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Original Research Article

Evaluation of Improved Malt Barley Varieties in North Shewa Zone, Oromia, Ethiopia

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Abstract: Malting barley is barley that will produce high quality malt. It is a specialty crop for which a premium price is paid by domestic maltters and exporters. Quality requirements for malting barley are reasonably strict and are directly related to processing efficiency and product quality in the malting and brewing industries. Many of the characteristics required are under the control of the producer. Others are determined by weather conditions during the growing and harvesting season. So this trial was conducted on eleven improved malt barley varieties at Fitche Agricultural Research Center for two consecutive years with the objective to identify adaptable, stable, high yielding and its malting potential. The experiment was layout in Randomized Complete Block Design with three replications. Nine agronomic traits data and four major malt quality parameters were evaluated. Analysis of variance detected significant difference among varieties for most observed traits both separated and combined analysis. Observation attained significant differences over years and locations for most traits. The combine ANOVA and the AMMI analysis for grain yield across environments revealed significantly affected by environments that hold 40.42% of the total variation. Genotype and genotype by environmental interaction were significant and accounted 38.11 % and 19.10 % respectively. Principal component 1 and 2 accounted 10. 9 % and 4.19 % of the GEI respectively with a total of 15.09 % variation, the interaction effect of variety by year and variety by location imposed significant effect on most traits. Among evaluated varieties; Singiten and EH1847 had significantly higher mean value of grain yield. Malt quality parameters were conducted in the laboratory of Food Technology and Process Engineering at Holleta Agricultural research center. The mean values of malt quality parameter had malt hot water extract, malt Friability, malt protein content and malt beta-glucan, 78.32%, 58.42%, 10.27% and 492.13mg/L respectively. The results obtained showed that most malt quality had differences among the varieties and some of the results found were within the acceptable limit of EBC (European Brewery Convention) standard even if a single variety may not fulfill all the quality requirements. Based on these findings, the Traveler and the HB1963 varieties fulfill some of the quality parameters that are specified in the EBC range.

Keywords: Adaptability, AMMI, Yield, malt quality barley.

1. INTRODUCTION

Barley (Hordeum vulgare L.) is grown as a commercial crop in some one hundred countries world-wide and is one of the most important cereal crops in the world. Barley is one of the most important small cereal crop which ranks fourth in total cereal production in the world after wheat, rice, and maize, each of which covers nearly 30% of the world's total cereal production (Fischbeck *et al.*, 2002). It is estimated that about 85% of the world's barley production is intended for feeding animals, while the rest is used for malt production.

The multipurpose composition of barley makes it suitable for feed, malt and food. Worldwide, barley is mainly utilized as feed (70%), with 20% use for malt, only 5% for food and 5% undefined uses (Alam *et al.*, 2007). Newman CW and Newman RK. (2006) confirmed that the most important uses of barley throughout the world is as malt for manufacturing beverages or malt enriched food products. According to Romagosa *et al.*, (1999) food is the largest uses of barley in Ethiopia (79%). Seed production and food consumption but also for production of starch either for food use or for the chemical industry (Kling and Hayes, 2004). It is the basic raw material for brewing. Its chemical composition, brewing, and technological indices are highly determinative for the beer quality and the economic efficiency of the brewing process.

Malting is a complex process that involves many enzymes. Malt production process is carrying out starting from raw barley cleaning and grading, steeping, germination and kilning. Barley is deficient in certain key enzymes (α-amylase) and malting increases these levels. During mashing, the malt enzymes are mixed with starch to produce maltose and other fermentable sugars. Malt also affords various nutrients for yeast growth, including amino acids, vitamins and minerals. The husk of barley malt provides the filter bed, fundamental for forming clear worst during lautering. Barley malt is preferred because, among the other reasons, it has high potential for extract development for yeast growth and fermentation. To increase brewing yield and efficiency, malts with high extract values, high enzymic activities and good modification are essential.

Barley can be classified according to the number of kernel rows in the head. Two forms have been cultivated; two-row, and six-row barley variety. In two-row barley only one spikelet at each node is fertile; in the six-row, all three are fertile. Each cultivar of barley, whether two-rowed or six-rowed, has unique malting and brewing characteristics. Two-row of the variety has lower protein content than six-row variety and thus more fermentable sugar gratified. Two form of it is commonly used for the malting development. Two-row barley produces malt with a large extract, lighter color, and less enzyme content than the 6- row type (Leistrumaite A, V.Paplauskiene, 2003). Barley quality criteria vary depending on its use. The most important grain quality parameters for different uses are; hot water extracts (HWE), Friability, protein content and beta-glucan.

