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Performance Evaluation of Food Barley (*Hordeum vulgare L.*) Varieties for Grain Yield and Other Agronomic Traits in Buno Bedele, South West Oromia, Ethiopia

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Abstract: Barley is a major cereal crop in Ethiopia accounting for about 20% of the total cereal production. It is grown in a wide range of agro-climatic regions under several production systems. Barley grows best on well drained soils and can tolerate higher levels of soil salinity than most other crops. Although many improved food barley varieties have been released nationally and regionally, these varieties have not been tested in Buno Bedele and subsequently are not well popularized as well. In this Zone, farmers are growing local varieties which are low yielder and susceptible to diseases and other stresses. Hence recently released food barley varieties were tested for their phenotypic performance to confirm their environmental adaptation using Randomized Complete Block Design in three replications for two consecutive years (2020 to 2021) in Gechi and Chora districts. Quantitative traits such as plant height, spike length, Biomass, and grain yield were collected and analyzed using RStudio and Genstat 18th edition software's. Qualitative trait such as days to maturity and days to heading were also collected. The combined analysis of variance indicated that the eight tested varieties showed significant variations for all traits. The highest combined mean grain yield was recorded from variety "Adoshe" (5184 kg ha^{-1}) followed by "HB 1966" (4758 kg ha^{-1}).

Keywords: Food Barley, Evaluation, RCBD, Variety

1. Introduction

Barley (*Hordeum vulgare* L.) is one of the world's most ancient food crops and it is an important cereal crop since the early stages of agricultural innovations 8,000-10,000 years ago [6]. It is an economically important crop, ranking fourth after wheat, rice and maize in the world, both in terms of quantity produced and in area of cultivation [4]. Barley is a cool season crop and early maturing cereal with relatively high-yield potential including in marginal areas where other cereal crops are not adapted [7, 13].

Barley is one of the most important traditional crops and landraces form the major genetic resources of cultivated barley in Ethiopia [2]. In Ethiopia, it is produced mainly for human consumption as one of the most important staple food crops. Its grain is used for preparing a diversity of recipes, and is deeply rooted in the culture and tradition of people's diets. The recipes are prepared in different forms of indigenous food and homemade beverages [19].

The main cropping season for barley cultivation is in meher (main rainy) season, which extends from June-September, while the minor cropping season is during the Belg season [2]. According to the research [3], the crop is grown in environments so diverse in terms of altitude, rainfall, soil and farming systems. Nationally, more than 85% of the total production comes from the major barley growing areas, which include Arsi, Bale, Shewa, Wello, Gojam, Bale, Gondar and Tigray.

In crop breeding, varieties need to be improved to obtain high and quality produce. However, the narrow genetic basis and genetic erosion of the crop are the major barriers against further improvement of yield and quality. The key steps to overcome this problem include the exploration, preservation, and utilization of diversity within germplasm resources [10].

Ethiopian barley breeding program was started in 1955 at Debrezeit Research Station and breeding was focused at selecting and evaluating landraces together with introduced materials. From this, success has been achieved in developing improved barely varieties from local landraces selection.

Although barley is considered as a highland crop, it is also among the major cereal crops grown in the low rainfall areas of the country, which are part of the early production system. In such areas, the availability and distribution of rainfall during the crop growing seasons is the major factor limiting yield. Farmers in drought-prone areas grow their own landraces that are well adapted to the environments, but with poor yielding ability. Hence, it is essential that barley productivity in moisture stress areas need to be improved to increase the contribution of this system to the overall barley grain production. Moreover, earliness in heading and maturity were also crucial for the adaptation of barley to such conditions [16].

There is shortage of improved barley varieties adapted to low-moisture stress areas of Ethiopia. Hence farmers are forced to grow low yielding cultivars. Little information is available on estimate of genetic variability and genetic relationships using morphological and agronomic traits in some parts of moisture stress areas of Ethiopia in barley genotypes. Genetic improvement of crop is largely dependent on the magnitude of genetic variability and the extent to which desirable traits are heritable [9]. The existence of genetic diversity and the association among various yield and yield related traits and their heritability is important in identifying potential genotypes for future crop improvement [15].

