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Adaptation Pattern and Feasibility of Food and Malting Barley (*Hordeum vulgare* L.) Varieties in the Central Highlands of Ethiopia

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Abstract

To identify the best food and malting barley (Hordeum vulgare L.) varieties for different environments and compare feasibility among barley types, six varieties of each type were studied at Adadi Mariam, Holetta and Jeldu in the central highlands of Ethiopia during the 2004 and 2005 main seasons. The best performing varieties varied across environments, and site regression ($SREG_2$) model GGE biplots (genotype plus genotype× environment) analyses clearly revealed the pattern. The food type barley 'Shege' suited most for lower altitude (Adadi Mariam, 2050 m a.s.l.) environment and the malting type 'Holkr' for higher altitude (Jeldu, 2850 m a.s.l.). Mid-altitude environment (Holetta, 2400 m.a.s.l.) shared the best food type, 'HB 1307', with the higher and malting types, 'Miskal' and 'HB 120', with the lower altitude environments. The improved food types out-yielded the malting and the local cultivars. The mean grain yield differential between improved food and malting types approached 16.3% while the advantage over the local was 23%. Malting grain quality parameters, protein content and thousand-kernel weight were within the acceptable levels for malt. However, to entice growers, premium for malting over food grain is a necessity, and its setting should consider relative yields and the prevailing food barley grain price along with the extra-efforts to maintain quality and access market. Considering the best varieties among the barley types at each location, the mean marginal rate of return for producing malting barley was found to be 242%. Therefore, malting barley production in the study areas seems feasible. Generally, in diverse agro-ecologies, maximizing the potentials of the areas and agricultural technologies largely harp on appropriate technology use and efficient enterprise choice through agronomic and economic fitness tests.

Key words: Adaptation pattern, barley, feasibility, *Horduem vulgare* L., premium, $SREG_2$ model, yield differential,

Introduction

Barley (*Hordeum vulgare* L.) cultivation is antique for Ethiopia, where it is predominant crop in the highlands that are characterized by rugged topography, degraded environment, and diverse agro-ecologies (Gamst, 1969; Birhanu *et al*., 2005). North, west and southwest Shewa zones in the central highlands of Ethiopia are among the major barley producing areas accounting for 15% and 16% of the nation's total annual barley area and production, respectively (CSA, 2009a, 2009b). Food type barley, with low productivity of 1.5 t ha^{-1}, is exclusively cultivated in those areas where experiences on malting barley production and information on its feasibility are lacking. On the other hand, with the upcoming establishment of more breweries, the nation's malt requirement is steadily growing. Currently, the national malt requirement excelled 60,000 t per year (personal comm.), but only about 35% of this is supplied by Assela Malt Factory (AMF) with deficit is being fulfilled through import (CSA, 2008a, 2008b, 2010). To fill the gap, AMF has expanded its capacity (currently receiving 33,000 t of raw barley per year) and the establishment of other new malt factory is also under way. The current and the future demand on raw malting barley is quite high; hence, focusing on local production to cope up with the growing need is of paramount importance since lack of foreign currency is making imports difficult. However, prior to venturing into the business, feasibility assessment both in agronomic performance and economic terms along with studying the basis for premium setting are relevant. So far such information are not documented in any barley growing areas of the country, though premium for malting over food barley grain is currently being exercised by the local maltsters.

Generally, to maximize the benefits from improved technologies and the potentials of different agro-ecologies, fitness tests with respect to farmers' circumstances, adaptability, and feasibility are relevant. Therefore, an adaptation trial of the existing food and malt barley varieties at different locations in the major barley growing central highlands of Ethiopia would be imperative in order to identify the most suitable food and malting barley varieties for the different environments and get indications for efficient enterprise choice among food and malting barley technologies.

