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Performance evaluation and stability analysis of malt barley (*Hordeum vulgare* L.) varieties for yield and quality traits in Eastern Amhara, Ethiopia

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Abstract

Background: Barley (*Hordeum vulgare* L.) is an annual cereal crop that belongs to the grass family Poaceae of the tribe Triticeae. It is the fifth most important cereal crop after teff, wheat, maize and sorghum in area coverage in Ethiopia. Important malting barley characteristics include kernel size, kernel protein content, extractable malt and diastatic power. Malt barely is an important crop in the study area; however, the productivity is low in the area varying from 15 kg ha^{-1} to 21 kg ha^{-1}. The aim of the study was to identify high yielding, standard quality and stable malting barley variety to the study areas and similar agro-ecologies. Field experiments were conducted using eight improved malt barely varieties during the main cropping seasons (from the first week of July to end of October) in 2016 and 2017 at two selected sites Dehana (Amede work) and Lalibela (Medagai)) in north east Ethiopia. Data on grain yield and yield related traits, and quality attributes were recorded. Days to 50% heading (DH), and days to 90% maturity (DM) were recorded on plots basis. Plant height (PH, in cm), spike length (SPL, in cm), and number of seeds per spike (SPS) were measured on five randomly selected plants per plot of the central four rows. Mean grain yield (GY; grams of grain produced per plot, converted in kg ha^{-1}), above ground dry biomass or biological yield (BY; dry weight of the above ground harvested biomass grams per plot, in kg ha^{-1}) and thousand grain weight (TGW; weight of 1000 kernels, in grams) were measured on whole plots. Data were analyzed using SAS software program and significance of the mean difference was tested in least significant difference Test (LSD).

Result: The analysis of variance for grain yield and quality traits showed that the main effects of both genotypes and environments, and their interaction effect, were highly significant ($P \leq 0.01$). The environment main effect accounted for 42%, 38% and 50% of the total grain yield, thousand kernel weight and kernel protein content variation, respectively. The average grain yield across varieties varied from 1652 kg ha^{-1} to 3377 kg ha^{-1}.

Conclusions: Three malting barley varieties (IBON174/03, EH1847 and Bahati) were found to be relatively high yielding, stable for grain yield and full fill the quality parameters. Therefore, these varieties are recommended for production. A further study is required on agronomic practices and brewing quality attributes in malt barley.

Keywords: AMMI analysis, Latent vectors, Kernel protein content, Stability parameters, Yield

Background

Barley (*Hordeum vulgare* L.) is an annual cereal crop that belongs to the grass family *Poaceae* of the tribe Triticale (Mather 1997). Barley ranks fourth in total production after wheat, rice and maize globally (Bedasa 2014). In

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Ethiopia, barley is an important cereal crop that is mainly grown by smallholder farmers (Zeleke 2017). It is grown in wide ranges of environments with altitudes varying from 1500 and 3500 m above sea level (Bekele et al. 2020) Barley is the fifth most important cereal crop after teff, wheat, maize and sorghum in area coverage in Ethiopia (CSA 2017).

Barley is mainly cultivated in Ethiopia for food purpose. It is prepared in different forms of indigenous food and homemade beverages. In recent years the demand for malting barley has increased in the country. This is because of development of new domestic breweries, which requires large quantities of malting barley. Malting barley has become a priority crop like that of food barley in the country. Barley production is concentrated in some parts of the country including Asela, Aresi, Debre berhane and North Gounder. This has limited barely production to meet local demands. As a result domestic breweries are importing malting barley from international markets. For example, the Asela and Gounder malt factory imported 20,000 metric tons of malting barley from abroad.

Producing high quality malting barley is crucial to the growth of the craft malting industry. Protein impacts barley's ability to modify and produce malt extract. Too much protein can also create haze in the resulting beer. Typically maltsters want barley between 9 and 12% proteins. Variety does affect protein, but the most influential element is nitrogen fertility management during growth.

The key attributes of malting barley include kernel size, kernel protein content, malt extract and diastatic power (Asres et al. 2018). These traits are inherited quantitatively and their performance depends on both genetic and environmental conditions (Mehari et al. 2014). Genotypes differ in these characteristics, and they are also influenced by environmental factors (Asres et al. 2018). Some genotypes may perform well in certain environments, but, fail in several others. The phenotypic performance of a genotype is not necessarily the same under diverse agro-ecological conditions. So far, malt barley varieties have not been evaluated in Wagimra zone and Lasta Districts for local production and market. Therefore, the objective of this trail was to identify high yielding standard industrial quality malting barley variety for production.

