Participatory evaluation of malt barley (*Hordium disticum* L.) varieties in barley-growing highland areas of Northwestern Ethiopia

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Participatory evaluation of malt barley (*Hordium disticum* L.) varieties in barley-growing highland areas of Northwestern Ethiopia

Misganaw Ferede¹* and Zina Demsie¹

Abstract: Although in Ethiopia, improved varieties of malt barley are released year after year, on-time promotion and distribution of released varieties to smallholder farmers are major research limitations. The study was initiated to explore the magnitude and extent of the performance of recently released malt barley varieties through farmers’ participation. The study was conducted at Guagusa Shikudad, Debaytilatgn, Farta and Lay Gaint, which represent barley-growing highland areas of Northwestern Ethiopia. Twelve malt barley varieties, Bahati, Bekoji-1, EH1847, Fanaka, Grace, HB1963, HB1964, Holker, IBON174/03, Sabini, Sington and Traveller, were used as experimental treatments. Treatments were laid out in a randomized complete block design with three replications. Malt barley varieties EH1847, HB1963 and IBON174/03, showed wider adaptable as well as relative stable across tested climatic zones. The farmers’ preference traits in malt barley varieties were relatively similar across tested highland areas. Moreover, disease resistant was ranked first across all climatic zones. The rank correlation analysis between varieties’ rank by farmers and varieties’ grain yield rank was positive across the tested climatic zones. Hereby, farmers could select the higher grain yield malt barley varieties based on agronomic preference traits to their agro-ecologies. Therefore, by considering both

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PUBLIC INTEREST STATEMENT

In Ethiopia, there have been released and recommended technologies that boost the production and productivity of malt barley. Moreover, it has huge areas suitable for barley production. Particularly, it has released malt barley varieties that are higher in grain yield, that are tolerant to barley diseases and that meet the quality standards of brewery factories. On the other hand, farmers grow older varieties which are lower in grain yield performance. Hence, due to the emergence of brewery factories, the local row malt barley production and two malt factory supply do not meet the demand of 12 brewery factories. Therefore, it is vital to consider the production and productivity of malt barley through farmers’ participation for the purpose of increasing farmers’ income and to slow down the foreign currency in case of high amount of malt import.
grain yield performance of the varieties and varieties’ rank by farmers, the recently released malt barley variety HB1963 should be pre-scale in barley-growing highland areas; also relatively older varieties EH1847 and IBON174/03 are used as genetic materials for the seed source in Northwestern Ethiopia.

Subjects: Agriculture; Environmental Sciences; Agriculture and Food

Keywords: farmers preference traits; malt barley; matrix ranking; pairwise ranking; preference ranking; rank correlation; stable variety

1. Introduction

Malt barley is becoming a major income source to smallholder farmers in the highland areas of Ethiopia, particularly where the agro-ecologies are not more productive to other cereal crops (Ministry of Agriculture [MoA], 2018). However, in Ethiopia, barley productivity (2.66 t/ha) is lower compared to that of other barley-producing countries such as United Arab Emirates, Belgium and Netherlands (8, 7.59 and 7.0 t/ha, respectively) (FAOSTAT, 2018). This is due to the combination of genetic, socioeconomic constraints and inappropriate use of integrated technologies (Bayeh & Stefania, 2011). In addition, malt barley requires optimum environmental factors (altitude, rainfall and soil pH are between 2,300 and 3,000 masl, 500 and 1,000 mm and 5.5 and 6.5, respectively and soil types are well-drained light brown and red soil) due to quality standards of beer factories (Bayeh & Stefania, 2011).

