academicJournals

Vol. 7(4), pp. 107-124, April 2015
DOI: 10.5897/JPBCS2013.0436
Article Number:7A94D9551393
ISSN 2006-9758

http://www.academicjournals.org/JPBCS

Journal of Plant Breeding and Crop Science

Full Length Research Paper

Performance of farmers' and improved varieties of barley for yield components and seed quality

Girma Megersa[1]*, Firew Mekbib[2] and Berhane Lakew[3]

[1]Department of Agriculture, College of Veterinary Medicine and Agriculture, Salale Campus, Addis Ababa University, Ethiopia.
[2]College of Agriculture and Environmental Science, School of Plant Science, Haramaya University, Dire Dawa Ethiopia.
[3]Holetta Research Center, Institute of Agricultural Research, Ethiopia.

Received 23 December, 2013; Accepted 17 February, 2015

The objective of this study was to assess the performance of farmers' and improved varieties of barley for yield and yield related traits and seed quality attribute in North Shewa Zone of Oromiya Region, Ethiopian. Seven farmer's varieties (FVs) and three improved varieties (MVs) of barley were tested at three locations in Degem Wereda in randomized complete block design (RCBD) design with three replications during 2010 Meher (June-September) cropping season. Barley seed obtained from experimental plots was used to make seed quality analysis such as physical purity, germination, vigour and health as per ISTA procedures and methods (1996). Garbuu Ggurracha was superior in yield potential and seed quality traits for meher season. Damoy is suitable variety for belg season production due to its early maturity and low moisture requirement. Statistically, grain yield was significant ($p<0.01$) variation was observed among varieties tested for important quantitative traits across locations indicating the presence of variability among genotypes. The analytical purity of seed samples collected from field experiment was ≥ 98.17% which was greater than the national seed standard (85%). At harvest, barley seed exhibited dormancy and germinate poorly. Significant differences in seed germination were observed between the first (after one month) and the second (after four months) test which could be attributed to thick hull character which may warrant further investigation. Sixteen different fungi genera were identified from the seed samples among which eight are known to be seed transmitted and the rest causing seed deterioration. In general significant different was observed among varieties for different pathogen infection. This study may indicate greater yield response through direct selection in barley landraces. This may be the nature of FVs' with better adaptive traits to variable environmental factors which has paramount importance for the local farmers to reduce risk. Minimum improvement for adopting early maturing varieties in an area of short rainfall to attain food security is vital. Attention should be given for conservation and improvement of farmers' varieties.

Key words: Barley seed, germination, vigour, food barley.

INTRODUCTION

Farmers' varieties are important crop genetic resources and are valued by plant breeders and farmers because of diversity (heterogeneous population), rarity (embodying unique traits) and adaptability (exhibiting wide ecological and socio-cultural adaptation) (Brush and Meng, 1998; FAO, 1998; Smale, 2006). Farmers throughout the world continue to maintain and manage farmers' varieties within their production systems (Hawkes, 1971; Duvick, 1984;

Brush et al., 1995; Brush, 2004; Jarvis et al., 2008; FAO, 2010). Yet the value they contain for the farming communities that maintain them has not been fully capitalized on.

Not all landraces and improved varieties are equally valued by farmers for yield and yield related components and seed quality attributes. Some landraces are adapted to marginal ecosystems (Vandermeer, 1995; Bezancon et al., 2009; Barry et al., 2007; Rana et al., 2008) or have cultural, religious, or nutritional values (Rana et al., 2007; Sthapit et al., 2008; Johns and Sthapit, 2004). Some landraces maybe highly valued but their use is constrained by poor access to quality and quantity of seeds for planting (Tripp, 2001; Almekinders et al., 2006; Sperling, 2008; Hodgkin et al., 2007). Landrace populations may, themselves, not be uniform in their adaptive or quality traits, having significant variation both within and amount populations (Teshome et al., 2001; Harlan, 1975; Mariac et al., 2006; Barry et al., 2007).

One way of distinguishing farmer's varieties that provide high public value is to classify those in terms of their immediate and future plant breeding benefits (Smale et al., 2004). This required consultation with farmers and breeders but also other concerned including consumers, wholesalers and retailers (Sthapit et al., 2001; Sperling et al., 2001; Bellon et al., 2003; Witcombe et al., 2005).

The recent approach in participatory and decentralized plant breeding over the last decade has shown that improving varietal performance in low input systems can help improve local livelihoods (Ceccarelli et al., 2000; Smith et al., 2001; Almekinders et al., 2006; Zeven, 2000; Dawson et al., 2008). Varieties can be improved by selection of preferred traits from the heterogeneous populations, collected locally before any crop improvement programme is initiated. However, insufficient attention has been given to the potential use of the existing landrace variability in production systems to provide direct benefits to local communities (Sthapit and Rao, 2009).

Damoy is considered nutritious and is preferred and selected for medicinal value believed for healing broken bone and for women during childbirth. *Garbuu Adii* is preferred for porridge during *Meskel* festival and for *kincheatetee (facasa)* for the blessing of God for an Ethiopian new year. *Garbuu Gurracha* preferred for socio-cultural (for labor sharing) values and for its high yield. *Damoy* and *G/gurracha* selected for their early maturity and malt for local beverage.

Variability in grain quality of landrace is the main concern for traders and consumers in marketing it. Consumers are willing to pay a high price for its purchase, but the landrace has a problem with quality variation. Therefore, this study was to assess the one year data for performance between farmers' and improved varieties of barley for some yield and yield related traits and seed quality attributes.

MATERIALS AND METHODS

Description of the study sites

The experiment was conducted at Degem Wereda, North Shewa Zone of Oromiya (Figure 1) selected for the following reasons: (i) Barley was the dominant crop in the area; (ii) Some FV's were still being grown; (iii) Less government attention to conservation of FV's of barley, and (iv) There was no similar study that could be used as a baseline in the area. This assumption emanates from the fact that the prevailing networks in the farmers' seed system had been highly influenced by the formal seed system.

Field experiment

Experimental design and treatments

Three representative peasant associations (PAs), namely; *Anno Degem, Anno Qarree* and *Tumno Abdii* were selected for the field experiment. The experimental design used was randomized complete block design (RCBD) with three replications. Ten food barley varieties were included in the field experiment, that is, five FV's currently under production (*Damoy*, *G/adii*, *Tolasee*, *G/gurracha* and *Magee*), two lost FV's (*Hadho* and *Karfee)* and three improved varieties (HB42, HB1307 and *Shagee)* (Table 1). Seeds were planted at a seed rate of 30 g plot^{-1} in a plot size of 3 m^2 (six rows of 2.5 m long spaced 0.2 m apart between rows).

The experiment was planted on May 23 and 24 /2010. The first weeding was carried out thirty days after crop emergence and the second weeding was performed thirty days after the first weeding. Data were collected on 11 developmental and yield related traits (Table 2).

Seed quality analysis

Barley seed obtained from experimental plots was used to make seed quality analysis. The experiment was conducted in a Complete Randomized Design (CRD) with four replications as per ISTA methods (1996).

Determination of physical seed quality (Experiment-1)

Analytical purity test: From submitted sample of 120 g two replicates of 60 g was analyzed (ISTA, 1996). The samples were divided into three; (I) pure seed, (II) other crop seed, and (III), inert matter. The components were weighed on precision balance to the nearest two decimal places and the percentage of each component was determined (ISTA, 1996).