Material and method

Experimental site, plant material, and experimental design

The experiment was conducted during the main cropping seasons for 2 years (2016 and 2017) at Dehana and Lalibela sites. These sites represent the varying agro-ecologies of barley growing areas in Waghimra zone and Lasta Districes. Each site and year was treated as a single environment. Eight nationally and regional released malting barley varieties were included in the trail. A randomized complete block design with three replications was used at each site. Description of the testing sites and the malting barley varieties are presented in Tables 1 and 2. Each experimental plot had six rows spaced 20 cm apart. The gross and the net harvesting plot area respectively used were 3 m^2 and 2m^2. A seed rate of 125 kg ha^{-1} was used. The fertilizer rate used was 30 kg ha^{-1} urea and 100 kg ha^{-1}, NPS as per the national recommendation. Urea in split form half dose at sowing and the remains half dose of the urea at vegetative stage before heading was applied and NPS full does at sowing was applied. And other agronomic practice like weeding (two times hand weeding at seedling and vegetative stage) was done. Four middle rows were harvested, dried and threshed for 1000 kernel weight and grain yield data.

Procedure and instrument used for kernel protein and starch analysis

Samples which were collected from the two testing site namely Dehana and Lalibella from different plots. 500 g per sample was taken after manually cleaned the grain to remove broken grain and other inert matter. Then the samples were packed into low density polyethylene bag (plastic bag). Quality traits (kernel protein moisture and starch) percentage, were analyzed at Amhara Agricultural Research institute (ARARI) cereal quality laboratory using NIRS analysis instruments. NIRS spectroscopy is analysis instruments and rapid tests on small samples of ground grain or non-destructively on whole grain.

Data collection and statistical analysis

Data on plant and plot based were measured and recorded. plot based data like Days to 50% heading (DH), and days to 90% maturity (DM), thousand grain weight (gr), dry weight of above ground biomass(kg ha^{-1}),Grain yield (kg ha^{-1}) was recorded on plots basis. Plant based

Table 1 Description of the testing sites used for evaluation of malting barley varieties in 2016 and 2017

Variable	Testing site	
	Dehana	Lalibela
Longitude	12 40, 10″ N	12 03, 11.3″ N
Latitude	38 30, 41″ E	39 02, 96″ E
Altitude (meter above sea level)	2400	2176
Average annual rainfall (mm)	713	768.5
Average maximum temperature(℃)	23.5	24.7
Average minimum temperature (℃)	11.1	13.6

Source: Kombolcha weather sub- station on the year 2016 and 2017 E.c

Table 2 Description the eight malting barley varieties used in the study

Variety	Altitude(m.a.s.l)	Maintainer	Year of releasing	Days to heading	Days to Maturity	Yield at on station (q ha^{-1})	Protein % during releasing	Disease reaction
Traveler	2000–2600	HEINKEN/ HARC	2013	79–93	130–160	20–40	10–11.1	Resistance to net blotch
Holker	2500–3000	HARC	1979	–	–	–	–	–
IBON174/03	2300–2800	HARC	2012	70	120	–	10	Scald tolerant
Sabini	2300–2800	KARC	2011	46	64–83	25–40	8.5	Susceptible to scald
Fre-Gebs	2300–3000	AARC	2010	62–87	100–127	20–25	9–10.5	Moderately Resistance to net blotch
EH1847	2200–2800	HARC	2011	71–90	126–161	35	106–11–7	–
Bahati	2300–2800	KARC	2011	72–85	126–158	25–40	8.7	Resistance to net blotch
Bekoji-1	2300–2800	KARC	2010	89–111	121–163	24–28	11–7	Resistance to net blotch and scald

m.a.s.l, meter above sea level; IBON, international barely observation nursery; HARC, Holeta Agricultural Research center; AARC, Adet Agricultural Research center; KARC, Kulimssa Agricultural Research center

Source: Ministry of Agriculture, Animal and plant health regulatory directorate, crop variety registers from 1979 to 2013 Addis Ababa, Ethiopia

data like Plant height (PH, in cm), spike length (SPL, in cm), and number of seeds per spike (SPS) were measured on five randomly sampled plants from the central four rows of each plot and grain and quality data like protein, starch and moisture content were measured. But grain moisture content is only used for grain yield and protein percentage adjustment. Data on important barely insect pest and weed are not collected because only some insect pest and weeds was observed during the experimental time. Simply it was managed at field level by two times hand weeding and once fungicide chemical spray for controlling of the disease like leaf and stem rust before heading stage of the crop.

