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Research Article

Performance and Stability of Food Barley (Hordeum Vulgare L.) Varieties in the Highlands of East Hararghe, Ethiopia

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Abstract

Food barley is a staple crop in the Ethiopian highlands, yet productivity remains low due to the use of low-yielding local varieties. This study evaluated the performance and adaptability of 11 food barley varieties (Abdane, Adoshe, Biftu, Guta, Robera, Cross#41/98, EH-1493, Harbu, HB-1965, HB-1966, and one local check) across six environments (Gurawa, Jarso, and Meta districts over 2019 and 2021 main cropping seasons). The experiment was conducted using a randomized complete block design with three replications. Combined analysis of variance revealed highly significant differences ($p < 0.01$) among varieties, environments, and their interactions for all traits. AMMI analysis indicated that environment explained 62.71% of total variation, genotype 5.74%, and genotype-by-environment interaction (GEI) 14.13%. The first two principal components of GEI accounted for 77.37% of the interaction variation. Varieties Abdane (4.81 t ha^{-1}) and Robera (4.41 t ha^{-1}) recorded the highest grain yields, outperforming the local check by 31.4% and 25.2%, respectively. GGE biplot analysis identified Abdane and Robera as the most stable and high-yielding varieties across environments, while Guta, Harbu, Cross#41/98, and the local check were unstable. Therefore, Abdane and Robera are recommended for further demonstration and production in East Hararghe highlands and similar agro-ecologies.

Keywords

Adaptability, AMMI, Food Barley, GGE Biplot, Grain Yield, Stability

1. Introduction

Barley (*Hordeum vulgare* L.) is a major cereal crop in Ethiopia, accounting for about 8% of total cereal production [1]. It has been cultivated for centuries and is considered to have originated alongside plow agriculture [2]. Barley is produced using various methods across diverse agroclimatic zones [3] and ranks as the fourth most important cereal crop globally, behind maize, wheat, and rice [4].

Ethiopia ranks 21st globally in barley production, with barley being the fifth most significant cereal crop in terms of area and production, following maize, sorghum, tef, and wheat [5]. In highland regions, barley is a staple cereal used to make *injera*, bread, soup, porridge, and both alcoholic and non-alcoholic beverages. Beyond grain value, barley straw is crucial for animal nutrition, especially during dry seasons when feed is scarce [6].

Barley is cultivated on approximately 0.93 million hectares

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in Ethiopia, with total production of 2.34 million tons. However, national average yield remains low at 2.52 t ha^{-1} [5]. In the Oromia region, barley covers about 440,702 hectares with a yield of 2.80 t ha^{-1} [5]. East Hararghe's food barley productivity is only 2.12 t ha^{-1}, below the regional average [7].

Nearly 90% of barley grown by subsistence farmers consists of landraces [8], cultivated with minimal external inputs. East Hararghe zones face chronic food insecurity, with maize and sorghum as main food crops. Barley is poorly planted in many highland and midland areas due to farmers' reliance on low-yielding, disease-susceptible local varieties. Evaluating improved food barley varieties across different agro-ecologies can enhance yield potential. This study aimed to assess adaptability and performance of food barley varieties and identify high-yielding, disease-resistant, and stable varieties for East Hararghe highlands.

2. Materials and Methods

2.1. Experimental Sites and Genotypes

The experiment was conducted over two main cropping seasons (2019 and 2021) at three districts: Gurawa, Jarso, and Meta, resulting in six environments (Gurawa-19, Gurawa-21, Jarso-19, Jarso-21, Meta-19, Meta-21). Eleven food barley varieties were evaluated, including ten improved varieties and one local check (Table 1). Varieties were obtained from Holetta Agricultural Research Center (HARC) and Sinana Agricultural Research Center (SARC).

