of variation, NS= Non-significant, *=significant at $P<0.05$ level, **=highly significant

3.3 The AMMI Model

The mean squares for all varieties evaluated under different environmental condition for grain yield are presented in Table 5. The result indicated that differences among all varieties were significant ($P \leq 0.05$). Variation due to genotypes by environments interaction was significant for the studied traits, indicating that genotypes differ genetically in their response to

different environment. The genotypes by environments interaction has significant effect on the grain yield, which explained 3.89 % of the total variation while the varieties, contributed 11.26 to the variation. However, large portion (39.90%) of the total variation was attributed to the environmental effect which indicates that the major factor that influence yield performance of Faba bean is the environment. Significant percentage of genotypes by environments interaction was explained by IPCA-1

(75.8%) followed by IPCA2 (23.16%). Accordingly, Gauch and Zobel (1996) recommended that the most accurate model for AMMI can be predicted by using the first two PCAs.

The genotypes by environments interaction components were smaller relative than to the genotype components and if they were related to predictable environment factor

(such as geographic areas, major pest problems,) the breeder searches for a genotype for the specific requirements of that environment while the interaction is small and unpredictable (micro climatic or yearly variation in weather and management practices) the breeder searches for a genotypes that has general adaptability and unversed performance over the range of environments.

Table 5: AMMI for grain yield of 12 Faba bean varieties

SOV	Degree of freedom	Sum Square	Mean Square	Ex. Sum square
ENV	2	14412.64	7206.32**	39.90
REP(ENV)	9	195.45	21.72 ^{ns}	0.54
GEN	11	4068.32	369.82**	11.26
GEN:ENV	22	1406.11	63.91**	3.89
IPCA1	12	1065.86	88.82**	75.8
IPCA2	10	325.69	32.57*	23.16
Residuals	207	1301.57	6.29	3.60
Total	273	36120.64	132.31	

Note: SOV=source of variation, ENV. = environment; GEN=genotype, GEN * ENV= Genotype by environment Interaction, IPCA= Interaction Principal Component Analysis. **=significance at $P < 0.01$ probability level, *=indicates significance at $P < 0.05$ probability level

3.4 Evaluation of Genotypes based on GGE-Bi plots

Stability can be identified using concentric circles and also ideal genotypes are at the center of the concentric circle i.e., high mean yield and stable genotype. The ideal genotype is the one with the highest mean performance and absolutely stable (Yan and Kang, 2003). Hence, the

GGE bi plots shows that Hachalu is an ideal genotype, while, Walki, Mosisa, and Alloshe are desirable varieties as they are closer to the ideal genotype on the bi plot. The varieties Gabalcho and Local check are the most undesirable genotypes as they are too far from the ideal genotype on the bi plot (figure 1). Similar result was reported by Farshadfar *et al.*, 2012).