Protein Content:

Barley protein accounts for 8- 13% (dry base) of malting quality barley (Royal Australian Chemical Institute, 2000). Generally, the less protein and higher starch contented, and finally, the malt have higher sugar content. Proteins are partly degraded in malting and mashing to amino acids and soluble peptides, which are needed as yeast nutrients and to produce good foam of beer. A high protein content of the barley may retard water up-take during steeping and result in high soluble protein content in wort, which may lead to a problem of haze formation in beer. Low protein content is also preferred for barley starch production to have high yields (Evers *et al.*, 1999).

Hot Water Extracts (HWE):

The quality of the extract is influenced by several factors like the environment (Weston *et al.*, 1993) which affects the varieties or the traits and composition and also affects the final level of the extract.

Like other crops, malt barley production and productivity and malting potential also affected by environmental factor, the interaction between malt barley and environment has its own effect on the increment and decrement of the production and productivity and level of malting potential. Interaction is the differential responses of different varieties across a range of environments (Kang MS., 2004). In breeding, varieties by environmental interaction (G x E), cause many difficulties, while the environmental factors determined the performance of the given varieties. The interaction reduces the genetic potential in plant breeding programs through minimizing the association between phenotypic and genotypic values (Firdissa *et al*., 2010). Accordingly, multi-environment yield trials (MET) are essential in assessing the interaction and identification superior varieties in the final selection stage (Kaya *et al*., 2006; Mitrovic *et al*., 2012). Phenotype is the result of genotype (G) and environment (E) components and interactions between them. G x E interactions complicate process of selecting genotypes with superior performance. Thus, multi-environment trails (METs) are widely used by plant breeders to evaluate the relative performance of genotypes for target environments (Delacy *et al*., 1996).

The AMMI model has also lead to more understanding in the complicated patterns of genotypic responses to the environment (Gauch HG, 2006). These models have been successfully related to biotic and abiotic factors. Yan *et al*., (2000), planned additional method known as GGE-biplot for graphical demonstrate of the interaction pattern of MET data with many advantages. GGE biplot is an effective method based on principal component analysis (PCA) which fully search MET data. It allows visual assessment of the associations among the test environments, the interactions. The first two principle components (PC1 and PC2) are used to produce a two dimensional graphical display of the interaction (GGE-biplot). If a large portion of the variation is explained by these components, a rank-two matrix, represented by a GGE- biplot, is an appropriate (Yan *et al*., 2003).

Therefore, *the objective of this study was to identify adaptable, stable, high yielding and malting potential of different malt barley varieties evaluated.*

2. MATERIALS AND METHODS

2.1 Description of the area

This experiment was conducted at three different rain fed locations for two consecutive years in North shewa zone of Fitche agricultural research center on Kuyu, Degem, Wachale, Derba-Libanos and Jida research sub site that represent the varying agro ecologies of malt barley potential areas of the zones during 2020-2022 main cropping season.

2.1.1 Experimental Material

Eleven malt barley varieties released from Regional and National Agricultural Research Center were evaluated (Table 1). The varieties were selected based on average performance and agro-ecological adaptation.

Table 1: Description of research materials

Varieties	Year of release	Maintainer (Seed sources)
Bahati	2011	KARC/EIAR
Beka	1976	HARC/EIAR
Bokoji	2010	KARC/EIAR
EH1847	2011	HARC/ EIAR
Fanaka	2015	Diageo/Meta Abo/HARC/EIAR
HB1963	2016	Holetta ARC/EIAR
HB1964	2016	Holetta ARC/EIAR
Ibon	2012	HARC/EIAR
Moata	2018	Sinana ARC / ORARI
Singitan	2016	Sinana ARC//OARI)
Traveler	2013	Heinken/ HARC/EIAR

Whereas, OARI= Oromia Agricultural Research Institute, EIAR= Ethiopia Agricultural Research Institute

