ORIGINAL ARTICLE

Improvement in Grain Yield and Malting Quality of Barley (*Hordeum vulgare* L.) in Ethiopia

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ABSTRACT

An experiment was conducted using six malt barley varieties in randomized complete block design with four replications at two testing locations during 2009 main cropping season. The objectives of this study were to estimate the progress made in improving grain yield potential of malt barley varieties, improvement in kernel quality attributes of malt barley and changes in agro-morphological traits associated with genetic yield potential improvement. Data were collected on agro-morphological traits and on some malting quality parameters. Analysis of variance showed that there was a significant difference among varieties for all traits except grain filling period, biomass yield and biomass production rate. On the other hand, grain yield potential of malting barley has risen at an average annual rate of 28.95 kg ha^{-1} (0.88%) $year^{-1}$ since 1979. There was also parallel improvement in total grain sink filling rate. Change in malt barley grain yield was markedly associated with biomass production rate and total grain sink filling rate while year of release was significantly correlated with grain yield and total grain sink filling rate. Moreover, kernel plumpness was significantly improved as kernel size ≥ 2.5 mm showed significant improvement (0.27%) $year^{-1}$and non standard seed size, i.e. ≤ 2.2 mm was substantially reduced as indicated in regression of kernel sieve test since 1973 when Holker was released (-0.21% $year^{-1}$), whereas other kernel quality parameters were within acceptable quality standard. Likewise, there was significant and positive association between improvements in kernel size greater than 2.5 mm and year of release of the varieties and varietal age was significantly and negatively correlated with nonstandard kernel size (≤ 2.2 mm). In general, future malt barley breeding effort should focus on comprehensive varietal development with further assessment of genetic gain in other malt quality attributes.

Key words/phrases: Malt Barley, Genetic gain, Yield potential

INTRODUCTION

Barley (*Hordeum vulgare* L.) is a diploid (2n=14) plant with high degree of self fertilization (Harlan, 1976) and it has a long history of cultivation in Ethiopia, which is reported to have coincided with the beginning of plow culture (Zemede, 2000). It is the most important cereal crop with total area coverage of *1,046,555.30* hectares and total annual production of about 1.7 million tons in main season (CSA, 2011). In the highland of the country barley can be grown in Oromia, Amhara, Tigray Regional States and part of SNNP in the altitude range of 1500 and 3500 m, but it is predominantly cultivated between 2000 and 3000 masl (Berhane *et al.,* 1996). Under extreme marginal conditions of drought, frost and poor soil fertility, barely is the most dependable cereal and is cultivated on highly degraded mountain slopes better than other cereal crops in the highland of Ethiopia (Mathre, 1997; Ceccarelli *et al.,* 1999). As barley is early harvested crop, it is popular hunger breaker or relief crop during season of food shortage in some parts of the country (Fekadu, 1995).

In Ethiopia, barley types are predominantly categorized as food and malting barley based on their uses. The highest proportion of barley production is allocated for food barley type. The share of malting barley production is quite low (about 10%) as compared to food barley in Ethiopia (Birhanu *et al.*, 2005) despite the country has favorable environment and potential market opportunity. The current malt barley supply is only one- third of grain demanded (Getachew *et al.*, 2011). Nevertheless, with the current 16% annual increase in local beer consumption, the demand for malt is also increasing with the same rate. According to Ethiopian Ministry of Industry demand and supply survey projection of annual malt barley in the year 2011/12 is around 67509.6 ton whereas; the full annual processing capacity of Asela Malt Factory (AMF) is about 36000 ton (Getachew *et al*., 2011).

Besides its malt grain value of barley as industrial crop, the straw is an indispensable component of animal feed especially during the dry season in the highland where feed shortage is prevalent (Aemiro et al., 2011). Barley straw is also used in the construction of traditional huts and grain stores as thatching or as a mud plaster, as well as for use as bedding in the rural area (Berhane *et al.,* 1997; Zemede, 2000).

Barley has been one of the experimental organisms for various studies and has gone continuous manipulation in an effort to optimize its use (Hockett and Nilan, 1985; Zemede, 2000; Kahrizi, 2009; Kahrizi and Mohammadi, 2009; Kahrizi, 2011). Genetics of traits, gene nomenclature, mutation, recombination and linkage have been extensively studied in barley (Hockett and

Nilan, 1985). In Ethiopia, research on barley improvement was started in the 1950s through introduction of exotic germplasm and collections from local landraces with an objective to improve grain yield potential, and grain quality (Hailu *et al.*, 1996). As a result of favorable access to international germplasm exchange and indigenous breeding materials, barley breeders have so far developed many barley varieties (Birhanu *et al*. 2005; Berhane and Alemayehu , 2011). Accordingly, Beka, Holker, HB-120, HB-52, HB-1533 and Miscal-21 are among the officially released, popular malt barley varieties in Ethiopia.

A successful crop breeding program is likely to generate genetic gain in grain yield potential (Heisey *et al*., 2002; Maniee *et al*., 2009; Kahrizi *et al*., 2010; Chaghakaboodi *et al*., 2012). Genetic improvement can be studied either by estimating level of genetic advance from a single or a series of selection cycles made at a time or from a long-term breeding effort made by a breeding program (Johanson *et al.*, 1955; Allard, 1960; Waddington *et al.*, 1986). Likewise, estimation of genetic progress from a breeding program and periodic evaluation of advancement in the genetic gain of a crop is required to understand changes produced by breeding activities, to assess the efficiency of past improvement works in genetic potential as well as to show future selection direction to facilitate further improvement. Even if considerable resources were allocated to barley variety development, there were no studies conducted to determine the progress in genetic gain in yield potential and associated agronomic traits, as well as malt quality attributes in Ethiopia. Hence, the present study was executed to estimate the progress made in improving genetic yield potential and malt quality traits as well as to assess changes in morpho- agronomic characteristics and thereby to identify their association with genetic potential improvement in malt barley varieties.

MATERIALS AND METHODS

Description of the study sites

The experiment was executed at Adadi testing site and Holetta Agricultural Research Center during the main cropping season in 2009 under rain-fed condition. Holetta Agricultural Research Center is located at 9° 00′N, 38° 30′E and an altitude of 2400 m above sea level. It is characterized with mean annual rainfall of 1044 mm, mean relative humidity of 60.6%, and mean maximum and minimum temperature of 22.1 and 6.2°C, respectively. Adadi testing site is situated at 8° 38′N and 38° 30′E with an altitude of 2050 m above sea level and an average annual rain fall of 900 mm (Gemechu, 2007).