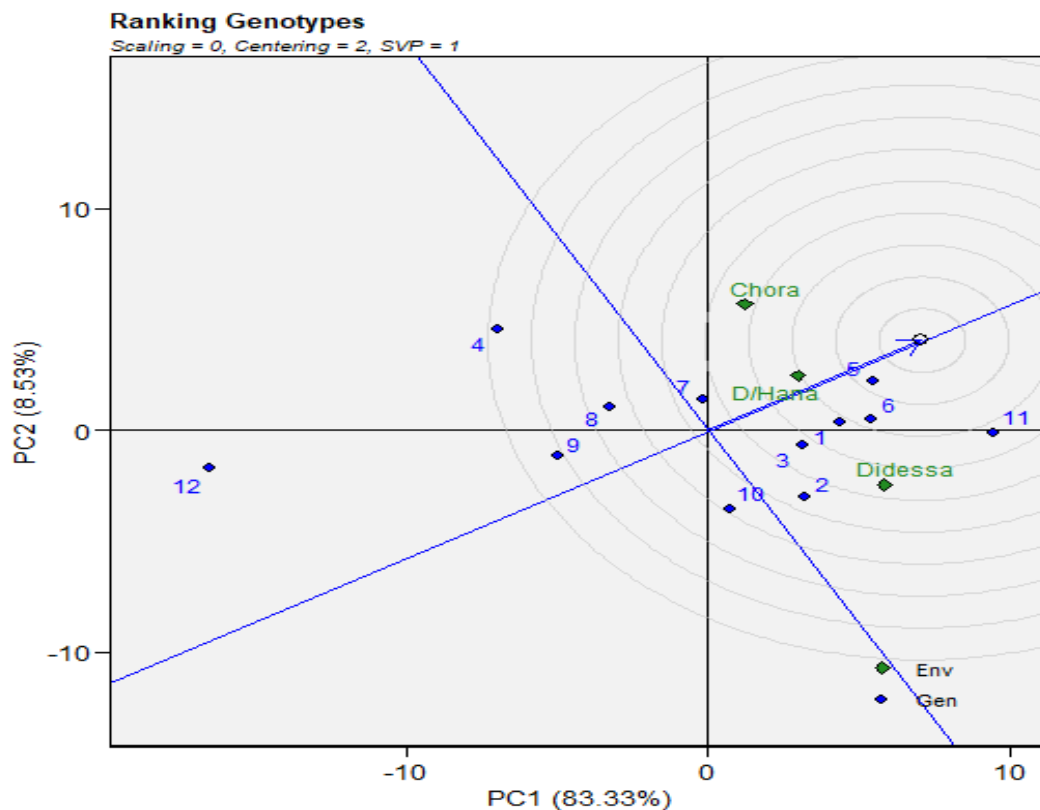


Figure 1 Ranking of the genotypes based on the ideal genotype

3.5 Evaluation of Locations based on GGE-Bi plots

The ideal test location is the most representative of the locations (ability to represent the mega-environment) and the most powerful to discriminate genotypes (ability to delineate the tested genotypes). Naroui *et al.*, (2013) reported that the ideal environment is the one located at the center of the concentric circles, and it is possible to identify desirable environments based on their closeness to the ideal environment. Mahdieh *et al.*, (2016) reported that a testing location has less power to discriminate

genotypes when located far away from the center of the concentric circle or to an ideal location.

Therefore, among the test locations, Didesa which is nearest to the center of concentric circles was an ideal test location being the most representative of the overall locations and the most powerful to discriminate the performance of the tested genotypes and Dabo Hana was close to the ideal location. While, Chora was detected as the weakest location to discriminate genotypes due to the great distance from the center of concentric circles (Figure 2). This result disagrees with that of Yirga (2016) and Habte *et al.*, (2019).