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

S. No.	Variety Name	Year of Release	Maintainer
1	Abdane	2011	Sinana ARC/OARI
2	Adoshe	2018	Sinana ARC/OARI
3	Biftu	2005	Sinana ARC/OARI
4	Cross#41/98	2012	Holeta ARC/EIAR
5	EH-1493	2012	Holeta ARC/EIAR
6	Guta	2007	Sinana ARC/OARI
7	Harbu	2004	Sinana ARC/OARI
8	HB-1965	2017	Holeta ARC/EIAR
9	HB-1966	2017	Holeta ARC/EIAR
10	Robera	2016	Sinana ARC/OARI
11	Local check	-	Farmers

2.2. Experimental Design and Crop Management

A randomized complete block design (RCBD) with three replications was used at each location. Each plot measured 1 m × 2.5 m, with six rows spaced 20 cm apart. Seeds were manually drilled at 125 kg ha^{-1}. Fertilizer was applied at 100 kg ha^{-1} NPS (all at planting) and 100 kg ha^{-1} UREA (half at planting, half at tillering). Standard agronomic practices were followed.

2.3. Data Collection

Data were recorded for days to maturity (DTM), plant height (PH, cm), spike length (SL, cm), and grain yield (GY, t ha^{-1}).

2.4. Statistical Analysis

Data were analyzed using R software. Combined ANOVA was performed with environments as random effects and genotypes as fixed effects. Bartlett's test confirmed homogeneity of variance. Treatment means were separated using Duncan's Multiple Range Test (DMRT) at $p < 0.05$. AMMI and GGE biplot analyses were conducted to partition GEI. The GGE biplot was constructed according to Yan et al. [9].

3. Results and Discussion

3.1. Combined Analysis of Variance

Combined ANOVA revealed highly significant differences

($p < 0.01$) among varieties for days to maturity, plant height, spike length, and grain yield (Table 2), consistent with previous reports [10]. Environment significantly affected all traits, and genotype × environment interactions were also significant for all parameters.

Table 2. Combined ANOVA for yield and agronomic traits across six environments.

Source of Variation	Df	DTM	PLH	SPL	GYLD (Kg/ha)
Replication	2	7.84 ^{ns}	66.1^{ns}	0.5921^{ns}	3425858**
Genotypes	10	508.03***	553.4***	2.2637***	2931649***
Environment	5	2607.07***	7150.3***	21.2478***	64008222***
Genotypes X Environment	50	30.7***	193.5***	1.2953***	1442158***
Error	130	11.45	50	0.489	630969

** = $p < 0.01$; ns = non-significant. DTM = Days to maturity, PH = Plant height, SL = Spike length, GY = Grain yield.

3.2. Mean Performance of Varieties

Days to maturity ranged from 98.8 days (Harbu) to 115.9 days (Cross#41/98). Robera matured earliest (102.1 days), while Cross#41/98 and EH-1493 matured latest (Table 3). Plant height ranged from 85.4 cm (Adoshe) to 106.0 cm (Biftu). Spike length varied from 7.2 cm (Harbu, Robera) to 8.1 cm (Cross#41/98).

Table 3. Mean performance of food barley varieties across six environments.

Variety	DTM (days)	PLH (cm)	SPL (cm)	GYLD (Qt/ha)
Abdane	102.3 c	100.5 b	7.8 abc	4.81 a
Adoshe	106.7 b	85.4 e	7.6 bcd	3.98 bc
Biftu	103.3 c	106.0 a	7.3 cd	4.16 bc
Cross#41/98	115.9 a	102.1 ab	8.1 a	3.73 cd
EH1493	114 a	97.6 bc	8.0 ab	4.16 bc
Guta	102.4 c	99.7 b	7.6 bcd	3.62 cd
Harbu	98.8 d	100.1 b	7.2 d	3.78 cd
HB1965	102.3 c	92.0 d	8.0 ab	3.99 bc
HB1966	107.5 b	98.7 bc	7.3 cd	3.94 bc
Robera	102.1 c	93.9 cd	7.2 d	4.41 ab
Local	102.9 c	99.2 b	7.6 d	3.30 d
Mean	105.3	97.8	7.6	3.99
CV (%)	3.2	7.2	9.2	19.9
LSD (P< 5%)	2.2	4.7	0.5	0.52

Means followed by the same letter are not significantly different ($p < 0.05$).

The highest mean grain yield was recorded from Abdane (4.81 t ha^{-1}) and Robera (4.41 t ha^{-1}), while the local check yielded lowest (3.30 t ha^{-1}). Across locations, mean grain yield ranged from 2.13 t ha^{-1} (Gurawa-21) to 5.44 t ha^{-1} (Meta-21) (Table 4). Abdane performed best at Gurawa-19, Gurawa-21, and Meta-19, while Robera performed best at Jarso-21.

