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Research Article

Performance Evaluation and Adaptability of Improved Faba Bean (Vicia Faba L.) Varieties in the Highlands of North Shewa Zone, Oromia

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Abstract

Field experiment was conducted at Degam, H/Abote, D/Libanos, Jida and Wachale districts of North Shewa Zone, Oromia region, Central Ethiopia with the objectives of evaluating adaptable and best yield performing improved Faba bean varieties for further demonstration and scaling up during the main cropping season of 2020, 2021 and 2022. The experiment was conducted using randomized complete block design (RCBD) with three replications. In the experiment, thirteen improved faba bean varieties and one local control were used to evaluate their performance. Parameters like seed yield (qt/ha), 1000 seed weight in gram, number of pod per plant, number of seed per pod, plant height (cm) were measured to assess the actual field performances of different faba bean varieties. The data were analyzed by R software. Grain yield and most of yield components were significantly affected by main effect of variety, environment and interaction of variety and environment. The results revealed that there were significant ($P < 0.01$) variations between the varieties for yield. Higher yield was recorded on Welki and Ashebeka varieties while low yield was recorded from Tosha and Shalo. In addition the stability analysis indicated that as the mean of grain yield is more stable across locations as compared to other variety. Also, in this study it was found that there is 24.5 % and 19.1% increment of yield using of Welki and Ashebeka variety respectively as compared to local variety at the study area. Therefore, farmers located at the study area are recommended to use those varieties to increase faba bean production yield.

Keywords

Adaptability, Faba Bean, GGE Biplot, Stability and Varieties

1. Introduction

Faba bean (Vicia faba L.) is a cool-season crop and grown worldwide as a grain and green-manure legume [4]. It is the first largest produced food legume globally [5]. Ethiopia is the second largest producer of faba beans in the world next to China. Also it is the most important food legume crop both in area coverage and volume of annual production in Ethiopia [3]. Nationally about 511,908.4 ha of land were covered annually by faba bean and 3,682,512 smallholder farmers were engaged in growing the crop [3]. Faba bean is a multi-purpose legume and a leading protein source for the rural people in Ethiopia [8, 12]. As a potential rotational crop, it plays an important role in soil fertility improvement through nitrogen fixation [11]. Moreover, the crop improves soil fertility as it fixes atmospheric nitrogen in large quantities and

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leaves a lot of N-related yield effect via its large biomass to subsequent crops [17]. Also, it serves as a source of foreign currency for the country [16].

Despite its huge importance and area coverage, the productivity of faba bean is about 2.1 tons ha^{-1} [3], far below the potential of the crop which reached approximately 5.2 tons ha^{-1}. This might probably be attributed to different biotic and abiotic factors. Of which the use of old and low yielding local cultivars and unavailability of high yielder improved varieties [2] and the newly emerged faba bean gall disease that causes up to complete crop failure in susceptible cultivars and under conducive prevailing conditions [1, 2, 18] were the most important factors.

Over the years, a number of faba bean varieties have been evaluated and released by national and regional agricultural research centers. However, farmers do not grow improved varieties which are high yielding, disease and pest resistance as these varieties were released without the participation of farmers in considered belts of crop commodity producing areas. And also, they have no sufficient information about agronomic practices and economic importance of the released faba bean varieties

Therefore, this research experiments was conducted with the following objectives;

1. To test the adaptability of improved Faba bean varieties in central highlands of Ethiopia
2. To recommend the best performing improved Faba bean varieties for further demonstration and scaling up technology dissemination system

2. Materials and Methods

2.1. Description of Experimental Areas

The experiment was conducted in North Shewa Zone Oromia, during the main cropping season of 2020- 2022 for three consecutive years under four locations of North Shewa Zone, Oromia. The locations were Degam, Hidebu Abote, Debra Libanos, Wachale and Jida district. The capital town of zone Fitche is located about 112km far from the capital city Addis Ababa to the Northern part of country.