Materials and Methods

Experimental treatments and test locations

Six malting and five food type improved barley varieties and one food type local cultivar from each location were compared with half and full recommended fertilizer rates (21/23 and 41/46, kg/ha, N/P_2O_5, respectively) during the 2004 and 2005 main seasons. Two fertilizer rates were used mainly to assess the effect on the quality of malting barley grain since most sites were new for malting barley culture. The improved varieties were earlier and recent releases. The test locations were Adadi Mariam, Holetta, and Jeldu, in the central highlands of Ethiopia. Adadi Mariam, located at 08^0 31' N, 38^0 34' E, and 2050 m above sea level, has a light vertic soil with a pH 7.5, and about 800 mm mean annual rainfall. Holetta, located at 09^0 03' N, 38^0 30' E, and 2400 m altitude, has Nitisol soil type with a pH 5.25 and 1000 mm mean annual rainfall. Jeldu, located at 09^0 16' N, 38^0 06' E, and 2850 m altitude, has Nitisol soil type with a pH 4.97 and a mean annual rainfall above 1200 mm.

Experimental design and management

Split-plot design with three replications was employed with fertilizer rates assigned to the main plots and varieties to the sub-plots. The sub-plot size was 2 m x 2.5 m = 5 m^2 (10 rows of 2.5 m length at 20 cm row spacing) of which 4 m^2 (the central eight rows) was harvested to measure grain and above ground biomass yields. Seed rate of 75 and 85 kg ha^{-1} was drilled for malting and food, respectively, as per the recommendations for each type (IAR, 1989). One herbicide spray and one hand weeding were practiced for weed control.

Data collection

On plot basis, data were taken on grain and above ground biomass yields, days to head and mature, plant height, lodging (%), major barley leaf diseases, hectoliter weight, and thousand-kernel weight. Besides, grain protein content (%) for the malting types was determined as per the Kjeldahl procedure (AOAC, 1980).

Data analysis

Homogeneity of error variance of the separate data were tested and combined analyses of variance were performed for grain and biomass yields, agronomic and quality traits following the procedures described in FAO (2002). $G \times E$ interaction was partitioned using joint regression and *AMMI* models. Sites regression ($SREG_2$) model was employed to display the varieties adaptation and environment patterns (Yan *et al*., 2001). Environmental variances (S_i^2) were also estimated to assess the stability of the varieties in the static concept and to compute grain yield reliability as Kataoka's Index (I_E) setting P value at 0.95. Indications on the associations of traits were obtained from simple correlation analyses. All analyses were done using the packages of SAS (1987) and IRRISTAT as per the detailed adopted procedures reported in FAO (2002). Partial budget analysis was employed to get indications on the feasibility of malting barley production.

Results and Discussion

Variations between locations and seasons

The combined analyses of variance revealed that locations significantly ($P \leq 0.05$) differed for days to head and maturie, disease incidence, and biomass yields. Where the varieties flowered and matured earlier, spot blotch and leaf rust incidences and biomass yield were higher in the lower (Adadi Mariam) than in the higher (Jeldu) altitude areas. Location effect on grain yield, 1000-kernel weight and protein content was not significant. However, year main and location × year interaction effects were highly significant ($P \leq 0.01$) on grain yield, 1000-kernel weight and protein content.

Grain yield and protein content were lower and 100-kernel weight was higher in 2005 at all locations mainly due to the excess rain of the season that caused severe water logging (data not shown). Change in rank for grain yield and 1000-kernel weight among locations and differences in the magnitude of the change in protein content were apparent indicating the cause for the significance of location × year interaction effects.

Although the higher fertilizer rate significantly hastened maturity, its effect on grain yield, 1000-kernel weight and protein content was not significant in the combined analyses. However, fertilizer × year interaction effect was highly significant ($P \leq 0.01$) on grain yield such that the response to the higher fertilizer rate was significant in 2004 but not in 2005 at all locations. The favorable condition of 2004 has increased grain yield and protein content and decreased 1000-kernel weight with an increase in fertilizer rate. Similarresults were also reported in previous studies with nitrogen rates (Bulman and Smith, 1993; Weston, *et al*. 1993). The prolonged rain of 2005 might have favored grain filling to improve 100-kernel weight though the excess rain was detrimental at an early stage to cause poor crop performance and inefficient fertilizer use, hence, lower grain yield and protein concentration.

Varietal and environmental influences

Owing to the differences in the error terms considered for the F tests in the combined analyses of variance and $G \times E$ analyses, inconsistencies in the significance of varietal differences for some traits were observed. Varietal main effects on grain yield and 100-kernel weight were not significant in the combined analysis of variance but significant in the $G \times E$ analysis, though differences on protein content were not significant under both situations.

