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Adaptation of Improved Lentil (*Lens Culinaries Medic.*) Varieties on the Highlands of North Shewa Zone, Oromia

Abreham Feyisa Bedada^{1*}, Gashaw Sefera Bedada² and Name Kinati Firisa³

¹Crop Sciences Process, Oromia Agricultural Research Institute, Fitcha Agricultural Research Center, Finfine, Ethiopia. E-mail: abrehamfeyisa@gmail.com

²Crop Sciences Process, Oromia Agricultural Research Institute, Fitcha Agricultural Research Center, Finfine, Ethiopia. E-mail: namerakinati@gmail.com

³Crop Sciences Process, Oromia Agricultural Research Institute, Fitcha Agricultural Research Center, Finfine, Ethiopia. E-mail: namerakinati@gmail.com

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Abstract

Lentil are among the major grain crops produced in Ethiopia with multipurpose advantages. However, it's production and productivity at the study areas was majorly hindered and affected by the lack and low adoptions of improved varieties even though the demand for the crop is too high. Therefore, a field experiment was conducted at Jida, Debre Libanos, Yaya Gulele and Wachale districts of North Shewa Zone, Oromia region, Central Ethiopia with the objectives of evaluating improved Lentil varieties to recommend adaptable varieties for further demonstration and scaling. Seven improved lentil varieties including one local variety as a control were used to evaluate their performance. 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 among the varieties for yield. Higher yield was recorded from Baredu and Debine varieties while low yield was recorded from Jiru. In addition, the stability analysis indicated that mean grain yield was more stable for both varieties across locations as compared to the other varieties. Also, in this study it was found out that there was 15.93 % and 8.06% increment of yield for Baredu and Debine variety (high yielder) as compared to the local variety. Therefore, those two varieties were recommended for production on the highlands of North Shewa Zone.

Keywords: Adaptability, GGE Biplot, Grain yield, Lentil, Stability and Varieties

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1. Introduction

Lentil (*Lens culinaris* Medikus) is one of the most important cool season food legumes grown in many parts of the world as food crop (Erskine et al., 2011). The total lentil cultivated area in the world is estimated at around 5.5 million hectares with annual production and productivity of 6.3 million tons and 1152 kg ha⁻¹, respectively (FAO, 2016). It is amongst the principal cool season food legumes in Ethiopia too (Joseph, 2014). It is widely grown in areas having altitudinal range of 1700-2400 meters above sea level with annual rainfall in the range of 700-2000 mm in Ethiopia (Korbu, 2009).

Ethiopia is considered as a center of diversity for lentil and currently lentil is an important pulse crop (Fikuru et al., 2007). This makes Ethiopia one of the major lentil-producing countries in Africa (FAOSTAT, 2017) and is among the top ten countries in the world (FAO, 2016). Lentil is grown as a source of protein; 23-24% (Addise and Asfaw, 1993) for

* Corresponding author: Abreham Feyisa Bedada, Crop Sciences Process, Oromia Agricultural Research Institute, Fitcha Agricultural Research Center, Finfine, Ethiopia. E-mail: abrehamfeyisa@gmail.com

human consumption and also is a rich source of minerals and vitamins for human nutrition and the straw is valuable for animal feed. It is a potential export and cash crop that has the highest price in domestic and international markets compared to all other food leguminous crops and cereals (Geletu *et al.*, 1996).

It is one of the major highland pulses of Ethiopia that grows in rotation with tef, wheat and barley particularly on heavy black soils (vertisol) (Jarso *et al.*, 2009). Lentil plays a significant role in human and animal nutrition and in maintenance and improvement of soil fertility (Sarker and Kumar, 2011).

Despite the country's potential and sustained development efforts to get the pulse sub-sector moving, the competitiveness of lentil and hence its contribution to economic development is threatened by low productivity and inconsistent supply of products that do not meet both export quality and quantity. The average yield of lentil in Ethiopia is not greater than 800kg ha⁻¹ (FAOSTAT, 2017). This is mainly due to inadequate supply and limited popularization of improved varieties to the smallholders on a larger scale. In addition to this, the changing climate and its consequences and other array of stresses lead to crop damage and result in reduction in the yields of lentil (Sarker and Kumar, 2011).