Experimental materials

Table 1 Description of malt barley varieties released since 1973

SN	Variety Name/ Pedigree	Origin/Description	Year of release
1	Beka	Introduction from France	1973
2	Holker (EH8B/F4.E.L.7.L)	A cross made at Holetta from Hol. mixed and Kenya Research	1979
3	HB-120 (EH 661/F2-6H-5-1.OH)	A cross made at Holetta with EH11/ F3.A.I.A.L. / Beka	1994
4	HB-52 (EH 172/F2-H.2.9H.2.2)	A cross made at Holetta with comp-29 / Beka	2001
5	HB-1533 (B/F2 (S x W) 179/86.7.4.3/	Introduction from ICARDA and selected at Holetta	2003
6	Miscal-21 (SHYRI//GLORIA-BAR/COPAL /3/SHYRI /GRIT)	Introduction from ICARDA/ CIMMYT and selected at Holetta	2006

Source: Fekadu, 1987 (NCIC); Crop variety registration, 2004, 2005, 2006

Experimental design and treatments

The experiment was conducted in a randomized complete block design with four replications. Each treatment was planted to a plot area of 3.0 m^2 consisting of six rows of 2.5 m long spaced 0.2 m apart between rows, 0.4 m between plots and 1.5 m between blocks. Seeds were treated with Gaucho® (Imidachlopride 70% WS) at 185 g with 125 kg seed per hectare to prevent barley shoot fly damage. Moreover, seeds were sown at a rate of 85 kg ha^{-1}. Fertilizer was applied during planting in the form of urea and Diamonium phosphate at the rate of 41/46 N/P_2O_5 ha^{-1}. Recommended weed management practice was undertaken and Propiconazol fungicide was sprayed at the rate of 0.5 l/ha in 200 liter of water to control foliar diseases. Besides, nylon and sisal string were used as a modified net to prevent lodging. Generally, maximum care was taken in this experiment to minimize the possible occurrence of yield limiting factors which could affect yield potential expression of the varieties as stated by Waddington *et al*.(1986); Evans and Fischer (1999); Abeledo *et al*.(2003).

Data collection

Description of data collection procedure is presented in (Table 2). Data on agro-morphological traits of malting barley varieties were collected on plot and plant basis according to Anderson *et al*. (2002) and descriptors for barley (IPGRI, 1994). Moreover, data on malting barley quality attributes were collected on plot basis.

Table 2 Descriptions of agro-morphological traits and quality parameters of malt and food barley varieties on plant plot basis

Traits	Description
Days for Flowering (DF)	Recorded as number of days from sowing to the date on which 50% of the plants in four central rows of a plot have produced their first flower
Days to Maturity (DM)	Recorded as number of days from sowing to the stage when 75% of the plants in four central rows of a plot have reached maturity
Grain Filling Period (GFP)	Number of days between days for flowering and days to physiological maturity
Thousand Kernel Weight (TKW)	Weight in gram of random sample of thousand seeds per plot
Hectoliter Weight (HLW)	Hectoliter weight is flour density produced in a hectoliter of the seed and it was determined using moisture and hectoliter analyzer
Biological Yield (BMY)	Determined by weighing the total air dried above ground biomass harvested from the four central rows and expressed in kg ha^{-1}
Grain Yield (GY)	Grain yield in kilogram of the four central rows adjusted to 12% moisture content expressed in kg ha^{-1}
Harvest Index (HI)	Calculated as a ratio of dry weight of the grain to dry weight of the total above ground biomass yield and expressed as a percentage
Biomass Production Rate (BMPR)	Computed by dividing the above ground biomass yield to number of days to physiological maturity and expressed as kg ha^{-1} day^{-1}
Total Grain Sink-Filling Rate (GSFR)	Calculated as the ratio of grain yield to number of days from flowering to physiological maturity and expressed as kg ha^{-1} day^{-1}
Spike Grain Sink-Filling Rate (SGSFR)	Calculated as the ratio of grain dry weight per spike to number of days from flowering to physiological maturity and expressed as mg $spike^{-1}$ day^{-1}
Plant Height (PH)	Measured as a height in centimeter from the soil surface to the tip of the spike excluding the awns at maturity and expressed as an average of ten plants per plot
Tillers Per Plant (TPP)	Number of tillers per plant excluding the main plant recorded at maturity and expressed as an average of ten plants per plot
Spikes Per Plant (SPP)	The number of fertile tillers per plant including the main plant recorded at maturity and expressed as an average of ten plants in a plot
Spikes Length (SL)	Spike length of main tiller measured in cm from base to tip excluding the awns and expressed as an average of ten plants in a plot

Table 2 Descriptions of agro-morphological…. (*Continued*)

Spikelet Number Per Spike (SNPS)	Recorded by counting the number of spiklet on each spike on main tiller of each a plant and expressed as an average of ten plants in a plot
Kernel Number Per Spike (KNPS)	Determined by counting the number of kernel produced on the main tiller of each plant and expressed as an average of ten plants in a plot
Spike Weight (SW)	Determined by weighing spike of the main plant as an average of ten plants in a plot
Sieving Test (ST)	Kernel size distribution for malting barley was determined using European normal sorting sieve machine which has oblong (slotted) holes of 2.8, 2.5 and 2.2 mm in width100 g barley seed sample was placed on the machine and by shaking it for five minutes Proportion of the seed trapped (passed) by each sieve was determined and converted to percentage
Moisture Content (MC)	Eight gram bulk seed sample from each plot was milled and five gram flour was placed in tarred moisture dishes and then oven dried for one hour at 130^{0}C. After oven dry the sample was weighed to determine moisture content
Germination Energy (GE)	Determined by germinating 100 seed sample on Petri dish and after 72 and 120 hours the germinated kernels were counted and the result was finally expressed as percentage of the total
Germination Capacity (GC)	Determined as the percentage of all living kernel in the sample. Two hundred seeds were soaked with 0.3 H_2O_2. Sample counting was done after 24 hrs and germination of seed calculated
Protein Content (PC)	Protein content was determined using Kjeldahl method, Nitrogen percent was calculated from the procedure as V_{HCL} is volume of HCL in litter consumed to the end point of titration V_{HCL} blank is volume of HCL consumed in liter to titrate the blank(sample containing all chemicals for Kjeldahl procedure), NHCL is Normality of the HCL used and 14.00 is Molecular Weight of Nitrogen
%Nitrogen =	$$\left(\frac{(V_{HCL} - V_{HCL\,blank})\ x\ N_{HCL}\ x14.00}{Sample\ Weight\ on\ DM\ basis} \right)$$ **Protein Content = %N x 6.25**