Table 4. Mean grain yield (t ha^{-1}) of varieties across six environments.

Variety	Jarso-19	Meta-19	Meta-21	Gurawa-19	Jarso-21	Gurawa-21	Mean
Abdane	5.89	53.97	5.81	5.00	3.10	3.64	4.81
Adoshe	5.77	30.00	5.11	4.36	3.62	2.02	3.98
Biftu	5.46	47.62	5.66	4.58	2.31	2.15	4.15
Cross#41/98	5.95	33.33	4.12	4.73	3.01	1.25	3.73
EH1493	5.68	39.37	6.17	4.45	2.73	1.99	4.16
Guta	4.80	43.97	5.33	4.11	1.56	1.54	3.62
Harbu	5.00	39.18	5.14	4.00	1.06	3.54	3.78
HB1965	6.53	30.48	6.20	4.29	2.72	1.14	3.99
HB1966	5.62	36.92	5.07	4.14	2.89	2.25	3.94
Robera	6.15	42.70	5.74	4.62	3.63	2.05	4.41
Local	2.74	43.02	5.44	3.66	1.76	1.89	3.30
E. Mean	5.42	40.05	5.44	4.36	2.58	2.13	3.99

3.3. AMMI Analysis for Grain Yield

AMMI analysis showed highly significant ($p < 0.01$) effects for environment, genotype, and GEI (Table 5). Environment captured the largest sum of squares (62.71%), followed by GEI (14.13%) and genotype (5.74%), indicating that environmental factors were the primary source of variation. This likely reflects rainfall distribution variability, soil type differences, and altitude range across locations [11].

Table 5. AMMI analysis of variance for grain yield across environments.

Source	d. f.	SS	MS	Explained%SS
Total	197	510.3	2.59	
Treatments	65	421.5	6.48**	82.58
Genotypes	10	29.3	2.93**	5.74
Environments	5	320.	64.01**	62.71
Block	12	22.6	1.88**	
Interactions	50	72.1	1.44**	14.13
IPCA 1	14	43.4	3.1**	60.18
IPCA 2	12	12.4	1.03*	17.19
IPCA3	10	9.5	0.95^{ns}	13.19
Pooled Error	120	66.3	0.552	

** = $p < 0.01$; * = $p < 0.05$; ns = non-significant.

The GEI was partitioned into IPCA1 (60.18%), IPCA2 (17.19%), and IPCA3 (13.19%), cumulatively explaining 90.56% of interaction. IPCA1 and IPCA2 were significant, justifying two-dimensional GGE biplot analysis [12, 13].

3.4. GGE Biplot Analysis

Which-won-where pattern: The GGE biplot (Figure 1) showed PCA1 and PCA2 accounting for 46.8% and 26.97% of GGE variation, respectively (73.77% total). Vertex genotypes (farthest from origin) were Abdane, Robera, HB-1965, Cross#41/98, and Local check—either best or poorest performers. Abdane was the best genotype at Gurawa-21, Meta-19, and Gurawa-19. Cross#41/98, Adoshe, and HB-1965 performed best at Jarso-19 and Jarso-21.

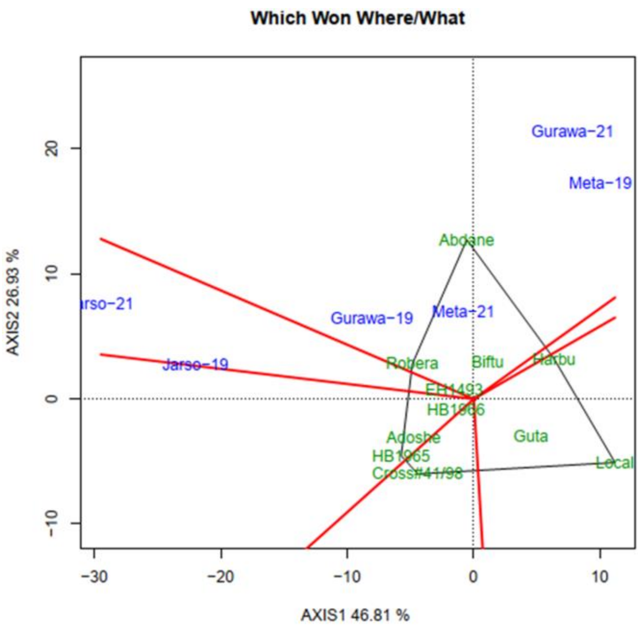

Figure 1. Polygon view of GGE biplot showing which-won-where pattern of genotypes and environments.