The demand for lentil and the price of the produce has been growing steadily in recent years and there is a high need to increase its production for both domestic and export markets in Ethiopia (Abraham, 2015). Even though there are suitable agro-ecologies and soil conditions for the production of lentil in Ethiopia; the production of the crop is currently limited to few areas. However many district of North Shewa Zone, in Oromia region have favorable climatic and soil conditions for lentil production. Federal Research Center, Regional Research Centers and Universities have released several high yielding and disease resistant lentil varieties with recommended packages. Even though efforts have been made to popularize improved varieties of different crops, the cultivation of lentil is not well progressed in North Shewa due to the fact that adaptable varieties were not tested and recommended. Therefore, to popularize, and expand its production for both domestic and export market, testing the varieties for their adaptability is very crucial. The objective of this experiment was thus to test the adaptability and yielding performance of improved lentil varieties as well as to identify and recommend the best variety that is high yielded and disease resistant/tolerance which suitable for production in North Shewa zone, Oromia.

2. Materials and Methods

2.1. Description of Study Area

The field experiments were conducted during the 2021-2022 consecutive main cropping seasons at four locations representing highland agro-ecologies of North Shewa Zone, Oromia region. The locations were Jida, Wachale, Debra Libanos and Yaya Gulele districts.

2.2. Experimental Materials and Design

Six improved lentil varieties along with the local check were tested for their adaptability and performance on yield and yield components during main cropping season at four locations of North Shewa Zone, Oromia. The treatments were arranged in Randomized Complete Block Design with three replications. The experimental plot consisted of six rows with a plot size of 1.2 × 4 m and spacing of 10 cm between plants and 20 cm between rows. The spacing between blocks (replications) was 1m; whereas plots were spaced 0.8m apart from each other. The experimental field was prepared following the standard practices for lentil production before sowing. The field was ploughed, leveled, and rows were prepared 20 cm apart from each other. All other recommended agronomic practices were applied uniformly in all experimental plots.

2.3. Data Collection

Data on days to 50% flowering, days to 90% physiological maturity, 100 seed weight (g) and grain yield (kg ha⁻¹), were assessed on plot bases, while plant height (cm), number of pods plant⁻¹, and number of seeds pod⁻¹ were recorded on three random samples of plants selected from the central rows of each plot. Mean values of the three random samples of plants plot⁻¹ were then used for the analysis of data collected on an individual plant basis.

3. Statistical Analysis

The analysis of variance (ANOVA) was undertaken for each location. Variance homogeneity was tested and combined analysis of variance was performed using the linear mixed model (PROC ANOVA) procedure to partition the total variation due to genotype/variety (G), environment (E) and G × E interaction effects into components. 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 5% probability level using R software (4.2.2 Version). The graphical

approach to assess performance and stability was concurrently undertaken on the physiological basis of yield stability according to the mean Coefficient of variability analysis introduced by (Francis and Kannenberg, 1978).

3.1. GGE Bi-plot and AMMI Stability Analysis

Stability parameters were estimated following the Eberhart and Russell (1966). A genotype with high mean seed yield, regression coefficient (b) close to unity and deviation from regression (S²d) near to zero was defined as a stable cultivar.

4. Results and Discussion

4.1. Combined Analysis of variance

Analysis of variance revealed that significant variations among main effect differences for varieties observed for all traits except for number of pods plant⁻¹ and seed per plant (Table 1). Likewise, test locations exerted highly significant ($p < 0.01$) effects on all traits except seed per plant. The interaction effects of locations and varieties were non-significant ($p < 0.05$) for all traits except of day’s maturity and grain yield (Table 1).

Source of Variation	Mean Squares							
	Df	DM	PPP	SPPlant	SPPod	Pht	GY	HSW
Variety(V)	13	38.2***	246.7 ^{NS}	352.4 ^{NS}	0.043*	349**	1579966***	4429.3***
Location(L)	5	1464.1***	515.7**	587.0 ^{NS}	0.281***	21878***	30805344***	914.9***
V* L	65	9.61**	113.8 ^{NS}	205.4 ^{NS}	0.469 ^{NS}	139 ^{NS}	1270643***	101.8
Residuals	83	3.92	109.1	264.2	0.016	126	337894	88.8

Keys: DM = Days maturity, PPP = Number of pods per plant, SPPlant = Number of seeds per plant, SPPod = 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.