Besides the landraces, introduced barley genotypes from CGIAR such as ICARDA (International Center for Agriculture Research in the Dry Areas) are promising source of materials to develop variety for moisture stress areas of Ethiopia. Through this introduction and evaluation of barely genotypes from ICARDA, a number of barely varieties have been developed and released in Ethiopia. Apart from simple screening of these introduced barely germplasm, detail study of their variability, genetic advance, character association and path analysis are important to enhance gain in barely breeding program. Hence, the present study was designed with the following objective:

To evaluate and select better adapted food barley varieties for yield and yield components and their stability across environments of the study areas and other similar agro-ecologies.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted in Chora and Gechi districts of Buno Bedele Zone on different farmers' field during 2020-2021 main cropping seasons.

2.2. Chora District

Chora is one of the districts in Buno Bedele Zone, Oromia Regional State Southwest part of Ethiopia. The district is bordered on the south by Setema, on the west by Yayo and Dorani, on the north by Dega, and on the east by Bedele districts. Chora district is located 513 km away from the capital city of the country and 36 km away from Bedele Town of Buno Bedele Zone. It is located at an average elevation of 1013-2200 masl and at $08^{0}13'33.7''$ to $08^{0}33'55.0''$ N latitude and $035^{0}59'59.7''$ to $036^{0}15'15.8''$ E longtude. It is generally characterized by warm climate with a mean annual maximum temperature of 25.5°C and a mean annual minimum temperature of 12.5°C. The driest season lasts between December and January, while the coldest month is December. The annual rainfall ranges from 1500-2200 mm. The soil of the area is characterized as Nitisol, Acrisol, Lithosol and Cambisol. The economy of the area is based on mixed cropping system and livestock rearing agricultural production system in which dominant crops are maize, tef, sorghum and wheat as well as also horticultural crops.

2.3. Gechi District

Gechi is one of the districts in Buno Bedele Zone, Oromia Regional State Southwest part of Ethiopia. The district is bordered on the south by Didessa, on the west by Didessa River, on the north by Bedele, and on the east by Jimma Zone. Gechi district is located 465 km away from the capital city of the country and 18 km away from Bedele Town of Buno Bedele Zone. The district is located at an average elevation of 1277-2467m.a.s.l and at 8°16'60''N latitude and 36°34'00''E longitude. The annual rainfall ranges from 1500-2100 mm. The economy of the area is based on coffee production system in which dominant crops are maize, tef, sorghum and wheat as well as horticultural crops.

Table 1. *Description of food barley varieties used in the experiment.*

Variety Names	Altituderanges (m.a.s.l)	Year of Release	Maintainer
Abdane	2200-2600	2011	SARC/OARI
Adoshe	2400-2600	2018	SARC/OARI
Biftu	2200-2600	2005	SARC/OARI
Guta	2000-2600	2007	SARC/OARI
HB 1965	2000-2800	2017	HARC/EIAR
HB 1966	>2400	2017	HARC/EIAR
EH 1493	2000-2600	2012	HARC/EIAR
HB 1307	2000-2800	2006	HARC/EIAR

KARC=Kulumsa Agricultural Research Center, SARC= Sinana Agricultural Research Center, BARC= Bako Agricultural Research Center, OARI= Oromia Agricultural Research Institute, EIAR= Ethiopian Institute of Agricultural Research, NA= non-available.