2.1.2 Experimental Design and Management

Randomized completed block design (RCBD) with three replications were used in all locations. Each experimental plot had six rows of 3m length and 20 cm apart with a plot area of 1.2 m x 3m. Sowing carried out by hand drilling with the same seed rate for all locations. Fertilizer was applied at a rate of 100kg and 100kg ha^{-1} of NPS and UREA. All NPS and half of UREA were applied during planting, while the rest half splits were applied at 35-40 days after sowing .Seed rate of 85 kg ha^{-1} was used. The data considered for analysis was from the candidates of the net plot, thus the four central harvestable rows. The harvested varieties were sundried before being tested for moisture content where 12% was the preferred average moisture content using moisture tester. Grain yield data was then obtained by weighing the dried grain using a digital scale. The seed was well composited and packed with the rate of 200g from each varieties and sent to laboratory of Food Technology and Process Engineering at Holleta Agricultural research center for malt quality evaluation

3. Data Collection Method

Eight plants were selected randomly before heading from each rows (four harvestable rows, which means two samples per rows) and tagged with thread and all the necessary plant based data were collected from these sampled plants.

3.1 Plot Basis: Days to heading (DH), Days to maturity (DM), Grain Filling Period (GFP) Grain yield (Kgh^{-1})

3.2 Plant Basis: Plant height (PH), effective tiller per plant (ETP) Spike length (SL), Spiklete per sspike (Spkltspike) and Seeds per spike (SdSpike)

3.3 Quality parameters: hot water extracts (HWE), Friability, protein content and beta-glucan

4. STATISTICAL ANALYSIS

Analysis of variance is calculated using the model:

Yij = μ + Gi + Ej + GEij

Where Yij is the corresponding variable of the i^{-th} genotype in j^{-th} environment, μ is the total mean, Gi is the main effect of i^{-th} genotype, Ej is the main effect of j^{-th} environment, GEij is the effect of genotype x environment interaction.

$Y_{ij} = \mu + g_i + e_j + \sum_1^N \lambda k\, \Upsilon ik\, \delta jk + \varepsilon ij$

4.1 The AMMI model used was:

Where Yij is the grain yield of the i^{-th} genotype in the j^{-th}environment, μ is the grand mean, gi and ej are the genotype and environment deviation from the grand mean, respectively, ʎk is the eigenvalue of the principal component analysis (PCA) axis k, Υik and δjk are the genotype and environment principal component scores for axis k, N is the number of principal components retained in the model, and Ɛij is the residual term.

4.1.2 AMMI Stability Value (ASV):

ASV is the distance from the coordinate point to the origin in a two-dimensional plot of IPCA1 scores against IPCA2 scores in the AMMI model (Purchase, 1997). Because the IPCA1 score contributes more to the GxE interaction sum of squares, a weighted value is needed. This weighted value was calculated for each genotype and each environment according to the relative contribution of IPCA1 to IPCA2 to the interaction sum of squares as follows:

$$\mathbf{ASV}=\sqrt{[(\mathbf{SSIPCA1} \div \mathbf{SSIPCA2})\ (\mathbf{IPCA1score})]\mathbf{2}\ +(\mathbf{IPCA2score})\mathbf{2}}$$

Where, SS_{IPCA1}/SS_{IPCA2} is the weight given to the IPCA1-value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares. The larger the ASV value, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller ASV values indicate more stable genotypes across environments (Purchase, 1997).

4.1.3 Genotype Selection Index (GSI):

Stability is not the only parameter for selection as most stable genotypes would not necessarily give the best yield performance. Therefore, based on the rank of mean grain yield of genotypes (RYi) across environments and rank of AMMI stability value RASVi), genotype selection index (GSI) was calculated for each genotype as:

$GSIi = RASVi + RYi$

A genotype with the least GSI is considered as the most stable (Farshadfar E., 2008). Analysis of variance was carried out using statistical analysis system (SAS) version 9.2 software (SAS, 2008). Additive Main Effect and Multiplicative Interaction (AMMI) analysis and GGE bi-plot analysis were performed using Gen Stat 15th edition statistical package (VSN International, 2012).

5. RESULT AND DISCUSSION

5.1 Analysis of Variance

ANOVA detected significant difference of varieties (Table 2), whereas individual location analyses show significant difference among varieties for most of the traits. Over year analysis also explained significant differences for most of the traits. On the other hands, ANOVA exhibited presence of significant interaction effect of variety by year, variety by location for most of agronomic traits were observed (Table 2). Thus, analysis of variance also shows that the existence of significant effect of fluctuating weather condition on mean performance of most of the traits which in agreement with the study previous report of Bedasa (2014).