The percentage by weight of each component fraction was calculated by the following formula (ISTA, 1996):

$$\text{Component (\%)} = \frac{\text{Weight of each component fraction}}{\text{Total test sample weight}} \times 100$$

Thousand kernel weight (TKW): Eight replicates of 100 seeds

*Corresponding author. E-mail: girma.megresa@yahoo.ca

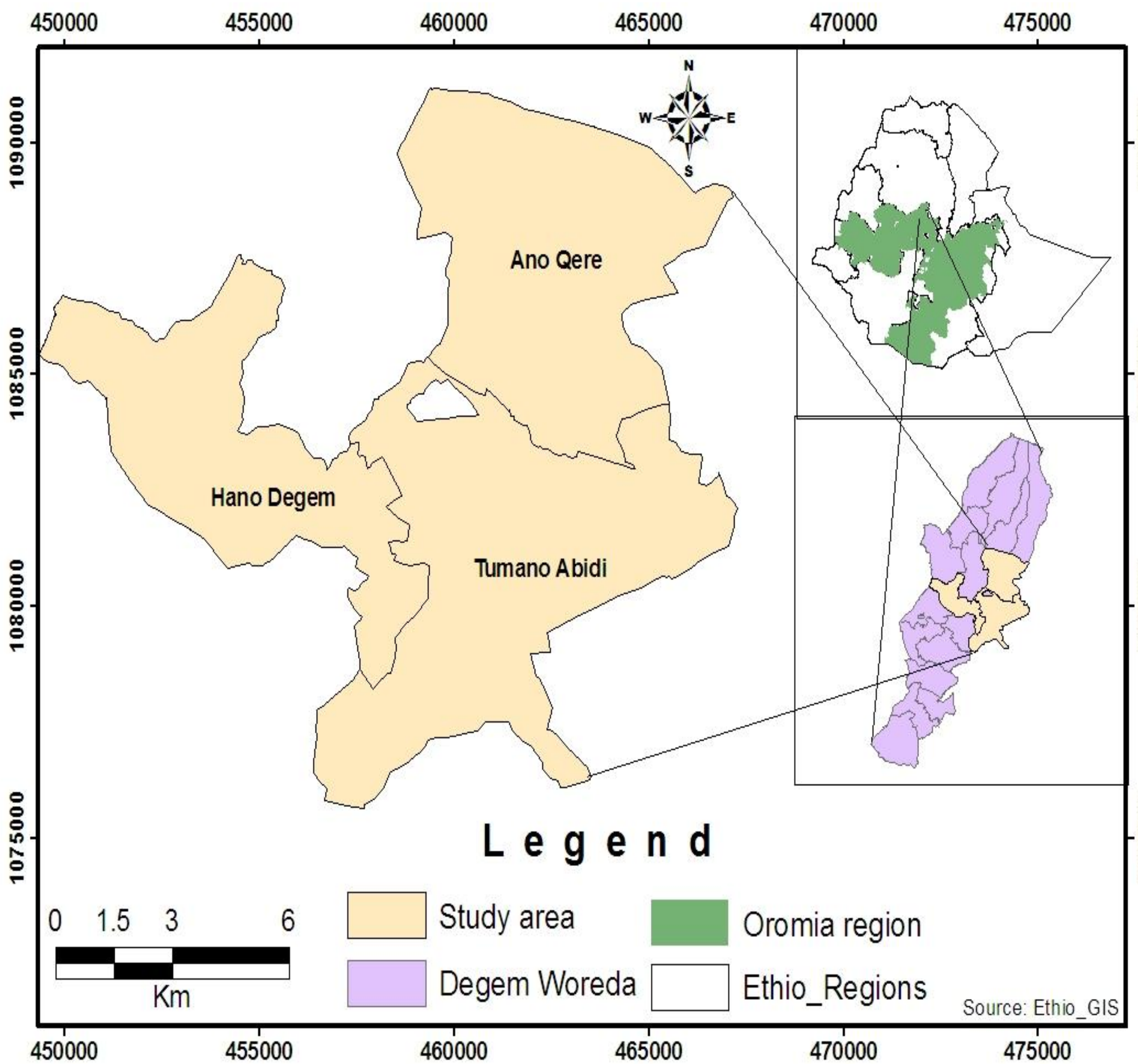

Figure 1. Map of Ethiopia, Oromiya and Degem Wereda showing the study area.

Table 1. List and description of barley varieties used for the field experiment.

S/N	Name	Pedigree	Year of release	Seed color	Row type
1	*Garbuu adii*	Farmers' variety	-	White	6R
2	HB-1307*	A cross made at Holetta from Awura gebs-1/IBON 93/91	2006	White	6R
3	*Garbuu hadho*	Farmers' variety	-	Purple	Irregular
4	HB-42*	A cross made at Holetta from IAR/H/81/Comp29/Comp 14/20/Cost	1985	White	6R
5	*Damoy*	Farmers' variety	-	White	6R
6	*Garbuu gurracha*	Farmers' variety		Black	6R
7	*Shagee* (Line 3333-20)*	Landrace selection from Arsi collection	1996	White	6R
8	*Tolasee*	Farmers' variety	-	White	6R
9	*Karfee*	Farmers' variety	-	Black	6R
10	*Magee*	Farmers' variety	-	Purple	6R

*Source: Fikadu (1987) and IAR (2006) Crop variety registration.

Table 2. Traits measured and derived on a plot basis for the field experiment.

No.	Traits	Abbreviation	Description
1	Days to 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
2	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
3	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
4	Grain filling period	GFP	Number of days between days to flowering and days to physiological maturity
5	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
6	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
7	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}
8	Biological yield	BY	Determined by weighing the total air dried above ground biomass harvested from the four central rows and expressed in kg ha^{-1}
9	Grain yield	GY	Grain yield in kilogram of the four central rows adjusted to 12% moisture content expressed in kg ha^{-1}
10	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
11	Thousand kernel weight	TKW	Weight in gram of random sample of thousand seeds per plot

each were weighed from pure seed fraction (ISTA, 1996). The coefficient of variation was calculated to assess the acceptability of the test and the thousand kernel weight was calculated (Bishaw, 2004).

Determination of physiological seed quality (Experiment-2)

Several physiological tests such as standard germination, speed of germination, seedling shoot length, and seedling root length and seedling dry weight were measured to assess the vigour of barley seed from field experiment.

(a) Standard germination (SG) test: SG test was done for all seed samples obtained from all treatments. Four hundred (400) seeds of the pure seeds component were divided into four replicates of 100 seeds each in germination box size of 18, 9 and 13 cm (length, height and width, respectively), which were then sown in sterilized sand media. The planted seeds were incubated at a temperature of 20°C for 7 days as specified by International Seed Testing Agency (ISTA, 1996). At the end of the incubation period the germination boxes were removed and the seedlings were evaluated. Germinated seedlings were divided into (I) normal seedlings, (II) abnormal seedlings, and (III) dead seeds to determine the percentage of different seedlings.

$$\text{Germination (\%)} = \frac{\text{Total number of normal seedlings}}{\text{Total number of seeds tested for germination}} \times 100$$

(b) Seed vigour test: Seed vigour is an important quality parameter which needs to be assessed to supplement germination and viability tests to gain insight into the performance of a seed lot in the field or in storage.

Seedling shoots and root length: The seedling shoot length and seedling root length were assessed after the final count in the standard germination test. Ten normal seedlings were randomly selected from each replicate after 7 days of seed sowing. The shoot length was measured from the point of attachment to the cotyledon to the tip of the seedling. Similarly, the root length was measured from the point of attachment to the cotyledon to the tip of the root. The averages shoot and root lengths were computed by dividing the total shoot or root lengths by the total number of normal seedlings measured (ISTA, 1996). Varieties producing the taller seedlings were considered more vigorous than the varieties producing shorter seedlings.

Seedling dry weight: Ten randomly selected seedlings from each replicate were cut from the cotyledons and placed in envelops to be dried in an oven at 80°C for 24 h. The dried seedlings were weighed to the nearest milligram using sensitive balance and the average seedling dry weight was calculated. The seedling dry weight provides additional information for assessing seed vigour.