Ethiopia has large suitable cultivated land for barley production, which covers about 970,053 ha per year. It produces 347,497 tons barley per year (Central Statistics Agency, Ethiopia [CSA], 2018). Similarly, Ethiopia has a high demand for raw malt barley products due to the older established and new emerging malt and brewery factories. It has a total of four malt (two on process) and 12 brewery factories (Asokoinsight, 2019). In consideration of suitable agro-ecology and high demand for malt barley products by malt and brewery factories, Ethiopia has established a malt barley market value chain from the farmers to malt and brewery factories (Addisu, 2018; NBE, 2017). As Berhanu (2013) reported, farmers in the highland areas of Ethiopia have simply produced barley for food security and local markets at lower prices due to lack of market value chains. Now due to the emergence of malt and brewery factories, contract farming is evolved in malt barley commercialization among farmers, cooperatives, unions, seed enterprises and malt and brewery factories which have a 10% price advantage over noncontracted farming (Addisu, 2018). Even if the malt barley production and productivity are increased year after year, the supply does not meet the demand of emergence of malt and brewery factories. The brewery factories demanded about 118,000 tons malt per year, while the local malt source is 52,000 tons which covers only about 50% of it (Addisu, 2018; Business innovation facility BIF, 2018; NBE, 2017).

Although genetic advances in malt barley varieties have increased year after year through agricultural research institutes and nongovernmental agricultural research organizations, timely adaptation, promotion and diffusion of improved varieties of malt barley by smallholder farmers in the Western Amhara Region are limited, which widely and commonly grows older malt barley variety like Holker released in 1979. However, in Ethiopia, there have been recently released malt barley varieties that have attainable grain yield and malt quality in barley-growing areas (MoA, 2018).

Farmers’ participation in variety evaluation and development in Amhara Region also is not emphasized as much as demanded in the research system. However, improved varieties may not be adaptable to different agro-ecologies without the smallholder farmers’ participation and involvement of their indigenous knowledge in variety development due to climate variability (Chiara et al., 2017) and may also affect the speed and duration of variety development and the acceptance of released varieties by farmers without their involvements (Assefa et al. 2006). Moreover, farmers’ participation in variety evaluation is a pertinent technique to alleviate the
farmers doubt’ on the technologies, to select demanded varieties, to create skills and knowledge on genetic diversities in the breeding program (Ceccarelli, 2012) and to reduce time and resource wastage for technology diffusion as well (Bellon & Reeves, 2002). Farmers can be evaluating the number of varieties for performance-based criteria adapting to their agro-ecosystems (Smolders, 2006). Hereby, it is important to assess the genetic potential and farmers’ preference traits in malt barley varieties to their agro-ecologies. The study was initiated with the objectives of evaluating recently released malt barley varieties through farmers’ participatory variety evaluation approach to select and promote the high-grain-yielding malt barley varieties and to create awareness of the variety development process and technology distribution to the end-users.

2. Materials and methods

2.1. Description of study areas
The study was conducted in Guagusa Shikudad, Debaytilatgn, Farta and Lay Gaint, which represent the barley growing areas of the Western Amhara Region. The experimental sites of agro-ecological data are listed in Table 1.

2.2. Experimental materials and design
Twelve malt barley varieties, namely, HB1963, HB1964, Singitan, Traveler, Fanaka, Grace, EH1847, IBON174/03, Sabini, Bahati, Bekoji-1 and Holker, were used as experimental treatments (Table 2). The treatments were laid out in a randomized complete block design with three replications. The gross and net harvestable plot area were 2.5 m by 2 m and 2.5 m by 1.6 m, respectively. Spacing between rows, plots, and replications was 0.2 m, 0.4 m and 1.5 m, respectively.

2.3. Management practices
The trial was planted between the end of May up to the second week of June, with a seed rate of 100 kg/ha. Fertilizer rates were NPS 100 kg/ha for all environments and urea for debaytilatgn was 100 kg/ha, while that for Guagusa Shikudad, Farta and Lay Gaint were 150 kg/ha. All NPS and one-third of urea were applied at planting, whereas the remaining two-third of urea applied at the tillering stage. Weeding was done two times at tillering and booting growth stage across environments.

2.4. Data collection and statistical analysis

2.4.1. Biological data collection and analysis
The collected agronomic traits such as days to physiological maturity, plant height, spike length, number of seeds per spike, thousand seed weight and test weight were analyzed using GenStat software (17th edn) for the analysis of variances of varieties, environments and their interactions. Fisher’s protected least significant difference method (P ≤ 0.05) was used for mean separation among varieties.

