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Malt Barley (*Hordeum distichon* L.) varieties performance evaluation in North Shewa, Ethiopia

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Malt barley is the most important cereal crop grown in highland parts of Ethiopia. Even though Ethiopia has favorable environment and potential market opportunity, the share of malting barley production is quite low (about 15%) as compared to food barley. One reason for low production is the use of low yielding varieties. The present investigation was conducted in a randomized complete block design with three replications in Debre Berhan, Ethiopia, during 2015 and 2016 main cropping seasons to assess the performance of malt barley varieties for yield and yield related traits. Eight released and promising genotypes (Beka, EH1847, Bahati, Bekoji-01, Traveller, Holker, Sabini and Miskal-21) were evaluated. The mean square due to genotypes, year, and interaction effect were significant (P<0.05) for all traits studied except harvest index. Variety by year interaction effect also differed significantly for all characters except spike weight and harvest index. The highest yields were found from EH1847, Beka and Holker, (3.69, 3.53 and 3.72 ton/ha respectively) while the lowest yield (2.72 ton/ha) was recorded from Miskal-21. Variety EH1847 scored high yielding in both years hence, the use of either of EH1847 variety with full package for mass production in Debre Berhan and similar agroecology would increase malt barley production.

Key words: Evaluation, malt barley (*Hordeum distichon* L.), variety selection, yield, correlation.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is the most staple food and subsistence crop in the country. It is grown in diverse environments with the altitude range of 1500 and 3500 masl, but predominantly grown from 2000 to 3000 masl (Berhane et al., 1996). It is the fifth most cultivated crop of the world (Eshghi and Akhundova, 2010). In Ethiopia, it is ranked fifth next to tef, wheat, maize and sorghum (CSA, 2017). In 2016/2017 cropping season the total area covered by barley in Amhara Region is about 323,600 hectares (CSA, 2017). Cultivated barley is normally divided into three subgroups; six-row (*H. vulgare*), two-row (*Hordeum distichon*) and the seldom cultivated intermediate (*Hordeum irregulare*).

Both two-row and six-row barleys are used for malting, but the best malt quality for beer is produced from two-row varieties. The international and national demand of

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Table 1. Description of malt barley varieties evaluated at Debre Berhan during 2015 and 2016 main cropping season in North Shewa zone, Ethiopia.

Varieties	Year of release	Released center	Grain yield (t/ha) at a time of release	Recommended agro-ecology zone
				Altitude (masl)
EH1847	2011	HARC	3.5-4.0	2300-2800
Traveler	2013	Heinken/HARC	20-40	2000-2600
Miscal-21	2006	HARC	2.5-4.6	1550-2850
Sabini	2011	KARC/HARC	2.5-3.0	2300-2800
Bahati	2011	KARC/HARC	2.5-3.0	2300-2800
Beka	1973	HARC	2.5-3.8	2300-2800
Bekoji-01	2010	KARC	3.5-4.0	2300-3000
Holker	1979	HARC	2.4-3.1	2300-3000

HARC: Holeta Agricultural Research Center, KARC: Kulumsa Agricultural Research Center Crop Variety Register (1995-2016).

malt barley is directly associated with the expansion of the brewery industries. In Ethiopia, malt barley is the major (90%) raw material for beer production (MoARD, 2010); hence the country faced a shortage of malt barley to meet the demand of the local breweries (Mohammed and Getachew, 2003). To fulfill the increasing malt barley demand, and to ensure higher cash return to the farmers, expansion of the malt barley production is very important. Even though Ethiopia has favorable environment and potential market opportunity, the share of malting barley production is quite low (about 15%) as compared to food barley. The local malt barley production covers about 35% malt demands; as a result the breweries are forced to import malt from abroad (Molla et al*.,* 2018). One reason for low production, particularly at Debre Berhan is the lack of improved malt barley varieties. To challenge the boosting demand and stunted supply of malt barley, it is important to make malt barley varieties evaluation. Hence, the present investigation is set with the objective of evaluating and selecting adaptable and high yielding malt barley variety (ies).