4.2. Estimate Analysis of Variance Components

According to the results of combined ANOVA for grain yield, Variety × Location interaction, varieties, locations , error and replication within locations contributed to 37.82%, 15.24%, 6.96%, 1.78% and 0.38 %, respectively (Table 2) of the

Source	Df	SS	MS	Ex. SS %	Pr(>F)
Locations	3	472015	15338*	6.96	< 0.001
Rep (Locations)	8	25568	3196	0.38	0.282
Variety	7	1033227	172204**	15.24	<0.001
Variety: Location	18	2563366	142409**	37.82	< 0.001
PC1	8	2100590	262574		<0.001
PC2	6	393831	65639		<0.001
PC3	4	68945	17236		<0.001
Residuals	48	120882	2518	1.78	
Total	101	6778424	67113		

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

total sum of squares. The interaction effect of $V \times L$ accounted for higher proportion from the total variation in grain yield. This indicated the tested varieties were interacted with the environments differently and they were highly variable and that there were large differences among the test locations on yield performance of lentil varieties.

4.3. Performances of Agronomic Yield Components

There was significant variation ($p < 0.01$) in terms of yield components among the lentil varieties in the combined analysis over locations (Table 3) 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 lentil varieties, ‘Baredu’ followed by ‘Alemaya’ and ‘Derash’ were relatively late in maturity at 115.83, 115.17 and 115.17 days where as ‘Local’ variety matured early at 111.33 days respectively (Table 3). The highest number of pods per plant and seed per plant (38.42, 48.47) were scored on variety ‘Derash’ which is followed by ‘Alemaya’ variety whereas lowest was recorded on ‘Jiru’ variety for both parameters (Table 3). This variation could be due to genetic inherent of those improved lentil varieties produced more number of pods per plant and seeds per plant and its interaction with environment.

Varieties	DM	PPP	SPPlant	SPPod	Pht(cm)	TSW(g)
Baredu	115.83 ^a	29.50 ^{bc}	41.94 ^{ab}	1.44 ^a	33.31 ^a	33.92 ^b
Alemaya	115.17 ^{ab}	36.14 ^{ab}	47.67 ^a	1.36 ^{ab}	33.31 ^a	31.58 ^{bc}
Derash	115.17 ^{ab}	38.42 ^a	48.47 ^a	1.27 ^b	31.44 ^{ab}	26.55 ^d
Jiru	114.00 ^{bc}	25.89 ^c	33.97 ^b	1.32 ^b	30.69 ^{bc}	30.12 ^c
Debine	112.42 ^{cd}	36.17 ^{ab}	45.81 ^{ab}	1.29 ^b	30.11 ^{bc}	28.68 ^{cd}
Asanno	112.00 ^d	27.94 ^{bc}	37.06 ^{ab}	1.33 ^b	30.89 ^{ab}	38.48 ^a
Local	111.33 ^d	32.50 ^{a-c}	41.97 ^{ab}	1.27 ^b	28.36 ^c	26.93 ^d
Mean	113.70	32.08	42.41	1.32	31.16	30.89
LSD (5%)	1.63	8.57	13.34	0.11	2.49	3.03
CV (%)	1.74	22.08	28.32	9.69	9.76	11.94

Keys: DM = Days maturity; PPP = Number of pods per plant; SPPlant = Number of seeds per plant; SPPod = Number of seeds per pod; Pht = Plant height; TSW = Thousand seed weight; $LSD_{0.05}$ = Least significant difference at 5% level; CV = Coefficient of variation and values in a column sharing the same letter/s are non-significant.

