

Research Article

Performance Evaluation of Malt Barley (*Hordeum Vulgare L.*) Varieties for Yield and Quality Attributes in East Gojjam Zone of Amhara Region

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Abstract

Background: The production and productivity of Malt Barley is still low and area coverage has not been expanded due to lack of improved malt barley varieties. Hence Identification of adaptable quality malt barley varieties for specific environments is critical to enhance productivity. **Objective:** To evaluate and identify well adapted malt barley varieties for the study area. **Materials and Methods:** The study was conducted at Debre-Markos Agricultural Research Center and Sinan district from 2019 and 2020 main cropping season. Fifteen Malt barley varieties were evaluated using a randomized complete block design with three replications at plot sizes of 2m width and 2.5m length. **Results:** The analysis of variance results showed that there were significant differences ($p < 0.001$ among tested varieties. Varieties IBON174/03 ($3125.00 \text{ kg h}^{-1}$) and HB1964 ($2929.17 \text{ kg h}^{-1}$) scored maximum grain yield at DebreMarkos and IBON174/03 and M-21 scored maximum grain yield at Sinan district; The combined analysis of variance result showed that highly significant difference at $P < 0.001$. IBON174/03 ($2736.08 \text{ kg h}^{-1}$), HB 1964 ($2362.08 \text{ kg h}^{-1}$), and M-21 ($2301.28 \text{ kg h}^{-1}$) varieties were the first three best performing varieties with an average grain yield greater than the grand mean. The analysis of variance for quality traits revealed that there is significant variation among tested varieties for all traits. Varieties M-21(11.32%), EH1847 (10.65%), IBON174/03(9.96%), and HB1964 (9.77%) scored the acceptable range of kernel protein content. **Conclusion:** The three varieties; IBON174/03, M-21, and HB1964 were relatively high yielder and fulfilled the acceptable range of standards set by the National Standard Authority for kernel protein content of malting barley. Therefore; these varieties are recommended for production in the East Gojjam zone and similar agro-ecologies. Further studies are required for malting quality parameters on malt barley varieties across locations.

Keywords

Adaptation, Barley, Performance, Protein Content, Quality, Variety, Yield

1. Introduction

Barley (*Hordeum vulgare L.*) was domesticated in approximately 10,000 BC and is considered one of the oldest cultivated grain [1]. Due to its ability to be cultivated in a wide range of climates, the crop is essential in a world where food

security is an issue [2]. Moreover; barley has also been used as a principal food source in places where other cereals are more challenging to grow [3]. Barley is the major gain of choice for malt production worldwide since it has a high starch to protein

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Received: 2 November 2024; **Accepted:** 18 November 2024; **Published:** 25 December 2024



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ratio [4]. The utilization of barley in the beer industry has given this crop the status of an industrial crop and a crop of interest for entrepreneurs, farmers, and researchers [5]. Ethiopia is a center of barley domestication and diversity, an important place in African dryland agriculture in general, and of global significance due to its improved traits including disease tolerance [6]. Barley farming holds a unique place in Ethiopia, and various sources agree that it has been in cultivation for at least the past 5000 years in the country. Barley is an important grain crop in Ethiopia and has diverse ecologies being grown from 1800 to 3400 m altitude in different seasons and production systems [7] and makes Ethiopia the second largest producer in Africa, next to Morocco, accounting for about 25% of the total barley production in the continent.