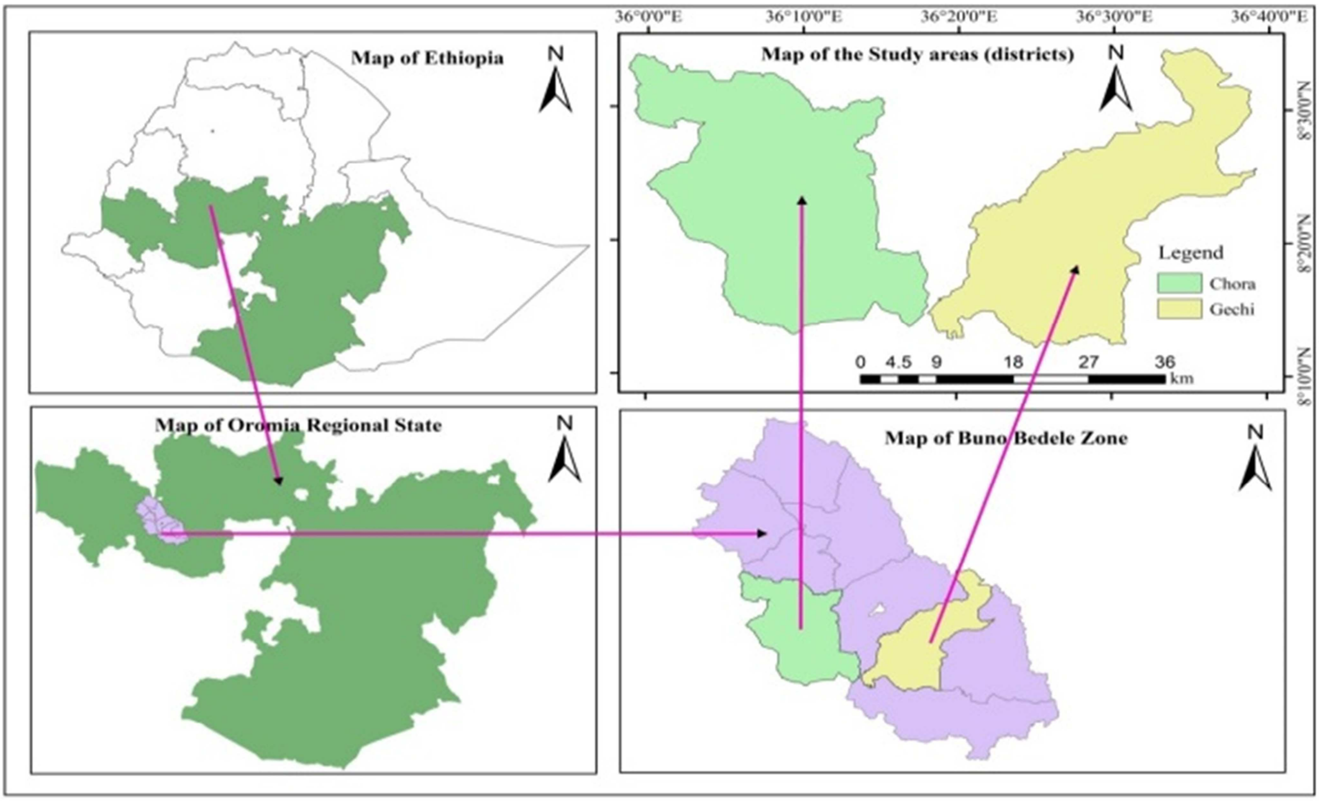

Figure 1. *Map of the study areas (Chora and Gechi) districts.*

2.4. Experimental Materials and Design

Eight food barley varieties (Table 1) were brought from Sinana, Kulumsa and Holetta Agricultural Research Centers and evaluated as experimental materials. 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 $3m^2$ (2.5m x 1.2m) having six rows with a row-to-row spacing of 20cm. Planting was done by drilling seeds in rows at a seed rate of 125kg ha^{-1}. NPS fertilizer was applied at the rate of 100kg ha^{-1} (30g per plot) at the time of planting; and Urea was also applied at vegetative stage at the rate of 150 kg ha^{-1}.

2.5. Data Collected

Data were recorded on plot and single plant basis and taken from the central rows of the plot. Individual plant-based data were taken from five plants in each plot, taken randomly from the central rows of each plot.

2.6. Data Collected on Plot Basis

Days to heading (DH): The number of days from 50% of the plots showing emergence of seedlings up to the emergence of the tips of the panicles from the flag leaf sheath in 50% of the plot stands.

Days to Maturity (DM): The number of days from 75% of the plots showing drying of spike from emergence of seedlings up to the date of drying spikes.

Total biomass yield (g/plot): The weight of all the central row plants including tillers harvested at the level of the ground.

Grain yield (g/plot): The weight of grain for all the central row plants including tillers harvested at the level of the ground.

Harvest index (%): The value computed as the ratio of grain yield to the total (grain plus straw) biomass multiplied by 100.

2.7. Data Collected on Plant Basis

Plant Height (cm): Measured as the distance from the base of the stem of the main tiller to the tip of the panicle at maturity.

Spike Length (cm): The length from the node where the first spike branch starts up to the tip of the main spike at maturity.

