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Varietal adoption and seed commercial behavior: Barley seed system landscape in the highlands of Ethiopia

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Acronyms

AI	attainment index
ARC	agricultural research center
ASE	Amhara Seed Enterprise
CSA	Central Statistical Agency
DI	demand index
EIAR	Ethiopian Institute of Agricultural Research
ESE	Ethiopian Seed Enterprise
MoA	Ministry of Agriculture
NSPDC	National Seed Production and Distribution Committee
OARI	Oromia Agricultural Research Institute
OSE	Oromia Seed Enterprise
SI	supply index
SSE	South Seed Enterprise
Std	standard deviation

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The views and opinions expressed in this Working Paper are purely those of the authors and do not necessarily reflect the views of their employers.

Executive summary

In Ethiopia, barley is among the major cereal crops and is also a food security crop in the highlands and an industrial commodity for the emerging brewing industry. This Working Paper documents barley yield gaps, varietal adoption and preferences, and seed commercial behavior based on primary data collected in 2014 from 549 randomly selected barley growers in four major crop production regional states: Amhara, Oromia, Southern, and Tigray.

The results indicate that the national average yield (1.5 metric tons ha^{-1} in 2014) is 61 and 29 percent lower than the yield achieved on research stations and farmers' fields with improved varieties and recommended practices, respectively. This significant yield gap indicates limited availability of and access to technologies, information, and knowledge, and reflects inadequate performance of the seed system, extension services, and other input delivery systems.

A total of 37 food barley and 16 malt barley varieties were released, primarily by the national agricultural research system, with a few by the private sector, up until 2015. In total, 23.3 and 9.5 percent of barley producers are full and partial adopters, respectively, on a total of 40.6 percent of the area, with variation between food and malt barley. For food barley, 23.3 percent (2.6 percent are women) are full-adopters and the rest (9.5 percent) are partial adopters (<1 percent are women). In contrast, all malt barley growers are adopters, linked with the recent introduction and promotion of the crop for malt supply in the emerging brewing industry. Of released food barley varieties, only seven were identified and grown by farmers: HB-42 (1.3 percent), Shege (1.7 percent), Meserach (5.1 percent), Dimtu (1 percent), Estayish (1 percent), HB-1307 (2.1 percent), and Gobe (<1 percent). Similarly, among 16 released malt barley varieties, farmers identified and used only four varieties: Beka (1.5 percent), Holker (33.3 percent), Miscal 21 (12.8 percent), and Sabini (15.8 percent). The weighted average ages of 16.8 and 23.7 years for food and malt barley varieties, respectively, show low varietal replacement rates in farmers' fields.

Both food and malt barley varieties are considered good for one or more attributes but poor for the others. Consequently, breeding programs need to consider developing varieties with better performance for a broader range of attributes and their dissemination targeting farmers' unique preferences.

In terms of seed use, 15.2 percent of barley producers use certified seed, whereas 14.1 percent purchase non-certified seed and 70.7 percent use their own saved seed. Among the adopters of improved varieties, only 8.3 percent of food barley and 38.5 percent of malt barley growers purchase certified seed. This is associated with the huge gap in supply of demanded seed, with only 9 percent of revealed barley seed demand being supplied (4 percent for food and 17 percent for malt barley) and with an emphasis on older varieties in 2014.

Commercial behavior concerning food barley seed indicates that 21.2 percent of farmers engage in buying and selling either certified or non-certified seed and the remaining 78.8 percent are in an autarkic seed market position, where they do not engage in the seed market. This indicates the potential of boosting the productivity and production of food and malt barley in the country by enhancing the seed system for better access and use of quality seed of improved varieties.

1. Introduction

Barley (food and malt) is one of the most important crops for food and nutritional security of smallholder farmers in the mixed crop–livestock farming systems of the Ethiopian highlands. It is generally grown twice a year during the small (*belg*) and main (*meher*) rainy seasons[1]. According to estimates by CSA (2014), it is cultivated on about 1.02 million ha with a total grain production of 1.8 million tons[2] at an average productivity of 1.71 tons ha^{-1} engaging about 4.5 million smallholder farmers during the *meher* season; corresponding values for the *belg* season are about 150,000 ha, 86,300 tons, 0.58 tons ha^{-1}, and 833,000. This accounts for about 10 and 8 percent of the total annual area and production for major cereal crops, respectively, during the *meher* season; and correspondingly 17 and 14 percent during the *belg* season.

Barley is important for two reasons: food security in the highlands, where it is one of the few well-adapted traditional major cereal crops; and commercial opportunity, because of the important role it plays as an input to the ever-increasing domestic brewing industry and as a cash crop for smallholder farmers. Accordingly, boosting its productivity and production is crucial. Currently, barley has received due attention in national development plans. For instance, the Growth and Transformation Plan II (2015–2020) sets different targets for food barley as a food security crop and for malt barley as an industrial crop. It sets targets of increasing average productivity from 2.05 tons ha^{-1} achieved in 2015 to 3.01 tons ha^{-1} by 2020 for food barley, and correspondingly from 1.8 to 2.64 tons ha^{-1} for malt barley, through boosting the availability of certified seed, chemical fertilizers, credit, and extension services (MoA 2015).

Currently, the availability of and access to improved crop varieties and associated crop management practices are limited, resulting in low productivity of barley. The yield gaps between research managed and national yield levels are still very high across crops and agro-ecologies including barley. Likewise, performance of the formal seed sector varies considerably by crop type and agro-ecology (Spielman et al. 2010). The formal seed sector is dominated by wheat and maize for the mid-altitude agro-ecologies. Accordingly, the bulk of certified seed produced and distributed for these two crops represents more than 72 percent of the total formal seed supply in the country (Lakew and Alemu 2012; Alemu and Bishaw 2015; Bishaw and Atilaw 2016). However, given the increased importance of barley as a food and industrial crop, involvement of the formal seed system is increasing from year to year. In this regard, a better understanding of the dynamics of the seed system and its performance in terms of trends in the availability of certified seeds, farmers' commercial behavior concerning seed, farmers' preferences for available varieties, and adoption levels are crucial.

This paper presents the performance of the barley seed system in Ethiopia. It specifically presents an overview of the importance of barley; current yield gaps; performance of the formal seed sector; attributes, perceptions, and adoption of improved varieties; commercial behavior related to seed; and associated implications of these components.

2. Approaches and methods

2.1. Sampling and sample size

The study was based on a nationally representative sample of 549 barley growers selected from 19 districts in 13 zones of the four major administrative regions of the country (Amhara, Oromia, Southern Nations, Nationalities, and Peoples and Tigray) during the 2014 cropping season (Figure 1). Adoption rates were estimated based on two approaches at household level: (i) number of plots and varietal use and (ii) plot size (area) allocated for improved varieties. In addition, secondary data on certified seed demand and supply were collected from the National Seed Production and Distribution Committee that operates under the Ministry of Agriculture (MoA).