2.4.2. Social data collection and analysis
Participant farmers were selected by Kebele Agricultural Experts regardless of their age, sex, religion and education level per district. Farmers were drawn up the preference traits of malt barley varieties based on their interest through focus group discussion. A total of 40 farmers, with 10 farmers per environment, participated in between dough to physiological maturity growth stages of malt barley varieties. Among seven environments, four environments were selected which show vigor in performance for variety evaluation by farmers. Each farmer per environment ranked each variety per preference traits in three groups as very good (1), good/medium (3) and poor (5). Farmers’ preference traits were analyzed using pairwise ranking. According to the collected social data, varieties’ rank by farmers was done using preference ranking for Debaytilatgn and Guagusa Shikudad nd using matrix ranking for Farta and Lay Gaint. Rank correlation analysis was done between varieties’ grain yield rank and varieties’ rank by farmers using Spearman’s rank correlation analysis as per the following equation:
Table 1. Agro-ecological data of the experimental areas

| Districts          | Code | Altitude (masl) | Soil type       | Rainfall (mm) | Temperature (°C) | Humidity |
|--------------------|------|-----------------|-----------------|---------------|------------------|----------|
|                    |      |                 |                 |               | Maximum          | Minimum  |          |
| Lay Gaint          | E1   | 3,002           | Brown           | 1,106         | 18.5             | 9.4      | 75.8     |
| Lay Gaint          | E2   | 2,950           | Light brown     | 1,106         | 18.5             | 9.4      | 75.8     |
| Farta              | E3   | 2,883           | Light brown     | 779           | 21.8             | 11       | 69.7     |
| Farta              | E4   | 2,650           | Light brown     | 779           | 21.8             | 11       | 69.7     |
| Debaytilatgn       | E5   | 2,862           | Brown           | 1,082         | 21.1             | 6.2      | -        |
| Debaytilatgn       | E6   | 2,660           | Light brown     | 1,082         | 21.1             | 6.2      | -        |
| Guagusa Shikudad   | E7   | 2,413           | Red             | -             | -                | -        | -        |

Source: Ethiopia Meteorology Agency, Bahirdar Branch.
Table 2. Description of malt barley varieties used for the study

| Variety name | Code | Pedigree | Breeder center | Year of release | Altitude (masl) | Rainfall (mm) | DM | Grain yield (qt/ha) | Protein (%) | Extraction (%) |
|--------------|------|----------|----------------|----------------|----------------|--------------|-----|------------------|-------------|---------------|
|              |      |          |                |                |                |              |     | Research field    | On farm     |               |
| HB1963       | V6   | PFC9215/3/ ZHEDAR#SHYRI//OLMO | HARC           | 2016           | >2,300         | 500-700      | 146 | 35-60            | -            | 10.6          | 81           |
| HB1964       | V7   | RECLA78/SHYRI/3/ ATA92/GOB | HARC           | 2016           | >2,300         | 500-700      | 138 | 3,356            | -            | 11.5          | 80           |
| Singitan     | V11  | IBON-MRA | SARC           | 2016           | 2,200-2,600    | 750-1,000    | 119 | 3,141            | 21-35        | 11.5          | 78           |
| Fanaka       | V4   | HKBL1512-5 | HARC       | 2015           | 2,000-2,600    | 500-1,000    | 125 | 2,638            | 23-31        | 10.5          | 78           |
| Traveler     | V12  | -        | HARC           | 2013           | 2,000-2,600    | 500-1,000    | 145 | 2,545            | 20-40        | 10.5          | -            |
| Grace        | V5   | -        | HARC           | 2013           | 2,000-2,400    | 500-1,000    | 125 | 2,040            | 18-35        | 10.4          | -            |
| IBON17/03    | V9   | -        | HARC           | 2012           | 2,000-2,800    | 500          | 120 | 3,057            | -            | 10.4          | -            |
| Sabini       | V10  | -        | KARC           | 2011           | 2,300-2,500    | >700         | 135 | 49               | 25-40        | 8.5           | -            |
| EH184.7      | V3   | E1H184/7/F4.2p5.2 (BEA/IBON64/91) | HARC | 2011           | 2,200-2,800    | >500         | 141 | 44               | 35           | 11            | -            |
| Bohali       | V1   | -        | KARC           | 2011           | 2,300-2,800    | >700         | 142 | 48               | 25-40        | 8.7           | -            |
| Bekoji-1     | V2   | E1H129/3/2-1BB-11-1-14-18 | KARC           | 2010           | 2,300-2,800    | >700         | 142 | 50               | 23-28        | 11.7          | -            |
| Hakker       | V8   | -        | HARC           | 1979           | 2,300-3,000    | 500-800      | -   | 2.4-3.1           | -            | -             | -            |