Ethiopia has a high demand for raw malt barley products but the share of malt barley produce is very low having a share of 10% of the total produce of barley which is very low to cover the domestic consumption and the demand of malt and brewery factories of the country demand about 118,000 tons of malt per year, while the local malt source is 52,000 tons which cover only about 50% of it [8]. In Ethiopia, barley is the fifth most important cereal crop after Tef, wheat, maize, and sorghum and it covers 3,915,584 million smallholder farmers which cover 950,742.01 ha of land with the production of 23,780,102.92 quintals on average productivity of 25.01 q ha⁻¹ [9]. In the East Gojjam zone barley is the fourth most important crop next to Tef, wheat, and maize. It was grown in the highlands of the zone and cultivated by 97,886 small scale farmers with an area coverage of 48,978.82 ha of land with a production of 1,318,772.55 q ha⁻¹ on average productivity of 26.93 qha⁻¹ [9]. Regardless of the enormous potential for producing malt barley in the study area; only a negligible amount of produce has been produced by the farmers. To satisfy the increased demand for raw material for malt and brewery factories increasing the production and productivity of the crop is crucial to maximize import substitution since huge potential areas are available for the production of malt barley. However, the production and productivity of the crop are still low and area coverage has not been expanded mainly due to the lack of improved malt barley varieties and the low seed supply of improved varieties for producers in the study areas. Hence improved varieties played an important role in increasing the quality and productivity of malt barley; the selection of suitable and quality malt barley varieties for specific environments is critical to enhance the

quality and productivity. Considering the importance of the crop as an industrial raw material; evaluation of varieties for their adaptability at the highlands of the study area is fundamental. Therefore; the present study was initiated to evaluate and identify well-adapted quality malt barley varieties for the study area.

2. Materials and Methods

2.1. Study Area

The experiment was carried out by crop research process for two years 2019 and 2020 cropping seasons at Sinan district and Debre-Markos Agricultural Research Centre, which is located in the East Gojjam zone of the Amhara Regional State. The geographical location of DebreMarkos Agricultural Research Centre is between 10° 16.2386" North Latitude and 037° 6919' East Longitude with an elevation of 2471 m.a.s. having the mean annual rainfall of 1341 mm per year. The annual temperature varies between 11 °C -15 °C with the growing period between 120–180 days. Leptosols, Alisols, and Nitisols are the dominant soil types. The Sinan district is also characterized by Hilly and Mountainous highlands ranging between 2800 and 3800 m. The annual temperature ranges from 7.5 °C to 10 °C and the growing period is between 61 and 120 days. The Soils are predominantly Leptosols and Luvisols.

2.2. Study Design

For this experiment 15 Malt barley varieties were used (Table 1). A randomized complete block design with three replications was used. Each plot consists of 10 rows of 2.5m length. Fertilizer and lime were applied based on local recommendations. NPS fertilizer was applied at the rate of 121 kg h⁻¹ and one-third of nitrogen fertilizer from 150 kg h⁻¹ was also applied at planting time whereas 2/3 of the remaining urea was applied at tillering stage. Lime was applied at a rate of 2000 kg h⁻¹. Barley seed was sown in late June at a seed rate of 85 kg h⁻¹. Other agronomic managements recommended for Malt barley were done as required for better establishment of the crop in the experimental site.

Table 1. Description of 15 malt barley varieties used for the study.

	Variety	Year of release	Maintainer	Altitude	Rainfall(mm)
1	Holker	1979	HARC	2500-3000	500-800
2	Bekoji-1	2010	kARC	2300-2800	>700
3	HB1963	2016	HARC	>2300	500-700

	Variety	Year of release	Maintainer	Altitude	Rainfall(mm)
4	Fatima	2018	HARC		
5	Bahati	2011	KARC	2300-2800	>700
6	IBON 174/03	2011	KARC	2300-2800	>700
7	Fanaka	2015	HARC	2000-2600	500-1000
8	Henerik	2018	HARC	-	-
9	EH1847	2011	HARC	2200-2800	>500
10	M-21	2006	HARC	1550-2850	500-800
11	Traveller	2013	HARC	2000-2600	500-1000
12	HB1964	2016	HARC	>2300	500-700
13	Sabini	2011	KARC	2300-2500	>700
14	Grace	2013	HARC	2000-2400	500-1000
15	Planet	-	-	-	-

2.3. Data Collection and Analysis

The data was collected on plant and plot base. Day to heading, days to maturity, grain yield, thousand-grain weight, and biomass yield was recorded on the plot base, whereas plant height, panicle length and kernels per spike were measured on the plant base from five randomly selected plants of central rows. Grain quality parameters like grain protein content, Extract content, Friability, and β -Glucan content were measured at the laboratory using near-infrared spectroscopy (NIRS grain analyzer model 1241) Data analysis was performed using PROC GLM Procedure recommended for randomized complete block design using SAS software version 9.0 [10]. Mean comparisons among treatment mean were conducted by the least significant difference (LSD) test at 0.05 level of significance.