Vigour Index-I and Vigour Index-II: For each sample, two vigour indexes were calculated. Seedling vigour index-I was calculated by multiplying the normal germination percentage with the average sum of shoot and root length after seven days of germination and vigour index-II were calculated by multiplying the standard germination with mean seedling dry weight.

Vigor Index I=Standard germination (%) × Seedling length (cm)

Vigor Index II=Standard germination (%) × Seedling dry weight (mg)

Speed of germination: 100 seeds were replicated into four from each sample and kept at 20°C for maximum of 7 days in an incubator. Each day, normal seedlings were removed. Then speed of germination (GS) was calculated as follows (Maguire, 1962):

$$GS = \frac{\text{Number of normal seedlings}}{\text{Number of days to first count}} + \ldots + \frac{\text{Number of normal seedlings}}{\text{Number of days to final count}}$$

The varieties having greater germination index were considered more vigorous.

Table 3. Mean values of yield components of food barley varieties combined across locations at Degem Wereda 2010.

Varieties	DF	DM	GFP	BMPR	PH
Garbuu adii	107.4[ab]	135.6[ab]	28.1[d]	57.7[bcd]	105.8[abcd]
HB 1307	101.2[c]	135.4[b]	34.2[a]	79.6[a]	99.2[def]
Hadho	100.9[c]	132.7[c]	31.8[ab]	50.3[d]	97.3[ef]
HB42	105.3[b]	136.0[ab]	30.7[bcd]	50.5[d]	108.4[abc]
Damoy	91.1[e]	115.0[f]	23.9[e]	49.5[d]	103.6[bcde]
G/gurracha	96.9[d]	128.4[e]	28.1[d]	78.5[a]	111.9[a]
Shagee	101.2[c]	135.0[b]	33.8[a]	51.1[cd]	103.3[cde]
Tolasee	108.1[a]	136.0[ab]	27.9[d]	62.8[b]	111.6[a]
Karfee	99.7[c]	130.3[d]	30.7[bcd]	37.3[e]	94.9[f]
Magee	108.6[a]	137.1[a]	28.6[cd]	59.4[bc]	111.4[ab]
Mean	102.0	132.2	30.1	57.7	104.8
CV (%)	2.3	1.3	10.7	15.8	15.9

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, DF=Days to flowering; DM=Days to maturity; GFP=Grain filling period; BMPR=Biomass production rate; PH=Plant height.

Seed health testing (Experiment-3)

The agar plate method: About 15 ml of sterilized medium was poured in each Petri dish (9 cm, Pyrex, USA) under aseptic conditions under micro flow. Four hundred seeds from each sample were surface sterilized in 1% NaOCl for ten minutes, rinsed with sterilized water, and then 20 seeds were plated in each Petri dish. The set was incubated at 22 ± 2°C for 12 h of alternating cycles of day and night under fluorescent light (Anon, 1996). Colonies and fruiting bodies of the fungi were identified using stereo and compound microscopes with aids of appropriate reference materials.

Mycological evaluation: Mycoflora associated with barley seed were detected by standard methods (Anonymous, 1996). The presence and type of fungi were determined according to their development on the seed, which were incubated on Potato Dextrose Agar (PDA) medium. Seeds were examined by Binocular microscope, Compound microscope and CIMMYT Manual for Detection of Seed-borne Microorganisms and Descriptions (1998). Fungi appearing on Petri plates were directly identified up to the species level with the help of a compound microscope and relevant literature (Booth, 1971; Ellis, 1976; Sutton, 1980; Nelson et al., 1983; CIMMYT, 1998). Percent incidence of fungi was recorded. Data collected on incidence of fungi were analyzed statistically.

$$\text{Percent incidence} = \frac{\text{No. of infected seeds}}{\text{Total number of seeds examined}} \times 100$$

Data coding and entry

Semi structured and structured questions were properly coded and entered into the computer using Microsoft Excel Application Program. Quantitative data were organized to suit the different statistical packages used in the analysis. For better interpretation of results, some of the data sets were transformed into standard units. Qualitative data were organized in such a way that cumulative of the respondent’s information was presented.

Data analysis

Data collected from the field and laboratory experiments were subjected to analysis of variance using software SAS version 9 and Genstat discovery edition. Treatment means were separated using Least Significance Difference (LSD) test and Duncan’s Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Performance of improved and farmers’ varieties for yield and yield components

The performance of ten food barley varieties for various phenological and agronomic traits is presented subsequently.

Days to heading and maturity

Both days to heading and days to maturity differed significantly among varieties. Days to flowering ranged from 91 to 109 days with a mean value of 102 days. Days to maturity ranged from 115 to 137 days with a mean value of 132.15 days. *Damoy* was the earliest variety to heading (91 days) and maturity (115 days) while *Mage*e took longer days to heading (109) and maturity (137 days). *Hadho*, *G/gurracha* and *Karfee* were medium maturing varieties. Variety *Damoy* was the dominant variety grown during the *belg* season where rainfall variability is high. The variation for both phenological traits was high among the test varieties and this was more apparent on the FV’s compared to improved varieties which all were late maturing (Table 3).

Grain filling period and plant height

Grain filling period ranged from 23.88 to 34.22 days with mean value of 30.11. The shortest grain filling period was observed on *Damoy* and the longest on *G/adii* (Table 3).

Table 4. Yield and yield related components.

Varieties	SL	NSPS	BY	GY	HI	TKW
G/ adii	6.7[a]	47.9[ab]	6190.6[c]	2672.1[cd]	0.44[a]	44.5[a]
HB-1307	6.1[a]	40.8[b]	8058.6[a]	3446.5[ab]	0.42[a]	44.2[a]
Hadho	6.6[a]	42.9[ab]	5068.8[d]	2354.9[cd]	0.44[a]	42.7[a]
HB-42	6.2[a]	47.4[ab]	5288.6[d]	2187.5[d]	0.40[a]	45.0[a]
Damoy	6.4[a]	51.1[a]	4504.6[de]	2178.5[d]	0.48[a]	43.6[a]
G/gurracha	6.3[a]	50.1[a]	7625.0[ab]	3573.6[a]	0.46[a]	44.1[a]
Shagee	6.4[a]	45.1[ab]	5155.9[d]	2306.9[cd]	0.44[a]	42.4[a]
Tolasee	6.7[a]	51.3[a]	6787.0[bc]	2933.8[bc]	0.43[a]	44.9[a]
Karfee	4.6[b]	42.2[ab]	3711.4[e]	1489.2[e]	0.39[a]	44.4[a]
Magee	5.8[a]	51.1[a]	6442.9[c]	2892.7[bc]	0.45[a]	45.5[a]
Mean	6.2	47.0	5883.3	2603.6	0.44	44.1
CV (%)	7.9	21.4	16.1	26.0	21.26	12.1
R^2	0.72	0.33	0.87	0.74	0.27	0.35

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; SL=Spike length; NSPS=Number of spike per spikelet; GY, Grain yield (kg ha^{-1}); BY, Biomass yield (kg ha^{-1}); HI, Harvest index (%); TKW= Thousand kernel weight.

Varieties with the shortest grain-filling period had the advantage to escape terminal moisture stress and good character to cope up with the rainfall variability in the highlands of Degem.

Variation for plant height among the varieties ranged from 94.9 to 111.1cm with mean site value of 104.75. *Karfee* was the shortest variety (94.9 cm) whereas *G/gurracha and Magee (*111.5 cm) were the tallest varieties. Most of the FV's were tall with weak stem, which was the common character of the local FV's. The improved varieties were relatively short with strong stem. Fekadu (2010) also reported that modern varieties are shorter in plant height compared to the FV's.