Statistical analysis

All measured agro-morphological traits and malting quality parameters were subjected to analyses of variance using SAS software version 9.00 (SAS, 2002). Bartlett's test for homogeneity of variance was carried out to determine the validity of the individual experiment and thereafter, combined analyses of variance were performed using PROC GLM procedure where genotypes were fixed and locations were random. Percent data on kernel size test of malting barley parameter were transformed by arcsine for kernel sieve test 2.8 mm and square root for the rest according to Gomez and Gomez (1984). Log transformation was used for those data which exhibited heterogeneity of variance. Mean separation was carried out using Duncan's Multiple Range Test (DMRT) at 5% of significance.

Linear regression analysis was used to calculate the genetic yield potential gain for each trait considered in the study. The breeding effect was estimated as a genetic gain for grain yield, quality and other agronomic traits in barley improvement by regressing mean of each character for each variety against the year of release of that variety using PROC REG procedure. The relative gain achieved over the year of release period for traits under consideration was determined as a ratio of genetic gain to the corresponding mean value of oldest variety and expressed as percentage. Pearson product moment correlation coefficients among all characters were computed using means of each variety in each year using PROC CORR procedure.

Individual location ANOVA Model

$$Y_{ij} = \mu + G_i + B_j + e_{ij}$$

Y_{ij} = observed value of genotype i in block j

μ = grand mean of the experiment, G_i = effect of genotype i, B_j = effect of block je_{ij} = random error effect of genotype i in block j

Combined ANOVA Model

$$Y_{ijk} = \mu + G_i + E_j + GE_{ij} + B_{k(j)} + e_{ijk}$$

Y_{ijk} = observed value of genotype i in block k of location j; μ = grand mean, G_i = effect of genotype i, E_j = Environmental or location effect GEij = the interaction effect of genotype i with location (environment) j $B_{k(j)}$ = effect of block k in location (environment) j e_{ijk} = random error (residual) effect of genotype i in block k of location(environment) j The functional form of linear relationship between a dependent variable **Y** and independent variable **X** is represented by the following equation.

$$Y = \beta_0 + \beta_1 x,$$

Where Y= the value of the dependant variable, X= the independent variable, β_0 = the intercept of the line, β_1= the regression coefficient or slope of the line, or the changes in y per unit change in x.

Annual rate of gain (b) = $\dfrac{CovXY}{VarX}$

Where: Cov = Covariance, Var = Variance, X= the year of release of the variety, Y= the mean value of each character for each variety. The relative annual gain achieved over the last 36 years for food barley and 33 years for malting barley was determined as a ratio of genetic gain to the corresponding mean value of oldest variety and expressed as percentage.

$$r_{xy} = \frac{Cov(X,Y)}{\sqrt{V(X)V(Y)}}$$

Where: r_{xy} = correlation coefficient between x and y, Cov (x,y) = Covariance between x and y; V(x) = Variance of x, V(y) = Variance of y

RESULTS AND DISCUSSION

Varietal performance in grain yield and other agro-morphological traits

Mean squares from the combined analysis of variance for different morpho-agronomic traits indicated significant genotypic effect for days to flowering, days to maturity, harvest index, plant height, and spike length and spikelet number per spike while the remaining traits including grain yield showed no significant difference (Table 3). Mean squares for genotype by location interaction were significant for most of the traits except biomass yield, biomass production rate, and number of tillers per plant, number of spikes per plant and spike length, indicating similar performance of these traits in different locations. Moreover, there were significant location effects for most of the traits except grain yield, biomass production rate, and plant height, number of tillers per plant, spike length, spikelet number per spike, and kernel number per spike.

Mean performance of agro-morphological traits

Mean grain yield, biomass yield and harvest index of malt barley varieties in each location and mean values combined over locations is presented in (Table 4).The highest location mean grain yield was obtained at Adadi. Malt barley varieties showed significant ($P< 0.01$) difference from each other for mean grain yield at Holetta and Adadi locations. At Holetta all varieties showed similar performance except Holker which gave the lowest mean value. At Adadi, Holker gave significantly lowest grain yield of 3441.5 kg ha^{-1}, while HB-120 produced the highest grain yield of 4719.4 kg ha^{-1} though it was at par with HB-120 and Miscal-21 varieties.

Combined analysis over locations mean grain yield of malt barley varieties ranged from 3279.5 kg ha^{-1} for Holker to 4449.7 kg ha^{-1} for Miscal-21. Differences among varieties for grain yield were non-significant. The recent released varieties such as HB-1533 and Miscal-21 are early maturing, tolerant/resistant to the major barley diseases compared to Beka which is susceptible to leaf diseases. This indicates that barley breeders focused more on other traits like malt grain qualities and disease resistance than grain yield per se in malt barley improvement. It was also reported that improvement in yield potential often slow owing to stringent quality requirement (Burger and LaBerge, 1985; Douches *et al*., 1996; Heisey *et al*., 2002). However, several authors in different countries ascertained that grain yield of modern barley varieties were markedly higher than that of the oldest ones (Riggs *et al*., 1981; Wych and Rasmusson, 1983; Martintello *et al*., 1987; Boukerrou and Rasmusson, 1990; Bulman *et al*., 1993; Ortiz *et al*., 2002 and Abeledo *et al*., 2003).