[1] According to CSA, *belg* season are crops planted and harvested during the months of March (*Megabit*) to August (*Nehase*) and *meher* season are crops produced during September (*Meskerem*) to February (*Yekatit*).

[2] Metric tons are used throughout.

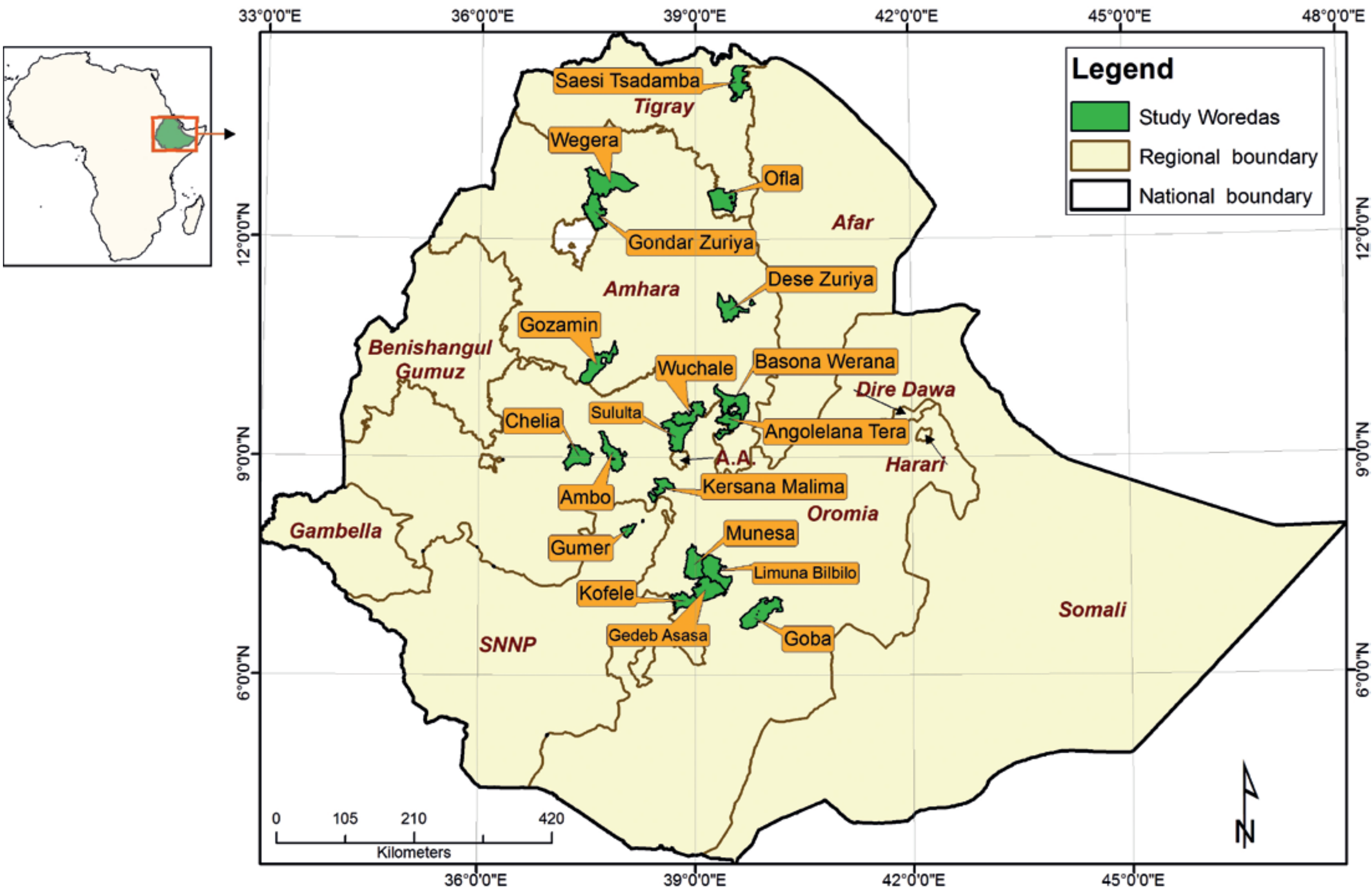

Figure 1. Distribution of sample districts

2.2. Estimation of varietal adoption

The adoption rates were estimated based on two approaches at householder level: (i) without considering plot size but considering plot numbers and varietal use and (ii) based on plot size allocated for improved varieties. In both cases, full adopters, partial adopters, and non-adopters were identified.

a) Estimation considering plot numbers and varietal use:

- Non-adopters are households who do not use any improved variety in any plots where barley is grown.
- Partial adopters are those who use improved varieties in one or more barley plots.
- Full adopters are those who use an improved barley variety in all plots.

b) Estimation based on plot size allocated for improved varieties.

The adoption rates based on land allocation were estimated using estimates of the proportion of total land allocated to improved barley varieties over the total land allocated for barley by all sample households:

$$BA = \frac{\sum_{i=1}^{n} BPI_{ij}}{\sum_{j=1}^{N} BP_j}$$

where:

BA = adoption rate of improved barley varieties
BPIij = size of barley plot "i" of farmer "j"
BPj = size of all plots of barley fields of farmer "j"
n = number of plots with improved barley varieties
N = number of farmers growing barley

2.3. Estimation of varietal preferences

To elicit farmers' varietal preferences, we followed two steps. The first step was identifying the list of attributes that helps farmers to characterize the different barley varieties. Because attributes may vary for food and malt barley, the assessment was made independently for each barley type. The attributes were initially identified by barley breeders and further validated by the farmers. The attributes for food barley include grain yield, grain size, plant stand, tillering capacity, lodging, spike (row) type, spike length, early maturity, drought resistance, smut resistance, aphid resistance, quality for food making, quality for local drinks, straw yield, and marketability. The attributes for malt barley are the same as for food barley with the addition of malt quality.

The second step was eliciting farmers' perceptions using these attributes for the local and improved food and malt barley varieties currently grown by farmers. Farmers' perceptions about the different food and malt barley varieties using the above attributes were elicited using an empirical approach applied by Sall et al. (2000), Alemu and Mamo (2007), and Alemu and Bishaw (2015). The approach uses an index that describes how well a certain variety attributes meet farmers' preferences. It involves the application of quasi-arbitrary ordinal weights in which farmers rank the importance of each attribute and how well these attributes are embodied in different varieties.