In contrast to our findings, Martiniello et al. (1987) reported that modern genotypes showed trends towards earliness in both six and two row barley genotypes compared to landraces. It was reported that most modern barley varieties were relatively earlier than the landraces whereas maturity time was similar among all varieties (Wych and Rasmusson, 1983). Furthermore, similar observation was also reported in hard red winter wheat in USA (Cox et al., 1988), in spring wheat in Australia (Perry and D'Antuono, 1989), in wheat in UK (Austin, 1999) and in winter wheat genotypes in Great Plains (Donmez et al., 2001) that modern varieties reached flowering and maturity earlier than the older ones. Metzger et al. (1984) indicated that selection for grain filling duration was not promising to improve yield of barley in Minnesota, suggesting that grain-filling duration is not yield limiting factor in barley.

Spike length and number of spikletes per spike

The spike length ranged from 4.6 to 6.7 cm with mean value of 6.2 cm (Table 4). The total variation among the varieties was small and almost most of the varieties had spike length of 6.1 to 6.7 cm. Among the varieties, *Karfee* had the shortest spike length (4.6 cm) while *G/adii* and *Tolasee* were the longest (6.67 cm). The mean difference between the number of spikletes per spike varied from 40.8 for HB-1307 to 51.3 for *Tolasee* with the mean value of 47. The number of spiklets per spike for most of the varieties was in the range of 45 to 51 cm. Although, no significant difference was observed among varieties on number of spikelets per spike, kernel weight, spikelets per spike and spike length are observed as the main components of yield (Table 4). The morphology of spike is a major concern in crop improvement. Similarly, Bensemane (2011) reported that the yield components, spikes per square meter followed by kernels per spike exerted the greatest effect on grain yield. Similarly, Sinebo (2002) reported that barley spike is a source and sink of assimilates that ultimately determines grain yield.

Biomass yield, grain yield, thousand kernel weight and harvest index

Mean differences were observed among the barley varieties for biomass and grain yield, but not for thousand kernel weight and harvest index (Table 4). Biomass yield ranged from 3711.4 for *Karfee* to 8058.6 kg ha^{-1} for HB-1307 with mean value of 5883.3 kg ha^{-1} (Table 4).Varieties such as *Magee*, *Tolasee* and *G/adii* was on par in biomass yield. The variation for grain yield per hectare ranged from 1489.2 for *Karfee* to 3573.6 kg ha^{-1} for *G/gurracha* 2603.6 kg ha^{-1} (Table 4).

The site mean value of grain yield was 2554.6 kg ha^{-1} at *Anno Degem*, 2282.4 kg ha^{-1} at *Anno Qarree* and 2973.8 kg ha^{-1} at *Tummano Abdii*. Grain yield potential of *Anno Degem* was intermediate while that of *Tummano*

Table 5. Phenological/developmental traits of ten-food barley varieties at Degem Wereda in 2010.

Variety	Locations											
	Anno Degem				*Anno qarree*				*Tumano*			
	DF	PH	DM	GFP	DF	PH	DM	GFP	DF	PH	DM	GFP
G/adii	106.3^{a}	98.7^{abc}	135.3^{a}	29.0^{cd}	108.0^{a}	103.3^{abcd}	135.7^{a}	27.7^{cd}	108.0^{a}	115.3^{ab}	135.7^{a}	27.7^{cde}
HB-1307	100.0^{bc}	101.3^{abc}	135.7^{a}	35.7^{ab}	101.0^{b}	93.0^{cd}	135.3^{a}	34.3^{ab}	102.7^{b}	103.3^{bc}	135.3^{a}	32.7^{ab}
Hadho	101.0^{b}	101.7^{ab}	133.0^{ab}	32.0^{abc}	101.0^{b}	87.0^{d}	132.7^{b}	31.7^{abc}	100.7^{bc}	103.3^{bc}	132.3^{b}	31.7^{abc}
HB-42	100.0^{bc}	108.7^{a}	136.7^{a}	36.7^{a}	108.0^{a}	95.7^{abcd}	135.7^{a}	27.7^{cd}	108.0^{a}	121.0^{a}	135.7^{a}	27.7^{cde}
Damoy	87.0^{e}	96.0^{bc}	112.7^{d}	25.7^{d}	95.7^{b}	100.0^{abcd}	117.0^{d}	21.3^{d}	90.7^{d}	115.0^{ab}	115.3^{d}	24.7^{e}
G/gurracha	95.0^{d}	106.0^{ab}	128.3^{c}	33.3^{abc}	97.0^{b}	112.0^{a}	128.0^{c}	31.0^{abc}	98.7^{c}	117.7^{a}	129.0^{c}	30.3^{bcd}
Shagee	104.3^{a}	97.7^{bc}	133.7^{ab}	29.3^{cd}	99.7^{b}	103.7^{abcd}	136.3^{a}	36.7^{a}	99.7^{bc}	108.7^{abc}	135.0^{a}	35.3^{a}
Tolasee	105.0^{a}	106.7^{ab}	135.3^{a}	30.3^{bcd}	110.0^{a}	111.0^{ab}	136.7^{a}	26.3^{cd}	109.3^{a}	117.0^{a}	136.3^{a}	27.0^{de}
Karfee	98.0^{c}	90.7^{c}	130.7^{bc}	32.7^{abc}	100.0^{b}	93.3^{bcd}	130.0^{c}	30.0^{bc}	101.0^{bc}	100.7^{c}	130.3^{bc}	29.3^{bcd}
Magee	105.7^{a}	106.3^{ab}	137.3^{a}	31.7^{abc}	110.0^{a}	110.3^{abc}	137.0^{a}	27.0^{cd}	111.0^{a}	117.7^{a}	137.0^{a}	27.0^{de}
Mean	100.23	101.37	131.87	31.63	103.00	100.92	132.40	29.37	102.87	112.00	132.20	29.33
CV (%)	1.26	6.16	1.92	10.07	3.32	10.29	0.88	12.89	1.74	6.90	0.93	8.89
S.E	1.03	5.10	2.07	2.60	2.79	8.48	0.96	3.09	1.46	6.34	1.00	2.13

Means followed by a common letters with in a column are not significantly different from each other at P < 0.05 according to Duncan's Multiple Range Test. DF=Days to flowering, DM=Days to maturity; GFP=Grain filling period; PH= Plant height.

Abdii was relatively higher than both locations. The low yield obtained at *Anno Qarree* and high yield at *Tummano Abdi* could be attributed to low and high soil fertility respectively (Table 5).

Garbuu gurracha gave the highest grain yield followed by the recently released stiff straw variety HB-1307. Grain yield performance of HB-42 and *Shagee* varieties was lower compared to other varieties except *Damoy*, which was the least in grain yield (Table 4). Harvest index ranged from 39 to 48% ha^{-1} with mean value of 44%. Table 4 indicates that majority of the varieties had harvest index, between 40 and 48%.

No significant variation was observed among varieties for spike length, harvest index and thousand kernel weights. Number of spikelet per spike ranged from 42.2 to 51.1 with site mean value of 47.0 (Table 4).

Performance of improved and farmers' varieties of barley for yield and yield components at each location

At *Anno Degem*, the analysis of variance revealed highly significant differences (P<0.001 or P<0.01 or P<0.05) among the varieties for all the traits measured, except for TKW. Plant height was significantly different at P<0.05, while grain filling period was significantly different at P<0.01. Moreover, most yield and yield related traits showed highly significant at P<0.0001. However, number of spikelet per spike and thousand kernel weights were not significant.

The analysis of variance carried out at *Anno Qarree* on the eleven quantitative traits revealed highly significant differences among the varieties for most of the traits measured. Days to heading, grain filling period, biomass production rate, and biomass yield were significantly different at P≤0.01. Days to maturity and grain yield were highly significant different at P<0.0001. However, spike length, plant height number of spikelet per spike, harvest index and thousand kernel weights did not show any significant differences among the varieties.