Table 2: Combined Analysis of variance (ANOVA) for grain yield and yield related traits

S.V	D.F	DH	DM	GFP	PH	SL	SdSpike	Spkltspike	ETP	Kgha
Yr	1	776.1**	303.2**	2049.3**	6.97ns	0.07ns	45.7ns	8054.2**	37.96**	997988**
Loc	5	279.5**	189.9**	341.9**	3018.3**	14.1**	296.98**	64.2*	2.5**	5189326**
Vrt	10	1164.2**	53.4**	1042.0**	472.4**	10.1**	556.4**	459.8**	0.6ns	2540277**
Yr*Vrt	10	28.9*	106.0**	52.6**	58.18ns	1.3ns	72.4**	134.7**	0.5ns	246586**
Loc*Vrt	50	61.4**	25.4**	82.04**	77.6*	1.5*	32.9*	30.6*	0.29ns	205309**

Where, DF= degree of freedom, DH= days to heading, DM= days to maturity, ETP= effective tiller per plant, GFP= grain filling period, PH= plant height, SL = spike length, YLDKgha = grain yield kg per hectare, Loc= location, Yr= year, Vrt= varieties, SdSpike= seed per spike, Spkltspike = spikelete per spike

5.1.2 Combined Mean Performance

The mean value of days to heading various from 67.1 for Bahati and 68.5 Ibon varieties to 89.2 for HB1963 with the overall mean value of 77.8, HB1963 had the longest days to heading, where Bahati and Ibon recorded short days to heading. The mean value of days to maturity ranged from 118.1 for Moata to 124.2 for HB1963 with over all mean value of 120.9. Therefore, HB1963 had significantly longer mean value of days to maturity even if statistically non significant with Ibon variety (Table 3). This result supported with Girma (2012), Wosene *et al.*, (2015) and Tashome (2017) who reported significant variation of varieties for days to heading and days to maturity. The study also indicated significantly in plant height. The mean value of plant height ranged from 49.7cm for Traveler to 67.3cm for HB1847 varieties with the overall mean value of 58.2cm which in line with Bedasa (2014) that reported significantly difference in plant height. In this study, statistically non significant differences between Beka and Traveler varieties in terms of plant height which is responsible for against lodging problem. In opposing to these, HB1847 and HB1964 varieties were recorded highest plant heights that have a possibility of susceptible to lodging problem.

The mean value of grain yield varied from 417.3kgha^{-1} for Traveler to 1532.5kgha^{-1} for HB1847 with the mean value of 980.1kgha^{-1}, where HB1847 (1532.5kgha^{-1}), Singiten (1405.9b kgha^{-1}), and Bahati (1361.8 kgha^{-1}) showed significantly high mean of grain yield over the rest varieties. Beka and Traveler variety attained significantly low mean value of grain yield (Table 3).

Table 3: Combined mean performance of grain yield and yield attributing traits

varieties	**DH**	**DM**	**GFP**	**ETP**	**PH**	**SL**	***Spkltspike***	***SdSpike***	**Kgha**
Bahati	67.1g	119ef	51.9a	2.5abc	59.3cd	6.4b	17.1b	20.3b	1361.8b
Beka	86.7b	120.7b-e	33.9f	2.2bcd	50.4e	6.3bcd	18.9b	22.2b	457.5h
Bokoji	85.3bc	122bc	36.7de	2.1cd	61.65bc	5.8d	17.7b	20.6b	771.9fg
EH1847	73.7f	120.5b-e	46.8b	2.4a-d	67.3a	6.6b	16.98b	20.9b	1532.5a
Fanaka	81.2d	119.3def	38.1d	2.4a-d	56.9d	5.8cd	16.97b	20.4b	755.3g
HB1963	89.2a	124.2a	35ef	2.3bcd	56.8d	6.1bcd	17.1b	20.6b	816.5f
HB1964	77.1	121.9bc	44.8bc	2.5ab	63.5ab	8.0a	17.9b	21.7b	1089.5d
Ibon	68.5g	122.4ab	53.9a	2.4a-d	58.5cd	6.2bcd	16.8b	20.2b	1217.1c
Moata	74.2f	118.1f	43.9c	2.1d	57.5d	4.9e	34.05a	39.2a	955.7e
Singiten	68.1	121.2bcd	53.2a	2.7a	58.7cd	6.2bcd	16.6b	19.9b	1405.9b
Traveler	84.4c	120.4cde	36def	2.3bcd	49.7e	6.4bc	18.9	21.8	417.3h
Mean	77.8	120.9	43.1	2.4	58.2	6.2	19	22.5	980.1
LSD 5%	2.1	2	2.5	0.4	4.1	0.6	2.6	2.7	52.2
CV %	4.2	2.5	8.9	22.8	10.7	13.6	20.7	18.4	8.1