Table 3 Mean squares of agro-morphological traits from the combined analysis of variance for malt barley varieties grown at Adadi and Holetta

		Mean squares (MS)					
No.	Trait	Genotype(5)□	Location(1)	Gen x Loc (5)	Error (30)	Mean	CV (%)
1	DF	335.34*	3250.52**	61.67**	5.80	93.19	2.59
2	DM	471.67**	14386.69**	58.64**	1.87	143.10	0.96
3	GFP	28.58ns	3960.33**	202.68**	5.08	49.92	4.51
4	TSW	77.61ns	311.61**	36.97**	1.59	47.79	2.64
5	HLW	14.62ns	499.23**	10.23**	1.62	69.42	1.83
6	BMY	19860250.00ns	37276875.00*	4865625.0ns	2822437.50	12225.00	13.74
7	GY	761401.28ns	285206.79ns	555146.87**	172679.87	4128.91	10.06
8	HI	127.19**	412.31**	6.95ns	7.74	34.53	8.06
9	MBPR	619.26ns	866.49ns	221.71ns	131.52	85.91	13.35
10	GSFR	191.92ns	13648.51**	786.68**	98.35	86.65	11.44
11	SGSFR	36.76ns	991.72**	48.39**	7.81	32.11	8.70
12	PH	1574.11**	215.18ns	45.29**	11.58	114.81	2.96
13	TPP	3.51ns	0.25ns	1.73ns	0.87	7.93	11.73
14	SPP	3.82ns	7.97*	1.59ns	0.92	7.19	13.34
15	SL	9.93**	1.93ns	0.37ns	0.16	9.33	4.27
16	SNPS	33.36*	8.20ns	6.09*	2.11	28.69	5.07
17	KNPS	13.48ns	5.13ns	4.59**	1.43	28.99	4.12
18	KWPS	0.09ns	0.25*	0.05**	0.005	1.55	4.70
19	SWT	0.22ns	1.03**	0.08**	0.01	1.88	5.31

□ = Numbers in parenthesis represent degrees of freedom; ** Significant difference at ($p < 0.01$); * Significant difference at ($P < 0.05$)

DF-Days to flowering (days); DM- Days to maturity (days); GFP -grain filling period (days); HLW-Hectoliter weight (kg/hl); GY-Grain yield (kg ha^{-1}); BMY-Biomass yield (kg ha^{-1}); HI- Harvest index; BMPR -Biomass production rate (kg ha^{-1} day^{-1}); GSFR-Total grain sink filling rate (kg ha^{-1} day^{-1}); SGSFR -Spike grain sink filling rate (mg $spike^{-1}$ day^{-1}); TPP -Tillers per plant (No.); SPP- Spikes per plant (No.); PH-Plant height (cm); SL -Spike length (cm); SW -spike weight (g); KWPS-kernel weight per spike (g); KNPS -kernel number per spike; TKW -Thousand kernel weight (g); SNPS -Spikelet number per spike

There were significant differences among malt barley varieties for biomass yield at both test locations. At Holetta, HB-1533 gave the highest biomass yield though it was at par with the oldest varieties excluding Holker. Similar biomass yield performance was noticed at Adadi location, the highest being for HB-120 variety though it was at the same level with Beka, HB-52 and HB-1533 where as Holker gave the lowest mean value. The lowest mean biomass yield was recorded at Holetta while the highest was at Adadi. This indicates favorable growth condition at Adadi as compared to Holetta. Besides, over location mean biomass yield depicted that there was non-significant difference among varieties.

There was also significant difference for harvest index among the genotypes at all locations. Miscal-21 exhibited discernibly ($P< 0.01$) higher mean harvest index than other varieties at both locations. Moreover, over locations mean harvest index exhibited significant difference among varieties, the highest mean being Miscal-21 whereas the rest of the varieties were at par with each other.

Malt barley varieties combined over Adadi and Holetta showed significant ($P< 0.05$) variations in days to flowering and days to physiological maturity, but marked difference was not detected among genotypes in grain filling period (Table 5). Average number of days to reach flowering ranged from 80 days for Miscal-21 to 98 days for Beka. However, the modern variety HB-1533 was not different from Beka in days to flowering. On the other hand, days to physiological maturity markedly ranged from 128 to 147 days. Significantly shortest days to flowering and physiological maturity were for the new variety Miscal-21 while the other varieties except Holker showed similar trend of longer period to reach physiological maturity. Muluken (2007) reported that the recently released variety Miscal-21 mature early and best fits to the early barley system of the country besides its high yield potential.

Table 4 Mean values of grain yield, biomass yield and harvest index of malt barley varieties over two locations and at each location

YoR	VARIETY	Locations						Over Location Mean		
		Holetta			Adadi					
		BMY	GY	HI	BMY	GY	HI	BMY	GY	HI
1973	Beka	15113.0a	4236.6a	28.4c	11675.0ab	4105.3bc	35.2bc	13393.8	4171.7	31.4c
1979	Holker	10238.0c	3117.4b	33.9b	9400.0c	3441.5d	38.7b	9818.8	3279.5	33.4c
1994	HB-120	13763.0ab	3781.1a	27.4c	12913.0a	4719.4a	36.7bc	13337.5	4250.3	32.0c
2001	HB-52	13000.0abc	4020.4a	30.9bc	12525.0a	4455.8ab	35.9bc	12762.5	4238.1	33.4c
2003	HB-1533	15113.0a	4435.3a	29.4bc	11337.5abc	3809.5cd	34.0c	13368.8	4122.4	31.7c
2006	Miscal-21	11125.0bc	4395.1a	39.6a	10212.0bc	4504.3ab	44.1a	10668.8	4449.7	41.9a
Mean		13106.3	3997.7	31.6	11343.8	4172.7	37.5	12225.0	4085.3	33.9
CV (%)		14.9	10.7	9.67	12.0	8.4	6.61	13.74	10.06	8.1
R^2		0.67	0.68	0.76	0.66	0.75	0.78	0.70	0.63	0.84

Means followed by a common letters with in a column are not significantly different from each other at P≤ 0.05 according to Duncan Multiple Range Test;GY-Grain yield (kg ha^{-1}); BMY-Biomass yield (kg ha^{-1}) and HI- Harvest index (%)

Malt barley varieties released since 1973 showed significant ($P< 0.01$) variation in plant height, and spike length (Table 5). In this study the mean plant height combined over locations, was significantly higher for HB-1533 (128 cm) while Miscal-21 and Holker had the shortest height 98 and 96 cm respectively. Similarly, varieties exhibited marked difference in spike length ranging from 7.5 to 10.2 cm. They also showed variation in spikelet number per spike. Beka, HB-120 and HB-52 showed similar trend of the highest mean spikelet number per spike while the rest of the varieties showed similar performance. Moreover, combined data of malt barley varieties showed no marked difference for all the other agronomic traits. Significantly high spike length was recorded in HB-120, HB-52 and Beka, while Holker produced the shortest spike length. According to ESA (2001) the standard set by National Standard Authority of Ethiopia, 1000-kernel weight and hectoliter weight in malt barley ranged from 35 to 45 g and 60 to 65 kg hl^{-1} respectively. In this study, despite the fact that there was no significant difference in thousand kernel weight and hectoliter weight among varieties released in different era, mean values of all varieties were greater than the minimum standard indicating consistency in maintaining quality requirement for these traits in malt barley improvement in Ethiopia(Table 5).