2.2. Experimental Materials, Design and Field Management

Thirteen improved released faba bean varieties and one local check variety was used to test adaptability and stability of varieties at representatively selected area. The treatments were arranged in Randomized Complete Block Design (RCBD) with three replications. Each variety was planted on a plot size of 9.6 m^2 with 40 cm between rows and 10 cm between plants. All other recommended agronomic practices were applied uniformly in all experimental plots.

Table 1. *Description of tested Varieties.*

Variety	Pedigree	Seed Size	Year of Release	Adaptation area(m.a.s.l)	Breeder/Maintainer
Shallo	EH011-22-1	Small	2000	2300-2800	SARC
Walki	EH96049-2	Medium	2008	1800-2800	HARC
Dosha	Coll 155/00-3	Medium	2009	1900-2800	HARC
Tumsa	EH99051-3	Large	2010	2050-2800	HARC
Gora	EK 01024-1-2	Large	2013	1900-2800	KARC
Mosisa	EH99047-1	Medium	2013	2300-2800	SARC
Didea	EH01048-1	Large	2014	1800-2800	HARC
Alloshe	EH03043-1	Medium	2017	2300-2800	SARC
Dagim	Grarjarso 89-8	Small	2002	1900-2800	HARC
Ashebeka	EH010755-4	Large	2015	1900-2800	KARC
Tosha	EH00021-1	Medium	2019	2300-2600	SARC
Moybon	EH011088-3	Large	2019	2300-2600	SARC
Hachalu	EH00102-4-1	Medium	2010	2100-2800	HARC
Local		Small			

Source: Crop Variety Register

2.3. Data Collected

Data were collected both on a plot and plant basis. The four central rows were used for data collection based on plots, for grain yield (kg/ha). Three plants from the central rows were randomly selected for the data collection on a plant basis and the averages of the three plants in each experimental plot were used for statistical analysis for traits such as plant height, number of pods/plant, number of seeds/pod and number of seeds/plant and hundred seed weight.

2.4. 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/variety (G), environment (E) and G x E interaction effects. Genotype/Variety was treated as a fixed effect and environment as a random effect. Comparison of varietal means was done using Protected Least Significant Difference Test (LSD) at the 5% probability level using R software (4.2.2 Version). The graphical approach to assess performance and stability concurrently also undertaken on the physiological basis of yield stability according to the mean Coefficient of variability analysis introduced by Francis (1977).

2.5. GGE Biplot and AMMI Stability Analysis

The GGE biplot was used to evaluate the test environments. An environment is considered ideal for genotype testing when it discriminates the genotypes and represents the environments [20]. The presence of correlation between two environments means that similar information about the genotype performance is derived from them [6] and therefore could be an option to reduce the number of test environments and, as a result, to establish a cost-effective breeding program.In addition, GGE biplot is an effective visual tool for identifying the mega-environment issues and showing the specific adaptation of the genotypes and which cultivar won in which environments [19]. A mega-environment is defined as a group of locations that consistently share the same best cultivar(s) [21].

3. Results and Discussion

3.1. Combined Analysis of Variance

The analysis of variance for the measured traits of the tested varieties showed there were significant differences (*P*<0.01) for both main effect of variety and locations in all parameters. However, the interaction of variety and location showed significant difference (*P*<0.01) only on days to physiological maturity and grain yield where as non-significant for pod per plant, seed per plant, plant height and hundred seed weight parameters (Table 2). Hence, the parameters were varying among varieties over locations. The observed differences among the varieties could be due to variation in the genetic makeup of these varieties and influence of environmental factors. On the other hand, means of the interactive effects of variety by Location was significant only for days to physiological maturity and grain yield (Table 2).