For quality data, like protein and starch content 500 g per sample was taken after manually cleaned the grain to remove broken grain and other inert matter. Then the samples were packed into low density polyethylene bag (plastic bag). Quality traits (protein and starch content) were analyzed at Amhara Agricultural Research institute (ARARI) cereal quality laboratory using NIRS analysis instruments. NIRS spectroscopy is analysis instruments and rapid tests on small samples of ground grain or non-destructively on whole grain laboratory.

Analysis of variance and LSD test were performed using SAS software program. Additive main effects and multiplicative interaction analysis of variance for grain yield and quality traits of malting barley varieties and stability analysis were computed using GENSTAT software 18th edition (Goedhart and Thissen 2016). Bartlett's test (Gomez and Gomez 1984) was used to assess homogeneity of error variances prior to combine analysis over environments to determine the effects of environment, genotype, and their interaction. The data of each trait was subjected to a combined analysis of variance to estimate effects of environment, genotype and genotype x environment interaction.

Mean separation was carried out using least significant difference (LSD) at 5 percent level of significance. Stability analysis was conducted to identify stable varieties for grain yield and quality traits. Various stability models were used such as Lin and Binns's cultivar performance measure (Linn and Binns 1988), Wricke's ecovalence analysis (Wricke 1962), and Shukla's stability variance (Shukla 1972) and additive main effect and multiplicative interaction stability value.

Genotype and genotype by environment interaction bi plot analysis (Yan 2002) was computed using GENSTAT software program 18th edition (Goedhart and Thissen, 2016). The principal component analysis was conducted for all studied traits to identify the principal components that could explain much of the total variation.

Result

Grain yield, quality and agronomic traits

Additive main effects and multiplicative interaction analysis for grain yield and quality traits of the eight malting barley varieties tested across four environments is presented in Table 3. The AMMI analysis of variance for grain yield and quality traits showed that the main effects of both genotypes and environments, and the interaction effect, were highly significant ($P \leq 0.01$). The environment main effect accounted for 42%, 38% and 50% of the total grain yield, thousand kernel weight and kernel protein content variation, respectively. A large sum of squares for environments indicated the environments are diverse, with large differences among environmental means causing most of the variation in grain yield, and quality protein content. Similarly, Friedrich et al. 2017 also reported that yield and quality traits are influenced by genotype, environment and their interaction effect and the need for stability analysis to identify stable variety across environments.

A combined analysis of variance for eight traits of the eight malting barley varieties tested across four environments is presented in Table 3 The mean sum of squares due to varieties and environments were highly significant ($P \leq 0.01$) for all studied traits indicating the presence of genetic variability among the tested varieties and environments. The variety x environments mean square component of the total variation also displayed a highly significant effect for all traits except plant height and biomass traits of malting barley varieties. This indicates that genotype, environment and their interaction are important in governing the expression of these traits.

Table 3 Combined analysis of variance from eight malting barley varieties for eight traits

Traits	Env (3)[†]	Var (7)	Env × Var (21)	Pooled error	R-square
DH	2.94**	99.52**	22.53**	6.76	0.85
DM	741 **	78.84**	21.89**	12.19	0.83
PH	3123**	1112**	135 ns	88.58	0.81
SL	6.96**	1.07**	0.46 ns	0.40	0.67
SS	10.05**	7.69**	138.58**	4.03	0.77
BM	101**	16*	3.48 ns	6.12	0.60
KMc	14**	0.02**	0.084**	0.001	0.99
KSc	32**	0.15**	3.51**	0.24	0.93

Numbers in parenthesis represent degrees of freedom, ns, *, **, Non Significant; significant at P ≤ 0.05 and significant at P ≤ 0.01 respectively, Env, Environments three(3); Var, Varieties which are seven(7); Env * Var, environment by variety; DH, Days to heading; DM, Days to maturity; PH, plant height (cm); SL, Spike length (cm); SS, Seed per spike (No); TKW, 1000 kernel weight (g); GY, Grain yield (kg/ha); BM, Above ground biomass (kg/ha); KPc, Kernel protein content (%); KSc, Kernel starch content (%); KMc, Kernel moisture content (%)