Performance of malt barley varieties in some quality attributes

Mean squares from the combined analysis of variance for malting quality characters revealed that, genotypes were not significantly different from each. Moreover, locations significantly affected kernel size and grain protein content. Genotype by location interaction was also significant for sieve size test and grain protein; indicating differential performance of genotypes across locations with respect to these traits (Table 6). Mean values of different malt quality characters for successively released malt barley varieties since 1973, combined over Holetta and Adadi is presented in Table 7. Kernel sizes distribution for malting barley varieties were graded using standard procedure. Accordingly, there was no significant difference among varieties for different screen sizes tested. Mean values of kernel retained on screen size (2.5 mm + 2.8 mm) ranged from 81.57% for Beka to 92.27% for HB-1533 variety. Similarly, the mean kernel size that pass through the sieve which is <2.2 mm screen ranged from 3.63% for Beka to 0.89% for Miscal-21. According to ESA (2001) and Williams *et al*. (1988), percent kernel sample retained on (2.8 mm +2.5 mm) screen sizes should be greater than 65 to 75% while kernel sample which pass through sieve size < 2.2 mm should not be more than 4 to 6%. From this study it is evident that in an effort to improve grain yield potential of malting barley varieties, required quality standard in kernel plumpness has been maintained. Miscal-21 showed significantly low percent mean value for germination energy at both 72 hr and 120 hr which might be attributed to relative seed dormancy of this variety. In agreement to this result Muluken (2007) in the study of genotype by environment interaction in malt barley reported that Miscal-21 showed low germination energy as compared to other barley varieties. Generally, this indicates the need for determination of seed dormancy period for each variety before commencing to malting process. However, combined analysis over locations revealed that there were non-significant differences among varieties for mean germination energy and germination capacity test though Miscal-21 showed relatively low mean value. Nonetheless, as per the suggestions of Kinaci and Donmez (1998) and ESA (2001), all varieties demonstrated required standard set for malt barley quality for both germination energy and germination capacity which ranged from 90 to 95% and 96 to 98% respectively. However, combined mean of malt barley varieties didn't exhibit marked difference for protein content. However, Muluken (2007) indicated that protein content of Miscal-21 was relatively higher than the other released malting barley varieties. However, mean value of kernel protein content in this study was within the range of acceptable quality standards set by National Standard Authority. The acceptable standard limit for malt barley kernel protein content should be within the range of 9 to 12% (ESA, 2001). The recommended protein level for six and two row barley in USA also varies from 12.0 to 13.5 and 11.5 to 13.0 respectively (Burger and LaBerger, 1985). Mean values of malt barley varieties showed non-significant difference for moisture content which ranged from 7.9 to 8.4% (Table 7). Primarily, moisture determination in malting barley is to permit other quality factors to be expressed on dry matter basis and for safe storage (Burger and LaBerge, 1985). Generally in the last thirty years in Ethiopia, barley breeders developed varieties within the range of kernel quality standard while improving yield potential of morphological traits of malt barley varieties. Wych and Rasmusson (1983) stated that breeding goal in malt barley is to maintain the required quality levels, thus little or no changes in quality characters indicate effective selection.

Table 5 Agro morphological attributes of malt barley varieties grown in yield potential trial combined over Adadi and Holetta, 2009

Variety	DF Ω	DM	GFP	BMPR	GSFR	SGSFR	PH	SL	TKW	HLW	TPP	SPP	SNPS	KNPS	KWPS	SWT
Beka	98.00a	147.30a	49.60	90.90	88.70	31.80	123.50b	9.94ab	46.00	69.90	8.20	7.50	29.92a	29.35	1.54	1.79
Holker	94.90b	143.90b	49.00	69.00	78.50	34.20	96.40c	7.50d	48.50	67.40	7.20	6.50	26.81b	28.54	1.58	1.95
HB-120	94.80b	146.50a	51.80	92.50	87.20	32.50	122.20b	10.20a	46.60	70.70	8.50	7.80	31.04a	30.36	1.62	1.97
HB-52	94.50b	147.00a	52.50	88.10	85.60	31.00	120.70b	10.16a	46.00	70.50	8.80	8.10	30.58a	30.42	1.57	1.89
HB-1533	97.00ab	146.40a	49.30	91.00	86.20	34.70	128.30a	9.73b	53.80	69.90	7.60	6.70	27.27b	28.19	1.65	2.08
Miscal-21	80.30c	127.60c	47.40	84.00	93.70	28.60	97.60c	8.41c	45.80	68.20	7.30	6.60	26.52b	27.11	1.35	1.61
Mean	93.20	143.10	49.90	85.90	86.70	32.10	114.8	9.30	47.80	69.4	7.90	7.20	28.70	29.00	1.60	1.90
CV (%)	2.58	0.96	4.51	13.35	11.44	8.70	2.96	4.27	2.64	1.83	11.7	13.3	5.07	4.12	4.70	5.31
R^2	0.97	0.99	0.97	0.64	0.88	0.87	0.96	0.92	0.95	0.93	0.54	0.59	0.79	0.74	0.88	0.90

Table 6 Mean squares of quality characters from the combined analysis of variance on malt barley varieties at Holetta and Adadi

No.	Kernel Quality Test	Mean squares (MS)			Error (30)	Mean	CV (%)
		Genotype(5)$^{\psi}$	Location(1)	Gen x Loc (5)			
1	2.8 mm size	499.17^{ns}	7432.90**	125.91**	27.69	26.08	18.13
2	2.5 mm size	415.09^{ns}	1738.69**	145.71**	21.55	62.66	4.77
3	2.2 mm size	75.94^{ns}	1296.77**	75.69**	3.75	9.53	23.85
4	< 2.2 mm size	7.66^{ns}	65.43**	5.16**	0.64	1.79	34.84
5	2.8+ 2.5mm size	127.67^{ns}	1981.73**	121.37**	5.92	88.74	3.99
6	GE at 72 hr	29.15^{ns}	0.75ns	22.45*	8.16	98.13	1.46
7	GE at 120 hr	4.00^{ns}	0.75ns	5.45ns	2.40	99.00	0.75
8	GC (H_2O_2)	0.18^{ns}	9.76ns	0.05ns	0.07	99.92	0.15
9	MC	0.29^{ns}	6.89ns	0.69ns	0.57	8.15	4.64
10	KPC	2.08^{ns}	65.1**	0.85**	0.29	10.78	3.00