Table 2. *Mean square values of agronomic characters of faba bean varieties from combined analysis of variance over Location.*

Source of Variation	Mean squares						
	Df	DM	PPP	SPP	Pht	GY	HSW
Variety	13	30.2***	144.6***	1106***	349**	1579966***	4429.3***
Location	5	8856.7***	1077.9***	4937***	21878***	30805344***	914.9***
Variety* Location	65	34.3***	20.2^{NS}	109^{NS}	139^{NS}	1270643***	101.8
Residuals	83	9.3	20.9	115	126	337894	88.8

Keys: DM = Days maturity, PPP = Number of pods per plant, SPP = Number of seeds per pods, Pht = Plant height, GY = Grain yield, HSW = Hundred seed weight; *=significant at 5% probability level, **= significant at 1% probability level, NS = non-significant

3.2. Estimate Analysis 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 33.1%, 6.12%, 18.31%, 28.0% and 0.2 %, 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 [10, 13]. 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 was 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 [7, 13].

Table 3. *Combined analysis of variance for grain yield (kg ha^{-1}) of 14 faba bean varieties across six locations during 2020-2022 main cropping season.*

Source	Df	SS	MS	Ex.SS %	Pr(>F)
Environments	4	119882855.4	29970714^{**}	33.1	< 0.001
Rep(Environments)	10	628842.3	62884.23	0.2	1.00
Genotype	13	22178421.8	1706032^{**}	6.12	<0.001
Genotype: Environment	52	66073415.9	1270643^{**}	18.24	< 0.001
PC1	16	39640773.8	2477548^{**}	-	<0.001
PC2	14	7510037.8	536431.3	-	0549
PC3	12	3112051.2	259337.6	-	0.945
PC4	10	1686184	168618.4	-	0.983
Residuals	172	101436658.8	589748	28.01	
Total	303	362149240.9	1195212		

Keys: DF=degree of freedom, SS=sum of squares, MS=mean squares, EX. SS%=Explained Sum of square, PC=Principal Component Axis, ** = highly significant at the level of 1% probability, ns = non-significant

3.3. Performances of Agronomic Yield Components

There was significant variation ($P < 0.01$) in yield components among the faba bean varieties in the combined analysis over location (Table 4) at all sites. The interaction of variety with location also significantly affected days to physiological maturity and grain yield in the combined analysis. Among the tested varieties the 'Ashebeka' followed by 'Hachalu' delay in maturity at 145.9 and 144.3 days where as variety 'Aloshe' matured early at 140.1 days respectively (Table 4). The highest number of pods per plant (20.1, 19.4) were scored on variety 'Dagim' which is followed by 'Local' variety and number of seeds per pod(51.6) also scored on Dagim variety where as lowest was recorded on 'Tosha' variety for both parameters (Table 4). This variation could be due to genetic inherent of those improved faba bean varieties produced more number of pods per plant and seeds per plant. This result is similar with the report of previous studies [9].

Seed weight of these varieties ranged from 32.1 to 84.5g. Variety Ashebeka produced the highest hundred seed weight (84.5g) whereas; the local check was recorded for the smallest hundred seed weight (32.1g) (Table 4). The observed differences in hundred seed weight might be due to inherent genetic differences among the varieties which enhance the grain filling of crops and thereby results to large seed size. This is in line with the report of [9, 14] who reported the highest hundred seed weight of variety Tumsa among the varieties they tested which is one of large size type.

Table 4. *Mean of yield components and yield of Faba bean crop at different location of North Shewa Zone, Oromia during main cropping season.*

Variety	DM	PPP	SPP	Pht	GY	HSW
Welki	142.1^{b-e}	14.9^{b}	35.1^{b}	110.2^{ab}	3087.74^{a}	52.6^{e}
Ashebeka	145.9^{a}	12.9^{b-e}	30.9^{b-e}	114.6^{a}	2952.41^{ab}	84.5^{a}
Gora	143.2^{b-d}	10.9^{de}	26.6^{de}	107.9^{a-c}	2763.65^{cd}	79.6^{a}
Didea	143.1^{b-d}	14.3^{bc}	34.7^{b}	109.6^{ab}	2682.48^{d}	70.8^{bc}
Dosha	141.0^{de}	14.9^{b}	33.9^{bc}	105.4^{bc}	2861.64^{bc}	67.8^{b-d}