Where CV = coefficient of variation, LSD = least significant difference, DH = days to heading, DM = days to maturity, GFP = grain filling period, ETP = effective tiller per plant, PH = plant height, SL = spike length, Spkltspike = spike lets per spike, SdSpike = seeds per spike YLDkgha^{-1} = yield kilogram per hectare

5.1.3 Mean separation for grain yield

5.1.3.1 Yield mean performance over year and location

Grain mean performance of the tested malt barely varieties over growing seasons and tested environments (Table 4) Due to environmental and growing seasons fluctuation, some varieties were vary across locations and season while some of them were consistently performed in a set of tested environments and season . For example, Bokoji and HB1963 varieties recorded the highest grain yield of 1629.2kgha^{-1} and 1509.3 kgha^{-1} respectively at Jida site, in 2022 growing season and recorded lower grain yield of 235.2kgha^{-1} and 135.8kgha^{-1} respectively at kuyu sub site in the same year. In 2020 growing season, EH1847 variety was recorded the highest grain yield at Degem and kuyu 2362.8 kgha^{-1}and 2313.8kgha^{-1} respectively and medium grain yield at Wachale (945.2kgha-1) in the same year. Grain yield and yield parameter performance fluctuation indicating high influence over year fluctuating weather condition even on the same trait of single variety Girma (2012). Singiten variety was almost constantly recorded grain yield performance over location and growing season and obtained over all mean grain yield of 1405.9kgha^{-1} this might be due to the genetic potential of the varieties (Mengistu *et al*., 2013). The difference in yield rank of varieties across the growing environments displays the prevalence of G×E interactions (Purchase *et al*., 2000; Yang *et al*., 2007). Therefore, these varieties (EH1847 and Singiten) were identified for better mean performance of grain yield and some yield contributing traits.

Table 4: Grain yield (kg/ha) Across Location and year

	Grain Yield Kg/ha-1						
	year						
	2020			2022			Mean
	Locations						
Varieties	Degem	Wachale	Kuyu	D.Tsige	Jida	Kuyu	
Bahati	2171.4a	1151a	1037.4b	1917.8b	937.4f	955.9c	1361.8
Beka	678.8f	212.5d	165.4ef	1029.03g	602.8g	56.4i	457.5
Bokoji	1305.3de	211.53d	232.8e	1017.6g	1629.2a	235.2fg	771.9
EH1847	2362.8a	945.2b	1323.8a	1730.7c	1319.9bc	1512.5a	1532.5
Fanaka	1532c	259.9d	553.1c	1348.8f	645.4g	192.8g	755.3
HB1963	1147.5e	250.1d	496.7cd	1359.6ef	1509.3a	135.8h	816.5
HB1964	1470.4cd	598.8c	1061.1b	1452.1def	1070.7e	883.9d	1017
Ibon	1447cd	694.7c	1024.7b	1561.5d	1369.5b	1205.1b	1217.1
Moata	1487.2cd	882.8b	388.1d	1481.3de	1221cd	274.0f	955.7
Singiten	1857.5b	1178.2a	1399.9a	2122.5a	1051.97ef	825.1e	1405.9
Traveler	317.1g	42.5e	113.2f	717.2h	1115.3de	198.6g	417.3
mean	1434.3	584.3	708.7	1430.7	1133.8	588.7	
LSD5%	214.8	99	111.5	130.5	128.2	56.3	
CV%	8.8	9.95	9.2	5.4	6.64	5.6	

Key kgha^{-1} = kilogram per hectare, YLA = yield advantage, LSD = least significant difference, CV = coefficient of variation

5.1.3.2 AMMI Analysis for Grain Yield

The AMMI analysis (Table 5) of grain yield indicated the interaction were highly significant (P≤0.01). Similar result was report by Ntawuruhunga *et al*., 2001. This indicates that one of the basic factors that affect GEI could either be genotypic or environmental in nature (Debelo *et al*., 2000; Anandan *et al*., 2009) also reported that 74.3% of the interaction sum of squares was explained by IPCA1.