4.4. Performances of Lentil Grain yield Across Locations

The performance of test varieties showed variations across locations. Average grain yield ranged from 70.4 to 1374.6 kg ha⁻¹ (Table 4). Variety Baredu followed by Debine and Derash had maximum mean grain yield (Table 4). In line with this

Varieties	Mean Grain Yield (kg ha ⁻¹) (2022)				Combined Mean GY (kg ha ⁻¹)	Yield Adv. (%)
	Jida	Wachale	D/Libanos	Y/Gulele		
Debine	799.3 ^{ab}	1279.4 ^a	794.3 ^{ab}	862.41 ^{ab}	957.1 ^a	8.06
Derash	1048.4 ^a	1055.19 ^{ab}	794.3 ^{ab}	878.61 ^{ab}	957.5 ^a	8.11
Baredu	1374.6 ^a	1050.97 ^{ab}	631.7 ^b	884.91 ^{ab}	1026.8 ^a	15.93
Asanno	805.4 ^{ab}	1117.35 ^{ab}	1051.3 ^a	799.17 ^{ab}	930.8 ^a	5.09
Jiru	70.4 ^b	845.46 ^{bc}	747.6a ^b	671.67 ^b	576.3 ^b	-34.93

Table 4 (Cont.)						
Varieties	Mean Grain Yield (kg ha ⁻¹) (2022)				Combined Mean GY (kg ha ⁻¹)	Yield Adv. (%)
	Jida	Wachale	D/Libanos	Y/Gulele		
Alemaya	1293.7 ^a	738.15 ^c	600.6 ^b	865.69 ^{ab}	871.4 ^{ab}	-1.62
Local	1041.0 ^a	705.83 ^c	787.7 ^{ab}	907.69 ^a	885.7 ^{ab}	0
LSD (5%)	282.87	304.89	271.98	228.55	323.1	
CV (%)	20.76	17.67	16.59	15.32	17.6	

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.

findings Erksine (2003) reported that grain yield had a wide variation (from 10 to 3257 kg/ha) among lentil genotypes. This result indicated that seed yield potential in lentil may vary from cultivar to cultivar. In the current study, the variations among test varieties in grain yield were significant and the maximum yield (1374.6 kg ha⁻¹) was recorded from variety Baredu; similarly this variety produced average grain yield of 1026.8 kg ha⁻¹ (Table 4). Variety Jiru gave the least yield (576.3 kg ha⁻¹). The high yielding varieties Baredu followed by Debine gave grain yield of 1026.8 kg ha⁻¹ and 957.1 kg ha⁻¹, respectively, with yield advantage of (15.93%) and (8.06%) in that order as compared to the local check (Table 4).

4.5. 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 varieties and represents the environments (Yan and Kang, 2003). The presence of correlation between two environments means that similar information about the genotype performance is derived from them (Gedif and Yigzaw, 2014) and therefore could be an option to reduce the number of test environments and, as a result, to establish a cost-effective breeding program. The correlations observed in our study between two environments are reliable as grain yield biplots accounted for more than 60% of the total variation (Yan et al., 2000). Yang et al., (2009) claimed that a GGE biplot is considered useful if the two PCs account for more than 60% of the (G+GE) variability.

GGE biplot is an effective visual tool for identifying the mega-environment issues and showing the specific adaptation of the varieties and which variety won in which environments (Yan et al., 2000). A mega-environment is defined as a group of locations that consistently share the same best Variety(ies) (Yan and Rajcan, 2002). ‘Which-won-where’ plots constructed in the present study grouped the test environments that represent a combination of location-variety treatment into different mega-environments. In addition, GGE-biplot provides a summary of the relationship between test environments. Two environments are positively correlated as the angle between the two corresponding vectors was nearly 90%, no correlation if it was right angle (90%) and negatively correlated if the vectors angle was obtuse (Yan and Tinker, 2006). Based on this, the grain yield biplot (Figure 1) showed positive and high correlation between Jida and Yaya

