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

Abebe Assefa*, Getawey Girmay, Tesfaye Alemayehu and Alemu Lakew

**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* ≤ 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

---

*Correspondence: assefaabebe1921@gmail.com
Department of Crop Research Directorate, Sekota Dry Land Research Center, P.O. Box 62, Sekota, Wollo, Ethiopia

© The Author(s) 2021. Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated in a credit line to the data.
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 trial 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 agroecologies of barley growing areas in Wagimra zone and Lasta Districces. 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 m² and 2 m². 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

| 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(°C)         | 23.5          | 24.7    |
| Average minimum temperature (°C)        | 11.1          | 13.6    |

Source: Kombolcha weather sub-station on the year 2016 and 2017 E.c
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. 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 program 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 (Lin 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 biplot 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 ≤ 0.01). The environment main effect accounted for 42%, 38% and 50% of

| 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
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 ≤ 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.

**Discussions**

The average grain yield across varieties varied from lowest at 1652 kg ha⁻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 3 Combined analysis of variance from eight malting barley varieties for eight traits

| Traits | Env (3) | Var (7) | Env x Var (21) | Pooled error | R-square |
|--------|---------|---------|----------------|--------------|----------|
| DH     | 2.94**  | 99.52** | 225.3**        | 6.76         | 0.85     |
| DM     | 741**   | 78.44** | 218.9**        | 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

### 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  | 2217  | 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 genotype in average
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 variety 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 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  | 0.5  | 0.1   | 0.76 |
| C.V. (%) |        | 4   | 3   | 11  | 9   | 9   | 25  | 6   | 0.5  | 0.1   | 0.8 |
| 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.

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

| No | Varieties | Pi  | Wi  | δ²i | Pi  | Wi  | δ²i | Pi  | Wi  | δ²i |
|----|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 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; δ²i, Shukla's stability variance.
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 thousand kernel weight, kernel starch content and protein percentage. Grain yield is positively and significantly correlated with all the agronomic and quality traits except days to heading as maturity and plant height. A similar finding was also reported by Kashif and Khaliq (2014) on wheat shows that grain yield is positively correlated with yield related traits. But there is a negative correlation of days to maturity with plant height and kernel protein content.

### 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-Gebis   | 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 barley Observation nursery; IPCA1, interaction principal component analysis 1; IPCA2, IPCA1, interaction principal component analysis 2; ASV, Additive stability value

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

| Traits                        | 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 | −0.249|
| 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.

Acknowledgements

The author acknowledges the Amhara Agricultural Research Institute (ARARI) for financial support to conduct this study and Mr. Danieal Tesfay for conducting grain quality parameters analysis at the ARARI grain quality Laboratory. Special gratitude is to Aemiro Bezabih for assisting in the write up, and data analysis.

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.

Funding

Amhara Agricultural Research Institute, Sekota Dry land Research Center.

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.

Received: 23 January 2021 Accepted: 29 June 2021

Published online: 21 August 2021

References

Asres T, Tadesse D, Wossen T, Sintayehu A. Performance Evaluation of Malt barley for malting quality and Breeding Perspective. J Crop Sci Biotech. 2018;21:451–70.

Bedasa M. Selection of barley varieties for their yield potential at Low Rain Fall Area Based on Both Quantitative and Qualitative Characters North West Tigray, Shire, and Ethiopia. International Journal of Plant Breeding and Genetics. 2014;8:205–13.

Bekele S, Yoseph T, Ayalew T. (2020). Growth, Protein Content, Yield and Yield Components of Malt Barley (Hordeum vulgare L.) Varieties in Response to Seeding Rate at Sinana District, Southeast Ethiopia. International Journal of Applied Agricultural Sciences. 6. (4), 61–71.

Central Statistical Agency, CSA. (2017). Report on Area and Production of Crops. Statistical Bulletin 584, Volume I, Addis Ababa.

Goedhart PW, Thissen JTNM. Biometrics Gene stat Procedure Library Manual. Wageningen, Nether lands: Wageningen University; 2016.

Gomez AK, Gomez AA. Statistical Procedures for Agricultural Research. 2nd ed. New York: John Wiley and Sons; 1984.

Kashif and Khaliq. Heritability, correlation and path analysis coefficient analysis for some metric traits in wheat. Int J of Agro and Biol. 2014;1:138–42.

Laidig F, Piepho HP, Rentel D, Drobek T, Meyer U. Breeding progress, genotypic and environmental variation and correlation of quality traits in malting barley in German official variety trials between 1983 and 2015. Theor Appl Genet. 2017;130:2411–29.

Lin CS, Binnis MR. A superiority measure of cultivar performance for cultivar x location data. Can J Plant Sci. 1988;68:193–8.

Mather DE. Compendium of Barley Diseases. 2nd ed. Montana: APS Press; 1997.

Muez M, Sentayehu A, Berhane L, Haddis Y, Mizan T. Parametric Stability Analysis of Malt Barley Genotypes for Grain Yield in Tigray. Ethiopia World Journal of Agricultural Sciences. 2014;10(5):210–5.

Shukla GK. Some statistical aspects of partitioning genotype-environmental components of variability. Heredity. 1972;29:237–45.

Wricke G. Uber eine method zur Erfassung der Okologischen streuberite in Feldversuchen. Z Pflanzerzuentz. 1962;47:92–6.

Yan W, Kang M. GGE biplot analysis: A graphical tool for breeders, geneticists’ agronomists. Boca Raton, Florida: CRC Press, 2002.

Zeleke T. Evaluation of Host Reaction and Yield Performance of Malt Barley Cultivars to Net Blotch. Pyrenophora teres in Bale. Journal of Plant Sciences. 2017;5(1):43–7.

Publisher’s Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.