Accordingly, each farmer was asked to judge each attribute of the food and malt variety that they grow on two scales: first, what is the importance of a given attribute to the farmer (very important, important, and not so important); and, second, what is the quality of the attribute presented by a given variety (very good, good, and poor). Thus, for N farmers, with each one ranking the characteristics according to their importance and quality, the response matrix is shown in Table 1. Each entry in the matrix, n_{ij}, represents the number of farmers who rank a particular attribute based on their perception of its importance, j, and their satisfaction with the quality provided by variety, i. The bottom row entries, C_j, are the total number of farmers who rank the characteristic according to its importance. The row total, r_i, is the total number of farmers who rank the characteristics as embodied in a variety at a certain level of satisfaction. Given the above description, the following must hold:

$$\sum C_j = \sum r_i = \sum \sum n_{ij} = N$$

Table 1. The response matrix of farmers' perceptions of varietal attributes

	Attribute			
Variety	Very important	Important	Not so important	Row total
Very good	n_{11}	n_{12}	n_{13}	r_1
Good	n_{21}	n_{22}	n_{23}	r_2
Poor	n_{31}	n_{32}	n_{33}	r_3
Column total	c_1	c_2	c_3	N

Source: Alemu and Mamo (2007) and Sall et al. (2000)

The weighting matrix is presented in Table 2. The row totals (S_i) present the supply weights, which are weights assigned to the farmers' perceptions of how well a specific attribute is embodied in a given variety. The column totals (d_i) present the demand weights, which are assigned to the farmers' perceptions of how important the specific attribute is. Each cell in the matrix is then calculated as:

$$W_{ij} = S_i d_j$$

Reed et al. (1991) and Sall et al. (2000) propose certain restrictions to be imposed on the weights, so that the following inequalities hold:

a) $w_{1j} > w_{2j} > w_{3j}$ for all j. This implies that regardless of how important a characteristic is, the more favorably the farmer perceives that characteristic being present in the variety under evaluation, the higher the weight is.
b) $w_{i1} > w_{i2} > w_{i3} > 0$ for all i which is rated good or better. This inequality implies that whenever a characteristic embodied in a variety is rated as good or better, the weight should be positive and increase in value as its level of importance increases.
c) $w_{i1} < w_{i2} < w_{i3} < 0$ for all i which is rated poor. This implies weights for characteristics rated as poor should be negative and decrease as their importance increases.
d) The above inequalities imply the following restrictions when constructing the supply and demand weights: $S_1 > S2 > 0 > S_3$ and $d_1 > d_2 > d_3 > 0$.

All demand weights (d_i) are positive, while the supply weight for a characteristic ranked as poor is negative. The stated weighting scheme ensures that the highest weights will be given to those characteristics considered very important and embodied very well. Likewise, the lowest weights will be given to those characteristics considered least important. Given the response weighting matrices, indices can be calculated as follows:

$$D = \frac{1}{d_1 N} \sum_{j-1}^{3} d_j c_j$$

The demand index (D) is a measure of how important the farmers perceive a particular characteristic to be. A value of 1 indicates that all farmers perceive the characteristic to be very important. The minimum value of the index is $(d_3/d_1) > 0$, and is attained when all farmers perceive the characteristic to be of little importance.

$$S = \frac{1}{s_1 N} \sum_{i=1}^{3} s_i r_i$$

The supply index (S) is a measure of the perception of farmers on how well a characteristic is embodied in a variety. A maximum value of 1 indicates that all farmers perceive the characteristic supplied as being very good quality. The minimum value will be attained if all farmers perceive the quality of the characteristic being supplied as poor.

$$W = \frac{1}{w_{11} N} \sum_{j=1}^{3} \sum_{i=1}^{3} w_{ij} n_{ij}$$

The attainment index (W) provides a measure of how well farmers' perceptions of the importance of the characteristic match their perceptions of how well it is supplied in the variety. The maximum value of W is 1, which implies a perfect match. In such a situation, all farmers rank a particular attribute as very important and rank the quality supplied by the variety as very good. The minimum value of the index depends on the chosen supply weight, Si, and is calculated to be $(s_i/s_1) < 0$.

Table 2. The weighting matrix for farmers' perceptions of varietal attributes

	Attribute			
Variety	**Very important**	**Important**	**Not so important**	**Row total**
Very good	w_{11}	w_{12}	w_{13}	s_1
Good	w_{21}	w_{22}	w_{23}	s_2
Poor	w_{31}	w_{32}	w_{33}	s_3
Column total	d_1	d_2	d_3	

Source: Alemu and Mamo (2007) and Sall et al. (2000)

3. Results and discussion

3.1. Barley production and trends

Barley is both a food security and cash crop for farmers living in the highlands of Ethiopia. It is a food security crop because it grows in most marginal highland areas where there is a major problem of food deficit. It is a cash crop as its production has considerable demand from the ever-expanding brewing industry in the country. The increased domestic production of malt barley also has direct implications on import substitution and savings on foreign currency reserves. To this end, the national research system has been striving to develop improved varieties and production technologies of food and malt barley that can be adapted to the different agro-ecologies and fit various production systems, in order to increase yield and ultimately attain food and nutritional security and provide quality malt for the brewing industry (Mulatu and Lakew 2011).

Major barley-producing areas are found in Amhara, Oromia, Southern Nations, Nationalities, and Peoples and Tigray regions—accounting for more than 98 percent of the total annual area and production (CSA 2014). The production and productivity of barley at a national level have demonstrated gradual increases but area coverage has remained relatively stable (Figure 2). The area allocated for barley has increased from about 0.9 million ha in 2004 to 1 million ha in 2014; correspondingly, national average barley yield increased from 1.17 to 1.87 tons ha^{-1}, annual barley production increased from 1.079 to 1.902 million tons, and the number of farmers involved in barley production increased by from about 3.5 million to about 4.5 million (CSA 2015).