[†] means that the treatment is significance at 0.05 level of significance

Discussions

The average grain yield across varieties varied from lowest at 1652 kgha^{-1} in Env3 (Lalibela 2016) to the highest at 3377 kg ha^{-1} in Env 4 (Labella 2017) (Table 4). The mean grain yield of malting barley varieties across environments ranged from 1687 kg ha^{-1} for Holker to 3271 kg ha^{-1} for Bahati (Table 4). The mean grain yield over all the varieties and environments was 2748 kg ha^{-1}. Bahati, IBON174/03, and EH1847, were the first three best performing varieties with average grain yield greater than the grand mean. Varieties, Bahati (Dehana 2016, and Dehana 2017), IBON174/03 (Lalibela 2016) and EH1847 (Lalibela 2017), each ranked first in the indicated environments. The combined mean analysis over four environments showed that Bahati was the best with an average grain yield of 3254 kg ha^{-1} followed by IBON174/03, and EH1847. Maximum biomass (straw) was recorded on the variety Bekoji (1181 kg ha^{-1} and the minimum biomass was recorded on the variety Traveler (843 kg ha^{-1}). Most of the mean value of the traits shows a positive correlation with grain yield and quality traits at 5% level of significance. But there is a negative correlation among the quality traits (Table 8).

The mean thousand kernel weight of varieties across environments ranged from 38.63 g for Traveler and 45 g for Fre-Gebs (Table 5). Kernel protein content of environments averaged from all varieties was between 9.98% for Bekoji-1 and 11% for EH1847 (Table 6). The standards set for thousand kernel weight and kernel protein content

Table 4 Mean grain yield (Kg ha^{-1}) of malting barley varieties across four testing environments

No	Varieties	Env 1	Env 2	Env 3	Env 4	Mean
1	Traveler	2395	1758	1401	3775	2332
2	Holker	2423	1188	1134	2003	1687
3	IBON174/03	3642	3046	**2217**	**41**10	**3254**
4	Sabini	3172	1998	1908	3625	2676
5	Fre-Gebs	2753	3912	1402	3371	2860
6	EH1847	2978	3614	2088	**4216**	**3224**
7	Bahati	**4247**	**4302**	1367	3168	**3271**
8	Bekoji-1	3458	2834	1705	2737	2684
Mean		3135	2831	1652	3377	2748
C.V (%)		17	11	14	13	15
LSD (5%)		9.36	5.66	4.19	7.74	3.28

Env1, Dehana 2016; Env 2, Dehana 2017; Env 3, Lalibela 2016; and Env 4, Lalibela 2017, Bold values indicates the yield of the gnotype in average

Table 5 Mean values of agronomic and quality traits of malting barley varieties tested at four Environments

No	Varieties	DH	DM	PH	SL	SS	BM	TKW	KPC	KMC	KSC
1	Traveler	63	94	69.10	6.94	20.93	843	38.63	10.33	10.03	64
2	Holker	62	94	78.95	6.82	21.05	874	40.67	10.30	9.98	63
3	IBON174/03	57	90	75.38	6.67	21.93	890	41.92	10.30	9.88	64
4	Sabini	55	88	78.42	7.58	22.42	964	40.96	10.48	9.98	65
5	Fre-Gebs	58	88	92.47	6.86	21.20	1022	45.13	10.33	9.95	63
6	EH1847	59	91	88.97	7.14	22.45	1052	42.83	11.11	9.96	64
7	Bahati	59	93	83.78	7.30	23.05	1067	43.21	10.33	9.95	64
8	Bekoji-1	62	94	98.32	7.21	22.58	1181	43.42	9.85	9.98	65
Mean		59	91	83	7	22	10	42	10	9.96	64
C.V. (%)		4	3	11	9	9	25	6	0.5	0.1	0.76
LSD (5%)		2.12	2.85	7.69	0.52	1.64	2.02	2.04	0.04	0.01	0.39

DH, Days to heading; DM, Days to maturity; PH, plant height (cm); SL, Spike length (cm); SS, Seed per spike (No); TKW, 1000 kernel weight (g); BM, Above ground biomass (kg/ha); KPc, Kernel protein content (%); KSc, Kernel starch content (%); KMc, Kernel moisture content (%). IBON, international barely observation nursery; LSD, least significant difference; C.V, coefficient of variation

by National Standard Authority (NSA) ranged from 35 to 45 g and 9 and 11.5%, respectively. Accordingly, the results indicated that all tested varieties are under acceptable range of the standard set by NSA for thousand kernel weight and kernel protein content. The mean value of the kernel moisture content ranged from 9.98 to 10.03%