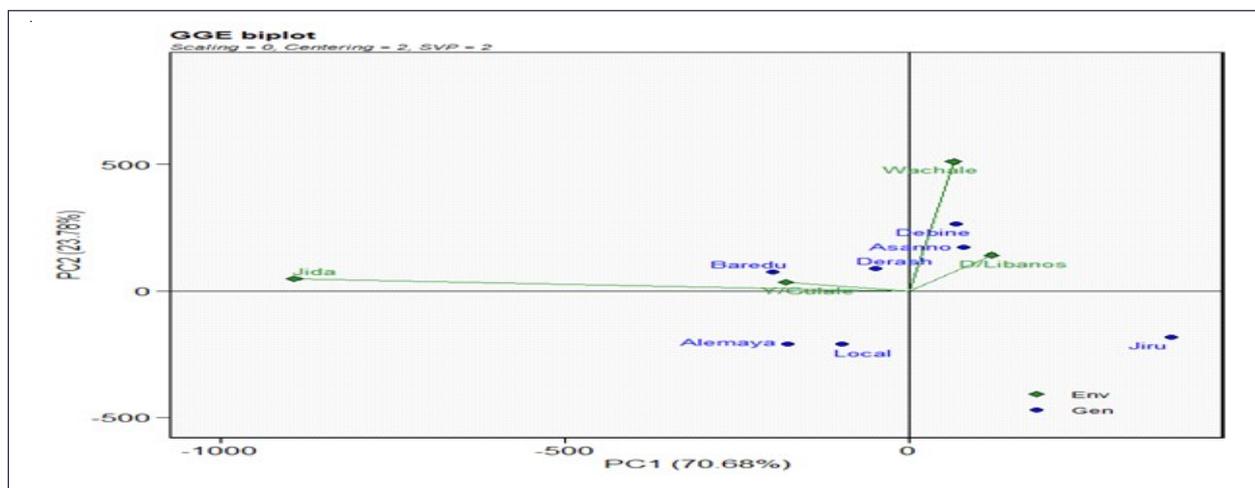


Figure 1: GGE Biplot Analysis for Grain Yield of Lentil Varieties

Gulale as well as Debre Libanos and Wchale. In GGE biplot (Figure 1), PC1 and PC2 explained 70.68 and 23.78 %, respectively, of the lentil varieties by locations interaction and made a total of 94.46%.

4.6. Performance of Tested Varieties

An ideal genotype is defined as one of the highest yielding across the test environments and is stable in performance (Yan and Kang, 2003). Figure 2 shows that among the varieties higher grain yield above the average, Baredu, Debine and Derash were the most stable as they had the shortest projection to the ATA and found near to the concentric circle. On the other hand, despite being moderately adapting with good grain yield performance across tested locations, Jiru variety was the least stable among all the varieties given that it had the longest projection to the ATA. Figure 3 show the ranking of varieties based on grain yield performance and stability in tested environments. The mean yield performance and stability of varieties were evaluated using an average tester axis (ATA) that passes through the origin (Yan and Rajcan,2002). Based on Figure 3, five varieties were shorter than the average grain yield across the tested environments as they are located on the left side and above of ATA. The other 2 varieties were taller than the average across the 4 environments as they are located on the right side and below of average tester axis.