MATERIALS AND METHODS

The study was conducted at Debre Berhan during the main cropping season for two years (2015 and 2016). Debre Berhan is located in the North Shewa Zone of the Amhara Region, about 130 kilometers north east of Addis Ababa on the paved highway to Dessie, the town has a latitude and longitude of 9°41’N39°32’E and an altitude of 2840 masl. The annual average temperature and rainfall is 12.85°C and 927 mm respectively.

The experiment comprised eight nationally released malt barley varieties (Traveler, Sabini, Bekoji, Bahati, EH-1847, Beka, Holker, and Miskal-21) (Table 1). The varieties were laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental plot contained ten rows of 2.5 m length with the spacing of 0.2 m between rows. The spacing between plot and blocks were 0.5 and 1 m respectively. Planting was carried out by hand drilling using seed rate of 100 kg/ha. Recommended fertilizer rate of 100 kg/ha Urea and 100 kg/ha NPS was used as per the package. During initial crop development weed management was carried out manually to avoid competition and weed interference.

Data collection and analysis

Data were collected on days to heading, days to maturity, biomass, spike length, spike weight, plant height, number of tiller per plant, spike weight, number of kernels per spike, thousand kernel weights, grain yield, and harvest index. The data were collected from eight middle rows. Replications and years were considered as random effects whereas varieties were considered as fixed effect. To reveal the total variability present within the tested varieties, the data were computed for all the characters measured as per Gomez and Gomez (1984). The data were subjected to analysis of variance (ANOVA) following statistical procedures appropriate for the experimental design using Statistical Analysis System (SAS) program package version 9.1. Whenever treatment effects were significant at 0.05 level of error, the means were delineated by using the least significant difference (LSD) procedures. Correlation analyses were determined through simple correlation coefficient between yield and other traits studied.

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) was carried out to determine the main effect of varieties, years and their interaction on yield and yield components of malt barley varieties (Table 2). There were statistically significant ($P<0.05$) variation in varieties and years for all investigated traits except harvest index. Variety by year interaction also differed significantly for all characters except harvest index and spike weight. This result is in agreement with Daniel (2010), Yetsedaw et al. (2013) and Bankole et al*.* (2015).

The mean performances across the two years for all studied traits are presented in Table 3. Days to heading ranged from 78.17-88.17 days, and Sabini was early to heading whereas Beka was too late to head. It takes 125 days to mature for variety Sabini and for Beka 143.33 days. Maximum plant height (126.85 cm) was recorded for Beka, while minimum (81.18 cm) for Traveler. Bekoji-01 needs shortest (43.5) days to fill grain, whereas Traveler needs 56.33 days. Total biomass yield varied from 8.45 -11.92 tons per hectare with a mean of 11.42, and 11.92 tons per hectare was recorded for Bahati and

Table 2. Mean squares from combined analysis of variance for the effects of year, and variety on different parameters studied evaluated in 2015 and 2016 at Debre Berhan.

Traits	Year (Y) (Df = 1)	Rep.(R) (Df= 4)	Variety (V) (Df=7)	G*Y (Df = 7)	Error (Df=28	Mean	R^2	CV (%)
DH	75.00***	0.13^{ns}	63.38***	3.62***	0.34	82.50	0.98	0.71
GFP	221.02***	0.15^{ns}	111.35***	5.07***	0.41	50.48	0.99	1.26
DM	200.08***	0.77*	162.38***	1.85***	0.25	131.58	0.99	0.38
PH	921.38***	61.57^{ns}	1171.36***	325.59***	41.17	103.29	0.91	6.21
FTNPP	199.27***	1.40^{ns}	16.56***	15.82***	0.95	11.33	0.94	8.59
SL(cm)	1.66***	0.04^{ns}	3.15***	0.50***	0.03	7.57	0.97	2.35
NKPS	8.38*	0.70^{ns}	13.89***	8.06***	1.47	27.05	0.80	4.49
SW(g)	0.71***	0.01^{ns}	0.06*	0.25ns	0.02	1.37	0.68	10.87
TSW(g)	5143.95***	47.74^{ns}	102.53*	93.94*	34.64	83.55	0.87	7.04
TBY/Ha (ton)	5.93***	0.31^{ns}	9.75***	6.37***	0.37	10.10	0.93	6.00
GY/ha (ton)	5.65***	0.01^{ns}	0.70***	0.465***	0.026	3.30	0.95	4.93
HI	0.003	0.0002	0.005	0.004	0.0004	0.32	0.87	5.99