Genotype × environment ($G \times E$) interaction effects were highly significant ($P \leq 0.01$) on grain yield, 1000-kernel weight, and protein content (Table 1). The major significant variance components contributing to the significant *G×E* interaction effects were genotype × location on 1000-kernel weight, genotype × year on grain yield, 100-kernel weight, and protein content, genotype × location × year on grain yield, genotype × location × year × fertilizer on grain yield and 100-kernel weight (data not shown). However, except the year main effects, location × year, and genotype × year interaction effects, the main effects of locations, fertilizer and varieties were not significant on the protein content of the malting types.

Since the proportion of the variance of lack of genetic correlation among environments and the *G×E* variance component are higher (>282% and >301%, respectively, relative to the genotypic variance) and the pooled genetic correlation is feeble (r_g = 0.26) for grain yields, considering yield stability in recommending the varieties was relevant. To this effect, results from joint regression and *AMMI* models are as shown on Table 1. In the *AMMI* model four principal components were significant (*AMMI4*), though, *AMMI2* lacked clarity in displaying genotype and environment patterns due to the large and complex *GE* interaction. Rather, $SREG_2$ model has better displayed the pattern. Regression slope (*b*) values, the environmental variances (S_i^2), and Kataoka's Index (I_E) were both efficient in discriminating the most unstable varieties, 'HB 42' and 'ARDU 12-60B', among the top-yielders unlike the ordinary *lsd* 5% and Dunnet's one-tailed test mean separations based on the actual mean grain yield (Table 2).

Table 1. Summary of analyses of variance for grain yield, 100-kernel weight and protein content of 12 barley varieties grown in 12 environments with the partitioning of genotype and *GE* interaction by a) genotype groups and within groups b) joint regression analysis and c) *AMMI* analysis

Source [a]	Degrees of freedom[b]	Grain yield		100-kernel weight	Protein content (%)
		Mean squares [c]	Variance component $(t/ha)^2$	Mean squares [c]	Mean squares [c]
Environment	11	13.63 **		242.52 **	25.26 **
R(E)	24	0.26 **		13.18 **	4.54 **
Genotype	11 (5)	3.91 **	0.085	257.15 **	0.59 ns
a) Group	1	18.23 *		135.68 ns	-
Within group	10	2.48 **		269.29 **	-
G × E	121 (55)	0.87 **	0.256	34.42 **	2.49 **
a) E × g	11	1.95 **		157.76 **	-
E × G(g)	110	0.76 **		20.09 **	-
b) Regression	11	1.86 *	0.049	-	-
Deviations	110	0.77		-	-
c) *PC1* to *PC4*	72	5.01 **	0.129	-	-
Residual	49	0.22		-	-
Pooled error	264 (120)	0.097	0.097	4.57	0.59
Total	431 (215)	0.77		25.95	2.78

[a] E= environment, R= replication, G= genotype, g = genotype group, G(g) = genotype within group; [b] figures in parentheses are degrees of freedom for protein (%) of malting types;
*, ** = significant at P ≤ 0.05 and P ≤ 0.01, respectively, 'ns' = not significant

Variations among barley groups (g)

Barley groups (types) were comparable in plant height, tolerance to the major leaf diseases, maturity, and biomass yields (data not shown). This might be due tothe commensurate attentions given to the traits in the process of variety development. Besides, the similarity among barley types for disease reaction and biomass yields imply their insubstantial influence on enterprise choices since no additional costs for disease control and trade-offs in biomass yields could occur.

Barley groups (g) significantly ($P \leq 0.05$) differed for grain yield. The mean grain yield performance of the improved food types was significantly superior to the malting types and the local cultivars while the malting types were comparable to the local variety (Table 2). Regarding 1000-kernel weight barley groups (g) did not show significant differences; however, their interaction with location (gL) and year (gY) were significant. The 1000-kernel weight of the malting types was higher at Holetta and Adadi Mariam and lower at Jeldu; and higher in 2004 and lower in 2005 than the food types. Significant higher order interaction effects on grain yield and 1000-kernel weight were more apparent for within groups ($G(g)LY$, and $G(g)LYF$) than for groups. Differences in yield stability among barley groups were not distinct since both stable and unstable varieties prevailed in both types.