Variety	DM	PPP	SPP	Pht	GY	HSW
Tumsa	141.6^{c-e}	12.6^{b-e}	26.8^{de}	106.8^{bc}	2523.05^{e}	71.5^{b}
Mosisa	141.4^{c-e}	13.8^{b-d}	29.4^{b-e}	105.6^{bc}	2508.84^{e}	64.6^{cd}
Hachalu	144.3^{ab}	14.0^{bc}	32.9^{b-d}	110.6^{ab}	2469.35^{ef}	63.7^{d}
Local	142.8^{b-d}	19.4^{a}	45.6^{a}	101.8^{cd}	2479.15^{ef}	32.1^{f}
Dagim	143.8^{a-c}	20.1^{a}	51.6^{a}	104.4^{bc}	2392.64^{ef}	33.8^{f}
Moybon	141.3^{de}	11.5^{c-e}	25.0^{e}	102.0^{cd}	2341.16^{f}	82.7^{a}
Aloshe	140.1^{e}	12.8^{b-e}	28.1^{b-e}	106.7^{bc}	2329.29^{f}	63.6^{d}
Shalo	141.1^{de}	12.5^{b-e}	27.6^{c-e}	104.3^{bc}	2059.77^{g}	64.0^{d}
Tosha	141.2^{de}	10.1^{e}	24.2^{e}	96.9^{d}	2047.76^{g}	66.5^{b-d}
LSD (5%)	2.47	3	7.06	7.38	152.45	6.2
CV (%)	2.15	22.84	23.19	10.56	9.14	14.7

Keys: DM = Days maturity, PPP = Number of pods per plant, SPP = Number of seeds per pods, Pht = Plant height, GY = Grain yield, HSW = Hundred seed weight, $LSD_{0.05}$=Least significant difference at 5% level, CV=Coefficient of variation and Column sharing the same letter/s are non significant.

3.4. Performances of Faba Bean Grain Yield Across Environments

The significant interaction effect suggests that grain yield of varieties varied across the tested environments. Thus, the highest mean grain yield was exhibited by the variety Welki (3087.74 kg ha^{-1}) followed by Ashebeka with mean grain yield of 2952.41 kg ha^{-1}. The change in yield performance with environments among varieties was also reported by [13] in faba bean crop. Among the locations, the grain yield varied from 1059.2 kg ha^{-1} at Debra Libanos to 5324.6 kg ha^{-1} at Degam. The mean grain yield averaged over locations and varieties was 2535.64 kg ha^{-1} (Table 5). A large yield variation between locations indicated that the environments were diverse, whereby some of environments were favorable for faba bean varieties to produce high yield. On the other hand, genetic variability of individual crops contribute high role for interacting differently in each environments for yield traits and yield of crops. This is in line with the finding of [15] who reported the highest (3.35 tons ha^{-1}) grain yield was recorded by Welki variety among the varieties they tested. Although from the experiment implemented over locations the calculation result revealed that there was about 24.5 % and 19.1% increment of yield using of Welki and Ashebeka variety respectively as compared to local variety at the study area.

Table 5. Combined Mean of Faba bean Grain Yield at different location of North Shewa Zone, Oromia.