*, ** and *** = significant at P<0.05, P<0.01, and P<0.001, respectively. ns = nonsignificant difference, Days to Heading (DH), grain filling period (GFP), Days to maturity (DM), Plant Height (PH), Fertile tiller number per plant (FTNPP), Spike length (SL), Number of kernels per spike (NKPS), Spike weight (SW), Thousand seed weight (TSW), Total biomass yield (TBY), grain yield (GY), and Harvest Index (HI).

Holker varieties.

Number of kernels per spike was also significant (P<0.01) among varieties, maximum number of kernel per spike (27.76, 28.19 and 28.56) was recorded for EH1847, Beka and Bekoji-01 respectively. Similarly, reports have shown the variation of number of kernels per spike as a function of barley genotypes (Ryan et al., 2009; Biruk et al., 2016). In terms of fertile tiller number EH1847 and Beka give highest tiller number and they were statistically at par with the score of 13.52 and 12.6 respectively. The least fertile tiller producer variety was Miskal-21 (8.15). The longest spike length (8.8 cm) was recorded for Beka and shortest (6.58 cm) for Holker. Thousand kernel weight was significantly different among the varieties. This result agrees with those obtained by other authors (Rashid and Khad, 2008; Bagheri and Sadeghipour, 2009), who reported significant variation between malt barley genotypes in number of kernels per spike. The range observed for thousand seed weight was 79.5-89.97 g with overall mean of 83.5 g. Highest thousand seed weight (89.97, 88.68 and 86.15 g) was recorded for Behati, Holker and Bekoji-01 respectively, which is also in line with findings of Aliyi et al. (2016). The mean grain yield ranged from 2.72-3.72 tons per hectare. The highest grain yield (3.72, 3.69 and 3.53 t/ha) was recorded by Holker followed by EH1847 and Beka while the least was recorded by Miskal-21 (2.72 t/ha). The best yielding ability of EH1847 variety might be attributed to larger tiller number per plant, number of kernel per spike, and thousand seed weight. This is in line with Moral et al. (2002), who reported that the number of fertile tiller number per plant, number of kernel per spike and thousand seed weight are important features of cereals in determining the yield potential.

The result of variety by year interaction effect shows a highly significant difference indicating differential varieties performance in each year. The variation of rainfall amount and distribution of the years 2015 and 2016 might have contributed significantly to the differences observed between the years for the characters studied. Significant variety by year interaction has also been reported by different scholars (Afzal et al., 2011; Anley et al., 2013; Bankole et al., 2015). Most varieties perform better for plant height, fertile tiller number, thousand seed weight, total biomass and grain yield in 2016 compared to 2015 season (Table 4). Variety EH1847 is high yielding in both years, whereas Miskal-21 variety was the least.

Correlation between traits taken

Correlation analysis provides the information of interrelationship of important plant characters and hence leads to a directional model for direct and indirect improvement in grain yield (Khan et al., 2004). Correlation coefficient among yield and yield components is presented in Table 5. The correlation analysis indicates there was significant positive relation between grain yield and date of maturity, plant height, fertile tiller number, number of kernel per spike, thousand seed weight, and total biomass yield. A positive and highly significant (r = 0.604) correlation between grain yield and fertile tiller number was found, while a very weak but non-significant (r = 0.031) correlation between grain yield and spike length was also noticed. This suggests that grain yield will increase at longest maturity period, highest plant height, fertile tiller number, kernel number per spike, thousand seed weight, and total biomass yield. Total biomass yield correlated with date of heading, plant height, and number of kernel per spike (r = 0.423, r =

Table 3. Combined mean performance of malt barley varieties for yield and yield components evaluated in 2015 and 2016 at Debre Berhan.