2.8. Data Analyses

Genstat 18^{th} edition software was used to analyze all the collected data from individual farmers and the combined data over locations. Mean separations was carried out using least significant difference (LSD) at 5% probability level.

3. Results and Discussions

The combined analysis of variance (ANOVA) over locations and years for grain yield character of eight food barley varieties is presented in Table 2. The analysis of variance (ANOVA) indicated the presence of highly significant differences (P≤0.001) among the food barley varieties for years, treatments, year*locations, year*treatments, locations*treatments and year*locations*treatments interactions. This indicates the presence of effects of years across locations on the response of varieties. Therefore, it was found to be important to conduct stability analysis for year*locations*treatments interaction effects to see which environment is ideal for the tested food barley varieties and which varieties could be stable across years and locations (Table 2).

Table 2. *Combined mean ANOVA of eight food barley varieties for grain yield (kg ha^{-1}) in 2020-2021 cropping season.*

	Degree of freedom	Sum of squares	Mean of squares	F value	Pr (>F)
Year	1	8615.3	8615.3	54.62	1.495e-11**
Locations	1	48.9	48.9	0.31	0.58
Treatments	7	5929.7	847.1	5.37	1.969e-05**
Replications (Env't)	8	483.8	60.48	1.53	0.22
Year*Locations	1	2534.7	2534.7	16.07	0.0001016**
Year*Treatments	7	3170.4	452.9	2.87	0.0080090**
Locations*Treatments	7	2377.0	339.6	2.15	0.0424214*
Locations*Replications	4	55.9	27.9	0.18	0.84
Year*Locations*Treatments	7	1143.1	163.3	1.04	0.0096446**
Residuals	56	20820.5	157.7		

Combined Mean for Grain Yield and Yield Related Traits

Mean value of days to heading varied from 68.95 (HB 1965) to 50.29 (Guta) with over all mean of 59.10. The mean value of days to maturity ranged from 108.8 for EH 1493 to 96.5 for Abdane with over all mean of 102.14 (Table 3). This result is supported by the findings of the researches [6, 17, 18] who reported significant variations among varieties for days to heading and days to maturity. The study also found significantly shorter (Adoshe and HB 1965) and taller (Biftu and HB 1966) mean value of plant height which agreed with a research [1] who reported significantly higher mean of plant height, grain yield for Biftu. The lowest mean value of 7.23 (Biftu) and the highest mean value of 7.98 (EH 1493) was recorded for spike length with over all mean value of 7.57 cm. The higher mean value of biomass yield was recorded EH 1493 (21556 kg/ha) and the lowest was recorded for Adoshe (7556 kg/ha). On the other hands, the mean value of grain yield varied from 34.61qt/ha (Guta) to 51.84 qt/ha (Adoshe) with the mean value of 42.37qt/ha. Adoshe (51.84 qt/ha), HB 1966 (47.58), EH 1493 (44.22 qt/ha) and HB 1307 (46.78 qt/ha) showed significantly higher than mean of overall grain yield (Table 4). Abdane (42.03 qt/ha), Biftu (35.68 qt/ha), Guta (34.64 qt/ha), HB 1965 (36.42 qt/ha) had significantly lower mean value of grain yield than overall mean values (Table 4). However, the researches [6, 8] reported the highest mean value of grain yield for HB-1307 than overall mean values. Therefore, from the result of this study, varieties Adoshe, and HB 1966 were identified for better mean performance of grain yield and diseases resistance.

Table 3. *Combined mean yield related traits of Food Barley varieties over two years at Gechi and Chora districts.*

Varieties	DH (days)	DM (days)	PH (cm)	SL (cm)	BMY (kg/ha)	HI (%)	BLSc
Abdane	55.24^{de}	96.5^{c}	87.33^{ab}	7.91^{ab}	12889^{bc}	51.97	5r
Adoshe	56.19^{cde}	100.6^{bc}	74.25^{c}	7.58^{ab}	7556^{c}	53.51	5r
Biftu	52.10^{e}	100.3^{bc}	91.60^{a}	7.23^{b}	12778^{bc}	44.25	10mr
Guta	50.29^{e}	98.0^{bc}	89.08^{a}	7.38^{ab}	6889^{c}	41.84	10mr
HB 1965	68.95^{a}	101.4^{bc}	81.79^{b}	7.79^{ab}	11333^{bc}	48.80	15mr
HB 1966	61.52^{bcd}	103.9^{ab}	89.89^{a}	7.32^{ab}	17333^{ab}	50.12	5r
EH 1493	65.90^{ab}	108.8^{a}	87.40^{ab}	7.98^{a}	21556^{a}	35.54	5r
HB 1307	62.62^{abc}	107.6^{a}	86.37^{ab}	7.39^{ab}	18000^{ab}	44.25	10mr
GM	59.10	102.14	85.96	7.57	13542	46.06	
LSD (0.05)	6.89	6.07	5.77	0.71	7248	25.75	
CV%	19.1	9.7	11.0	15.5	30.6	31.9	
P-value	**	*	*	*	*	NS	