Varieties	Mean Grain Yield (kg/ha) 2020 Degam	2021 H/Abote	2021 D/Libanos	2022 Degam	2022 Wachale	2022 Jida	Combined Mean of GY(Kg/ha)	Yield Adv.(%)
Welki	4899.9^{a}	2085.2^{gh}	2987.4^{e}	4929.2^{b}	1586.1^{ef}	2038.6^{b}	3087.74^{a}	24.5
Local	3611.9^{b}	2367.5^{cd}	1324.6^{j}	3703.9^{f}	1834^{cd}	2032.1^{b}	2479.15^{ef}	0
Dosha	3590.2^{b}	2399.6^{c}	1102.6^{k}	5324.6^{a}	1646.3^{ef}	3106.5^{a}	2763.65^{cd}	15.4
Mosisa	3034.7^{c}	2259.2^{de}	1930.4^{h}	4832.2^{b}	1397.4^{g}	1599.2^{b}	2508.84^{e}	1.2
Aloshe	2618.5^{d}	2252.2^{d-f}	1371.4^{j}	4388.7^{c}	1479.1^{fg}	1865.8^{b}	2329.29^{f}	-6.1
Shallo	2533.5^{de}	1666.9^{i}	1059.2^{k}	4402.5^{c}	1098.8^{h}	1597.6^{b}	2059.77^{g}	-16.9
Hachalu	2398.5^{ef}	2197.0^{e-g}	2288.7^{g}	4095.5^{de}	2119.0^{b}	1717.4^{b}	2469.35^{ef}	-0.4
Moybon	2271.0^{fg}	2133.9^{f-h}	2206.3^{g}	4220.8^{cd}	1528.9^{e-g}	1686.0^{b}	2341.16^{f}	-5.6
Ashebeka	2129.4^{g}	2841.5^{b}	3923.5^{a}	4204.7^{cd}	2863.9^{a}	1751.5^{b}	2952.41^{ab}	19.1
Tosha	1915.5^{h}	1430.9^{j}	1759.7^{i}	4376.6^{c}	1364.3^{bc}	1439.6^{b}	2047.76^{g}	-17.4
Dagim	1776.0^{hi}	2016.0^{h}	3274.5^{d}	3848.2^{ef}	1688.9^{de}	1752.3^{b}	2392.64ef^{ab}	-3.5
Tumsa	1761.1^{i}	2359.7^{cd}	2772.0^{f}	4356.3^{cd}	1673.9^{de}	2215.3^{b}	2523.05^{e}	1.7
Gora	1567.2^{j}	2809.4^{b}	3419.2^{c}	4849.4^{b}	2153.7^{b}	1782.9^{b}	2763.65^{cd}	11.4
Didea	1076.7^{k}	3140.4^{a}	3612.1^{b}	4287.8^{cd}	1910.1^{c}	2067.9^{b}	2682.48^{d}	8.2
Mean	2513.2	2282.8	2359.4	4415.7	1738.9	1903.8	2535.64	

Varieties	Mean Grain Yield (kg/ha)						Combined Mean of GY(Kg/ha)	Yield Adv.(%)
	2020	2021		2022				
	Degam	H/Abote	D/Libanos	Degam	Wachale	Jida		
LSD (5%)	151.7	122.8	109.1	268.9	172.9	865.2	152.45	
CV (%)	3.6	3.2	2.8	3.6	5.9	27.2	9.14	

Keys: GY = Grain yield, $LSD_{0.05}$=Least significant difference at 5% level, CV=Coefficient of variation and Column sharing the same letter/s are non- significant.

3.5. GGE Biplot and Stability Analysis

GGE Biplot provides a summary of the relationship between test environments. Two environments are positively correlated if the angle between their vectors is less than 90^0 [22]. Based on this, the grain yield biplot (Figure 1) showed positive and high correlation between H/Abote, Wachale and D/Libanos as well as Degam and Jida districts.

As shown in Figure 2 and Figure 3, mean stability and ranking varieties (with biplot total 83.89%) relative to the ideal variety is the use of GGE biplot. Varieties found in the center of a concentric circle on the average environments are stable. Therefore, Ashebeka, Welki and Gora are the ideal genotypes (of which both stable and high yielders) that were found near to the concentric circle.