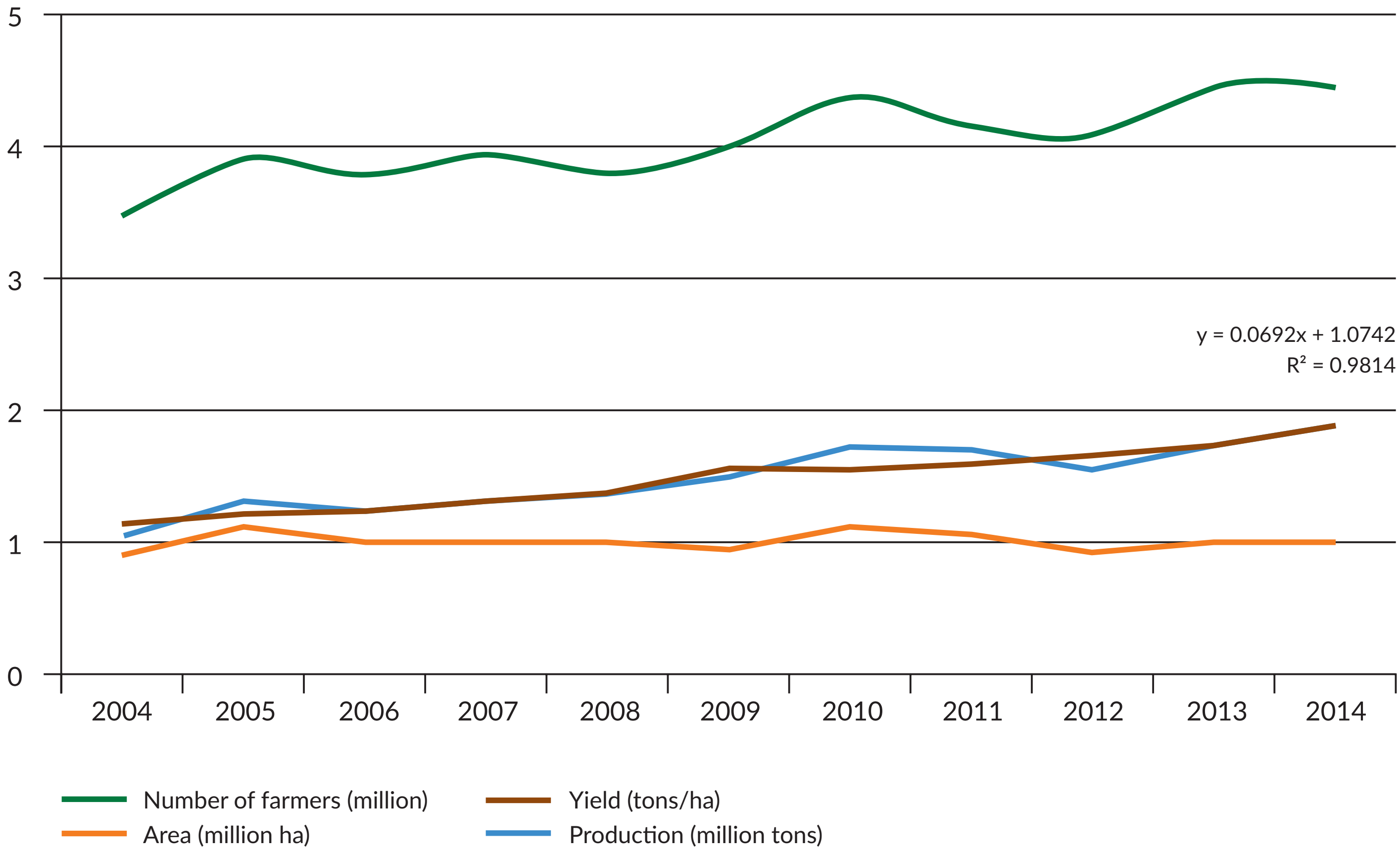

Figure 2. Trends in barley area, production, and productivity (2004–2014)

Source: Data compiled from Central Statistical Agency annual reports 2004–2014

In terms of barley production, the results show that farmers grow food barley, malt barley, or both barley types (Table 3). About 70.5 percent, 10 percent, and 19.5 percent of farmers grow food barley, malt barley, or food and malt barley, respectively. In total, about 656 plots are planted with both barley types. This implies that 75.3 percent of the the plots of sampled farmers are planted with food barley and 24.7 percent are planted with malt barley. We also present the importance of barley production at household level in terms of average size of land allocated and proportion of land covered with barley from the total land cultivated based on our survey (Table 3). Accordingly, on average, farmers allocate 0.67 ha of land for barley production, but the average land allocated for food barley is 0.56 ha and for malt barley is 0.58 ha. The proportion of land allocated for food barley is 37.4 percent, for malt barley is 27.8 percent, and for both types is 41.7 percent of the total land cultivated, implying the importance of barley production for farmers in these highland areas.

3.2. Barley yield gaps

Yield gaps based on a comparison of productivity levels achieved at national level, those in farmers' fields under farmers' practices and under recommended practices, and those on-station at research stations, may serve as indicators of the availability of and access to technologies, knowledge, and information—thereby reflecting the performance of a seed system, other input delivery systems, and extension services (Spielman et al. 2010; van Ittersuma et al. 2013).

There is a clear yield gap due to variety and application of recommended crop management practices for both food and malt barley. The national average yield (1.5 tons ha^{-1}) is 44 and 61 percent lower than the yield achieved in farmers' fields with improved varieties and recommended practices and on research stations for food barley, respectively; and correspondingly 46 and 55 percent lower for malt barley. These trends indicate the potential for narrowing the yield gaps through improved access to varieties and quality seed along with associated extension advice on recommended agronomic practices (Table 4).

3.3. Varieties, adoption, and perceptions

3.3.1. Availability of improved barley varieties

The barley seed system is composed of both the formal and informal sector. The formal sector comprises federal and regional agricultural research institutes that develop improved varieties and supply early generation seed (breeder and pre-basic or sometimes basic seed) that are multiplied into large-scale certified seed by federal and regional public seed enterprises and private seed companies. These bodies then market the seed through cooperatives under the regulatory oversight of federal and regional Bureaus of Agriculture to ensure the quality of seed used. Although different public and private actors are involved in seed production, the pricing and marketing of seed is centrally coordinated by the

Table 3. Land allocation for barley production per household

Barley type	Indicators	Mean	Std	No. of farmers
Food barley	Size of land allocated per farmer (ha) Proportion from total land cultivated (%)	0.56 37.4	0.41 24.20	494
Malt barley	Size of land allocated per farmer (ha) Proportion from total land cultivated (%)	0.58 27.79	0.41 17.79	162
All barleys	Size of land allocated per farmer (ha) Proportion from total land cultivated (%)	0.67 41.72	0.48 24.38	547
Total cultivated area	**(ha)**	**1.85**	**1.25**	

Source: Own survey, 2014
Note: Std, standard deviation

Table 4. Yield gaps of barley in the highlands of Ethiopia

		Yield achieved (tons ha^{-1})		
Crop		Research fields	Farmers' fields with recommended practice	National average*
Food barley	Range	2.4–5.2	2.1–3.3	1.17–1.9
	average	3.8	2.7	1.5
Malt barley	Range	2.3–4.3	1.9–3.8	1.2–1.9
	average	3.3	2.8	1.5

Source: Data compiled from Central Statistical Agency (CSA) annual reports 2004–2014 and MoA (2012)
Note: *Considers both food and malt barley from national CSA data

government along with the provision of credit. The distributors of seed are mostly cooperative unions and their respective member primary cooperatives.

Barley research is nationally coordinated by the Holeta Agricultural Research Center (Holeta ARC) of the Ethiopian Institute of Agricultural Research (EIAR), but currently transferred to Sinana ARC of the Oromia Agricultural Research Institute (OARI). However, both federal and regional research institutes are involved in barley improvement, including Holeta and Kulumsa ARCs of EIAR; Adet, Debre Berhan, and Sirinka ARCs of the Amhara Regional Agricultural Research Institute; Fedis and Sinana ARCs of OARI; Hawasa ARC of the Southern Agricultural Research Institute; and Mekele University. So far, 37 food and 16 malt barley varieties have been released for use (Table 5). The ARCs that release the varieties are responsible for varietal maintenance and early generation seed multiplication (breeder, pre-basic, and basic seed).