Table 5: Additive main effects and multiplicative interaction analysis of variances (AMMI) for grain yield of malt barley varieties evaluated at six environments

Source of variation	D.F.	S.S.	SS%	M.S.	F PR
Total	197	66653570	100	338343	
Treatments	65	65078696	97.64	1001211	<0.001
Genotypes	10	25402773	38.11	2540277	<0.001
Environments	5	26944617	40.42	5388923	<0.001
Block	12	172501	0.26	14375	0.2705
Interactions	50	12731306	19.10	254626	<0.001
IPCA 1	14	7266254	10.90	519018	<0.001
IPCA 2	12	2793540	4.19	232795	<0.001
Residuals	24	2671511		111313	<0.001
Error	120	1402373		11686	

Key: SV = source of variation, DF = degree of freedom, SS = sum of squares, MS = mean squares, IPCA = Interaction Principal Component Axis, EX. SS% = Explained Sum of square ns *, ** non-significant, Significant at the 5% and 1% level of probability respectively

5.1.4 Genotype and genotype by environment interaction (GGE) biplot analysis

The average environment is defined by the average values of PC1 and 2 for the all environments and it is presented with a circle (Purchase, 1997). The average ordinate environment (AOE) is defined by the line which is perpendicular to the AEA (average environment axis) line and pass through the origin. This line divides the varieties in to those with higher yield than average and in to those lower yield than average. By projecting the varieties on AEA axis, the varieties are ranked by yield; where the yield increases in the direction of arrow. In this case, the highest yield had Singiten and HB1847 varieties, but the lowers grain yield were recorded by Beka and Traveler (Figure 1). Stability of the varieties depends on their distance from the AE abscissa. Varieties closer to or around the center of concentric circle indicated these varieties are more stable than others. Therefore, the greatest stability in the high yielding varieties were singiten and HB1847, whereas the most stable and yielder of all was HB1847 variety (Figure 1). An ideal variety is defined as one that is the highest yielding across test environments and it is completely stable in performance (that ranks the highest in all test environments; such as HB1847 and Singiten varieties (Farshadfar *et al*., 2012; Yan *et al*., 2003), Even though such an "ideal" varieties may not exist in reality, it could be used as a reference for variety evaluation (Mitrovic *et al*., 2012). A variety is more appropriate if it is located closer to "ideal" variety (Farshadfar *et al*., 2012; Kaya *et al*., 2006). So, the closer to the "ideal" variety in this study was HB1847 (Figure 1).

The ideal test environment should have large PC1 scores (more power to discriminate varieties in terms of the variety main effect) and small (absolute) PC2 scores (more representative of the overall environments). Such an ideal environment was represented by an arrow pointing to it (Figure 2). Actually, such an ideal environment may not exist, but it can be used as an indication for variety selection in the multi-environment trials (METs). An environment is more desirable if it is located closer to the ideal environment. Therefore, using the ideal environment as the center, concentric circles were drawn to help visualize the distance between each environment and the ideal environment (Yan *et al*., 2002). For that reason, Degem which fell into the center of concentric circles was an ideal test environment in terms of being the most representative of the overall environments and the most powerful to discriminate varieties (Figure 2).

5.1.5 Stability Analysis

5.1.5.1 AMMI Stability Value (ASV)

Considering AMMI stability value (ASV) that takes into account, the scores of the IPCA2, varieties with least ASV scores are the most stable, whereas those with high ASV score are unstable (Farshadfar E., 2008; Bantayehu M., 2009; Issa A. B., 2009). Accordingly, varieties HB1847 and Singiten were appeared to be among those showing low ASV and were stable. In opposite to these, Bokoji and HB1963 varieties indicate the highest ASV and were thus considered to be unstable. Stability by itself should, however, not be the only parameter for selection, as the most stable variety would not necessarily give the best yield performance (Mohammadi *et al*., 2007). Therefore, the study indicated that Ibon and Beka were recorded the lower ASV (Table 6), but recorded lower yield. Therefore, if Ibon and Beka will be selected based on ASV per se, there will be a risk of yield reduction. The stable varieties were followed with mean grain yield above the grand mean and this result was in agreement with Hintsa *et al*., (2013), who has used ASV as one method of evaluating grain yield stability of bread wheat varieties in Tigray and similar reports been made by Abay *et al*., (2009);