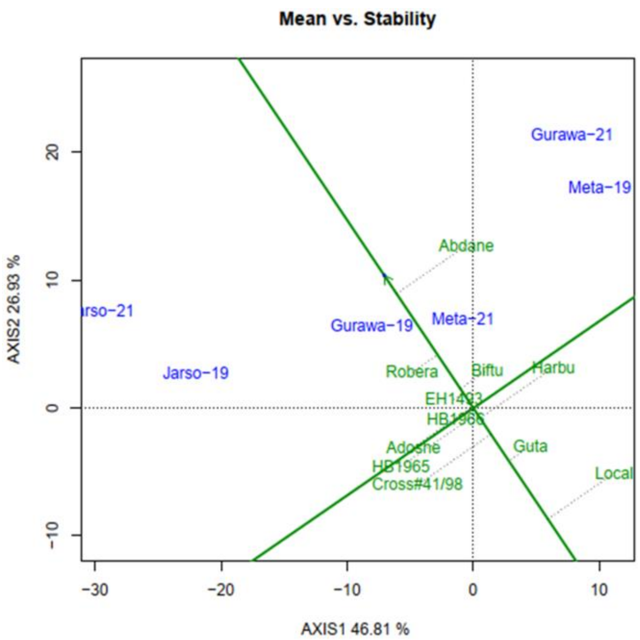

Figure 2. Average environment coordination (AEC) view of GGE biplot for mean performance and stability.

Stability and mean performance: Using average environment coordination (AEC) (Figure 2), genotypes with high PC1 scores have high mean yield, while those with low PC2 scores are stable [14]. Abdane, Robera, Biftu, and EH-1493 had above-average yields. Abdane showed the greatest stability (low PC2). The local check, Guta, Harbu, and Cross#41/98 were unstable.

Comparison with ideal genotype: An ideal genotype has high mean yield and high stability (close to concentric circle center). Abdane and Robera were closest to the ideal genotype (Figure 3), confirming their superior stability and yield.

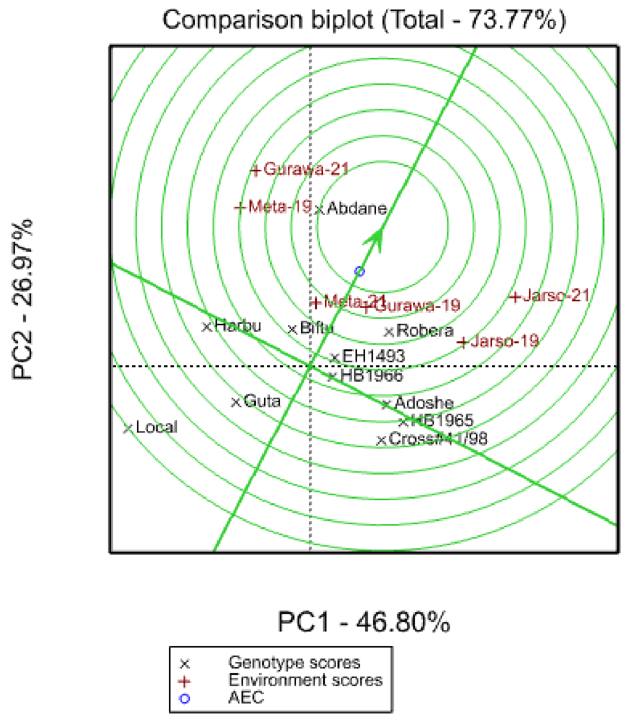

Figure 3. GGE biplot comparing genotypes with ideal genotype for grain yield.

4. Conclusion and Recommendation

Significant variation among food barley varieties, environments, and their interactions was observed. Environment explained the largest portion (62.71%) of total variation, highlighting the importance of multi-environment testing. AMMI and GGE biplot analyses consistently identified Abdane and Robera as the highest-yielding and most stable varieties across all six environments. These varieties out yielded the local check by 31.4% and 25.2%, respectively. Varieties Abdane and Robera are recommended for further demonstration and popularization in East Hararghe highlands and similar agro-ecologies. Meta-21 and Gurawa-19 were the most favorable testing environments and should be prioritized in future breeding programs. The local check, Cross#41/98, Guta, and Harbu were unstable and not recommended for wider adoption.