Varieties	DH	GFP	DM	PH (cm)	FTNPP	SL (cm)	NKPS	SW (g)	TSW (g)	TBY/Ha (ton)	GY/ha (ton)	HI
Beka	88.17^{a}	51.83^{d}	140.33^{a}	126.85^{a}	12.60^{ab}	8.80^{a}	28.19^{a}	1.35^{b}	79.50^{c}	11.07^{bc}	3.53^{ab}	0.32^{de}
EH1847	79.17^{f}	52.83^{c}	129.33^{e}	98.12^{cd}	13.52^{a}	8.20^{b}	27.76^{a}	1.28^{b}	80.37^{c}	9.93^{d}	3.69^{a}	0.38^{a}
Bekoji-1	85.00^{b}	43.50^{h}	127.00^{g}	111.77^{b}	12.22^{bc}	7.09^{e}	28.56^{a}	1.35^{b}	86.15^{abc}	10.40^{cd}	3.15^{d}	0.31^{de}
Holker	83.83^{c}	50.00^{e}	133.17^{d}	108.90^{b}	11.83^{bcd}	6.58^{f}	26.08^{b}	1.40^{b}	88.68^{ab}	11.42^{ab}	3.72^{a}	0.33^{cd}
Travller	81.67^{d}	56.33^{a}	135.83^{b}	81.18^{e}	10.05^{e}	7.97^{c}	27.31^{ab}	1.38^{b}	79.93^{c}	8.98^{e}	3.17^{cd}	0.35^{bc}
Sabini	78.17^{g}	48.33^{f}	125.00^{h}	90.95^{d}	10.97^{de}	7.46^{d}	27.45^{ab}	1.32^{b}	81.47^{c}	8.45^{e}	3.07^{d}	0.36^{ab}
Miskal-21	83.17^{c}	46.33^{g}	127.67^{f}	108.65^{b}	8.15^{f}	7.49^{d}	23.75^{c}	1.29^{b}	82.37^{bc}	9.15^{e}	2.72^{e}	0.3^{ef}
Bahati	80.83^{e}	54.67^{b}	134.33^{c}	99.87^{c}	11.30^{cd}	6.94^{e}	27.28^{ab}	1.59^{a}	89.97^{a}	11.92^{a}	3.36^{bc}	0.28^{f}
Mean	82.50	50.48	131.58	103.29	11.33	7.57	27.05	1.37	83.55	10.10	3.10	0.32
R2	0.98	0.99	0.99	0.91	0.94	0.97	0.80	0.68	0.87	0.93	0.95	0.87
CV (%)	0.71	1.26	0.38	6.21	8.59	2.35	4.49	10.87	7.04	6.00	5.36	5.99

Table 4. Mean performance of some traits of malt barley varieties across two consecutive years.

Varieties	2015					2016				
	PH (cm)	FTNPP	TSW (g)	TBY/Ha (ton)	GY/ha (ton)	PH (cm)	FTNPP	TSW (g)	TBY/Ha (ton)	GY/ha (ton)
Beka	120.27^{a}	9.0^{abc}	69.77^{b}	10.53^{bc}	2.87^{bc}	133.43^{a}	16.2^{ab}	89.23	11.6^{ab}	4.19^{a}
Eh1847	88.0^{c}	9.83^{ab}	63.8^{b}	7.73^{d}	3.28^{a}	108.23^{bcd}	17.2^{a}	96.93	12.13^{a}	4.10^{a}
Bekoji-1	119.7^{a}	10.23^{ab}	79.9^{a}	9.73^{c}	3.08^{ab}	103.83^{cde}	14.20^{c}	92.40	11.07^{bc}	3.22^{cd}
Holker	107.9^{b}	10.43^{a}	80.9^{a}	11.33^{ab}	3.14^{ab}	109.9^{bc}	13.23^{c}	96.45	11.5^{abc}	3.7^{b}
Travller	66.1^{d}	8.67^{bc}	68.1^{b}	7.37^{d}	2.37^{e}	96.27^{de}	11.43^{d}	91.75	10.6^{cd}	3.97^{a}
Sabini	86.77^{c}	8.63^{bc}	69.17^{b}	7.2^{d}	2.7^{cd}	95.13^{e}	13.3^{c}	93.77	9.7^{de}	3.43^{c}
Miskal-21	100.13^{b}	9.43^{abc}	68.8^{b}	9.37^{c}	2.47^{de}	117.17^{b}	6.87^{e}	95.93	8.9^{e}	2.97^{e}
Bahati	102.37^{b}	8.1^{c}	85.17^{a}	12.27^{a}	3.15^{ab}	97.37^{cde}	14.83^{bc}	94.77	8.8^{e}	3.1^{de}
LSD	9.03	1.7	9.48	1.17	0.28	13.08	1.68	11.07	0.91	0.24