Sivapalan *et al*., (2000) in barley in Tigray and bread wheat using AMMI stability value. A variety with the least of genotype selection index (GSI) is considered as the most stable variety (Farshadfar E., 2008). Consequently, EH1847 and Singiten were more stable with the low of genotype selection index (GSI) and higher mean grain yield (Table 6).

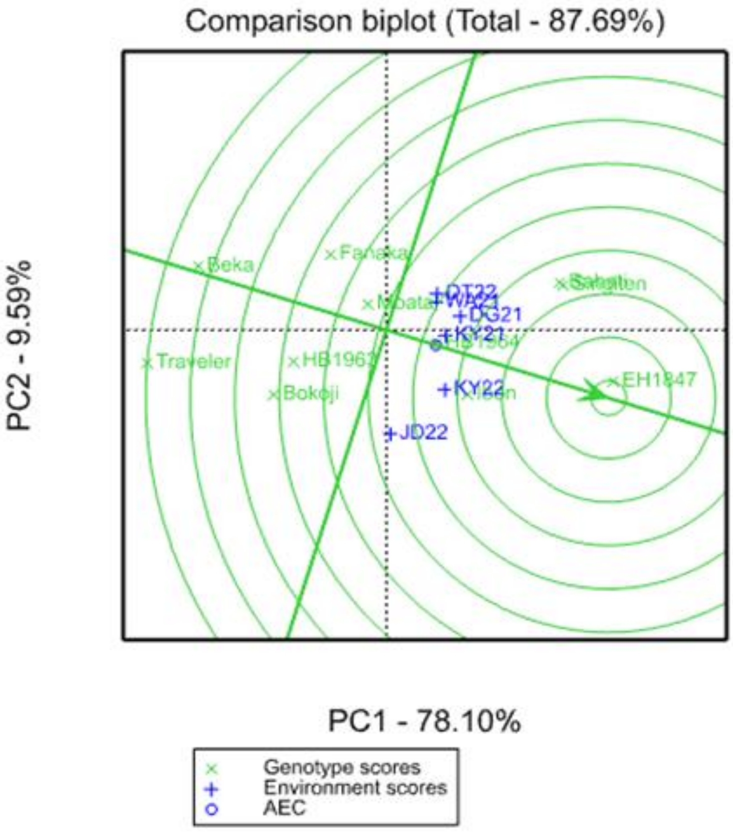

Fig 1: GGE bi-plot comparison of varieties for their yield potential and stability

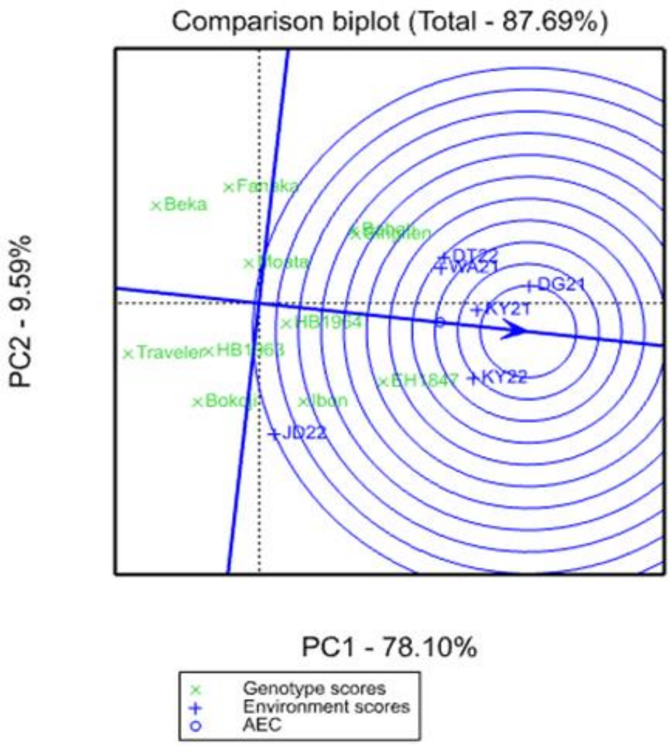

Fig 2: The scatter plots showing the which-won-where pattern of the GGE biplot

Table 6: AMMI stability value, AMMI rank, Yield, yield rank and genotype selection index (GSI)