At *Tumano,* the analysis of variance revealed significant differences among the varieties for most of the traits, except for spike length, number of spikelts per spike and thousand kernel weights. Plant height was significantly different at P≤0.01.

Table 6. Mean values for biomass production rate, spike length and number of spikelet per spike at the three sites.

Varieties	*Anno Degem*			*Anno qarree*			*Tumano*		
	BMPR	**SL**	**NSPS**	**BMPR**	**SL**	**NSPS**	**BMPR**	**SL**	**NSPS**
G/adii	74.8^{a}	7.3^{ab}	49.3^{a}	24.0^{d}	5.^{a}	44.0^{a}	74.3^{bc}	7.7^{a}	50.3^{a}
HB-1307	79.6^{a}	5.7^{cd}	42.7^{a}	76.8^{a}	5.7^{a}	38.0^{a}	82.5^{ab}	6.7^{ab}	41.7^{a}
Hadho	78.9^{a}	6.7^{bc}	46.3^{a}	28.4^{d}	6.0^{a}	38.3^{a}	43.4^{e}f	7.0^{a}	44.0^{a}
HB-42	62.4^{b}	5.3^{d}	54.0^{a}	32.1^{bcd}	6.7^{a}	45.7^{a}	57.1^{de}	7.0^{a}	43.3^{a}
Damoy	45.5^{c}	6.7^{bc}	53.3^{a}	54.0^{b}	6.0^{a}	48.0^{a}	49.0^{de}f	6.7^{ab}	52.0^{a}
G/gurracha	64.7^{b}	6.3^{bcd}	53.7^{a}	80.2^{a}	5.7^{a}	47.7^{a}	90.8^{a}	7.0^{a}	49.0^{a}
Shagee	38.7^{d}	7.0^{ab}	54.0^{a}	51.7^{b}	6.0^{a}	45.7^{a}	62.9^{cd}	6.3^{ab}	35.3^{a}
Tolasee	61.5^{b}	8.0^{a}	54.7^{a}	50.5^{bc}	5.0^{a}	49.3^{a}	76.4^{abc}	7.0^{a}	50.0^{a}
Karfee	43.9^{cd}	2.7^{e}	45.7^{a}	28.7^{cd}	5.0^{a}	46.0^{a}	39.2f	5.0^{b}	43.3^{a}
Magee	61.8^{b}	7.3^{ab}	55.0^{a}	38.7^{bcd}	5.0^{a}	38.0^{a}	77.7^{ab}	6.0^{ab}	52.3^{a}
Mean	61.19	6.3	50.9	61.19	5.6	44	65.31	6.63	46.1
CV (%)	6.27	11.3	17.47	6.2	21	17.1	12.89	15.2	27.6
S.E	3.14	0.4	7.26	10.42	1	6.43	6.89	0.82	10.4

Means followed by a common letters with in a column are not significantly different from each other at P < 0.05 according to Duncan's multiple range test; BMPR=Biomass production rate; SL=Spike length; NSPS=Number of spikelet per spike.

The other morphological and yield related components showed highly significant differences at P<0.0001.

Genotypic performance for phenological traits at each site

Mean phenotypic variation for phenological/ developmental/, of the 10 food barley varieties are shown in (Table 5). The amount of variation among the varieties for most of phenological traits was relatively high between the testing sites. At *Anno degem,* days to heading ranged from 87 to 106 days while at *Anno qarree* from 96 to 110 days and at *Tumano* it ranged from 91 to 111 days. The overall mean difference in DF among varieties were small (100, 103 and 103 days for *Anno degem, Anno qarree* and *Tumano*, respectively).

At *Anno degem,* plant height ranged from 90.7 to 108.7 cm with site mean of 101.4 cm while at, *Anno qarree* from 87 to 111 cm with site mean of 100.9 cm, and at *Tumano* from 100.7 to 121 cm with site mean value of 112 cm (Table 5). The variation in plant height across the three sites ranged from 100.9 to 112 cm, at *Anno qarree* and *Tumano*.

Mean days to grain filling period across the sites was 31.6 days at *Anno degem,* 29.4 days at *Anno qarree* and *Tumano*. The highest grain-filling period was observed by variety HB 42 (37 days) at *Anno degem* followed by variety *Shagee* (37 and 35 days) at *Anno qarree* and *Tumano,* respectively. Generally, FV's showed relatively short days to flowering and days to grain filling than the improved varieties (Table 5).

Agronomic / yield component traits / of food barley

Mean performance for agronomic/ yield component/ trait of 10 food barley varieties are shown in Table 6. The amount of variation among the varieties for most traits was relatively high among the testing sites. At *Anno Degem* biomass production rate (BMPR) ranged from 38.7 to 79.6 days while at, *Anno qarree* from 24.0 to 80.2 days and at *Tumano* from 39.2 to 90.8 days. There were no significant difference in overall mean among varieties in BMPR at *Anno degem* and *Anno qarree,* however, significant different was observed at *Tumano* site which was (65.3).

At *Anno degem,* spike length ranged from 2.7 to 8 cm with mean of 6.3 cm at *Anno qarree* from 5 to 6.7 cm with mean of 5.6 cm, at *Tumano* from 5 to 7.7 cm with site mean value of 6.6 cm (Table 6).

At *Anno degem,* number of spikelet per spike ranged from 42.7 to 55 with mean of 50.9 while at *Anno qarree* from 38 to 49 with mean of 44 and at *Tumano* from 35.3 to 52.3 with site mean of 46.1 (Table 6). The variation in number of spike per spikelet was relatively high across the three sites, it ranged from 44 to 50.9 at *Anno qarree*, and *Anno degem*.

Grain yield, biomass yield, thousand kernel weight and harvest index at each location

Mean values for grain yield, biomass yield, thousand kernel weigh and harvest index of each genotype and testing sites are shown in Table 7. At *Anno degem*, the grain yield ranged from 1722.2 kg ha^{-1} for variety *Shagee* to 3437.5 kg ha^{-1} for variety *G/adii* followed by 3395.8 kg ha^{-1} for variety *Hadho* while at, *Anno qarree* it ranged from 1037 kg ha^{-1} for *Karfee* to 3777.8 kg ha^{-1} for *G/gurracha* followed by 3596.3 kg ha^{-1} for HB1307. At *Tumano* grain yield varied from 1666.7 kg ha^{-1} for variety *Karfee* to 4244.4 kg ha^{-1} for variety *G/gurracha* followed

Table 7. Mean grain yield, biomass yield, harvest index and thousand kernel weight of food barley at each location.