Source: MoANR (1979–2016).
Rs = 1-(6∑d²/(n³-n)) expressed in percentage,

where $d^2$ = difference in the ranks assigned to the same individual or phenomenon and $n$ = number of individuals or phenomena ranked.

3. Results and discussion

3.1. Performance of yield-related traits in malt barley varieties across environments

The varieties, environments and their interaction were showed significant ($P \leq 0.05$) differences, except the interactions of varieties by environments for trait number of seeds per spike in the tested malt barley varieties. The variety Singitan was relatively early maturing, while Traveler, Grace, Fanaka, Bahati, HB1963 and HB1964 were late-maturing varieties. In height performance, the varieties HB1964, HB1963, Bekoji-1 and Holker were taller, whereas Grace and Traveler were shorter varieties. In spike length performance, HB1964 was higher, while Holker was of a lower variety. The varieties HB1963 and Fanaka were higher for thousand seed weight (TSW) and hectoliter weight (HLW), respectively, whereas Grace was lower for both TSW and HLW response (Table 3). The grain yield performance was significantly influenced by environmental factors and their interactions (Misganaw, 2016; Fentaw et al., 2015; Arega et al., 2013; Tesfaye et al., 2013).

3.2. Grain yield performance of malt barley varieties across environments

The additive main effects and multiplicative interaction (AMMI) analysis of variances for grain yield in the varieties, environments and their interaction showed significant ($P \leq 0.05$) differences. Grain yield performance variation of the tested malt barley varieties expressed by environments,
variety by environment interactions and varieties was 73.58%, 16.62% and 9.79%, respectively (Table 4). The malt barley varieties EH1847 (V3) followed by HB1963 (V6) and IBON174/03 (V9) were higher grain yielders and stable across tested environments. While the malt barley varieties Grace (V5), Fanaka (V4) and HB1964 (V7) were inadaptable and unstable across the tested environments (Table 5 and Figure 1). In the plot, the best-performing malt barley varieties are closer to the average environmental coordinate (AEC) circle with the ranking lines (Yan & Kang, 2003). The varieties in the biplot with PC1 scores>0 and PC2 scores near to zero are adaptable and stable, respectively, whereas PC1 scores<0 and higher PC2 scores both + and−sings from the biplot lines inadaptable and unstable, respectively, across the environments (Zerihun, 2011). As depicted in Figure 2, malt barley varieties EH1847 (V3) followed by IBON174 (V9) and HB1963 (V6) were highest grain yielders which are enclosed by concentric circles closer to the ideal circle and/or AEC than the tested varieties across the tested environments. The varieties closest to the ideal genotype drawn on the center of concentric and/or AEC are the highest yielders (Zerihun, 2011; Yan & Kang, 2003).

3.3. Farmers’ preference traits in malt barley varieties across environments

Farmers were ranked by their preference traits in malt barley varieties using pairwise ranking methods. The farmers’ preference traits were relatively similar across environments. Among the preference traits, disease resistant was ranked first across all environments as well as other trait ranks were relatively similar across tested environments (Table 6). The study was in line with Semagn et al. (2017) reports; farmers’ selection criteria were very diverse and different in potato varieties across agro-ecologies and growing seasons. On the other hand, Chiara et al. (2017) reported that farmers’ selected desirable trait rank was varied in durum wheat genotypes across environments. In this study, disease reaction was more emphasized by farmers, but in Chiara et al. (2017) study, early maturity was prioritized by farmers. It might be because of the fact that the studies were conducted in different agro-ecologies.