Adaptation pattern of barley types

The superiority of the improved barley varieties to the local cultivar in grain yield diminished with an increase in altitude. The improved food and malting types at Holetta were significantly ($P \leq 0.05$) superior to the local cultivar though most food and malting types were comparable. At Adadi Mariam, the food types were significantly ($P \leq 0.05$) superior to the local cultivar and comparable with most malting types; the local being comparable with the malting types. At Jeldu, the local cultivar significantly out-yielded some of the malting varieties but comparable with most food and few malting types, 'Holkr' and 'Miskal-21'.

In general, the improved food types were superior to the local and the malting cultivars in grain yield; the malting types being comparable with the local (Table 3). The low yielding potential of the malting types is mainly attributable to their lower number of kernels per spike since all were two-rowed unlike the six-rowed improved food types and the irregular local cultivars that are generally characterized by high number of kernels per ear (Kjaer and Jensen, 1996). Though barley groups did not significantly differ for 1000-kernel weight, the heavier grains were among the malting types and the local cultivars (Table 2) since grains from two-rowed and irregular spikes grow more lax and are generally characterized by high grain weight (Kjaer and Jensen, 1996). However, association between grain yield and thousand-kernel weight was not significant as also reported in previous studies in which lines with either large or small grain size gave achieve high or low grain yield (Lu *et al*., 2000).

Table 2. Mean grain yield (t/ha), environmental variance (S_i^2), slope of regression on environment mean yield (b), and Kataoka's yield reliability Index (I_E) of 12 malting and food barley varieties grown in 12 environments

No.	Variety ^{a}	Grain yield				1000-Kernel weight ^{e}	Protein content (%)
		b ^{b}	S_i^{2} ^{c}	t/ha			
				Actual ^{d}	I_E ^{d}		
1	Beka ^{M}	1.07	0.54 *	2.68	1.48	40.7 de	10.1
2	HB 1533 ^{M}	0.87	0.32 *	2.80	1.87 a	49.9 a	10.1
3	HB 120 ^{M}	0.76	0.53 *	2.73	1.53	42.3 cde	10.3
4	HB 52 ^{M}	0.71	0.40 *	2.70	1.66 a	42.4 cde	10.0
5	Holkr ^{M}	0.71	0.36 *	2.75	1.77 a	44.4 bc	9.9
6	Miskal-21 ^{M}	1.15 *	0.52 *	2.92	1.73 a	42.0 cde	10.2
7	HB 42 ^{F}	1.44 *	0.92	3.10 a	1.52	41.8 cde	-
8	ARDU12-60B ^{F}	1.70 *	1.33	3.38 a	1.48	42.9 cde	-
9	Shege ^{F}	1.40	1.04 *	3.37 a	1.69 a	41.9 cde	-
10	Dimtu ^{F}	1.04	0.59 *	3.11 a	1.84 a	43.4 cd	-
11	HB 1307 ^{F}	0.86	0.76 *	3.56 a	2.12 a	40.5 e	-
12	Local check ^{F}	0.29 *	0.41 *	2.53	1.48	46.7 b	-
	Mean			2.97	1.68	43.2	10.1

$^{a\,M}$ = malting barley and ^{F} = food barley. The improved varieties were earlier releases except 'Miskal-21' and 'HB 1307' that were released in 2006 though tested while in the pipeline; ^{b}* = different from unity at $P \le 0.05$; ^{c}* = not different from the most stable variety (HB 1533) at $P \le 0.05$ according to Ekbohm's test; ^{d} 'a' not different from the top-yielder at $P \le 0.10$ and $P \le 0.20$ according to Dunnet's one-tailed test; ^{e} Means followed by the same letter are not significantly different at $LSD_{0.05}$; CV (%), SE ±, and $LSD_{0.05}$ for variety means are 10.5, 0.16, and 0.43 for grain yield, 5.0, 0.98, and 2.74 for 1000-kernel weight, and 7.4, 0.26 and 0.75 for protein content, respectively.