Varieties	*Anno degem*				*Anno qarree*				*Tumano*			
	BY	**GY**	**HI**	**TKW**	**BY**	**GY**	**HI**	**TKW**	**BY**	**GY**	**HI**	**TKW**
G/adii	7958.3^{a}	3437.5^{a}	0.43^{ab}	42.4^{a}	2592.6^{d}	1203.7^{c}	0.46^{a}	42.9^{ab}	8020.8^{a}	3375.0^{c}	0.42^{d}	48.1^{a}
HB 1307	7958.3^{a}	2847.2^{a}	0.36^{c}	47.0^{a}	7759.3^{a}	3596.3^{ab}	0.46^{a}	44.7^{ab}	8458.3^{a}	3895.8^{abc}	0.46^{bc}	41.5^{ab}
Hadho	7968.1^{a}	3395.8^{a}	0.43^{ab}	43.0^{a}	2870.4^{cd}	2037.0^{abc}	0.54^{a}	47.5^{a}	4368.1^{c}	1631.9f	0.37^{e}	37.5^{b}
HB42	6236.1^{b}	2291.7^{c}	0.36^{c}	44.1^{a}	3463.0^{bcd}	2000.0^{abc}	0.48^{a}	45.2^{ab}	6166.7^{b}	2270.8^{de}	0.37^{e}	45.7^{ab}
Damoy	3958.3^{c}	1840.3^{d}	0.46^{a}	45.0^{a}	5111.1^{bc}	2514.8^{abc}	0.49^{a}	39.3^{b}	4444.4^{c}	2180.6^{e}f	0.49^{a}	46.7^{a}
G/guracha	6145.8^{b}	2698.6^{b}	0.44^{ab}	45.6^{a}	7777.8^{a}	3777.8^{a}	0.54^{a}	44.4^{ab}	8951.4^{a}	4244.4^{a}	0.47^{b}	42.4^{ab}
Shagee	4041.7^{c}	1722.2^{d}	0.42^{b}	42.4^{a}	5176.9^{b}	2400.0^{abc}	0.46^{a}	39.0^{b}	6250.0^{b}	2798.6^{d}	0.45^{c}	45.8^{a}
Tolasee	6458.3^{b}	3763.9^{b}	0.43^{ab}	46.8^{a}	5555.6^{ab}	2405.6^{abc}	0.43^{a}	44.6^{ab}	8347.0^{a}	3631.9^{bc}	0.44^{cd}	43.2^{ab}
Karfee	4305.6^{c}	1763.9^{d}	0.41^{b}	40.3^{a}	2870.4^{cd}	1037.0^{c}	0.35^{a}	47.9^{a}	3958.3^{c}	1666.7^{f}	0.42^{d}	43.2^{ab}
Magee	6527.8^{b}	2784.7^{b}	0.42^{b}	41.8^{a}	4259.3^{bcd}	1851.9^{bc}	0.45^{a}	48.2^{a}	8541.7^{a}	4041.7^{ab}	0.47^{ab}	48.4^{a}
Mean	6155.83	2554.58	0.41	43.85	4743.5	2282.41	0.47	44.3	6750.67	2973.74	0.44	44.24
CV (%)	6.193	6.822	4.658	14.99	28.22	48.66	34.5	10.06	13	11	3.3	10.9
S.E	311.269	142.292	0.016	5.37	1093.24	906.969	0.131	3.641	715.65	266.3	0.002	3.92

Means followed by a common letters with in a column are not significantly different from each other at $P \leq 0.05$ according to Duncan Multiple Range Test, GY, Grain yield (kg ha^{-1}), BY, Biomass yield (kg ha^{-1}), HI- Harvest index (%); TKW=Thousand kernel weight.

by 3895.8 kg ha^{-1} for variety HB1307. Location mean grain yield ranged from 2282.4 kg ha^{-1} at *Anno qarree* to 2554.6 kg ha^{-1} for *Anno degem* (Table 7). Variation for grain yield across the three sites was relatively high and ranged from 1037 kg ha^{-1} produced by *Karfee* at *Anno qarree* to 4244.4 kg ha^{-1} produced by *G/gurracha* at *Tumano.* Except HB 42, *Damoy* and *Karfee*, all varieties showed similar yield performance with HB-1307 (Table 7).

At *Anno qarree* mean grain yield ranged from 1037 kg ha^{-1} for variety *Karfee* to 3777.8 kg ha^{-1} for variety *G/gurracha*. Varieties *Hadhoo*, HB42, *Damoy*, *Shage* and *Tolasee* showed similar performance with an improved variety HB1307 and significantly higher than varieties *G/adii* and *Karfee* (Table 7). Moreover, the lowest and highest grain yield at Anno qarree was 1037 and 3777.8 kg ha^{-1} for varieties *Karfee* and *G/gurracha*, respectively. *G/gurracha* variety had significantly higher grain yield than the other varieties except at *Anno degem, G/adii* had significantly higher grain yield than the other local and improved varieties. This study showed that FV's of food barley had good yield performance than improved varieties on low input farmer's condition (Table 7). Similarly, Jalata (2011) reported that there was a differential yield performance among genotypes across testing environment mainly due to genotypic, genotypic and environmental interaction. Similarly, Sinebo (2002) reported that high straw yield was essential to high grain yield production.

Significant mean biomass yield differences among the varieties were observed at each site (Table 7). At *Anno degem*, mean biomass yield ranged from 3958 kg ha^{-1} for variety *Damoy* to 7968.1 kg ha^{-1} for variety *Hadho* followed by varieties *G/adii* and HB1307 (7958 kg ha^{-1}). Likewise, at *Anno qarree* mean biomass yield ranged from 2870 kg ha^{-1} for *Hadho* and *karfee* to 7777.8 kg ha^{-1} for *G/gurracha* followed by HB1307 (7759 kg ha^{-1}).

At *Tumano*, mean biomass yield ranged from 3958.3 kg ha^{-1} for *Karfee* to 8951.4 kg ha^{-1} for *G/gurracha* followed by variety HB1307 (8458 kg ha^{-1}). Location mean biomass yield for *Anno degem Anno, qarree* and *Tumano* were 6155.8, 4743.5 and 6750.7 kg ha^{-1}, respectively. Varietal difference for biomass yield was less marked at *Anno qarree* than the two sites, which might be due to better adaptation of all varieties to the growing conditions at Tumano, and *Anno degem*. Variety *G/gurracha* which gave the highest mean grain yield at *Anno qarree* and *Tumano* was also characterized by high biomass yield, 7777.8 and 8951 kg ha^{-1} at the two sites respectively. Moreover, the lowest mean biomass yield was obtained by varieties *Hadho* and *Karfee* (2870 kg ha^{-1}) at *Anno qarree* and the highest biomass yield was obtained by variety *G/gurracha* (8951.4 kg ha^{-1}) at *Tumano.* This result revealed that biomass yield was relatively related to grain yield for FV's except for HB-1307.

Similarly, Ortiz et al. (2002) reported that there was significant trend in increasing straw yield in Nordic spring barley germplasm whereas the biological yield of recent varieties and old varieties was almost the same. Fekadu (2010) also reported that the recent varieties (Dimtu and HB-1307) which gave high grain yield were also characterized by high biomass yield at all locations except HB-1307 at Holetta. Similarly, Sinebo (2002) reported that high biomass yield is essential to high grain yield production.

At *Anno degem*, the mean harvest index ranged from 0.36 for HB-42 and HB-1307 to 0.46 for *Damoy* while at *Anno qarree,* it was 0.35 for *Karfee* to 0.54 for *Hadho* and *G/gurracha* and that of *Tumano* was 0.37 for *Hadho* and HB-42 to 0.49 for *Damoy*. The highest and lowest varietal difference for harvest index was observed at *Anno qarree* than *Anno degem* and *Tumano*. The overall mean harvest index in this study varied from 0.35 for *karee* to 0.54 for *Shagee* and *G/gurracha* indicating FV's had shown significant variation for harvest index (Table 7).

There was no significant variation in thousand-kernel weight at *Anno degem*, however, at *Anno qarree* ranged from 39 to 48.2 gm with mean of 44.3 gm and at *Tumanno* ranged from 37.5 to 48.4 gm with mean of 44.24 gm. In this study, the effect of thousand-kernel weight is small for performance evaluation among the varieties tested. Similarly, Sinebo (2002) reported that the effect of kernel weight on grain yield was small.

Similarly, Hockett (2000) reported that mean values of the varieties were recorded within the range of barley yield potential performance study as described for yield potential of barley varies from state to state in America and ranged from 1451.0 to 5499.0 kg ha^{-1} and barley yield of ten top leading producing countries was within the range of 1730.0 to 5470.0 kg ha^{-1}.