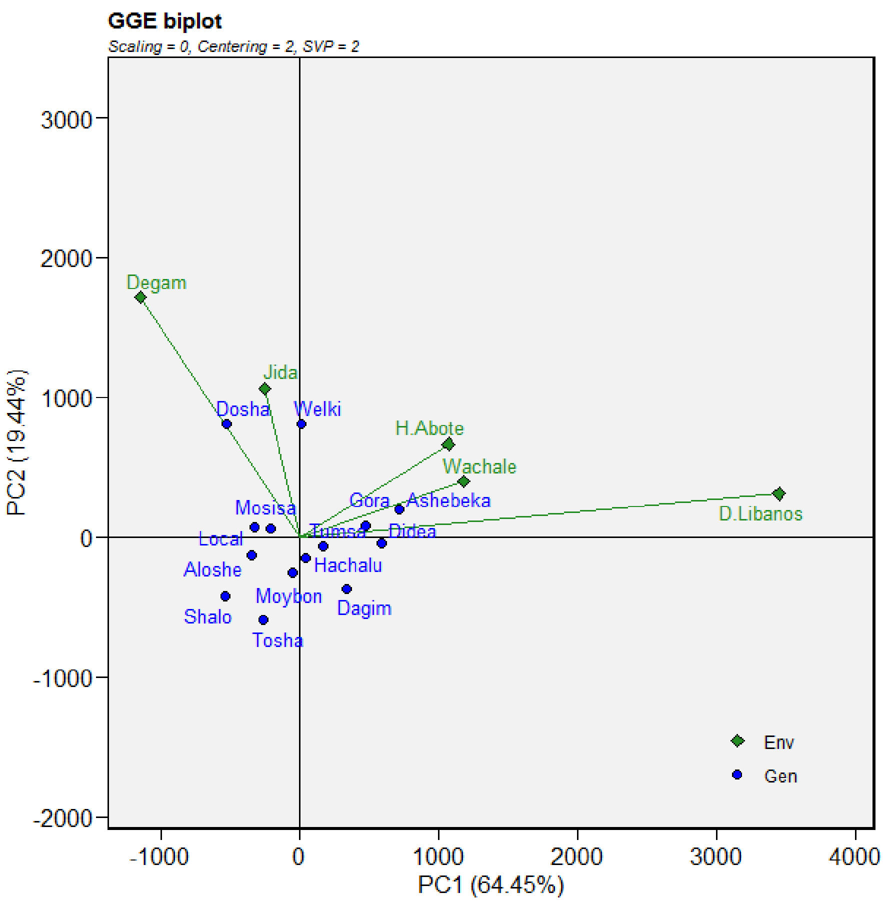

Figure 1*. GGE Biplot Analysis for grain yield of Faba bean Varieties.*

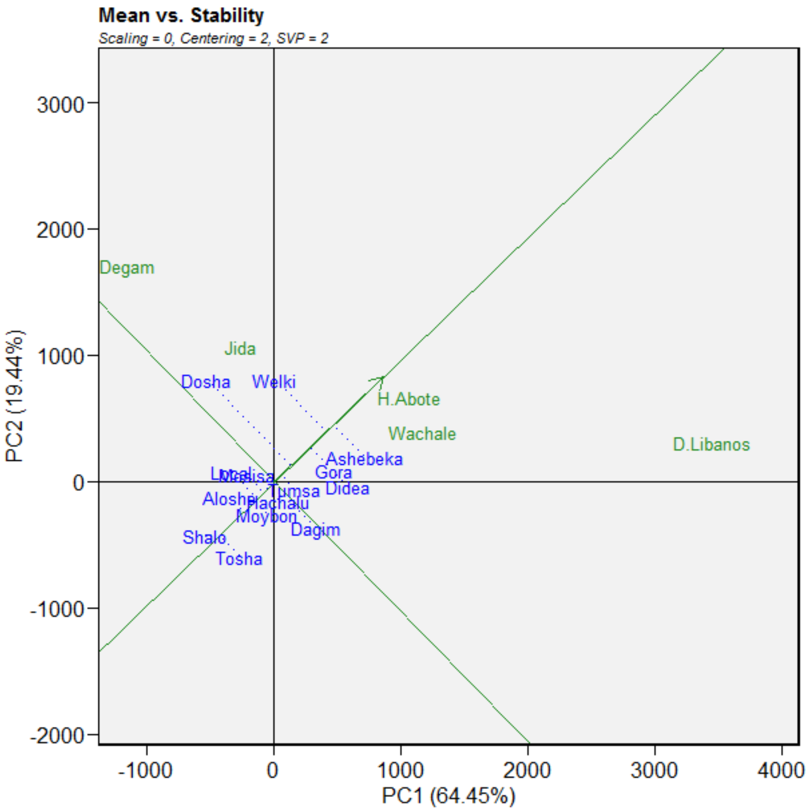

Figure 2. Stability Analysis for grain yield of Faba bean Varieties.

3.6. Performances of Tested Varieties across Locations

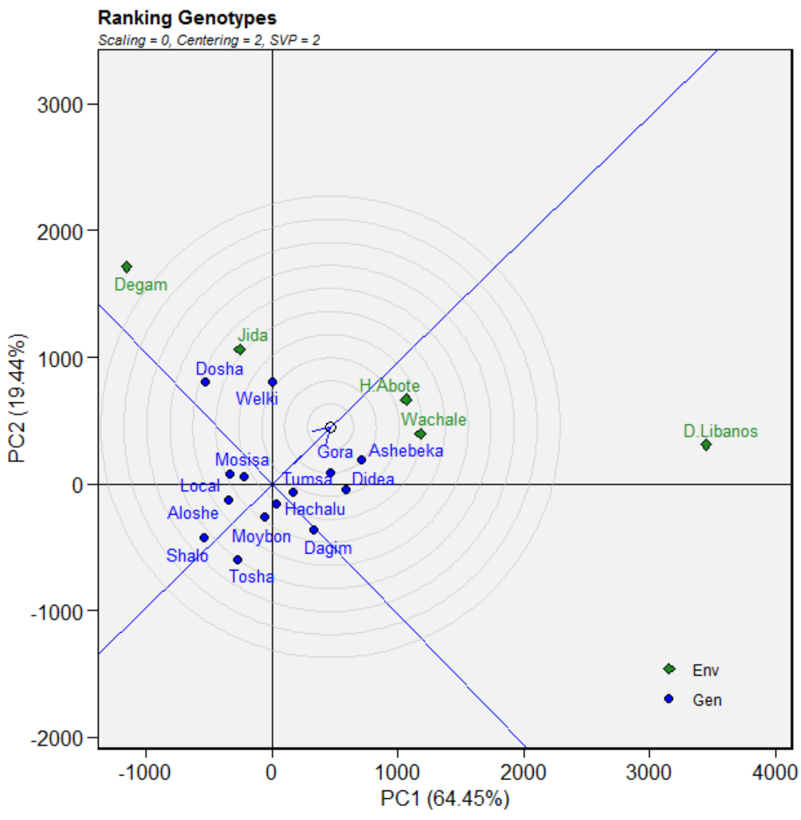

Figure 3. Performance ranking of Faba bean Varieties.

4. Conclusions and Recommendations

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 Welki and Ashebeka 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 variety, Didea is selected as it had high specific adaptation to environments of H/Abote.

Abbreviations

ANOVA: Analysis of Variance
GGE: Genotype, Genotype by Environment interaction
GxE: Genotype by Environment
LSD: Least Significant Difference
PC: Principal Component
RCBD: Randomized Complete Block Design

Authors Contribution

Abreham Feyisa Bedada: Research implementation, Data collection, curation, analyze and interprete the research results, revise and edit the paper.

Gashaw Sefara Bedada: conceptualization, designed the experiment, implementation, data curation, revise and edit the paper.

Name Kinati Firisa: implementation, data collection, curation, revise and edit the paper.

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Conflicts of Interest

The authors declare no conflicts of interest.

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