Table 5. Number of varieties released from the 1970s to 2015

	No. of varieties	
Period	Food barley	Malt barley
1970s	-	2
1980s	2	-
1990s	3	1
2000s	22	7
2015	10	6
Total	**37**	**16**

Source: MoA (2014)
Note: - denotes no release

3.3.2. Varietal adoption at household, plot, and area levels

Given the yield gap, information on varietal adoption is crucial as it is strongly associated with the productivity levels achieved and measures required. In this regard, the adoption of barley was assessed for food and malt barley independently and by season. All malt barley growers use improved varieties and these are only cultivated during the *meher* season. The adoption rates of improved food barley varieties were estimated considering the two seasons. Among food barley growers, 67.2 percent (4.9 percent are women) are non-adopters of improved varieties, of which 62.58 percent planted barley only during the *meher* season and the remaining 4.63 percent during both *meher* and *belg* seasons (Table 6). Among the adopters, 23.3 percent (2.6 percent are women) fully adopted improved varieties and almost all (22.94 percent) grow barley only during the *meher* season. The remaining barley growers (9.5 percent) are partial adopters (<1 percent are women) and grow both local and improved food barley varieties.

In terms of land allocation, the data for food barley show significant differences (P<0.01) among full adopters with an average allocation of 0.65 ha, partial adopters with 0.82 ha, and non-adopters with 0.47 ha. For the number of plots allocated to food barley per household, the data again show significant differences (P<0.01) among full

Table 6. Estimated adoption of improved varieties of food barley

Approach	Adoption status	Estimated adoption (%)
Households	Full adopters	23.3
	Partial adopters	9.5
	Non-adopters	67.2
Plots	Adopters	28
	Non-adopters	72
Area	Adopters	40.6
	Non-adopters	59.4

Source: Own survey, 2014

adopters with an average allocation of 1.23 plots, partial adopters with 2.28 plots, and non-adopters with 0.54 plots (Table 7).

An estimated 40.6 percent of barley land is covered with improved food barley varieties considering both full and partial adopters. Of the total 36 released food barley varieties, farmers report using only seven varieties: HB-42 used by 1.3 percent of food barley-growing farmers (released in 1984); Shege, 1.7 percent (1995); Meserach, 5.1 percent (1998); Dimtu, <1 percent (2001); Estayish, <1 percent (2004); HB-1307, 2.1 percent (2006); and Gobe, <1 percent (2012). Similarly, among the 16 released malt barley varieties, farmers identify using four varieties: Beka, used by 1.5 percent of farmers (released in 1976); Holker, 33.3 percent (1979); Miscal 21, 12.8 percent (2006); and Sabini, 15.8 percent (2011). The remaining 36.4 percent of farmers are not able to identify the improved malt barley varieties they grow. The food and malt barley varieties mentioned are very old with a weighted average age of 16.8 and 23.7 years, respectively, showing low varietal replacement rates in farmers' fields.

3.3.3. Farmers' perceptions of food and malt barley varieties

Using the methodology discussed above, we estimated the demand index (DI), supply index (SI), and attainment index (AI) for improved and local food and malt barley varieties grown by respondent farmers. The identified attributes are categorized into (i) yield and grain characteristics, which are grain yield, grain size, spike (row) type, spike length, and straw yield; (ii) field establishment, stand, and earliness, which are plant stand, tillering capacity, lodging, and early maturity; (iii) resistance or tolerance to biotic stresses (smut, and aphids) and/or abiotic stress (drought); and (iv) food and malt quality and marketability. The following section

Table 7. Land and plot allocation for food barley by adoption

Adoption	Indicator	Land allocated for food barley (ha)	No. of plots allocated for food barley
Full adopters (n = 121)	Mean	0.65	1.23
	Std	0.46	0.56
Partial adopters (n = 46)	Mean	0.82	2.28
Non-adopters (n = 327)	Std	0.47	0.54
	Std	0.35	0.63
Total (n = 494)	Mean	0.56	1.44
	Std	0.41	0.67
Mean difference	F-value	19.92***	52.54***

Source: Own survey, 2014
Note: *** indicate significance at P<0.01; Std, standard deviation

presents the results of perceptions for the different attributes of food and malt barley varieties.

a) Food barley varieties

In general, released barley varieties were developed through landrace selection, crossing, or introduction. Among the improved varieties of food barley grown by farmers during the time of the survey, HB-1307 and HB-42 were developed through crossing at Holeta ARC, whereas Meserach, Shege, and Harbu were developed through landrace selection at Debre Berhan, Holetta, and Sinana ARCs, respectively. These breeding mechanisms may have implications in the perceived AI of the different attributes (Table 8).

Yield and grain characteristics: Farmers' perceptions of grain characteristics show considerable differences among varieties both within and between improved and local varieties. The variety Shege has the highest grain yield AI compared to the other varieties but has the lowest value for straw yield. Varieties HB-42 and Harbu have lower AIs for grain yield compared to local varieties but higher AIs for attributes like straw yield and grain size.

Field establishment, stand, and earliness: In terms of plant stand, improved food barley varieties have better AIs compared to local varieties. Varieties HB-42, Meserach, and Harbu achieve better AIs for tillering capacity whereas Shege and HB-1307 are perceived to have lower tillering capacity compared to local varieties. There is an overall low AI for lodging resistance for both improved and local varieties, and only Meserach is perceived to have better lodging resistance. In terms of earliness, only Harbu has a better AI than local varieties.

Resistance to stresses: The AIs for drought tolerance are below 0.5 for both improved and local varieties while the DIs are higher than 0.7, indicating farmers' demand for drought-tolerant varieties, but the available varieties are perceived to have low tolerance to drought. The AIs for smut resistance indicate that, except for HB-1307, the improved varieties have better a perceived resistance compared to local varieties. Varieties HB-42 and HB-1307 are perceived to have the lowest resistance to aphids compared to local varieties and Harbu is perceived to be relatively resistant to aphids.

Food quality and marketability: In terms of grain quality for food making, Harbu and Meserach have higher AIs compared to other improved and local varieties. The perceived quality of improved food barley varieties, except HB-1307, for local drink making is lower compared to local varieties. In terms of marketability, Shege and Harbu (selected from local landrace Arusso) have better AIs compared to other improved and local varieties.