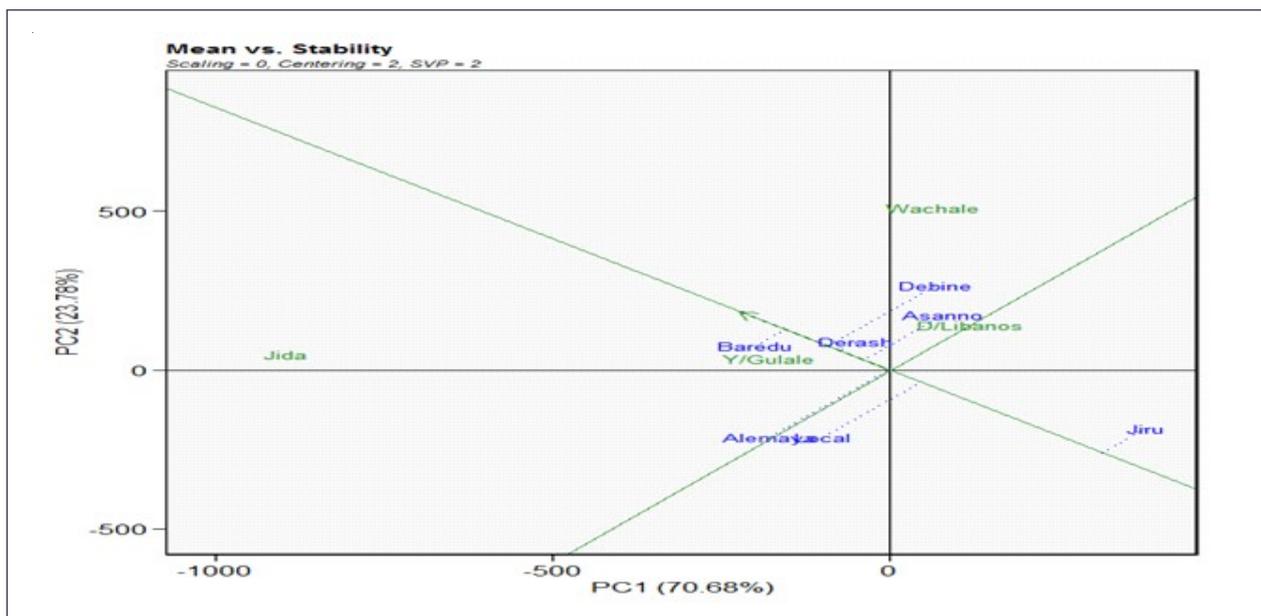


Figure 2: Stability Analysis for Grain Yield of Lentil Varieties

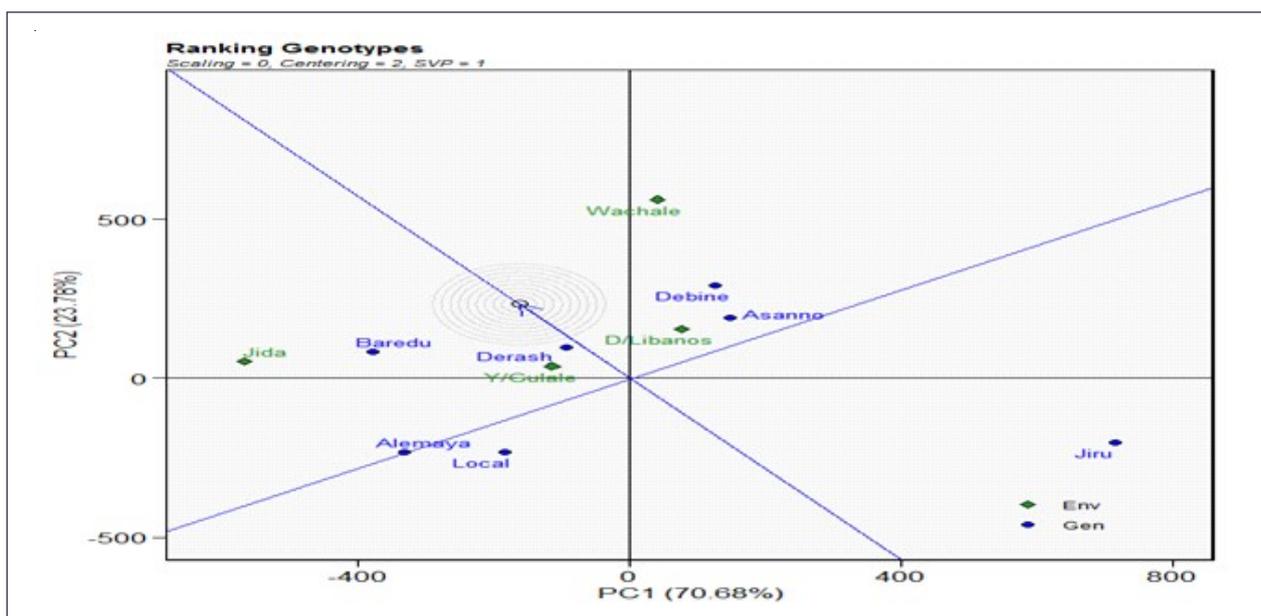


Figure 3: Performance Ranking of Lentil Varieties

5. Conclusions and Recommendations

The analysis of result revealed that most yield components and yield parameters were significantly affected by the main effect of varieties and locations where as the interaction effect significantly affected only days to maturity and grain yield. Estimate analysis of variance showed that the interaction effect of Variety \times Locations accounted for higher contribution of the total variation in grain yield. Varieties Baredu, Derash and Debine had a grain yield advantage of 15.93%, 8.11% and 8.06 % over the local check, respectively.

Mean versus stability measures for seed yield parameter stability analysis identified variety Baredu to be the most stable with highest mean seed yield followed by variety Debine. Generally, in the present study, variety Baredu followed by Debine was the most adapted and stable varieties for the present agro ecology of the highlands of North Shewa. Therefore, because of these attributes, varieties Baredu and Debine were recommended for production on the highlands of North Shewa.

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