Varieties	ASV	ASV rank	YLD	YLD rank	GSI	IPCAg1	IPCAg2
EH1847	32.1	6	1533	1	7	11.52	-12
Singiten	35.9	7	1406	2	9	13.62	5.249
Bahati	44.6	9	1362	3	12	16.98	5.518
Ibon	15.1	3	1217	4	7	-1.81	-14.8
HB1964	14.3	2	1090	5	7	4.104	-10.1
Moata	17	4	955.7	6	10	-2.62	15.11
HB1963	37.6	8	816.5	7	15	-14.1	7.532
Bokoji	46.2	10	771.9	8	18	-17.6	5.179
Fanaka	25.3	5	755.3	9	14	9.359	6.579
Beka	4	1	457.5	10	11	-1.44	0.986

5.1.6 Malt Quality Analysis

From the result (Table 7) of ANOVA analysis there is significant difference ($P < 0.05$) among the varieties. The malt protein content had ranged between 9.85% for Traveler to 10.93% for moata varieties. A reduction in protein content has been found in all varieties. This has happened because on malting; large molecules like proteins and carbohydrates will be broken down into simpler molecules that are utilized by the developing shoots (acrospires) and roots (Riis *et al*., 1989).

Hot Water Extracts (HWE) showed the existence of significant difference ($P<0.05$) among the varieties. The highest HWE was measured for Traveler (80.38%) and the lowest was for BH 1847 (74.85%) variety). Factors other than the disease like nature of the varieties and degree of the endosperm cells modification (particularly b-glucans and protein matrices that encapsulates starch granules) by the malt enzymes on malting and mashing might have interactively influenced the HWE (Bamforth CW, 2006; Asfaw *et al*., 2019).

Friability also showed that the existence of significant difference ($P<0.05$) among the varieties (Table 7). The malt Friability ranged from the lowest Ibon (42.92%) to the highest for Traveler (75.15%) varieties with the overall mean of 58.42%

Table 7: Malt Quality Parameters

Varieties	Hot water extract *(%)*	*Friability (%)*	*Malt Protein contents (%)*	*Beta-glucan (mg/L)*
Bahati	78.21f	54.86f	9.92i	634d
Beka	79.8c	68.5d	10.16g	190.2k
Bokoji	76.98j	52.47h	10.3f	476.8g
EH1847	74.85k	52.91g	10.4d	616.3e
Fanaka	78.16g	68.84c	9.86j	302.7h
HB1963	79.8d	71.71b	10h	300.6i
HB1964	80.3b	55.28e	10.39e	663.1b
Ibon	77.07i	42.92k	10.46c	761.2a
Moata	78.61e	49.86j	10.93a	530.9f
Singiten	77.36h	50.09i	10.75b	637.6c
Traveler	80.38a	75.15a	9.85k	300j
Mean	78.32	58.42	10.27	492.13

Table 8: Barley quality specifications for malting end users

Trait	Malting range
Protein content	9.0–12.0%db
Moisture content	12.5% max
Hot water extract:	> 80%
Fermentability	78.0–86.0%
Wort β-glucan	<400 mg/L
Friability	> 70%

Barley industry grain specifications (hulled grain) (MBIBTC 1995)

CONCLUSION AND RECOMMENDATION

Combined analysis of variance revealed significant effect of variety, location, year and their interactions for most of agronomic traits, indicating the significant influence of location and over year fluctuating weather condition on considered observation. The study found that HB1847 and Singiten had shown significantly higher mean values of grain yield.

So, this study clearly indicated that the different barely varieties for malting potential based on their malt quality parameters. Most malt qualities evaluated showed differences only among the varieties and the values found were within the acceptable limit and a single variety could not fulfill all the quality requirements. So based on quality specifications Traveler and HB1963 varieties gave good malting potential containing protein content Friability, hot water extract and *Beta-glucan*. Almost all verities approximately yield good percentage of extract, even though high yield of extract indicted these barely varieties are used for breweries but one or two quality parameters cannot determine the specified barley variety is used for beer production.

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