0.475 ($P<0.01$), and r = 0.293 ($P<0.05$) respectively).

Conclusion

The national demand of malt barley is increasing as a result of expansion of the brewery industries. However, malt barley production is unable to feed the malt barley market demand of the country. Lack of improved varieties leads greatly to low production in the study area. Development of superior crop varieties and/ or variety selection is the ultimate goal of the plant breeders to obtain higher grain yield to replace the existing low yielding malt barley varieties. Malt barley seed production can be enhanced through selecting varieties suitable for the area, which may result in varietal diversity for producers. The finding generated from the investigation discovered the presence of significant difference among

Table 5. Correlation coefficients of different traits of malt barley varieties combined over years.

	DH	DM	PH	FTN	SL (cm)	NKPS	SWt (g)	TSWt (g)	TBY (t/ha)	GY (t/ha)
DH	1									
DM	0.326*	1								
PH	0.704**	0.209ns	1							
FTN	0.338*	0.454**	0.227ns	1						
SL (cm)	0.078ns	0.078ns	0.059ns	0.089ns	1					
NKPS	0.177ns	0.186ns	0.145ns	0.599**	0.268ns	1				
SWt (g)	-0.207ns	-0.24ns	-0.142ns	-0.537**	-0.157ns	-0.13ns	1			
TSWt (g)	0.303*	0.573**	0.248ns	0.447**	-0.258ns	0.136ns	-0.328*	1		
TBY (ha/ton)	0.423**	0.088ns	0.475**	0.011ns	-0.071ns	0.293*	0.275ns	0.110ns	1	
GY (ha/ton)	0.182ns	0.335*	0.372**	0.604**	0.031ns	0.452**	-0.207ns	0.445**	0.331*	1
HI	0.017ns	0.262ns	-0.076ns	0.289*	0.106ns	-0.036ns	-0.399**	0.487**	-0.585**	0.131ns

*And ** = significant different at 0.05 and 0.01 level, respectively.

the varieties, and variety by year interaction for most parameters studied. On the bases of two years results of the study at Debre Berhan EH1847 performs best and maintains consistency in yielding potential in both years (3.69ton/ha). This variety also scored high value in number of fertile tiller number (13.52) and number of kernel per spike (27.76) which was highly correlated with grain yield. Therefore, authors recommend variety EH1847 for mass production; as a result small scale farmers can boost their income. However, further investigation is recommended on other improved varieties for stability over locations and years for yield and yield related traits since most of the customers were looking for high yielder, adaptable and stable malt barley variety.

Abbreviations

DH, Days to heading; **DM,** days to maturity; **PH,** plant height **SL,** Spike length; **GFP,** Grain filling period; **FTNPP,** Fertile tiller number per plant; **NKPS,** number of kernel per spike; **SW,** Spike weight; **TSW,** thousand seed weight; TBY/Ha, total biomass yield per hectare; **GY/Ha,** Grain yield per hectare; **HI,** Harvest index; **ANOVA,** Analysis of variance; **CV,** coefficient of variance;

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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