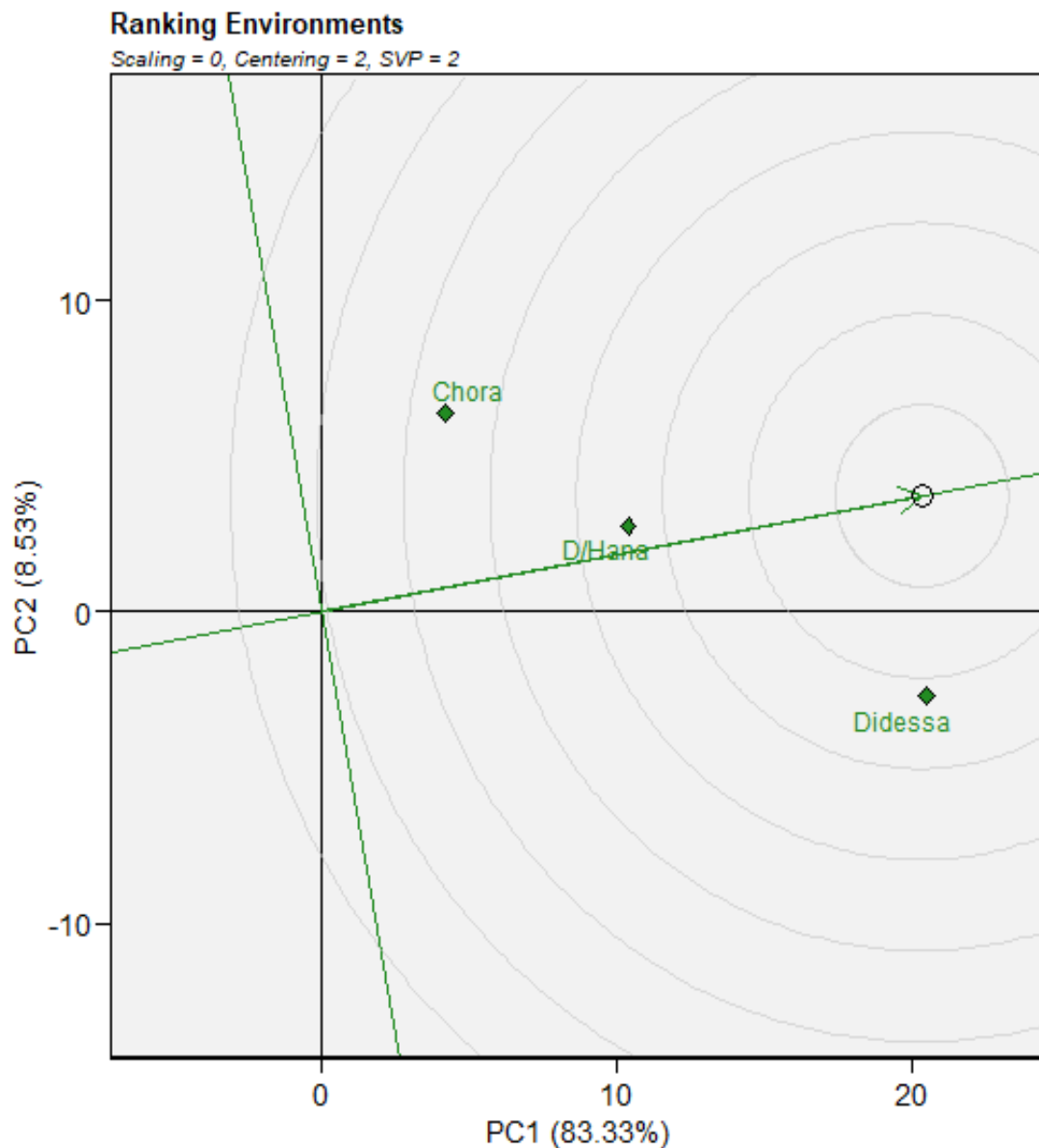


Figure 2: Ranking of the locations based GGE-Bi plot

3.6 The Which-Won-Where/What pattern

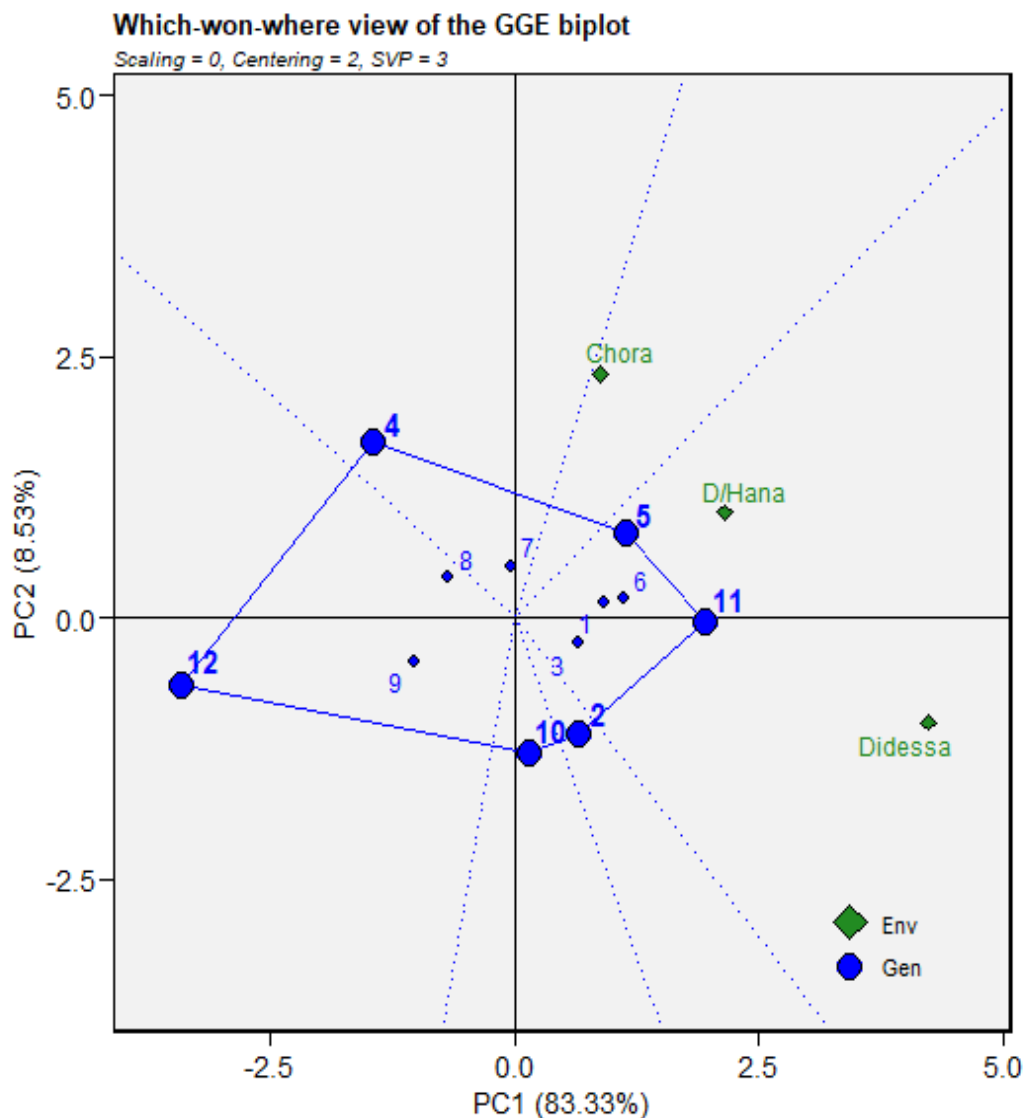


Figure 3: Which-won-where and mega- environment

According to Yan *et al.*, (2002), the polygon view of GGE bi plot indicates the best genotypes in each environment and group of environments. In this situation, the polygon is formed by connecting the genotypes that are farthest away from the bi plot origin, such that all the other genotypes are contained in the polygon. In this case, the polygon connects all the farthest genotypes and perpendicular lines divide the polygon into sectors. Sectors help to visualize the mega-environments. This means that winning genotypes for each sector are placed at the vertex. Polygon view of the Faba bean varieties tested at three locations presented in (figure 3). Genotypes at the vertex of the polygon are either the best or poorest in one or more environments (Alake *et al.*, 2012). The genotypes found at the vertex of the polygon perform best in the environments within the sector (Yan

and Tinker, 2006). Six rays divide the bi plot in to six sector and the locations fall in to three different mega-environments (Figure.3). Genotypes, Gabalcho (4), Local check (12), and walki (11) were the vertex genotypes. From this figure, Walki and Hachalu (11, 4) best performers at Dabo Hanna and Didesa in the first mega environment). From the figure, Gabalcho (4), local (12) and Tosha (10) had no environment on the vertex. This indicates that genotypes in the vertex without environment performed poorly in all the locations (Alake *et al.*, 2012). However, genotypes within the polygon, particularly those located near the bi plot origin were less responsive than the genotypes on the vertices, and the ideal genotype would be the one closest to the origin (Nwangburuka *et al.*, 2011). Therefore, varieties Moti

(7), Moyibon (8), Alloshe(1) and Dosh(3) were more stable (Figure.3)

4. CONCLUSION AND RECOMMENDATION

The lack of best performing and high yielding variety is the main challenge for faba bean production and productivity in Buno Bedele zone, south western part of Oromia. Twelve varieties including the local check were evaluated for their adaptability, yield and yield related traits. Walki variety was found to be the most adaptable and high yielding genotype followed by Hachalu.

The genotype and environment main effects and genotype x environment interaction effect were significant on Faba bean varieties. Walki and Hachalu varieties were the higher yielder than other varieties through the studied environments. However, Local check had the lowest yield potential through the tested locations. AMMI model shows the variation was largely due to environmental variation. The high percentage of environmental variation is an indication that the major factor that influence yield performance of Faba bean is the environment. Walki and Hachalu were plotted to the ideal varieties considered as desirable varieties based on GGE biplot graph and stable varieties while Dosh and Local check were far from the ideal varieties considered as most unstable varieties with poor performance across locations.

Hence, faba bean production and productivity could be improved by using better yielding varieties such as Walki and Hachalu. In addition, a strong and positive correlation between the different traits and seed yield of faba bean could be used as a selection criterion in order to improve faba bean production and productivity.

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