These results indicate that different varieties are good for one or more attributes but poor for the others. The breeding program needs to consider developing varieties with better performance for a broader range of attributes, and technology dissemination needs to consider preferences to ensure that different varieties are given to the target farmers with unique preferences for the different attributes.

b) Malt barley varieties

The level of attainment of the different attributes of malt barley varieties grown by farmers during the time of the survey is presented in Table 9. The preferences were assessed for three varieties for which adequate numbers of responses were collected: Holker, Miscal 21, and Sabini. The preferences for other improved varieties were aggregated to get an adequate number of responses—the number of farmers that grow respective varieties.

Yield and grain characteristics: Farmers' perceptions about yield and grain characteristics show considerable differences among the three improved varieties. In terms of grain and straw yield, Holker has higher AIs than Miscal and Sabini; however, it has lower AIs for grain size and spike length.

Field establishment, stand, and earliness: Better AIs of plant stand, tillering capacity, and non-lodging are observed for Miscal 21 followed by Holker and Sabini. For early maturity, Sabini scores better AIs than the other two varieties.

Resistance to stresses: Though all varieties demonstrate low AIs for drought resistance, Sabini has better AI compared to Holker and Miscal 21. Moreover, Miscal 21 is perceived to have relatively better smut and aphid resistance than the other varieties.

Table 8. Demand index (DI), supply index (SI), and attainment index (AI) for food barley varieties (2014)

		HB-42			Shege			Meserach		
Category	Varietal attributes	DI	SI	AI	DI	SI	AI	DI	SI	AI
Yield and grain characteristics	Grain yield	0.583	0.917	0.778	1.000	0.952	0.952	1.000	0.897	0.897
	Grain size	0.833	0.917	0.750	0.786	0.762	0.611	0.923	0.513	0.462
	Spike (row) type	0.833	0.583	0.528	0.905	0.476	0.429	0.962	0.051	0.038
	Spike length	0.792	0.833	0.653	0.952	0.667	0.651	0.859	0.846	0.756
	Straw yield	0.833	0.833	0.792	0.929	0.333	0.310	0.962	0.821	0.799
Field establishment, stand, and earliness	Plant stand	0.917	0.750	0.667	0.810	0.714	0.619	0.910	0.744	0.654
	Tillering capacity	0.875	0.917	0.792	0.857	0.619	0.524	0.974	0.718	0.709
	Lodging	0.833	0.583	0.306	0.881	0.476	0.421	0.962	0.487	0.474
	Early maturity	0.875	0.417	0.431	0.857	0.429	0.349	0.833	0.564	0.466
Resistance to stresses	Drought tolerance	0.750	0.333	0.306	0.795	0.590	0.453	0.987	0.487	0.474
	Smut resistance	0.833	0.583	0.528	0.846	0.487	0.419	0.974	0.538	0.513
	Aphid resistance	0.708	0.167	0.181	0.795	0.500	0.436	0.962	0.538	0.509
Food quality and marketability	Food preparation	0.750	0.667	0.528	0.881	0.667	0.373	0.949	0.897	0.855
	Local beverages	0.792	0.500	0.403	0.833	0.476	0.373	0.821	0.692	0.607
	Marketability	0.875	0.583	0.458	0.976	0.857	0.833	0.987	0.744	0.731

		Local			Harbu			HB-1307		
Category	Varietal attributes	DI	SI	AI	DI	SI	AI	DI	SI	AI
Yield and grain characteristics	Grain yield	0.940	0.822	0.781	0.974	0.744	0.718	0.958	0.917	0.889
	Grain size	0.867	0.699	0.620	1.000	0.641	0.641	0.917	0.625	0.583
	Spike (row) type	0.841	0.571	0.492	0.974	0.590	0.581	0.905	0.619	0.603
	Spike length	0.816	0.630	0.527	0.923	0.744	0.667	0.917	0.000	0.000
	Straw yield	0.838	0.704	0.689	0.846	0.795	0.795	0.844	0.600	0.667
Field establishment, stand, and earliness	Plant stand	0.841	0.705	0.612	0.923	0.795	0.786	0.917	0.667	0.625
	Tillering capacity	0.855	0.676	0.591	0.974	0.692	0.667	0.896	0.208	0.215
	Lodging	0.792	0.524	0.436	0.923	0.487	0.427	0.917	0.125	0.083
	Early maturity	0.826	0.572	0.487	0.923	0.692	0.615	0.867	0.354	0.393
Resistance to stresses	Drought tolerance	0.795	0.496	0.400	0.846	0.538	0.453	0.806	0.167	0.157
	Smut resistance	0.791	0.343	0.273	0.872	0.385	0.342	0.844	0.156	0.074
	Aphid resistance	0.759	0.327	0.264	0.667	0.385	0.769	0.897	0.111	0.111
Food quality and marketability	Food preparation	0.877	0.767	0.681	0.949	1.000	0.949	0.978	0.644	0.622
	Local beverages	0.834	0.770	0.672	0.744	0.692	0.607	0.923	0.846	0.786
	Marketability	0.911	0.793	0.731	0.974	0.846	0.821	0.952	0.571	0.540

Source: Own survey, 2014

Malt quality and marketability: The three varieties demonstrate different perceived malt quality and Miscal 21 is perceived to have better malt quality than the other two varieties. However, these varieties have similar perceived quality for local drink preparation. Perceived marketability seems to be associated with perceived malt quality.

3.4. Commercial behaviors in seed use and implications for barley seed demand assessment

3.4.1. Commercial behaviors in seed use

Farmers may use seed for sowing from different sources for various reasons (Bishaw 2004). Understanding the commercial behavior of smallholder farmers concerning seed in terms of purchasing practices or use of saved seed helps gauge the seed market and target promotions to create demand and ensure supply (Bishaw et al. 2011; Alemu and Bishaw 2015). The assessment reveals that of the total 23.3 percent of full adopters of improved varieties of food barley, 6.2 percent purchase certified seed, 3.4 percent purchase seed from local sources, and 13.7 percent use their own saved seed (Table 10). Among the non-adopters, 8.3 percent use purchased seed from local sources and 58.9 percent use saved seed. For malt barley, 38.5 percent of farmers use certified seed, 17.5 percent use locally purchased seed, and the remaining 44.1 percent use saved seed (Table 11).

These results indicate that most adopters of improved varieties still depend on the use of saved seed or locally purchased seed for barley, showing the predominance of the informal sector and the limited use of certified seed.