 = Numbers in parenthesis represent degrees of freedom; ** Significant difference at (p< 0.01); * Significant difference at (P< 0.05); and ns- non significant; MC- moisture content; GE- (%) Germination energy; GC- (%) Germination capacity; PC-Kernel protein content; hr-hour

Table 7 Mean values of quality attributes of malt varieties grown in yield potential trial at Adadi and Holetta

Variety	Sieve size					GE (%)◈at		GC (%)◈ H_2O_2	KPC (%)	MC (%)
	2.8 mm$^{\Phi}$	2.5 mm◈	2.2 mm◈	< 2.2 mm◈	2.8+2.5 mm◈	72 hr	120 hr			
Beka	18.86	62.71	14.81	3.63	81.57	99.13	99.63	100.00	10.49	7.94
	(25.22)	(8.28)	(3.00)	(1.28)	(9.40)	(9.98)	(9.98)	(10.00)	(3.17)	(2.79)
Holker	33.85	53.04	11.44	2.02	86.93	99.00	99.13	100.00	10.26	8.29
	(33.14)	(7.53)	(2.80)	(1.08)	(9.49)	(9.89)	(9.93)	(10.00)	(2.25)	(2.88)
HB-120	19.42	71.01	8.05	1.52	90.43	99.00	99.50	99.88	10.68	8.44
	(27.86)	(8.07)	(2.81)	(1.28)	(9.38)	(9.91)	(9.94)	(9.99)	(3.35)	(2.89)
HB-52	18.89	70.59	8.93	1.58	89.49	97.88	98.63	100.00	10.69	8.01
	(28.40)	(8.10)	(2.76)	(1.25)	(9.44)	(9.94)	(9.98)	(9.99)	(3.33)	(2.90)
HB-1533	35.47	56.80	6.59	1.14	92.27	99.38	99.38	100.00	10.84	8.05
	(34.24)	(7.44)	(2.81)	(1.16)	(9.42)	(9.96)	(9.96)	(10.00)	(3.27)	(2.79)
Miscal-21	29.98	61.79	7.34	0.89	91.77	94.38	97.75	99.63	11.74	8.19
	(28.66)	(7.87)	(3.23)	(1.22)	(9.33)	(9.75)	(9.91)	(9.99)	(3.29)	(2.85)
Mean	26.08	62.66	9.53	1.79	88.74	98.13	99.00	99.92	10.78	8.15
CV (%)	18.13	4.77	23.85	34.84	3.99	1.46	0.75	0.15	3.00	4.64
R^2	0.84	0.81	0.73	0.66	0.59	0.59	0.51	0.27	0.87	0.73

Numbers in parenthesis are transformed values; GE- Germination energy; GC- Germination capacity; MC- moisture content; KPC- Kernel protein content; hr- hour; Φ- arcsine transformation; ◈-square root transformation

Trend in improvement of grain yield potential and some quality traits

Yield potential improvement of malt barley varieties showed slow progress since 1973, when the first malt barley variety was released. Varieties differed in grain yield in both test locations, even though slope of regression since 1973 was not significantly different from zero at each location as well as over locations. Nonetheless, excluding Beka, yield potential increased from 3280 kg ha $^{-1}$ to 4450 kg ha^{-1} during the period from 1979 to 2006. Essentially, Beka was known for its yield potential for the last three decades and still under production (Tadese, 2011). Fekadu *et al.* (1996) also reported on yield potential of this variety and it has been among the parents frequently used in malt barely crossing program. Hence, linear regressions of the mean grain yield of varieties on the year of release of varieties since the release of Holker (1979) excluding Beka showed slope significantly different ($P< 0.05$) from zero (Table 8). The regression line (Figure 1D) and (Table 9) indicated that progress in grain yield potential improvement showed yield gain of 28.95 kg ha^{-1} (0.88%) year^{-1} over the last twenty seven years period. On the other hand, significant evidence of improvement was not detected for other morpho-agronomic traits except total grain sink filling rate. It was shown in some other crops that, progress in raising yields potential may be slowed owing to emphasis on other varietal characteristics, such as grain quality (Douches *et al*. 1996; Evans and Fischer, 1999; Heisey *et al*., 2002). Nonetheless, Wych and Rasmusson (1983) in their investigation of genetic improvement in barley since 1920, they found the average annual increase over 58 years period was 22.1 kg ha^{-1} (0.9%) year^{-1}. The annual gain for 36 years period was doubled (45.7 kg ha^{-1} or 2.0% per year).

Regression slope of malt barley sieving tests on year of release of the varieties showed significant ($P<0.01$) difference from zero for sieve sizes; 2.5 mm+2.8 mm, 2.2 mm and <2.2 mm screen sizes (Figure 1A, 1B, 1C). Kernel size retained on sieve size greater than 2.5 mm showed improvement of 0.27% year^{-1}. Likewise, kernel size which passes through ≤ 2.2 mm sieve significantly showed declining trends with year since 1973. On the other hand, regression coefficient for other quality attributes such as protein content, moisture content, germination energy and germination capacity were not significantly different from zero (Table 10). In line with this, genetic improvement in barley grain size was also attributed standard percentage change of 80% to 85% in the size of grain remaining on a 2.5 mm sieve size in Chile (Beratto, 2001). Wych and Rasmusson (1983) also reported significant achievement in improvement of kernel plumpness in malting barley varieties.