Table 3. Mean grain yields (t/ha) of malting and food barley varieties tested with two fertilizer levels (21/23 and 41/46, N/P_2O_5, kg ha^{-1}) during the 2004 and 2005 cropping seasons

Variety ^{a}	Holetta		Adadi Mariam		Jeldu		Variety mean ^{b}
	21/23	41/46	21/23	41/46	21/23	41/46	
Beka ^{M}	2.81	3.13	3.00	3.20	1.78	2.16	2.68 cd
HB 1533 ^{M}	2.83	3.13	2.90	3.29	2.16	2.52	2.81 cd
HB 120 ^{M}	3.12	3.22	2.87	3.32	1.79	2.08	2.73 cd
HB 52 ^{M}	2.87	3.14	2.86	3.04	1.94	2.36	2.70 cd
Holkr ^{M}	2.91	3.06	2.48	2.88	1.99	3.17	2.75 cd
Miskal-21 ^{M}	2.94	3.40	2.93	3.31	2.28	2.63	2.92 cd
HB 42 ^{F}	3.04	3.30	3.38	3.79	2.04	3.04	3.10 bc
ARDU 12-60B ^{F}	3.30	3.93	3.43	3.58	2.87	3.17	3.38 ab
Shege ^{F}	2.91	3.56	3.84	4.27	2.33	3.35	3.38 ab
Dimtu ^{F}	2.80	3.09	3.17	3.36	3.03	3.19	3.11 bc
HB 1307 ^{F}	4.09	4.20	3.05	3.58	3.03	3.40	3.56 a
Local check ^{F}	1.95	2.20	2.31	2.66	3.02	3.06	2.53 d
Mean ^{b}	2.96 bc	3.28 ab	3.02 abc	3.36 a	2.36 d	2.84 c	2.97

NOTE: $LSD_{0.05}$ and SE ± for variety means are 0.43 and 0.16 t/ha, for location × fertilizer means are 0.34 and 0.06 t/ha, and for *GLF* means are 0.57 and 0.19 t/ha, respectively; $^{a\,M}$ = malting and ^{F} = food barley type; ^{b} Means followed by the same letter are not significantly different at $LSD_{0.05}$.

Genotype main effect plus genotype × environment interaction (*GGE*) biplots of *SREG*$_2$ model graphically displayed the pattern efficiently where the vertex varieties are superior in environments contained between two lines drawn perpendicular to the sides of the polygon from the origin (Yan *et al*., 2001). Accordingly, except for the malting type 'HB 120' in one environment of Adadi Mariam, the food types was superior in all environments when all barley types were considered (figure not shown). Separate *GGE* biplots for food and malting type with the inclusion of the local cultivars in each set revealed better discriminating ability and representativeness of environments from Adadi Mariam and Holetta (Figures 1 and 2). Among the food types, 'HB 1307' was superior in three environments of Holetta and two environments of Jeldu, 'Shege' was superior in all environments of Adadi Mariam, two environments of Jeldu, and one environment of Holetta while the local cultivars was superior in none of the environments (Figure 1). When the malting barley types and the local cultivars were considered, 'HB 120' and 'Miskal-21' was superior in three and one environments of Holetta, respectively, while two each from environments of Adadi Mariam (Figure 2). The local cultivar was superior in all environments of Jeldu when compared with the malting types, however, if malting barley has to be grown; 'Holkr' seems appropriate (Figure 2).

Feasibility of improved barley types

Grain yield advantages from improved food barley varieties over the local at Holetta and Adadi Mariam were considerably higher while at Jeldu the optional use of few for their grain quality and diversity is advised. Mean grain yield advantages from the improved food barley varieties over the local approached 39.2% at Holetta, 30% at Adadi Mariam, and none at Jeldu though slight gains with the recommended fertilizer rate could be expected. Generally, the overall yield advantages that the improved food varieties could offer approached 23% compared to the local. Therefore, use of the best food barley varieties in the appropriate environments can bring a significant impact in ensuring food self-sufficiency.