DH= days to heading, DM= days to maturity, PH= plant height, SL= spike length, BLSc= barley leaf scald, GM= grand mean, LSD=least significant difference, CV= coefficient of variation, *= significant, **= highly significant.

Table 4. *Combined mean grain yield (qt/ha) of Food Barley varieties tested at Chora and Gechi districts for two years (2020/21-2021/22).*

Varieties	Chora District			Gechi District			
	1st Year	2nd Year	Combined	1st Year	2nd Year	Combined	Over all
Abdane	43.52^{ab}	44.00^{bc}	43.68^{b}	30.00^{bc}	51.57^{bcd}	40.79^{abc}	42.03^{bcd}
Adoshe	58.89^{a}	57.44^{a}	58.41^{a}	42.22^{a}	51.61^{bcd}	46.92^{abc}	51.84^{a}
Biftu	34.81^{b}	37.44^{c}	35.69^{bc}	26.67^{c}	44.67^{cd}	35.67^{c}	35.68^{cd}
Guta	33.89^{b}	41.22^{bc}	36.33^{bc}	33.33^{bc}	33.31^{d}	33.32^{c}	34.61^{d}
HB 1965	29.63^{b}	36.55^{c}	31.94^{c}	29.44^{bc}	49.48^{bcd}	39.46^{bc}	36.24^{cd}

Varieties	Chora District			Gechi District			
	1st Year	2nd Year	Combined	1st Year	2nd Year	Combined	Over all
HB 1966	34.63^{b}	47.67^{b}	38.98^{bc}	34.44^{abc}	73.61^{a}	54.03^{a}	47.58^{ab}
EH 1493	33.33^{b}	40.44^{bc}	35.70^{bc}	37.22^{ab}	63.98^{abc}	50.60^{ab}	44.22^{abc}
HB 1307	42.22^{b}	42.44^{bc}	42.30^{bc}	34.44^{abc}	65.83^{ab}	50.14^{ab}	46.78^{ab}
38.87	43.40	40.38	33.5	54.26	43.87	42.37	
15.80	8.91	10.69	8.61	20.24	14.39	9.55	
CV%	32.8	11.70	28.10	22.00	28.90	30.32	30.00
P-value	*	*	*	*	**	*	**

GM= grand mean, LSD=least significant difference, CV= coefficient of variation, *= significant, **= highly significant

Table 5. *Analysis of variance table from AMMI model showing the effect of variety, environments and their interaction on grain yield performance of food barley varieties and interaction principal components in 2020-2021 cropping season.*

Source	D. F	S. S.	M. S.	% Explained	F. cal	F prob.
Total	191	46528	243.6			
Genotypes	7	6587	941.0		6.77	<0.001**
Locations	3	11221	3740.4		48.39	<0.001**
Block	8	618	77.3		0.56	0.8124
Interactions	21	6971	331.9	14.98	2.39	0.0013**
IPCA 1	9	5973	663.6	85.68	4.77	<0.001**
IPCA 2	7	813	116.1	11.66	0.84	0.5598
Residuals	5	185	37.0		0.27	0.9308
Error	152	21130	139.0			

The principal component (PC1) explained 85.68% of the total variation; while the principal component (PC2) explained 11.66%. Finally, these two principal components summed up to 97.34% and accounted for the total variation in grain yield. The AMMI analysis of variance for grain yield of variety tested in four environments showed that the interaction effect of Varieties and Environments accounted for 14.98% (Table 5). The analysis revealed that variance due to genotypes, environment and their interactions was highly significant. Large difference among environments caused much of the variation in grain yield, which is in line with the findings of the researches [11, 12, 14] in finger millet production.