Table 8 Estimate of mean values, regression coefficient (b), coefficient of determination (R^2) and constant term for various agro-morphological traits from linear regression of malting barley varieties on YoR

No.	Traits	Overall mean	Since 1973			Since 1979		
			intercept/ constant	R^2	(*b*) based on Beka	intercept/ constant	R^2	(*b*) based on Holker
1	Days to flowering	93.19	98.04	0.27	-0.25	97.04	0.181	-0.27
2	Days to maturity	143.1	147.96	0.19	-0.25	147.21	0.133	-0.28
3	Grain filling period	49.92	49.87	0.002	0.002	50.18	0.064	-0.01
4	Thousand kernel weight	47.79	46.85	0.043	0.05	48.03	0.004	0.006
5	Hectoliter weight	69.42	69.04	0.037	0.02	68.21	0.209	0.063
6	Biomass Yield	12225.00	12078.00	0.004	7.45	10686.00	0.238	74.19
7	Grain Yield	4128.91	3864.92	0.352	13.42	3610.96	0.823	28.95*
8	Harvest index	0.35	0.32	0.144	0.0012	0.342	0.014	0.001
9	Biomass production rate	85.91	81.96	0.096	0.20	73.40	0.556	0.65
10	Total grain sink filling rate	86.65	83.45	0.202	0.16	78.66	0.742	0.43*
11	Spike grain sink filling rate	32.11	33.18	0.109	-0.05	34.39	0.296	-0.13
12	Plant height	114.81	113.73	0.003	0.05	103.38	0.157	0.54
13	Tillers per plant	7.93	7.89	0.001	0.002	7.58	0.059	0.02
14	Spikes per plant	7.19	7.22	0.001	-0.002	6.88	0.038	0.01
15	Spike length	9.33	9.05	0.029	0.01	8.16	0.285	0.06
16	Spikelet number per spike	28.69	29.18	0.028	-0.03	28.22	0.004	0.01
17	Kernel number per spike	28.99	29.43	0.054	-0.02	29.38	0.038	-0.03
18	Spike weight	1.90	1.89	0.002	-0.001	1.60	0.133	-0.004
19	Kernel weight per spike	1.55	1.58	0.048	-0.002	2.00	0.126	-0.006

* b values significantly different from zero at the probability level 0.05

Table 3 Estimate of mean annual relative genetic gain (%) and correlation coefficient of all traits with grain Yield (r_{gy}) and year of release of the varies (r_{yor})

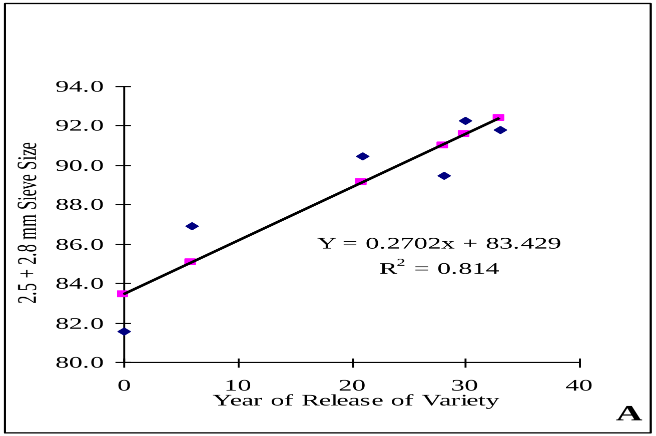
No.	Traits	Mean of traits of Holker	RGG (% year^{-1})	Correlation coefficient (r_{gy})	Correlation with YoR since Holker (r_{yor})
1	Days to flowering	94.88	-0.28	-0.47	-0.43
2	Days to maturity	143.88	-0.19	-0.37	-0.36
3	Grain filling period	49.00	-0.02	0.08	-0.06
4	Thousand kernel weight	48.50	0.01	-0.31	0.02
5	Hectoliter weight	67.35	0.09	0.52	0.46
6	Biomass Yield	9818.75	0.76	0.47	0.49
7	Grain Yield	3279.50	0.88	---	0.91*
8	Harvest index	0.334	0.003	0.12	0.12
9	Biomass production rate	69.03	0.94	0.80*	0.75
10	Total grain sink filling rate	78.58	0.55	0.93**	0.86*
11	Spike grain sink filling rate	34.17	-0.38	0.71	-0.54
12	Plant height	96.44	0.56	0.33	0.39
13	Tillers per plant	7.18	0.28	0.42	0.25
14	Spikes per plant	6.46	0.15	0.38	0.19
15	Spike length	7.50	0.80	0.58	0.53
16	Spikelet number per spike	26.81	0.04	0.31	0.06
17	Kernel number per spike	28.54	-0.11	0.002	-0.19
18	Spike weight	1.95	-0.21	-0.48	-0.35
19	Kernel weight per spike	1.58	-0.38	-0.44	-0.36

*, ** r significantly correlated at the probability level of 0.05 and 0.01 respectively

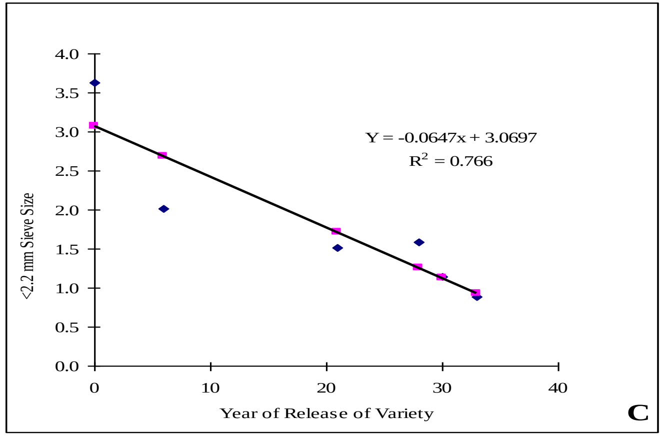
Table 10 Estimate of mean values, relative genetic gain, regression and correlation coefficients of some quality attributes of malt barley varieties combined over locations

Kernel Quality Test	Overall Mean	Mean of Beka	Regression (b)	R^2	Intercept	RGG% $year^{-1}$	Correlation	
							$r_{(yor)}$	$r_{(gy)}$
2.8 mm size	26.08	18.86	0.12	0.05	23.62	0.64	0.22	-0.43
2.5 mm size	62.66	62.71	0.15	0.08	59.78	0.24	0.27	0.65
2.2 mm size	9.53	14.81	-0.21**	0.87	13.68	-1.42	-0.94**	-0.38
< 2.2 mm size	1.79	3.63	-0.06**	0.81	3.07	-1.65	-0.90**	0.26
2.8+ 2.5 mm	88.74	81.57	0.27**	0.85	83.00	0.33	0.92**	0.32
GE at 72 hr	98.13	99.13	-0.07	0.29	99.60	-0.07	0.53	-0.54
GE at 120 hr	99.00	99.63	-0.03	0.37	99.62	-0.03	-0.61	-0.39
GC (H_2O_2)	99.92	100.00	-0.005	0.25	100.03	-0.01	-0.50	-0.58
MC	8.15	7.94	0.001	0.05	8.13	0.01	0.07	-0.19
KPC	10.78	10.49	0.03	0.53	10.25	0.29	0.73	0.74