3. Result and Discussion

At Debre Markos on station; the analysis of variance result showed that there were significant difference ($p < 0.001$) among tested varieties for days to heading, grain filling period, plant height, spike length, biomass yield and grain yield; similarly Days to maturity, grains per spike and thousand kernel weight ($p < 0.05$) (Table 2). The mean of days to heading ranged from 65 to 72. Four varieties IBON174/03, EH1847, Sabini and M-21 start heading earlier than others tested varieties. Zeynu and Asfaw, [11] also reported similar

results for IBON174/03 and SABINI varieties. The all-out plant height (104.40 cm) was recorded by variety Bekoji-1 and the shortest plant height (56.33 cm) was recorded by Traveller. The longest (10.34) spike length was recorded by variety HB1964; while the shortest (6.30 and 6.42) spike length was recorded by Fanaka and Holker varieties (Table 2). Biomass yield ranged from 3000.00 to 7416.67 kg. The maximum biomass yield was recorded by variety HB1964 (7416.67 kg h^{-1}) followed by Bekoji-1 (7083.33 kg h^{-1}) and IBON174/03 & EH1847 (6833.33 kg h^{-1}). In this study the variety HB1964 which records the longest spike length also records maximum biomass yield and the second maximum grain yield at Debre-Markos on station. In this study the mean kernel weight of the varieties ranged from 43.00 g for the Grace variety and 66.83 g HB1964; Thus the analysis result indicated that all tested varieties are at an acceptable range of standard requirement for the industry except the Grace variety (43.00).

Grain yield being a quantitative trait is a complex character of any crop which ranged from 1029.58 to 3125.00 kg h^{-1} . Among tested genotypes IBON174/03 scored maximum grain yield (3125.00 kg h^{-1}) followed by HB1964 (2929.17 kg h^{-1}) and M-21 (2508.33 kg h^{-1}). However, Henerik and Fanaka scored the lowest grain yield result among tested varieties. The overall analysis of variance results indicated that IBON174/03, HB1964 and M-21 showed good agronomic performance and high-yielder varieties and were recommended for Debre-Markos (Gozamin District) and similar agro-ecologies.

Table 2. The mean performance of yield and yield related traits of malt barley varieties during 2020 main cropping season at Debre Markos on-station.

Trt No	Variety	DH	DM	GFP	PH	SPL	GPS	BMV	GY	TKW
1	HB1964	68.67	110.67	42.00	95.73	10.34	29.73	7416.67	2929.17	66.83
2	HB1963	71.33	110.00	38.67	83.27	6.72	27.87	5666.67	1933.33	59.50
3	IBON174/03	65.33	109.00	43.67	79.03	7.30	26.67	6833.33	3125.00	54.67
4	Bekoji-1	70.33	112.67	42.33	104.40	6.76	29.60	7083.33	2292.29	55.33
5	EH1847	66.00	111.67	45.67	95.63	7.49	26.00	6833.33	2354.79	50.83
6	Bahati	71.00	111.67	40.67	91.40	6.84	27.33	4666.67	1485.21	63.67
7	Sabini	66.00	111.33	45.33	74.23	7.78	28.00	4500.00	1904.38	52.67
8	Fanaka	70.33	108.00	37.67	74.53	6.30	25.20	4583.33	1044.38	53.50
9	Holker	70.00	111.00	41.00	89.47	6.42	29.33	5083.33	1563.33	54.00
10	Traveller	71.67	112.00	40.33	56.33	7.93	26.80	4666.67	1677.92	47.33
11	Planet	72.33	110.00	37.67	58.03	7.93	28.93	3500.00	1303.13	48.83
12	Fatima	72.00	109.67	37.67	65.87	8.01	27.73	3916.67	1296.25	51.67
13	Henerik	72.00	109.00	37.00	60.43	8.15	27.07	3000.00	1029.58	58.67
14	Grace	71.00	108.33	37.33	61.70	8.98	26.93	3416.67	1205.00	43.00
15	M-21	66.00	111.67	45.67	88.97	7.17	25.60	6666.67	2508.33	61.00
Mean		69.60	110.44	40.84	78.60	7.61	27.52	5188.89	1843.47	54.77
CV		1.181	1.476	4.430	2.66	4.406	5.01	2.926	4.240	13.392
LSD		1.855	3.68	4.082	13.022	1.018	3.116	1802.6	772.39	16.549
P-value		<.0001	0.0293	<.0001	<.0001	<.0001	0.0046	<.0001	<.0001	0.0337