3.4. Rank of malt barley varieties by farmers across environments

Although the farmers’ preference traits were relatively similar across the tested environments, the ranks of varieties by farmers were relatively different across the tested environments (Tables 7, 8 and 9). Hence, it is important to correlate varieties’ grain yield performance rank and farmers’ rank in malt barley varieties. As depicted in Table 10, the Spearman rank correlation between grain yield rank of malt barley varieties and farmers’ rank of malt barley varieties was at Farta (r = 0.5) and Guagusashikuda (r = 0.56). Therefore, at Farta and Guagusashikudad, Farmers were strong positive to select the higher grain yielding malt barley varieties, while at Lay Gaint (r = 0.05) and Debaytilatgn (r = 0.12) were weak positive to select the higher grain yielding malt barley.

| Source               | DF  | SS     | MS    | F pr | % SS (Var+Env +Var*Env) |
|----------------------|-----|--------|-------|------|------------------------|
| Total                | 251 | 19,279 | 76.8  |      |                        |
| Treatments           | 83  | 15,794 | 190.3 | <0.001|                        |
| Genotypes            | 11  | 1,547  | 140.7 | <0.001|                        |
| Environments         | 6   | 11,622 | 1,937.1| <0.001| 73.58                  |
| Block                | 14  | 1,107  | 79.1  | <0.001|                        |
| Interactions         | 66  | 2,625  | 39.8  | <0.001| 16.62                  |
| IPCA 1               | 16  | 1,226  | 76.6  | <0.001|                        |
| IPCA 2               | 14  | 786    | 56.2  | <0.001|                        |
| Residuals            | 36  | 613    | 17    | 0.334 |                        |
| Error                | 154 | 2,377  | 15.4  |      |                        |
| Code | Varieties   | Environments                  | Mean      | CV % | LSD (5%) | P-level  |
|------|-------------|-------------------------------|-----------|------|----------|----------|
| 1    | Bahati      | Laigant-E1                   | 53.34     | 9.4  | 8.26     | 0.03**   |
| 2    | Bekoji 1    | Lay Gaint (E2)               | 34.96     | 9.4  | 5.7      | 0.01***  |
| 3    | EH1847      | Farta(E3)                    | 42.51     | 10.9 | 7.16     | 0.01**   |
| 4    | Fanaka      | Farta(E4)                    | 27.61     | 11.6 | 5.57     | <0.01**  |
| 5    | Grace       | Debaytilatgn (E5)            | 50.76     | 11.6 | 7.69     | 0.01**   |
| 6    | Hb1963      | Debaytilatgn (E6)            | 39.06     | 11.6 | 6.3      | 0.01**   |
| 7    | Holker      | Guagusa                      | 34.7      | 11.6 | 5.25     | <0.01**  |
| 8    | IBON174/3   | Shikudad (E7)                | 40.42     | 11.6 | 7.32     | <0.01**  |

** Highly significant at P ≤ 0.01; * significant at P ≤ 0.05; NS, nonsignificant GY, grain yield; Var, variety Env, environment; Var × Env, interaction of varieties by environments.
varieties, it might be due to when the environments were not discriminating the varieties which shows relatively similar in phenotypic performance. The study was in line with Mohammadi et al. (2011) Farmers were efficient in identifying the best genotypes for their specific environment, Zerihun et al. (2012) Farmers were able to identify the higher yielding varieties as breeders, Mahmoud et al. (2014) reported that a significant positive correlation between the farmers' score and the grain yield response ($r = 0.6$) in barley genotypes and Molla and Tsedalu (2012)
## Table 7. Matrix ranking of malt barley varieties by farmers in Farta and Lay Gaint in 2017 cropping season