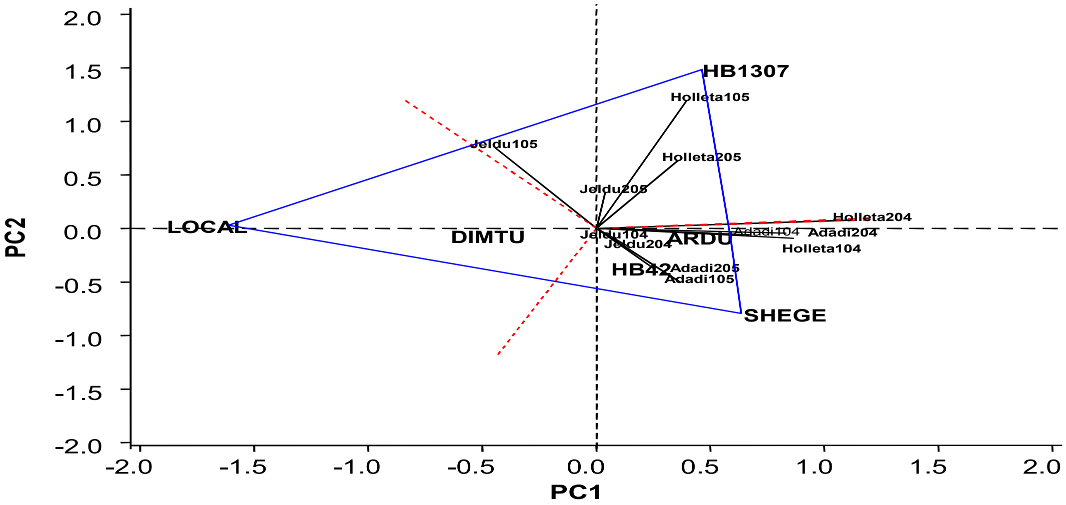

Figure 1. SREG$_2$ biplot of food barley varieties and environment main effects (PC1) and variety by environment interaction effect (PC2).The first digit after location names indicate fertilizer levels (1=21/23 and 2=41/43, kg/ha,N/P$_2$O$_5$) and 04 and 05 represent 2004 and 2005 cropping seasons respectively.

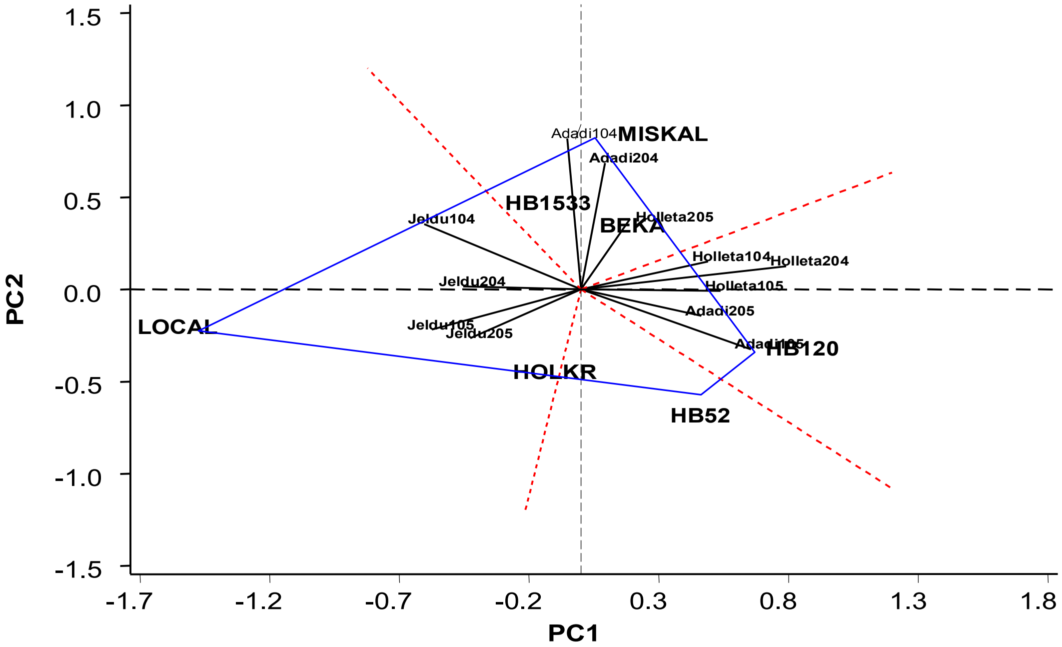

Figure 2. SREG$_2$ biplot of malting barley varieties and environment main effects (PC1) and variety by environment interaction effect (PC2). The first digit after location names indicate fertilizer levels (1=21/23 and 2=41/43, kg/ha,N/P$_2$O$_5$) and 04 and 05 represent 2004 and 2005 cropping seasons respectively.