The commercial behavior for food barley seed indicates that 21.2 percent of farmers engage in buying and selling either certified or non-certified seed and the remaining 78.8 percent are in an autarkic seed market position, where they do not engage in the seed market. Of the 8.1 percent of food barley producers, who purchase certified seed, about 2 percent simultaneously engage in selling

Table 9. Demand index (DI), supply index (SI), and attainment index (AI) for malt barley varieties (2014)

		Holker			Miscal 21			Sabini		
Category	**Varietal attributes**	**DI**	**SI**	**AI**	**DI**	**SI**	**AI**	**DI**	**SI**	**AI**
Yield and grain characteristics	Grain yield	0.964	0.958	0.925	0.976	0.913	0.892	0.991	0.874	0.877
	Grain size	0.899	0.857	0.764	0.952	0.857	0.820	0.955	0.730	0.694
	Spike (row) type	0.842	0.606	0.501	0.944	0.698	0.656	0.946	0.559	0.517
	Spike length	0.867	0.788	0.681	0.952	0.905	0.868	0.946	0.829	0.781
	Straw yield	0.842	0.867	0.867	0.881	0.754	0.738	0.955	0.667	0.643
Field establishment, stand, and earliness	Plant stand	0.857	0.917	0.780	0.968	0.937	0.910	0.973	0.829	0.805
	Tillering capacity	0.905	0.863	0.778	0.968	0.960	0.929	0.964	0.874	0.841
	Lodging	0.810	0.607	0.494	0.968	0.857	0.828	0.991	0.757	0.751
	Early maturity	0.812	0.733	0.681	0.873	0.857	0.746	0.874	0.883	0.781
Resistance to stresses	Drought resistance	0.836	0.685	0.586	0.829	0.701	0.604	0.883	0.090	0.690
	Smut resistance	0.827	0.605	0.488	0.838	0.821	0.678	0.853	0.725	0.631
	Aphid resistance	0.788	0.617	0.502	0.833	0.825	0.684	0.882	0.686	0.637
Malt quality and marketability	Malt quality	0.833	0.889	0.749	0.974	0.956	0.930	0.952	0.914	0.879
	Quality for local drinks	0.885	0.952	0.846	0.913	0.881	0.839	0.917	0.889	0.836
	Marketability	0.921	0.927	0.848	1.000	0.968	0.968	0.991	0.982	0.976

Source: Own survey, 2014

seed (Table 11). These trends have direct implications for food barley seed demand assessment and access to seed. If quality seed of preferred varieties is available at the right place and time with affordable prices, 21.2 percent of the food barley farmers can use quality seed under the current demand level. However, the remaining 78.8 percent who are in the autarkic market position require interventions related to demand creation in terms of both quality seed use and varieties.

3.4.2. Barley certified seed demand and supply

The demand and supply of seed from the formal sector is often challenged by poor demand assessment methods, the production capacity of seed suppliers, and farmers' demand shifts in response to emerging production and marketing issues (Alemu 2011). A review of barley seed demand and supply for 2014 shows interesting results for performance of the formal seed sector in Ethiopia (Table 12).

First, there are huge gaps in the seed demand and supply of food and malt barley varieties. In total only 9 percent of barley seed demand is met, with only 4 percent for food barley and only 17 percent for malt barley. Of the total barley seed supplied, the Oromia Seed Enterprise (OSE) contributes 65 percent, followed by the Ethiopian Seed Enterprise (ESE) with 30 percent; the remaining 5 percent is supplied by the Amhara Seed Enterprise (ASE) and the South Seed Enterprise (SSE).
Second, there is a mismatch between varietal choices and seed supply from the formal sector. For example, 80 percent of food barley seed supplied by the formal sector is for a single variety (HB-42), which is more than 30 years old. Similarly, for malt barley, two varieties over 37 years of age occupy 94 percent of the total seed supplied by the formal sector. These are the variety Holker, released 37 years ago and occupying 57 percent of the supply in the 2013/14 production season, and Beka, released 39 years ago and covering 37 percent. However, for food barley varieties HB-1307, Meserach, and Gobe, and the malt barley variety Sabini, hardly any seed is supplied (Table 12).

Third, linked with the characteristics of seed demand and supply, are the number and age of varieties. Of 37 food barley and 16 malt barley varieties released, the data indicate that the seed demanded is revealed only for six varieties each for both crops. Interestingly, of the six food barley varieties demanded, two varieties with

Table 10. Certified seed use by adoption and barley type

		Commercial behavior (% of barley producers)			
Crop	Adoption	Purchased certified seed	Purchased non-certified seed	Own saved seed	Total
Food barley	Full adopter (n = 124)	6.2	3.4	13.7	23.3
	Partial adopter (n = 51)	1.9	1.5	6.2	9.6
	Non-adopter (n = 358)	-	8.3	58.9	67.2
	Total (n = 533)	8.1	13.1	78.8	100.0
Malt barley	Full adopter (n = 162)	38.5	17.5	44.1	100.0
Total		**15.2**	**14.1**	**70.7**	

Source: Own survey, 2014

Table 11. Commercial behavior in food barley seed and certified seed use (% of food barley producers)

	Seed use			
Commercial behavior	Purchased certified seed	Purchased non-certified seed	Own saved seed	Total
Autarkic (n = 420)	-	-	78.8	78.8
Buy local (n = 41)	-	7.7	-	7.7
Buy improved (n = 31)	5.8	-	-	5.8
Sell improved (n = 10)	1.9	-	-	1.9
Buy both local and improved (n = 22)	0.4	3.8	-	4.1
Sell and buy local (n = 6)	-	1.1	-	1.1
Buy local and sell improved (n = 3)	-	0.6	-	0.6
Total (n = 533)	**8.1**	**13.1**	**78.8**	**100.0**

Source: Own survey, 2014

14,279.4 tons of certified seed (55 percent of demand) are more than 29 years old and the other two with 4,051.1 tons (15.6 percent of demand) are more than 16 years old. Similarly, of the six malt barley varieties demanded, two varieties with 17,412.3 tons of certified seed (81 percent of demand) are more than 35 years old.

Fourth, considering the national barley area of over 1.02 million ha, the estimated total annual potential seed requirement would be about 127,500 tons. The amount of certified seed supplied of 4,235.3 tons can cover only 33,882 ha of the total barley area or 3.3 percent of the total estimated annual seed requirement. However, conventional wisdom shows that, for self-pollinated crops like barley, farmers can keep and reuse seed for a few years once they have purchased certified seed. Assuming a seed replacement rate of four years for barley, the annual certified seed requirement is estimated at 31,875 tons to cover 25 percent of the barley area (255,000 ha). Therefore, the amount of certified seed distributed, estimated at 4,253.3 tons of the certified seed requirement, can in fact be used to plant up 13.3 percent of the barley area each year, at a 25 percent seed replacement rate. Ironically, seed demand does not truly reflect the actual seed requirement and the CSA estimates do not show actual certified seed coverage.

These facts imply not only an utter failure of estimating the demand and supply of barley seed but also a lack of comparable improved barley varieties to replace existing old commercial varieties or a lack of adequate information as a result of limited promotion by agricultural research or extension services. Moreover, the demand and supply gap also shows limited interest from either the public or the private sector to be engaged in barley seed delivery in the country.

The trends of a huge gap in demand and supply and varietal mismatch also imply that very few farmers are served by the formal sector despite high demand for quality seed of these crops. This is one of the major contributors to yield gaps at the national level as discussed in the next section.