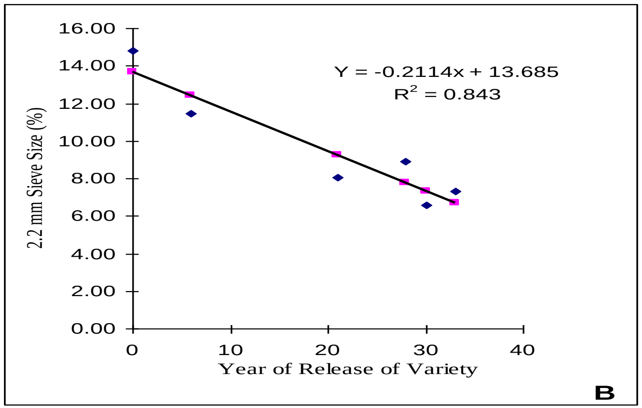
*, ** b and r values are significant at the probability level 0.05 and 0.01 respectively; MC- moisture content (%); GE- Germination energy (%); GC- Germination capacity (%); KPC- Kernel protein content; hr - hour



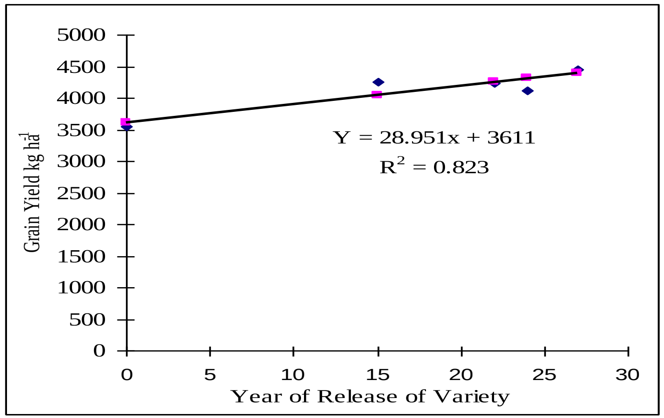
(A) Sieve test for 2.5 mm +2.8 mm kernel size



(C) Sieve test for <2.2mm kernel size



(B) Sieve test for 2.2 mm kernel size



(D) Plot of grain yield of malting barley varieties against years of release of varieties since 1979

Figure 1 Genetic improvement in grain yield and kernel plumpness of malt barley varieties

Association of characters with grain yield and some quality traits

Relative genetic gain of 0.88% $year^{-1}$ in grain yield was strongly (r= 0.93, P<0.01) associated with total grain sink filling rate and biomass production rate(r= 0.80, P<0.05). Moreover, grain yield and total grain sink filling rate showed significant (p<0.05) positive correlation with time of release of the varieties (Table 9). Besides, total grain sink filling rate significantly associated with biomass production rate. Moreover, year of release of the varieties significantly associated with improvement of kernel sieve size. There was significant and positive association between improvements in kernel size greater than 2.5 mm size and year of release of the varieties. Likewise, varietal age was significantly and negatively correlated with kernel size ≤ 2.2 mm size (Table 10). Nonetheless, there was no evidence for significant association between grain yield and those malting barley quality factors assessed in this study.

Selection for yield via highly correlated characters becomes easy if the contribution of different characters to yield is quantified (Dewey and Lu, 1959). Perry and D'Antuono (1989) in wheat, Wych and Rasmusson (1983), Martiniello *et al*. (1987), and Ortiz *et al*. (2002) in barley reported that gain in grain yield potential of modern varieties was largely attributed to improvement in harvest index. Ortiz *et al*. (2002) further noted that grain yield gain in new varieties of barley was associated with more spikes (fertile tillers) per unit area, superior lodging resistance and better adaptation to modern cultural practices. Donmez *et al.* (2001) indicated that kernel number was positively correlated with grain yield, biomass yield, harvest index, spike length and spkelet number and negatively correlated with heading date in the study of genetic gain in winter wheat. Tahir *et al.* (2000) found out that year of release of the variety was positively correlated with grain yield, thousand grain weight, harvest index and grains filling duration, but negatively correlated with days to flowering in wheat genetic improvement .

CONCLUSION

Yield potential experiments comprising six malt barley varieties were conducted to estimate progress made in grain yield and quality attributes of barley breeding in Ethiopia. Yield potential improvement of malt barley breeding was relatively less marked probably owing to stringent quality requirements. However, when 1979 is considered as a base year (the year Holker variety released) and excluding Beka, yield potential improvement has risen at annual rate of 28.95 kg ha^{-1}(0.88%) $year^{-1}$. Change in malt barley grain yield was markedly associated only with total grain sink filling rate and biomass production rate while year of release was significantly correlated with grain yield and total grain sink filling rate.

On the other hand, regression of kernel size of malting barley varieties on year of release showed that the slope significantly ($P< 0.01$) different from zero indicating improvement in kernel plumpness. Kernel size ≥ 2.5 mm showed significant improvement of 0.27% $year^{-1}$. Likewise, malt barley breeding in the past three decades substantially reduced nonstandard seed size in malt industry i.e. ≤ 2.2 mm as indicated in regression of sieve test since 1973 (-0.21%) $year^{-1}$. Besides, the other kernel quality parameters were maintained within the range of acceptable kernel quality standard. Moreover, there was significant and positive association between improvements in kernel size greater than 2.5 mm and time of release of the varieties and varietal age was significantly and negatively correlated with nonstandard kernel size ≤ 2.2 mm size.

In conclusion, absence of yield plateau indicated the potential for further progress in grain yield and grain quality parameters. In malt barley breeding, number of varieties released was very few and yield potential improvement showed slow progress. Hence, current malt barley breeding has to be supported by modern molecular techniques, small-scale micro malting and NIRS technology. This helps to identify and develop promising genotypes which are high yielding with acceptable quality standard suitable to the local breweries at preliminary stage of variety development. Moreover, the data generated in one season can be used as a baseline though it may not be comprehensive enough as a data found over many seasons and locations. Hence, it is suggested that other yield potential experiments need to be conducted in more locations and seasons with further emphasis to gain in relation to some physiological and other malt quality parameters.

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