| Districts          | Traits weighted score | Sabini | EH1847 | Grace | Holker | HB1963 | HB1964 | Bahati | Bekoji 1 | Traveler | IBON174 | Fanaka | Sington |
|--------------------|-----------------------|--------|--------|-------|--------|--------|--------|--------|----------|----------|----------|---------|---------|
| Farta (E1)         | Disease resistant (1)  | 19     | 12     | 30    | 18     | 10     | 11     | 13     | 11       | 21       | 20       | 12      | 30      |
|                    | Spike morphology (2)  | 26     | 28     | 22    | 44     | 34     | 24     | 36     | 44       | 32       | 32       | 40      | 26      |
|                    | Tillering (3)         | 45     | 39     | 39    | 63     | 33     | 54     | 60     | 60       | 48       | 39       | 60      | 90      |
|                    | Plant height (4)       | 84     | 40     | 116   | 48     | 40     | 52     | 72     | 48       | 116      | 84       | 96      | 108     |
| Total score        |                       | 174    | 119    | 207   | 173    | 117    | 141    | 181    | 163      | 217      | 175      | 208     | 254     |
| Rank               |                       | 6      | 2      | 9     | 5      | 1      | 3      | 8      | 4        | 11       | 7        | 10      | 12      |
| Lay Gaint - E1     | Disease resistant (1)  | 18     | 16     | 30    | 21     | 18     | 17     | 17     | 18       | 20       | 14       | 18      | 21      |
|                    | Grain filling status (2)| 40    | 34     | 38    | 50     | 28     | 40     | 44     | 34       | 54       | 26       | 26      | 50      |
|                    | Spike length (3)       | 48     | 54     | 51    | 78     | 42     | 30     | 54     | 63       | 51       | 36       | 45      | 36      |
|                    | Tillering (4)          | 96     | 68     | 100   | 100    | 60     | 80     | 64     | 48       | 84       | 72       | 52      | 80      |
|                    | Plant height (5)       | 105    | 80     | 140   | 95     | 60     | 70     | 65     | 55       | 150      | 100      | 55      | 100     |
| Total score        |                       | 307    | 252    | 359   | 344    | 208    | 237    | 244    | 218      | 359      | 248      | 196     | 287     |
| Rank               |                       | 9      | 7      | 12    | 10     | 2      | 4      | 5      | 3        | 12       | 6        | 1       | 8       |

Note: score of the variety = summation of rank of varieties (1–3) for each trait × number of farmers (1–10) and total score = summation of traits weighted score × score of the variety, the lower the score the variety was desirable by farmers.
indicated the statistically significant correlation (P < 0.01) among farmers and breeders with grain yield response of the varieties as well as between breeders and farmers.

### 4. Conclusion and recommendation

The AMMI analysis of variances for grain yield in the varieties, environments and their interaction showed significant (P ≤ 0.05) differences across environments. The variation for grain yield performance in malt barley varieties accounted by environments, variety by environment interactions and varieties was 73.58%, 16.62% and 9.79%, respectively. According to GGE ranking and comparison biplot analysis, among 12 malt barley varieties EH1847 (V3) followed by HB1963 (V6) and IBON174 (V9) showed higher grain yield and relative stability across tested environments. The preference traits indicated the statistically significant correlation (P < 0.01) among farmers and breeders with grain yield response of the varieties as well as between breeders and farmers.