Maltsters and brewers need for processing consistency and quality necessitates malting barley to fulfill more specific requirements than food types. Failure to meet quality standards in malting barley reduces the value of the grain. Therefore, meeting malting quality standards, grains with high malt extract and enzymatic activity, low protein content, and uniform plump kernels are important. To achieve these, different trait priorities were suggested in variety development depending on the spike type, two- or six-rowed (Anderson and Reinbergs, 1985) while others suggested protein content and kernel color to be the top traits to select for (Goblirsch *et al*., 1996; Canci *et al*., 2003). Though the suggested priority traits in two-rowed malting variety development are malt extract, enzymatic activity, protein content, and grain plumpness (Anderson and Reinbergs, 1985), the local breeding program exclusively focused on prediction tests that utilize unmalted barley (protein content and uniform plump grains) to develop two-rowed malting varieties. This was mainly due to the limitations in facilities and expenses for determining malt extract and enzymatic activity. Since use of adjuncts and other alternatives are uncommon, the local brewers are also interested in malt from low-protein varieties. The current study has also considered protein content and thousand-kernel weight since the former is the basic requirement and the later can complement for kernel plumpness or kernel size distribution (grain screenings). The protein content of the varieties under study was influenced by certain environmental factors but it has never been beyond the levels unacceptable for malt as the acceptable range is between 8.4% and 11.5% (Tadesse, 2003). The least recorded protein content for a variety was 9.05% and the highest was 11.4% across locations while the average for the varieties ranged from 9.9% to 10.3%. Past studies made on the relationships among malting quality attributes reported consistent negative association between protein content and malt extract and positive association between protein content and enzymatic activity or diastatic power (Ullrich *et al.*, 1981; Golbirsch *et al.*, 1996; Lu *et al.*, 2000). Therefore, the current protein content results are not too high or low to adversely affect malt extract and enzymatic activity, respectively. The least thousand-kernel weight for a malting variety was 39.4 g and the highest was 52.5 g across locations, the average range for the varieties being 40.7 to 49.9 g. Despite its more vulnerability to environmental influence than protein content, 1000-kernel weight results have also met the standard (above 40 g) set by the local maltsters (Tadesse, 2003) under all situations. Though some studies reported grain weight to be positively correlated with malt extract and negatively correlated with diastatic power and protein content (Hockett and White, 1981) and others indicated absence of strong associations (Ullrich *et al.*, 1981; Lu *et al.*, 2000), no significant relations emerged between 1000-kernel weight and protein content of the malting varieties in the current study.

Generally, indications for meeting the important grain quality standards of malting barley in the study area are strong. However, since the yielding potential of the malting types was lower than the food types with varying yield differentials across locations, considering relative yields to assess its feasibility is crucial. Actual mean grain yield differentials with the recommended fertilizer rate among the improved barley types (excluding the local cultivar) were 12.1%, 14.6% and 23.0% at Holetta, Adadi Mariam, and Jeldu, respectively, the mean difference being 16.3%. Yield differences among the best performing malting and food types at each location with the recommended fertilizer rate at Holetta, Adadi Mariam and Jeldu were 23.3% (HB 1307 and HB 120), 22.5% (Shege and Miskal), and 6.8% (HB 1307 and Holkr) , respectively, the mean being 16.6%. Therefore, to entice malting barley growers, maltsters have had to offer premium for malting over food barley grain. However, for setting premiums, considering the prevailing food barley price is also relevant besides yield differentials.

Studies made in the Queensland barley market based on price series data also suggested the use of feed barley prices as a leading indicator for malting barley prices but not *vice versa* (Gali and Brown, 2002). As the feed barley is to Australia, food barley prices could serve as an indicator for malting barley prices in Ethiopia since they share similar situations in production, price variation, and trading in the respective countries except for their differences in the end-uses. Currently, barley grains are being traded in the common markets around Assela in four classes (barley white, barley mixed, barley black and barley for beer) while the first three classes are common around Ambo (study area) since the production of malting barley is not wide spread (CSA 2005, 2006, 2007, 2008a, 2009c). According to the past five years average retail prices, barley white and barley for beer fetch the highest prices around Assela while barley black and barley white receive higher prices around the study area (Ambo) in the common markets. Barley white and barley for beer more or less assume same prices in the common market of Assela, hence, the five consecutive years average prices of these classes were considered to estimate factory gate prices of malting barley beginning in 2004/05 (CSA 2005, 2006, 2007, 2008a, 2009c). With the exception of 2008/09, the four years average food barley retail price at Ambo was higher by 23% than the price at Assela (CSA, 2005, 2006, 2007, 2008a). Therefore, the five years' average price of the food barley was considered to estimate gross food barley revenues around the study area (Table 4). Though the sky rocketed food grain prices since 2007 highly devastated the situation where farmers were getting higher prices for selling malting as food grain than maltsters can offer, on the average, maltsters were paying between 25% to 30% premium over the prevailing food barley prices at Assela (personal comm.). Considering the best performing varieties among barley types at each location and transportation as the major variable cost, the marginal rate of returns were 142%, 153%, and 361% for Holetta, Adadi Mariam, and Jeldu, respectively, the mean for the study area as a whole being 242% (Table 4).