Comparative yield potential of farmers' varieties and improved varieties over three sites

There were significant difference in performance of local against improved varieties in yield and yield related traits on low input and marginal environment. Accordingly, *G/gurracha* was the highest in grain yield followed by *Tolasee* and *Magee* among the FV's. Ceccarelli and Grando, 2001 cited in Brush (2000) reported that black-seeded FVs' was better adapted to dry areas and less vigorous in early growth, more cold resistant and more productive under stress than improved cultivars. However, HB-1307 gave high yield (3446.5 kg ha^{-1}) than other improved varieties and FV's except *G/gurrach* that gave 3573.6 kg ha^{-1}. High biological yield was obtained on HB-1307 (8058.6 kg ha^{-1}) and followed by FV's *G/gurrach, Tolasee, Magee* and *G/adii*. On the contrary, high TKW was observed by variety *Magee* followed by HB-1307. *Karfee* was the lowest in harvest index and *Damoy* was the highest in harvest index. In this study, *Karfee* was the lowest performing FV's. In contrast, HB-1307 gave relatively better yield and yield related traits over the other two improved varieties and the FV's except *G/gurrach*, which was superior in some traits (Table 8).

Correlation among the quantitative traits

The correlation coefficient among the quantitative traits was computed on the mean trait values of the two sites, that is, *Anno degem* and *Tumano* (Table 9). *Anno qarree* was excluded because of high CV value (>30%). Significant and strong positive correlation coefficients were found for DH with DM (0.88), BMPR with BY and GY (0.97 and 0.98, respectively) and BY with GY (0.97). Days to heading was positively correlated to grain filling period. On the other hand, days to grain filling period was negatively correlated to number of spikelet per spike at (r=-0.64) (Table 9). Similarly, (Ahmad, 2004; Tarekegn, 2009) reported that days to heading were positively and significantly correlated with days to maturity. Moreover, biomass yield showed significant correlation with grain yield. Sinebo (2002) reported that grain yield was correlated positively with mature heights, and grain-filling duration. On the contrary, grain yield was not correlated with kernel weight.

This finding suggests that characters showing positive correlation could effectively be utilized in improving FV's. The tendency of positive correlation among developmental traits, in spite of wide range of genetic diversity in FV's could effectively be utilized to improve barley FV's.

Seed quality analysis

Seed testing evaluates seed lot quality and is essential for both seed production and commercial seed transactions (AOSA, 1981). Seed testing is done to assess seed lot attributes to determine overall quality and value for production and storage. Seed testing standards provide set of procedures to conduct tests in a uniform manner to ensure comparable results that are within acceptable ranges (ISTA, 2005).

Analytical purity analysis

The analytical purity results of seed samples collected from field experiment were ≥ 98.17% which was greater

Table 8. Yield and yield related traits among local and improved varieties of barley in kg ha^{-1} at Degem in 2010.

Farmer varieties	**BY**	**GY**	**HI**	**TKW**
G/adii	6190.6	2672.1	0.44	45.5
Hadho	5068.8	2354.9	0.44	42.1
Damoy	4504.6	2178.5	0.48	30.7
G/gurracha	7625.0	3573.6	0.46	40.2
Tolasee	6787.0	2933.8	0.43	41.3
Karfee	3711.4	1489.2	0.39	34.8
Magee	6442.9	2892.7	0.45	46.8
Mean	5761.47	2584.97	0.44	40.20
Improved varieties				
HB-1307	8058.6	3446.5	0.42	46.2
HB-42	5288.6	2187.5	0.4	38.1
Shagee	5155.9	2306.9	0.44	39.5
Mean	6167.70	2646.97	0.42	41.27

Table 9. Estimates of Pearson correlation coefficient of combined location mean among the 10 traits.

	DF	**DM**	**GFP**	**BMPR**	**PH**	**SL**	**NSPS**	**TKW**	**BY**	**GY**	**HI**
DF	1	0.88**	0.23	0.06	0.37	0.08	-0.29	0.32	0.28	0.16	-0.4
DM		1	0.63*	0.19	0.16	0.01	-0.49	0.15	0.37	0.23	-0.54
GFP			1	0.09	-0.5	-0.2	-0.64*	-0.25	0.12	0.02	-0.57
BMPR				1	0.43	0.39	-0.28	-0.02	0.97***	0.98***	0.28
PH					1	0.36	0.2	0.18	0.5	0.53	0.37
SL						1	-0.09	-0.52	0.32	0.46	0.56
NSPS							1	0.42	-0.3	-0.3	0.03
TKW								1	0.05	-0.07	-0.54
BY									1	0.97***	0.19
GY										1	0.37
HI											1

*, **, *** r-values were significant at probability level of 0.05, 0.01 and 0.001 respectively, DF=Days to flowering; DM=Days to maturity, GFP=Grain filling period; BMPR= Biomass production rate; PH=Plant height; SL= Spick length; NSPS=Number of spikelet per spike; TKW=Thousand kernel weight; BY=Biomass yield; GY=Grain yield; HI= Harvest Index.

than 85% of the national standard for commercial seed in Ethiopia (ICARDA, FAO, AAR INENA and CIHEAM, 1999). Physical purity, however, ranged from 98.17 to 99.76% with an average of 99.38%. There was no difference in physical purity level between seed sources. However, varieties showed

Table 10. Physical purity of barley seed obtained from field experiment at Degem wereda 2010.

Variety	Composition by weight			
	ANPU	OCS	INM	TKW(g)
G/adii	99.76^{a}	0.14^{f}	0.00^{b}	45.7^{b}
HB 1307	99.69^{a}	0.17^{ef}	0.00^{b}	46.2^{ab}
Hadho	99.08^{b}	0.53^{c}	0.04^{a}	42.1^{c}
HB42	99.60^{ab}	0.24^{de}	0.00^{b}	38.1^{e}
Damoy	99.54^{ab}	0.25^{de}	0.04^{a}	30.7g
G/gurracha	99.59^{ab}	0.49^{c}	0.00^{b}	40.2^{d}
Shagee	99.55^{ab}	0.30^{d}	0.00^{b}	39.5^{d}
Tolasee	99.06^{b}	0.62^{b}	0.00^{b}	41.3^{c}
Karfee	98.17^{c}	1.12^{a}	0.00^{b}	34.8^{f}
Magee	99.74^{a}	0.27^{d}	0.00^{b}	46.8^{a}
Mean	99.38	0.41	0.01	40.58
CV (%)	0.24	9.14	45.15	2.68
R^2	0.87	0.99	0.97	0.95
Significance	0.0016	<.0001	<.0001	<.0001

Means followed by a common letters with in a column are not significantly different from each other at P< 0.05 according to Duncan's multiple range test; ANPU=%Analytical purity; OCS=Other crop seeds; INM=Inert matter; TKW=Thousand kernel weight (g).

significant difference for other crop seed, which ranged from 0.14 for *G/adii* to 1.12% for *Karfee* with mean of 0.41%. This variety contains more other crop seed than other varieties. Thousand seed weight also showed significant difference which ranged from 30.7 to 46.25 g with mean of 40.58 g. *Damoy* was the least in thousand seed weight followed by *Karfee,* which was 34.8 g. On the contrary, the highest seed weight was observed on *Magee* 46.8 gm followed by HB-1307 and *G/adii* (Table 10).

The presence of different "other seeds" species in the seed samples was identified. Major other crops seed observed were *Avena* spp., *Lolium*, *Triticum* and *Bromous* spp. *Avena* spp. and *Bromous* spp. were the major problematic weeds in Degem wereda. Significant (p<0.0001) mean differences were observed on other crop seeds between varieties. However, all local and improved varieties maintained the minimum purity standards. Moreover, all samples had less inert matter contamination than the standard (Table 10).