Where; DH=Day to heading, DM=days to maturity, PH=plant height, SPL=spike length, KPS= kernels per spike, BMV= biomass yield, GY=grain yield kg h^{-1} and TKW=thousand Kernel weight

At Sinan district; the analysis of variance showed that the tested varieties differed significantly ($p < 0.05$) for the grain filling period, and were highly significant ($p < 0.001$) for days to heading, days to maturity, plant height spike length, biomass yield, and grain yield. Thousand kernel weight showed a non-significant variation among the tested varieties (Table 3). The mean of days to heading ranged from 60 to 70. IBON174/03 variety starts heading earlier than other tested varieties (60 days). The variety IBON174/03 headed earlier than other tested varieties and also scored the minimum days to maturity. The maximum plant height (82.43 cm) was recorded by the variety Bekoji-1 and the shortest plant height (45.367 cm) was recorded by Planet variety. The longest (8.09) spike length was recorded by variety HB1964; while the shortest (5.56 and 5.66) spike length was recorded by Fanaka

and Holker varieties (Table 3). Biomass yield ranged from 3000.00 to 6916.67kg. The maximum biomass yield was recorded by variety IBON174/03 (6916.67 kg h^{-1}) followed by M-21(6083.33 kg h^{-1}) and EH1847 (5888.89 kg h^{-1}). The mean of varieties for Grain yield ranged from 618.33 to 2347.15 kg h^{-1} . Among tested genotypes IBON174/03 scored maximum grain yield (2347.15 kg h^{-1}) followed by M-21(2094.24 kg h^{-1}) and HB1964 (1847.57 kg h^{-1}); However, Henerik and Planet scored the least grain yield result among tested varieties. Generally, analysis of variance result indicated that IBON174/03 (2347.15 kg h^{-1}) followed by M-21(2094.24 kg h^{-1}) and HB1964 (1847.57 kg h^{-1}) performed well and high yielder varieties and recommended for Sinan District and similar agro-ecologies.

Table 3. The mean performance of yield and yield related traits of malt barley varieties during 2019 and 2020 main cropping season at Sinan District of Woleki.

Trt	Variety	DH	DM	GFP	PH	SL	BMV	GY	TKW
1	HB1964	64.33	107.67	43.33	79.100	8.09	4638.89	1795.00	59.00
2	HB1963	70.67	113.00	42.33	63.467	5.83	4361.11	1165.21	53.17
3	IBON174/03	60.67	100.33	39.67	71.567	6.28	6916.67	2347.15	58.17
4	Bekoji-1	65.33	102.67	37.33	82.433	6.16	5416.67	1418.06	51.50
5	EH1847	62.00	102.00	40.00	77.000	6.62	5888.89	1847.57	50.50
6	Bahati	66.67	105.33	38.67	74.267	5.76	4083.33	1035.21	50.50
7	Sabini	62.33	102.33	40.00	59.433	6.48	4111.11	1071.18	39.00
8	Fanaka	64.33	103.33	39.00	57.700	5.66	3250.00	778.89	45.83
9	Holker	68.00	107.00	39.00	67.633	5.56	4361.11	908.82	51.50
10	Traveller	67.00	111.67	44.67	53.700	7.25	5486.11	1713.33	52.67
11	Planet	69.67	109.67	40.00	45.367	6.42	3000.00	714.51	46.17
12	Fatima	70.33	108.33	38.00	50.033	5.86	4027.78	896.53	52.00
13	Henerik	68.33	106.67	38.33	46.333	6.06	3750.00	618.33	49.50
14	Grace	69.00	109.67	40.67	48.667	6.98	3722.22	1096.04	43.83
15	M-21	62.00	104.33	42.33	80.633	6.52	6083.33	2094.24	48.00
Mean		66.04	106.27	40.22	63.822	6.37	4606.48	1300.00	50.09
CV		2.97	2.30	5.60	2.73	5.56	4.555	4.462	13.54
LSD		4.427	5.533	5.087	10.271	0.9847	2069.7	659.03	15.303
P-value		<.0001	<.0001	0.0158	<.0001	<.0001	<.0001	<.0001	0.1082