Therefore, this can give a clue about the feasibility of malting barley production in the study area. However, unlike food barley that can be traded in a large number of small transactions, malting barley marketing demands a different arrangement where participants are few and limited. Producers are expected to supply bulks of similar variety to fetch factory gate prices. This might be possible only by very few individual farmers but the majority of the small farmers should have to organize themselves into groups or use other alternatives so that all their produces are collected and sorted by variety and supplied to the factory in bulks (as per the minimum marketable size specified by the factory). Otherwise, the benefits that growers could receive will be minimal or even sometimes unprofitable since malting barley grain in the common market is traded as food barley grain.

Generally, for a sustainable malting barley production, setting appropriate premium by considering yield differentials, the prevailing food barley grain prices, the extra efforts and handling costs needed for grain quality maintenance and marketing, and possible risks if quality standards are unmet are crucial. Therefore, the information on yield relationships, quality and management requirements, and possible risks in malting barley production are relevant for farmers, maltsters, and policy makers in setting producers' price and for efficient enterprise choices. So long as barley culture is an important activity in the study areas and similar agro-ecologies, commencing malting barley production to exploit opportunities is at least justifiable by five important points. First, meeting the important malting quality standards at all locations is possible. Secondly, it is a feasible business to the growers that can yield additional income under the prevailing conditions. Thirdly, it contributes to foreign currency saving. Fourthly, proximity to the malt factory or market is favorable, hence, minimal dockage transportation risks. Finally, no additional costs are incurred for disease control and there is no trade-off in straw yield since it is an important feed source in crop-livestock farming system.

Generally, the appropriate use of the improved food and malting barley varieties in the study areas and similar agro-ecologies could maximize their potential; hence, better food security and foreign currency savings and enhanced farmers' income could be realized.

Conclusions

The study was informative in determining appropriate technologies, thus, scaling-out the best bets in these areas could be an expedient for ensuring food self-sufficiency, enhancing farmers' income and for import substitution. Use of the most suitable food barley varieties in their respective agro-ecologies such as 'Shege' around Adadi Mariam and 'HB 1307' around Holetta and Jeldu can augment productivity and give greater yield advantage over the local cultivars; hence, it offers better chance for assuring food security. Moreover, scaling-out malting barley production with the appropriate varieties such as 'Holkr' around Jeldu and 'HB 120' and 'Miskal' around Holetta and Adadi Mariam can have multifaceted contributions that extend beyond enhancing farmers' income through import substitution since indications on its feasibility are strong.

Table 4. Partial budget analysis on mean grain yields of malting and food barley adaptation trials of 2004/05 and 2005/06 cropping seasons in the central highlands of Ethiopia

Item	Malting barley		Food barley
Average yield (kg ha^{-1})	3110		3730
Adjusted average yield (80%) (kg ha^{-1})	2490		2980
Gross benefit (birr ha^{-1})	12873		9894
Cost that vary (birr ha^{-1})			
• Transport	872		0
Net benefit (birr ha^{-1})	12002		9894
Marginal benefit (birr ha^{-1})		2108	
Marginal cost (birr ha^{-1})		872	
Marginal rate of return (%)		242	

Average food barley grain price between 2004/05 to 2008/09 at Ambo was 3.32 birr kg^{-1} and average factory gate malting barley price at Assela was 5.17 birr kg^{-1}; Average transportation cost from Ambo to Assela was 0.35 birr kg^{-1}; Sources: CSA 2005, 2006, 2007, 2008c and 2009c.

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