3.5. Farmers' varietal preference and commercial behavior with the formal barley seed markets

It is expected that farmers' varietal preferences and revealed demand play crucial roles in influencing the performance of the formal seed sector in aligning the supply of seed of more preferred and demanded varieties. The assessment of perceived varietal preference of barley producers and the relationship between revealed demand and the supply of seed from the formal sector show considerable mismatching.

The preferences of food barley producers were elicited using preference AI for varieties that they grow. The AIs for five varieties are presented, considering diverse varietal attributes (Table 8). Considering the value of AI for yield, the two varieties HB-42 and Harbu are less preferred, whereas Shege (AI = 0.952), Meserach (AI = 0.897), and HB-1307 (AI = 0.889) are highly preferred compared to local varieties, in order of importance. However, in terms of supply of certified seed from the formal sector, from the total 996 tons supplied, 80 percent (774 tons) is of HB-42 and the remaining 20 percent is for other varieties (Shege, Ardu 12 60B, and HB-1307) in the 2014 production season. This result indicates the clear mismatch of supply of certified seed with farmers' varietal preferences of food barley varieties. Similarly, there is a mismatch between the varietal preference and type of malt barley varieties for which certified seed is produced and supplied. In the 2014 production season, 57 and 37 percent of the total certified seed produced (3,269 tons) was for varieties Miscal and Beka, respectively, for which an adequate number of farmers were not able to reveal their preference. Only the remaining 6 percent of the total certified seed produced was for variety Holker, which has the highest AI value for yield (0.925).

4. Conclusions and recommendations

Barley is an important food security cereal crop in the highlands with a growing trend in terms of area, production, and productivity over time. Moreover, malt barley has become a cash crop due to the rapid increase in brewing, which has created a tremendous opportunity for commercialization and uptake of improved technologies by farmers to meet the potential demand from domestic and foreign markets.

Despite the availability of a large number of improved food barley varieties reported to perform better in many attributes, adoption levels appear to be very low. The study reveals that adoption of improved food barley varieties is very low, with 23.3 percent of farmers being adopters and 27.3 percent of the estimated land area covered by improved varieties. Among food

Table 12. Food and malt barley certified seed demand and supply (2014)

					Amount supplied (tons)					Supply gap		Share of each variety from total certified seed produced (%)	
Crop	Crop and variety	Year of release	Age (years)	Revealed demand (tons)	ESE	OSE	ASE	SSE	Total	Amount (tons)	%	Demand	Supply
Food barley	HB-42	1984	31	11,559	32	742	-	-	774	10,786	93	45	80
	Ardu 12 60B	1985	30	2,720	56	-	-	34	90	2,630	97	10	9
	Shege	1995	20	2,569	50	33	-	-	83	2,487	97	10	9
	Meserach	1997	18	1,482	-	-	-	-	-	1,482	100	6	-
	HB-1307	2006	9	6,538	-	-	-	20	20	6,518	100	25	2
	Gobe	2012	3	1,084	-	-	-	-	-	1,084	100	4	0
	Sub-total			*25,953*	*137*	*775*	-	*54*	*966*	*24,987*	*96*	*100*	*100*
Malt barley	Beka	1976	39	1,597	421	787	-	-	1,207	390	24	8	37
	Holker	1979	36	15,815	731	982	161	-	1,873	13,942	88	2	6
	HB-52	2001	14	92	-	-	-	-	-	92	100		
	HB-1533	2004	11	3	-	-	-	-	-	3	100		
	Miscal	2006	9	301	-	189	-	-	189	112	37	81	57
	Sabini	2011	4	1,636	-	-	-	-	-	1,636	100	8	
	Sub-total			*19,444*	*1,151*	*1,957*	*161*	-	*3,269*	*16,174*	*83*	*100*	*100*
Total				**45,396**	**1,289**	**2,732**	**161**	**54**	**4,235**	**41,161**	**91**		

Source: Data from the National Seed Production and Distribution Committee, 2014
Note: ESE, Ethiopian Seed Enterprise; ASE, Amhara Seed Enterprise; OSE, Oromia Seed Enterprise; and SSE, South Seed Enterprise

barley producers, adoption levels for the *meher* season (28.6 percent) are higher compared to the *belg* season (14.7 percent). In contrast, because malt barley is an introduced crop, all farmers have adopted improved varieties; however, varieties older than 37 years are dominant among the total of 16 released varieties available. The results show farmers' lack of information on recently released varieties and the need for promotion by research and extension services.

Barley seed demand and supply are quite mismatched in terms of availability of seed in desired quantities and a choice of varieties on the market. There is a huge demand and supply gap with seed of several old improved varieties released more than 30 years ago dominating the formal seed market both for food and malt barley. Moreover, there is limited commercial interest in barley seed production and marketing both by the public and private sector. This may change in coming years as malt barley becomes commercialized and contract farming is practiced by farmers, malt factories, and breweries.

The commercial behavior of farmers differs in relation to seed of food and malt barley. Among growers of improved food barley varieties, 8.1 percent use certified seed from formal sources and 13.1 percent purchase seed from local sources based on *meher* season production. However, 38.5 percent of malt barley growers buy certified seed and about 17.4 percent purchase seed from local sources. This implies that under the current demand and supply situation, the formal sector can target only 21.2 percent of food barley growers and 55.9 percent of malt barley growers that are in a purchasing position. This implies the need for demand creation both in terms of variety and quality seed for the remaining 79 percent of food barley producers.

The current state of barley production in terms of yield gaps, varietal adoption levels, and commercial behavior of smallholders in seed use demonstrates the following key challenges and future areas of attention:

- Barley is grown as a food security crop in the highlands of the country where there is limited crop diversity. Moreover, the barley farming landscape is characterized by low average yields with old commercial varieties dominating the formal sector for both food and malt barley, showing a low rate of varietal replacement. Therefore, promotion of newly released improved barley varieties to create awareness and enhance varietal choices and adoption is critical for increased productivity.
- There is a huge gap between demand and supply of certified seed, and mismatches in varietal choices of both food and malt barley. Moreover, the size of revealed demand for certified seed for both food and malt barley is very small and not commensurate with the total land allocated for these crops. To ensure realistic demand and supply of certified seed from the formal sector, better demand assessment measures must be put in place, taking into account shifts in farmers' demands in response to emerging production and marketing challenges. This should be coupled with creating demand for the use of certified seed and creating awareness of newly released varieties.
- The commercial behavior of farmers indicates the dominance of farmers' use of own saved seed or locally purchased seed even among adopters of improved varieties. Given the considerable use of saved seed of improved varieties, it will be important to promote decentralized and business-oriented seed production schemes by mobilizing communities or farmer groups that can contribute to improving the use of better quality seed.

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