Stability analysis for grain yield and quality traits

The results of stability analysis for grain yield and quality traits are shown in Table 7. According to Lin and Binns (1988) of stability statistic, the genotypes with the lowest cultivar performance measure (Pi) values are considered the most stable. Therefore, the most stable varieties in grain yield and thousand kernel weights according this analysis were Bahati, IBON174/03 and EH1847. These varieties were respectively ranked first, second and third for their overall mean grain yield. The result also showed that Sabini and EH1847 were the most stable in protein content. Wricke (1962) stated that genotype with low ecovalence have smaller fluctuations across environments is the most stable. Hence, the most stable varieties in grain yield according to the ecovalence method were IBON174/03, EH1847 and Bekoji-1. Bekoji-1 was not the best ranked for the mean grain yield. This stability parameter also identified IBON174/03 and EH1847 in thousand kernel weight, and Bahati and IBON174/03 in kernel protein content as stable varieties across environments.

The study used the stability parameter Shukla (1972), and found that the genotype with the lowest score is considered to be the best. Thus, this stability parameter allocated IBON174/03 as the most stable verity in grain yield. Holker and Sabini were also stable but not the best ranked for the mean grain yield. The result also showed that IBON174/03 was the most stable in thousand kernel weight and in kernel protein content. Variety Traveler was the most unstable for grain yield, kernel protein content and thousand kernel weight (Table 6).

Table 6 Estimates of stability parameters for grain yield and quality traits

No	Varieties	Grain yield			Thousand kernel weight			Kernel protein content		
		Pi	Wi	δ^2i	Pi	Wi	δ^2i	Pi	Wi	δ^2i
1	Traveler	134	123	4.67	30	42	8	0.9	3.4	12
2	Holker	239	85	0.25	17	27	6	0.7	0.1	0.1
3	IBON174/03	24	14	1.58	6.8	5	1	0.8	0.8	4.7
4	Sabini	86	80	1.58	9.9	5	2	0.6	1.6	7.0
5	Fre-Gebs	47	133	3.00	0.0	6	0	0.8	1.6	9.2
6	EH1847	26	63	2.92	3.0	4	0	0.1	0.6	0.7
7	Bahati	23	243	10.25	3.3	26	6	0.7	0.9	3.7
8	Bekoji-1	65	50	2.92	2.4	8	5	1.4	0.7	1.7

Pi, Lin and Binns's cultivar performance measure; Wi, Wricke's ecovalence analysis; δ^2i, Shukla's stability variance

Table 7 Mean grain yield and quality traits, IPCA1 score, IPCA2 score and AMMI stability value of eight malting barley varieties tested at four environments

Variety	Grain yield (kg ha^{-1})				1000 kernel weight (g)				Kernel protein content (%)			
	Mean	IPCA1	IPCA2	ASV	Mean	IPCA1	IPCA2	ASV	Mean	IPCA1	IPCA2	ASV
Traveler	2332	−2.06	1.14	4.64	39	−1.99	−0.85	10.69	10.33	−1.12	−0.45	2.31
Holker	1687	−1.05	−1.86	2.68	41	−1.64	0.31	8.79	10.30	0.15	0.02	0.33
IBON174/03	3254	−0.74	0.05	1.64	42	0.15	0.63	1.13	10.30	0.50	0.37	1.16
Sabini	2676	−1.81	−0.55	4.04	41	0.17	0.57	1.18	10.47	−0.58	0.69	1.42
Fre-Gebs	2860	1.89	1.75	4.35	45	0.68	−0.44	3.70	10.33	0.62	−0.41	1.38
EH1847	3224	0.04	1.98	1.41	43	0.58	0.20	3.14	11.11	−0.03	0.04	0.21
Bahati	3271	3.10	−0.95	6.86	43	1.38	−1.30	7.47	10.32	0.21	−0.71	0.94
Bekoji-1	2684	0.64	−1.55	1.88	43	0.67	0.88	3.71	9.85	0.24	0.44	0.82

IBON, international barely Observation nursery; IPCA1, interaction principal component analysis 1; IPCA2, IPCA1, interaction principal component analysis 2; ASV, Additive stability value

The AMMI stability value based on the AMMI model`s IPCA1 and IPCA2 scores for each variety is summarized in Table 8. In AMMI stability value method, a genotype with least ASV score has small interaction and is the most stable whereas genotypes with large ASV score has high interactions and is unstable; therefore, IBON174/03, and EH1847, were the most stable varieties in grain yield followed by Bekoji-1.The result also exhibited that IBON174/03 and Sabini were the most stable in thousand kernel weight while Traveler was the most unstable. Holker and EH1847 were the most stable in kernel protein content.