Where; DH=Day to heading, DM=days to maturity, PH=plant height, SPL=spike length, KPS= kernels per spick, BMV= biomass yield, GY=grain yield and TKW=thousand Kernel weight

The Combined Analysis

The combined analysis of variance across two locations for two years shows a highly significant difference at $P < 0.01$ for grain yield, plant height, spike length, biomass yield, days to heading, grain filling period, and a significant difference for Days to maturity and thousand-grain weight. The environment contributed to the significant level for evaluated parameters, however, the grain filling period showed no significance which indicates this trait was not affected by the environment.

Days to heading, days to maturity, and average grain filling; - The mean of days to heading for tested varieties ranged from 63 - 71 days. The lowest days to heading were recorded by variety IBON174/03 (63 days); while the maximum days to heading were recorded by three varieties namely HB1963, Planet, and Fatima (71 days). The present study was like-minded with Molla *et al.* [12] who reported the shortest days to heading for variety IBON174/03 (63 days). The average days to maturity ranged from 104-111 days. The lowest days to maturity were recorded by varieties IBON174/03,

Fanaka. EH1847 and Sabini (104, 105, and 106) days respectively. These four varieties are early maturing types among tested varieties. The average grain filling period ranged from 37.74 – 44 days. The maximum and minimum days for the grain filling period were exhibited by varieties Henerik (37.74 days) and M-21 (44 days).

Plant height and spike length;-The mean analysis of Plant height indicated that the longest plant height 93.42, 87.42, and 86.32 cm was recorded by varieties Bekoji-1, HB1964, and EH1847 respectively. Among tested varieties Planet (51.70 cm), Henerik (53.38cm), and Grace (55.18cm) recorded the shortest plant height value, the difference in plant height may be attributed to varietal difference. (Gezahegn and Kefale [13] reported that the varietal difference in plant height might be due to genetic behavior in combination with environmental conditions. The longest spike length was recorded by variety HB1964 (9.22 cm) and the shortest spike length was recorded by Fanaka variety (5.98cm).

Biomass yield; - The mean biomass yield ranged from 3250 to 6875kg. the maximum biomass yield was recorded by

variety IBON174/03 (6875 kg h⁻¹) followed by M-21 (6375 kg h⁻¹) and EH1847 (6371.11).

Grain Yield: The mean grain yield of tested varieties ranged from 832.96 for Henrick and 2736.08 for IBON174/03 (Table 4). Varieties; IBON174/03 (2736.08 kg h⁻¹), HB 1964 (2362.08 kg h⁻¹), and M-21 (2301.28 kg h⁻¹) were the first three best performing varieties with an average grain yield greater than the grand mean. The lowest grain yield was recorded by varieties Henrick (823.96), Fanka (911.63), and planet (1008.82). Therefore these three varieties. IBON174/03, HB 1964 and M-21 were recommended for the

study area.

Thousand Kernel Weight; - The mean kernel weight result ranged from 43.42 for the Grace Variety and 62.92 for the HB1964 variety. Variety HB1964 (62.92) scored the highest kernel weight followed by variety Bahati (57.08) and variety IBON174/03 (56.42). Thousand kernel weight should be greater than 45 g for two-rowed barley and greater than 42 g for six-rowed barley. Thus, the analysis result indicated that all tested varieties are at an acceptable range of a standard requirement for the industry except Grace Variety (43.42).