### Table 8. Preference ranking of malt barley varieties by farmers in Debaytilatgn in 2017 cropping season

| Variety   | Preference ranking by individual farmers | Rank index | Rank |
|-----------|-----------------------------------------|------------|------|
| HB1964    | 1 (1) 2 (6) 6 (1) 7 (1) 8 (1)           | 33         | 2    |
| HB1963    | 1 (6) 2 (4)                              | 14         | 1    |
| Singitan  | 10 (2) 11 (1) 12 (7)                     | 115        | 12   |
| Traveler  | 4 (1) 5 (1) 6 (1) 7 (5) 8 (1) 9(1)      | 67         | 7    |
| Fanaka    | 3 (2) 4 (6) 6 (1) 8 (1)                 | 36         | 3    |
| Grace     | 2 (1) 3 (1) 6 (1) 7 (1) 8 (1) 9(1) 10(4)| 75         | 9    |
| EH1847    | 2 (1) 3 (1) 5 (1) 7 (1) 8 (2) 9(2) 11(2)| 74         | 8    |
| IBON174/3 | 4 (1) 6 (1) 7 (1) 8 (1) 9 (2) 10(2) 11(2)| 85         | 10   |
| Sabini    | 2 (1) 6 (1) 9 (2) 10 (1) 11 (2) 12(3)   | 94         | 11   |
| Bahati    | 4 (2) 5 (3) 7 (1) 8 (1) 9 (2) 10(1)     | 66         | 6    |
| Bekoji 1  | 4 (2) 5 (1) 6 (3) 7 (1) 8 (3)           | 62         | 5    |
| Holker    | 3 (1) 5 (2) 6 (4) 7 (2) 9 (1)           | 60         | 4    |

Note: 1 (1) = first number was variety rank and numbers in brackets were number of farmers, rank index = summation of variety rank × number of farmers, the lower the rank index the variety was desirable by farmers.

### Table 9. Preference ranking of malt barley varieties by farmers in Guagusa Shikudad in 2017 cropping season

| Variety   | Preference ranking by farmers | Rank index | Rank |
|-----------|--------------------------------|------------|------|
| HB1964    | 1 (8) 6 (1) 9 (1)             | 23         | 1    |
| HB1963    | 1 (1) 6 (3) 7 (1) 8 (3) 10 (1)| 60         | 8    |
| Singitan  | 2 (6) 3 (1) 4 (1) 9 (1) 10 (1)| 38         | 3    |
| Traveler  | 11 (4) 12 (6)                 | 116        | 12   |
| Fanaka    | 5 (1) 6 (2) 7 (2) 8 (2) 9 (2) 10(1) | 57 | 6   |
| Grace     | 7 (1) 10 (1) 11 (5) 12 (3)    | 108        | 11   |
| EH1847    | 3 (1) 4 (3) 5 (1) 6 (1) 7 (1) 8(1) | 41 | 4   |
| IBON174/3 | 2 (4) 3 (3) 4 (2) 5 (1)       | 30         | 2    |
| Sabini    | 3 (4) 4 (1) 6 (1) 8 (1) 9 (1) 10(2) | 59 | 7   |
| Bohati    | 6 (2) 8 (1) 9 (2) 10 (5)      | 88         | 10   |
| Bekoji 1  | 3 (2) 4 (2) 5 (6)             | 44         | 5    |
| Holker    | 5 (1) 6 (1) 7 (5) 8 (1) 9 (1) 12(1) | 75 | 9   |

Note: 1 (8) = first number was variety rank and numbers in brackets was number of farmers, rank index = summation of variety rank × number of varieties, the lower the rank index the variety was desirable by farmers.
Table 10. Spearman rank correlation analysis between variety rank by grain yield response and farmers’ rank across environments