Abbreviations

AEC	Average Environment Coordination
AMMI	Additive Main Effects and Multiplicative Interaction
ANOVA	Analysis of Variance
ARC	Agricultural Research Center
CV	Coefficient of Variation
Df	Degrees of Freedom
DMRT	Duncan's Multiple Range Test
DTM	Days to Maturity
EIAR	Ethiopian Institute of Agricultural Research
GEI	Genotype-by-Environment Interaction
GGE	Genotype and Genotype-by-Environment
GY	Grain Yield
HARC	Holetta Agricultural Research Center
IPCA	Interaction Principal Component Axis
LSD	Least Significant Difference
MS	Mean Square
ns	Non-significant
OARI	Oromia Agricultural Research Institute
PC1	Principal Component 1
PC2	Principal Component 2
PCA	Principal Component Analysis
PH	Plant Height
RCBD	Randomized Complete Block Design
SARC	Sinana Agricultural Research Center
SL	Spike Length
SS	Sum of Squares

Author Contributions

Zeleke Legesse: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Writing – original draft, Writing – review & editing

Jifara Gudeta: Data curation, Investigation, Methodology, Supervision, Writing – review & editing

Fikadu Tadesse: Data curation, Investigation, Methodology, Supervision

Birhanu Diribsa: Data curation, Investigation, Methodology, Supervision, Writing – review & editing

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Wosene, G. A., Lakew, B., Haussmann, B. I. G., & Schmid, K. J. (2015). Ethiopian barley landraces show higher yield stability and comparable yield to improved varieties. *Journal of Plant Breeding and Crop Science*, 7(8), 275-291.

[2] Mulatu, B., & Grando, S. (Eds.). (2011). *Barley Research and Development in Ethiopia*. ICARDA.

[3] Megersa, G. (2014). Genetic erosion of barley in North Shewa Zone, Ethiopia. *International Journal of Biodiversity and Conservation*, 6(3), 280-289.

[4] FAO. (2017). Food and Agriculture Organization Statistical Yearbook. Rome.

[5] CSA. (2021). Agricultural Sample Survey Report on Area and Production of Major Crops. Addis Ababa, Ethiopia.

[6] Getachew, G., Tedila, A., Bediye, S., & Sebsibe, A. (1996). Improvement and utilization of barley straw. In *Barley Research in Ethiopia* (pp. 171-181). IAR/ICARDA.

[7] CSA. (2020). *Agricultural Sample Survey Report*. Addis Ababa, Ethiopia.

[8] Gebremedhin, W., Firew, M., & Tesfye, B. (2014). Stability analysis of food barley genotypes in Northern Ethiopia. *African Crop Science Journal*, 22(2), 145-153.

[9] Yan, W., Hunt, L. A., Sheng, Q., & Szlavnics, Z. (2000). Cultivar evaluation and mega-environment investigation based on the GGE biplot. *Crop Science*, 40, 597-605.

[10] Jimera, H., Hirpa, L., & Rao, C. P. (2015). Genetic variability in barley genotypes grown at Horo District, Western Ethiopia. *Science, Technology and Arts Research Journal*, 4(2), 1-9.

[11] Farshadfar, E., Safari, H., & Yaghotipoor, A. (2012). Chromosomal localization of QTLs controlling genotype × environment interaction in wheat. *Journal of Agricultural Science*, 4(12), 18.

[12] Yan, W., Kang, M. S., Ma, B., Woods, S., & Cornelius, P. L. (2007). GGE biplot vs. AMMI analysis of genotype-by-environment data. *Crop Science*, 47(2), 643-653.

[13] Purchase, J. L., Hatting, H., & van Deventer, C. S. (2000). Genotype by environment interaction of winter wheat in South Africa. *South African Journal of Plant and Soil*, 17, 101-107.

[14] Yan, W., & Tinker, N. A. (2006). Biplot analysis of multi-environment trial data. *Canadian Journal of Plant Science*, 86, 623-645.