Table 4. The performance of combined analysis of malt barley varieties for yield and yield related traits during 2020 -2021 main cropping season at Debere-Markos and Sinan District of Woleki.

Trt	Variety	DH	DM	GfP	PH	SPL	BMV	GY	TGW
1	HB1964	66.50	109	42.67	87.42	9.22	6027.78	2362.08	62.92
2.	HB1963	71.00	111.50	40.50	73.37	6.28	5013.89	1549.27	56.33
3.	IBON174/03	63.00	104.67	41.67	75.30	6.79	6875.00	2736.08	56.42
4.	Bekoji-1	67.83	107.67	39.83	93.42	6.46	6250.00	1855.17	53.42
5.	EH1847	64.00	106.83	42.83	86.32	7.05	6361.11	2101.18	50.67
6.	Bahati	68.83	108.50	39.67	82.83	6.30	4375.00	1260.21	57.08
7.	Sabini	64.17	106.83	42.67	66.83	7.13	4305.56	1487.78	45.83
8.	Fanaka	67.33	105.67	38.33	66.12	5.98	3916.67	911.63	49.67
9.	Holker	69.00	109.00	40.00	78.55	5.99	4722.22	1236.08	52.75
10.	Traveller	69.33	111.83	42.50	55.02	7.59	5076.39	1695.63	50.00
11.	Planet	71.00	109.83	38.83	51.70	7.18	3250.00	1008.82	47.50
12.	Fatima	71.17	109.00	37.83	57.95	6.93	3972.22	1096.39	51.83
13.	Henerik	70.17	107.83	37.67	53.38	7.10	3375.00	823.96	54.08
14.	Grace	70.00	109.00	39.00	55.18	7.98	3569.44	1150.52	43.42
15.	M-21	64.00	108.00	44.00	84.80	6.85	6375.00	2301.28	54.50
Mean		67.82	108.36	40.53	71.21	6.99	4897.69	1571.74	52.43
CV		2.32	2.73	6.45	2.75	5.69	5.44	5.65	13.8
LSD		2.41	4.53	3.99					11.05
Trt		***	**	***	***	***	***	***	**
loc		***	***	Ns	***	***	***	***	**

Where; DH=Day to heading, DM=days to maturity, PH=plant height, SPL=spike length, KPS= kernels per spick, BMV= biomass yield, GY=grain yield and TKW=thousand Kernel weight,

Quality Parameter of Malt Barley Varieties

The analysis of variance for evaluated quality parameters indicated that there is significant variation among tested varieties (Table 5). The mean Extract content (%) of the varieties ranged between 76.65% for variety EH1847 and 81.83% for variety Planet. In this study varieties Traveller (81.55),

Planet (81.83), Fatima (81.48) and Henerik (81.44) scored higher malt extract than other tested varieties which indicates higher malt modification. Friability is used to determine the modification of the cell wall of malt grains [4]. Maximum friability results were scored by Planet (87.57), Traveller (81.64) and Henerik 80.67) varieties, indicating high lautering

performance. Varieties that scored low friability values were HB1964 (52.11%), EH1874 (52.50%) and M-21(53.13%) indicating the varieties were under modification which leads to low wort clarification and lautering performance.

The mean kernel protein content of the varieties ranged from 7.46 for Planet and 11.32 for M-21. The standards set for kernel protein content of malt barley by the National Standard Authority Ranged from 9.5% and 11.5. Hence, M-21(11.32%), EH1847 (10.65%), IBON174/03(9.96%), and HB1964 (9.77%) fulfill the acceptable range of standards set by the National Standard Authority. However, the protein content of most varieties was less than 9.5 indicating the tested varieties were under the acceptable range for protein content. The mean of β -Glucan content was between 90.09 and 729.61. The

highest β -Glucan content was recorded by varieties IBON174/03 (729.61), EH1874 (726.42), and HB1964 (689.27). These varieties also scored the least friability values. The lower friability associated with the higher β -Glucan content leads to poor malt modification and incomplete hydrolysis of cell walls. Habschied *et al.* [14] reported the effect of high β -Glucan content resulted in poor malt modification and incomplete hydrolysis of cell walls, which in turn impede the diffusion of enzymes produced during the mobilization of kernel reserves and disrupts various quality parameters of finished malt, whereas the lowest β -Glucan content was observed by variety planet 90.09 followed by varieties Henerik 232.12 and Fatima 304.53 which leads to better malting performance.