| Variety            | Forta (E3) GYR | FR | DNR | D²  | Lay Gaint (E1) GYR | FR | DNR | D²  | Debaytilatgn (E6) GYR | FR | DNR | D²  | Guagusu Shikudad (E7) GYR | FR | DNR | D²  |
|--------------------|----------------|----|-----|-----|-------------------|----|-----|-----|----------------------|----|-----|-----|----------------------------|----|-----|-----|
| Bahati             | 42.51          | 4  | 8   | (4–8)| 16                | 53.34| 8   | 5   | (8–5)                | 9  | 39.06| 5   | 6   | (5–1)                      | 1  | 34.7| 8   | 10  | (8–10) |
| Bekoji 1           | 38.93          | 6  | 4   | (6–4)| 4                 | 50.84| 9   | 3   | (9–4)                | 36 | 41.36| 2   | 5   | (2–5)                      | 9  | 39.71 | 2   | 5   | (2–5) |
| BH1847             | 44.57          | 1  | 2   | (1–2)| 1                 | 57.12| 3   | 7   | (3–7)                | 16 | 39.19| 4   | 8   | (4–8)                      | 16 | 39.91| 1   | 4   | (1–4) |
| Fanaka             | 36.08          | 9  | 10  | (9–10)| 1                | 52.38| 5   | 1   | (5–1)                | 16 | 31.95| 12  | 3   | (12–3)                     | 81 | 34.91| 4   | 6   | (4–6) |
| Grace              | 31.76          | 12  | 9   | (12–9)| 9                | 46.46| 11  | 12  | (11–12)              | 1  | 33.03| 10  | 9   | (10–9)                     | 1  | 23.91| 12  | 11  | (12–11) |
| HB1963             | 44.21          | 2  | 1   | (2–1)| 1                | 50.85| 8   | 2   | (8–2)                | 36 | 40.17| 3   | 1   | (3–1)                      | 4  | 35.11| 7   | 8   | (7–8) |
| HB1964             | 34.12          | 11  | 3   | (11–3)| 64               | 48.66| 10  | 4   | (10–4)              | 36 | 32.33| 11  | 2   | (11–2)                     | 81 | 35.82| 6   | 1   | (6–1)  |
| Holker             | 36.28          | 8  | 5   | (8–5)| 9                 | 43.40| 12  | 10  | (12–10)             | 4  | 43.69| 1   | 4   | (1–4)                      | 9  | 35.92| 5   | 9   | (5–9)  |
| IBON174            | 42.54          | 3  | 7   | (3–7)| 16               | 37.35| 3   | 6   | (3–6)                | 9  | 38.25| 7   | 10  | (7–10)                     | 9  | 37.16| 3   | 2   | (3–2) |
| Sabini             | 41.64          | 5  | 6   | (5–6)| 1                | 52.17| 6   | 9   | (6–9)                | 9  | 33.95| 9   | 11  | (9–11)                     | 4  | 29.02| 11  | 7   | (11–7) |
| Singitan           | 34.94          | 10  | 12  | (10–12)| 4               | 52.11| 7   | 8   | (7–8)                | 1  | 38.67| 6   | 12  | (6–12)                     | 36 | 34.07| 9   | 3   | (9–3) |
| Traveler           | 37.95          | 7  | 11  | (7–11)| 16               | 58.46| 1   | 11  | (1–11)              | 100| 35.52| 8   | 7   | (8–7)                      | 1  | 31.25| 10  | 12  | (10–12) |
| ∑d²                | 142            |     |     |     | 273               |     |     |     | 252                  |     |     |     | 126                          |     |     |     |     | 0.5   |
| SRC = 1-(6*∑d²/(n³-n)) | 0.5           |     |     |     | 0.05              |     |     |     | 0.12                 |     |     |     | 0.56                          |     |     |     |     |
and the rank of traits by farmers were relatively similar across tested environments because the study was conducted in relatively similar highland barley-growing areas. Disease resistant in malt barley was ranked first across all environments. The ranks of varieties by farmers were relatively different across the tested environments. Hence, it is important to correlate varieties’ grain yield performance rank and farmers’ rank in malt barley varieties. The rank correlation between varieties’ grain yield performance rank and farmers’ rank in Forta (rc = 0.5) and Guaguashikudua (rc = 0.56) was strongly positive to select the higher yielding potential malt barley varieties, while that in Lay Gaint (rc = 0.05) and Debaytilatgn (rc = 0.12) was weakly positive to select the higher grain yield malt barley varieties. This might be due to when the environments were not discriminating the varieties in performance. Hereby, farmers could select the higher grain yielder malt barley varieties only using few agronomic traits and disease reactions. In the study, therefore, by considering both statistical significant grain yield differences and varieties’ rank by farmers in malt barley varieties, recently released malt barley variety HB1963 and relatively older varieties EH1847 and IBON174/03 should be demonstrated and/or pre-scale up in Forta, Lay Gaint, Guagusa Shikudad and Debaytilatgn. Plant Breeders could be considered the farmers preference traits in malt barley breeding investigation to develop farmers demanded variety.

Cover Image
Source: Author

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