A negative correlation was observed between Thouesed kerenel weight,kerenel starch containent and protein perecntage. Grain yield is postivelly and signifcance corelated with all the the agronomic and quality traits execpt days to heading days to maturity and plant height. A similar finding was also reported by Kashif and Khaliq (2014) on wheat shows that grain yield is postivlly corelated with yield related traits. But there is a ngetaive correlation of days to maturity with plant hight and krenel protein containet.

Principal component analysis for eleven traits

The first three PCs describe 70% of the total variance (Table 9). The first PC (43% of the total variation) was associated with days to heading, days to maturity, grain yield, kernel protein, kernel moisture, plant height and thousand kernel weight with a loading of, −0.335, −0.327, 0.328, 0.314, 0.370, 0.325 and 0.300, respectively. The variables with the highest loadings on the second PC (16%) were biomass (0.358), kernel protein content (−0.363), kernel starch content (0.435), plant height (0.371) and seed per spike (0.353). The third PC, accounting for just 11% of the total variation, was dominated by biomass, kernel protein, spike length, seed per spike and thousand kernel weight with loadings of 0.425, −0.312, −0.527, −0.429 and 0.360, respectively. Among traits having relatively high loadings, the kernel protein, plant height, biomass, thousand kernel weight and seed per spike were the major contributors to the total variation. Therefore, these traits may be considered as a good source for traits in future malt barley breeding programs.

Table 8 Correlation between agronomical and quality traits at 5% level of significance

	DH	DM	PH	SL	SS	BM	TKW	KPC	KSC
DH	1								
DM	0.8947**	1							
PH	0.0095 ns	−0.0797 ns	1						
SL	−0.3225 ns	−0.1356**	0.2138 ns	1					
SS	−0.3847 ns	−0.0555**	0.4114 ns	0.6822**	1				
BM	−0.0361 ns	0.0159 ns	0.9088**	0.4862**	0.7061**	1			
TKW	−0.3163**	−0.381 ns	0.8497**	0.0369 ns	0.3951 ns	0.7446**	1		
KPC	−0.3286 ns	−0.337**	−0.1325 ns	0.1179 ns	0.0951 ns	−0.1408 ns	−0.0381 ns	1	1
KSC	−0.2044 ns	0.62 ns	0.1044 ns	0.7044 ns	0.6488 ns	0.4084 ns	−0.1339 ns	−0.1633 ns	
GY	−0.5423 ns	−0.452 ns	0.3404 ns	0.0682**	0.5951**	0.456**	0.6202**	−0.3248	0.1813 ns

Table 9 Variance explained by the three principal components for eleven traits

Traits	Latent vectors (loadings)		
	PC1	PC2	PC3
Biomass	0.255	0.358	0.425
Days to heading	−0.335	0.069	0.131
Days to maturity	− 0.327	0.229	− 0.280
Grain yield	0.328	0.275	0.049
Kernel protein content	0.314	− 0.363	− 0.312
Kernel mouture content	0.370	− 0.270	0.029
Kernel starch content	− 0.279	0.435	0.108
Plant height	0.325	0.371	0.143
Spike length	0.200	0.286	− 0.527
Seed per Spike	0.242	0.353	− 0.429
Thousand kerner weight	0.300	− 0.039	0.360
Eigen value	4.753	1.731	1.199
Individual percent variation explained	43	16	11
Cumulative percent variation explained	43	58.94	70

Conclusion and recommendation

Based on the results, three malting barley varieties (IBON174/03, EH1847 and Bahati) were found to be relatively high grain yielder and full fill quality parameters. Moreover, these varieties fulfilled quality parameters requirements set by National Standard Authority for malting barley. Therefore, these varieties are recommended for production for their high yield, kernel size and protein content. Further study is required on agronomic practices and brewing quality attributes in malt barley. Especially Bahati for Dehana IBON174/03 and ESH1847 for lalibela.

Abbreviations

AMMI: Additive main effects and multiplicative interactions; IPCA1 and IPCA2: Principle component axis for interaction one and two; CSA: Central Statistical Agency; CV: Coefficient of variation; VC: Variance component; Env: Environment; Var: Variety; ASV: Additive stability Value; RCBD: Randomized complete block design; SAS: Statistical analysis System; ARARI: Amhara Agricultural Research Institute.

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Authors' contributions

AA contributed in Research data collection, data analysis, and data Interpretation and article writing. GG, TA and AI contributed in research proposal writing. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study available from the Corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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