Table 5. The mean analysis of malt barley varieties for Quality Parameter.

Trt	Variety	EC	FB	PC	β GI
1	HB1964	78.73	52.11	9.77	689.27
2.	HB1963	80.90	74.93	7.79	399.16
3.	IBON174/03	78.70	54.09	9.96	729.61
4.	Bekoji-1	80.30	67.69	8.88	417.71
5	EH1847	76.65	52.50	10.65	726.42
6.	Bahati	80.07	66.59	9.20	639.51
7.	Sabini	79.80	59.09	9.27	623.04
8.	Fanaka	78.77	60.82	8.84	590.05
9.	Holker	80.32	70.61	8.40	418.81
10.	Traveller	81.55	81.64	8.78	377.35
11.	Planet	81.83	87.57	7.46	90.09
12.	Fatima	81.48	76.34	8.53	304.53
13.	Henerik	81.44	80.67	8.48	232.12
14.	Grace	80.26	75.29	8.58	369.98
15.	M-21	77.14	53.13	11.32	621.51
Mean		79.86	67.54	9.06	481.94
CV		1.91	11.42	10.14	20.70
LSD		3.4578	17.406	2.0744	225.1
P-values		0.0043	<.0001	0.0015	<.0001

Where; EC=Extract content (% dm), FR=, Friability (%), PC= protein content (% dm), BGC= β -Glucan content (mg/L)

4. Conclusion

Ethiopia has a high demand for raw malt barley products due to the older established and new emerging malt and brewery factories. But the share of malt barley produce is

very low having a share of 10% of the total produce of barley. In the East Gojjam zone, barley is the forth important crop next to Tef, wheat, and maize. Due to the lack of improved malt barley varieties and low seed supply of the varieties the production and productivity of the crop are still low and area coverage has not been expanded. Therefore selection of

suitable and quality malt barley varieties for specific environments is essential to enhance quality and productivity. The combined analysis of variance results showed that highly significant difference among treatments. Varieties IBON174/03 (2736.08 kg h⁻¹), HB 1964 (2362.08 kg h⁻¹) and M-21 (2301.28 kg h⁻¹) were the first three best-performing varieties. The three varieties; IBON174/03, M-21, and HB1964 were relatively high yielders and fulfilled the acceptable range of standards set by the National Standard Authority for kernel protein content of malting barley. Therefore; these varieties are recommended for production in the East Gojjam zone and similar agro-ecologies. Further studies are required for malting quality parameters on malt barley varieties across locations.

Abbreviations

cm	Centi Meter
CV	Coefficient of Variation in Percent
Ha	Hectare
HARC	Holeta Agricultural Research Center
LSD	Least Significant Difference at 5% Probability
Loc	Location
KARC	Kulumsa Agricultural Research Center
kg	Kilogram
kg h ⁻¹	Kilogram Per Hectare
q ha ⁻¹	Quintal Per Hectare
NPS	Nitrogen, Phosphorus and Sulfur
Trt	Treatment

Significance Statement

This research work focuses on the performance evaluation of released malt barley varieties to recommend the best adapted and high-yielder quality malt barley varieties in the study area. The study will help the researcher uncover the critical area of selection criteria for the identification of traits and genotypes associated with improving grain yield and quality by selecting appropriate varieties that many researchers were not able to explore. Accordingly, intensive efforts are required to fully explore the main quality traits in selection programs.

Conflicts of Interest

The authors declare no conflicts of interest.

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