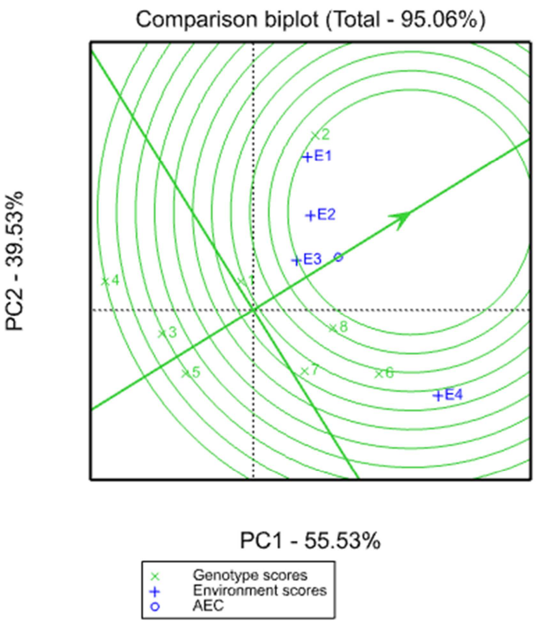

Figure 2. *GGE Biplot for which won where pattern of variety by environment in grain yield of food barley varieties Chora and Gechi.*

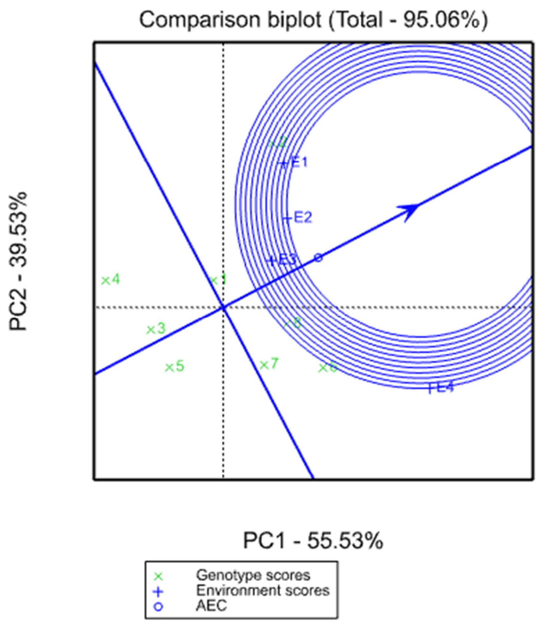

Figure 3. *GGE Biplot of the relationship among three environments in grain yield of food barley in Chora and Gechi, E1 and E2 represent Chora which was best locations and it is an ideal location for the varieties (Figure 3).*

Table 6. *Genotypes mean and their Interaction principal components axis of genotypes/varieties.*

Genotype	Ng	Gm	IPCAg [1]	IPCAg [2]
G1	1	42.27	0.73622	1.43028
G2	2	52.54	2.87319	1.22549
G3	3	35.90	0.68286	0.31296
G4	4	35.44	2.61930	-2.11705
G5	5	36.28	-0.44472	-0.92542
G6	6	47.59	-3.03875	0.06745
G7	7	43.75	-1.95805	-1.14773
G8	8	46.24	-1.47006	1.15402

Ng= Number of genotypes, Gm= Genotype mean, IPCAg (1&2) = Interaction principal Components Axis of genotype 1&2.

Genotype 2 (G2) / Adoshe and genotype 8 (G8) HB 1307 were the winning genotypes in all locations. This pattern suggests that G2 and G8 can be selected for further demonstration and promotion of these varieties in food barley growing areas of Buno Bedele Zone and other similar agro-ecologies in the Western and South Western parts of Ethiopia (Figure 2).

4. Conclusion and Recommendation

The result of the experiment showed that food barley varieties showed better performance in their potential. Genotypes were highly affected by environments which show the selective adaptation to specific location favoring their production. The mean performance of genotype at Chora and were relatively good and this shows the potential area for this crop. Generally, Adoshe and HB 1966 were one of the best genotypes that showed variation on mean grain yield Therefore; these two varieties were recommended and can be used as improved varieties.

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