Thousand kernel weight

The overall average of thousand-kernel weight was 40.5 g ranging from 30.7 g for *Damoy* to 46.8 g *Magee*. Significant difference in seed weight was observed among different varieties at (p<0.0001) (Table 10). Seed sample of *Magee* were on average heavier than the grand mean and ranked first followed by HB-1307. This study revealed that except HB-1307, improved varieties had low 1000 kernel weight than the local ones. These results agreed with Sahilu (1999) and with Briggs (1978) in which they recorded that Ethiopian barleys were characterized by very high seed weights.

Physiological seed quality

Standard germination: Physiological seed quality analysis was conducted at different time. This was because of the appearance of seed dormancy on different varieties. The first laboratory analysis was conducted one month after harvest and the second was four months after harvest.

During the first germination test, there were high standard germination mean differences, which ranged from 5.25% for *Magee* to 98.25% for *Damoy*. Four varieties *Damoy*, HB-1307, *G/gurracha* and *Karfee* had germination percentage of 98.25, 97.75, 93.5 and 88.0%, respectively. Although these varieties were in the range of barley germination standards, the rest of the varieties were out of the standards due to seed dormancy (Table 11). Hence, further evaluation was conducted to capture this quality trait.

Accordingly, the second germination testing was made after four months of harvest. During the second germination test, mean differences for the trait ranged from 98.5% for *Tolese* and HB-42 to 99.75% *Shagee*. The result indicated that all varieties were above nationally recommended standard germination range after breaking dormancy following four months of storage.

Significant in seed germination differences were observed between the first and the second time of analysis (Table 11). This study revealed that seed dormancy was broken after-ripening (dry storage) for four

Table 11. Mean physiological quality (vigour) of barley seed from field experiments at Degem wereda 2010

Varieties	SG1 (%)	SG2 (%)	SPG	SL (cm)	RL(cm)	SDWT(g)	VIG1	VIG2	TKW
G/adii	13.25^{g}	99.25^{a}	19.76^{bc}	14.94^{b}	13.59^{a}	0.055^{ab}	2831.99^{bc}	5.23^{ab}	45.7^{b}
HB-1307	97.75^{ab}	99.00^{a}	18.47^{c}	16.56^{a}	11.67^{c}	0.032^{b}	2780.22^{bc}	3.23 ^{b}	46.2^{ab}
Hadho	83.50^{d}	99.25^{a}	18.48^{c}	16.69^{a}	13.25^{ab}	0.047^{ab}	2972.28 ^{a}	4.48^{ab}	42.1^{c}
HB-42	54.00^{e}	98.50^{a}	20.24^{b}	15.02^{b}	12.67^{b}	0.077^{a}	2729.25^{bc}	7.63 ^{a}	38.1^{e}
Damoy	98.25^{a}	98.75^{a}	22.46^{b}	16.19^{a}	12.90^{b}	0.025^{b}	2873.35^{ab}	2.47 ^{b}	30.7^{g}
G/gurrach	93.5^{b}	98.75^{a}	22.86^{a}	15.74^{ab}	10.22^{d}	0.055^{ab}	2564.94^{ef}	5.44^{ab}	40.2^{d}
Shagee	7.25h	99.75^{a}	19.60^{bc}	14.61^{b}	11.67^{c}	0.047^{ab}	2621.91^{de}	4.74^{ab}	39.5^{d}
Tolasee	41.75^{f}	98.50^{a}	19.29^{bc}	13.15^{c}	11.84^{c}	0.075^{a}	2462.35 ^{f}	7.39 ^{a}	41.3^{c}
Karfee	88.00^{c}	99.50^{a}	20.25^{b}	15.65^{ab}	12.99^{ab}	0.032^{b}	2849.5^{abc}	7.68^{a}	34.8^{f}
Magee	5.25h	99.00^{a}	20.25^{b}	13.31^{c}	11.84^{c}	0.075^{a}	2790.52^{ef}	3.23^{b}	46.8^{a}
Mean	58.25	99.02	20.16	15.19	12.25	0.052	2117	5.15	40.58
CV (%)	5.3	0.9	5.13	3.35	3.54	52.15	3.57	52.16	2.68
R^2	0.99	0.2	0.7	0.8	0.86	0.37	0.79	0.37	0.95
Signific^{a}nce	<0.001	0.58	<0.001	<0.001	<0.001	0.06	<0.001	0.07	0.001

Means followed by a common letters with in a column are not significantly different from each other at P <0.05 according to Duncan's multiple range test; SG1=Standard germination after one moth of harvest; SG2=Standard germination after four month of harvest; SPG=Speed of germination; SL(cm)=Shoot length; RL (cm)=Root length; SDWT (gm)=Shoot dry weight; VIG I=Vigor index I; VIG II= Vigor index II; TKW=Thousand kernel weight.

months although varieties had different period of seed dormancy (Figure 2).

Hull thickness has an effect on barley seed germination. Those varieties showed seed dormancy during germination test after one month of harvest have thick hull. At harvest, intact barley grains exhibited dormancy and germinate poorly. Bradrord et al. (2008) reported similar result that restriction to germination is attributable to the presence of the glumellae or hulls, as their removal or excision of the embryos greatly improves germination capacity. The restriction of germination by the hull has been attributed largely to its ability to reduce the availability of O_2 to the embryo (Lenoir et al., 1986). Bradford et al. (2008) reported that germination rates and percentages improved following after breaking dormancy for both seeds and embryos. This finding was supported by five months of after dormancy break allowed almost complete germination of seeds in 21% O_2, but germination remained highly sensitive to O_2 percentage as (Bradrord et al., 2008).

Speed of germination: Mean difference in speed of germination ranged from 18.47 for HB-1307 and *Hadho* to 22.86 for *G/gurracha*. The others were in par for this trait. Least mean shoot length was observed on *Magee* while, *Hadho* was the highest in shoot length. Likewise, *G/gurraha* was the shortest in root length but *G/adii* was the longest (Table 11). The speed of germination measures the rate at which the seeds were germinating and those seedlings with higher index or highest germination were expected to show rapid germination and seedling emergence and to escape adverse field conditions.

Seedling shoots and roots length: Mean difference in seedling shoots length ranged from 13.15 cm for *Tolasee* and 16.69 cm for *Hadhoo* with grand mean of 15.19 cm. Moreover, *Hadhoo*, HB-1307 and *Damoy* were in par for this trait. Likewise, mean difference in root length ranged from 10.22 cm for *G/gurracha* to 13.59 cm for *G/adii* with grand mean of 12.25 cm. *Hadhoo,* HB42 *Damoy* and *Karfee* were in par for the trait considered (Table 11). HB1307, *G/gurracha, Hadho, Damoy* and *Karfee* showed longer in their shoot length and *G/adii, Hadho* and *Karfee* showed longer in their root length. Significant variations were observed among varieties for seedling shoots and root length at (p<0.0001). Seedlings with well-developed shoot and root systems would withstand any adverse conditions and provide better seedling emergence and seedling establishment in the field.

Seed vigour test (Viguor Index I and Viguor Index II): Mean difference in vigour index I ranged 2462.35 for *Tolasee* to 2972.28 for *Hadhoo* with grand mean of 2117. *G/adii*, HB1307, HB 42 and *Karfee* were in par for this trait. *Hadho, Damoy* and *Kerfee* showed higher vigor index I while *Tolasee, Magee* and *G/gurracha* were lower in vigor index I (Table 11). Significant variations were observed among varieties for vigour index I at (p<0.0001). On the other hand, no significant difference observed among varieties for vigour index II at (p<0.05).

Varieties that had higher speed of germination were generally considered more vigorous. Moreover, vigorous varieties could be stored for longer periods without loss of germination. Vigor tests measure the potential for rapid, uniform emergence of seeds under a wide range of field conditions (Elias et al., 2010). Its results may be more

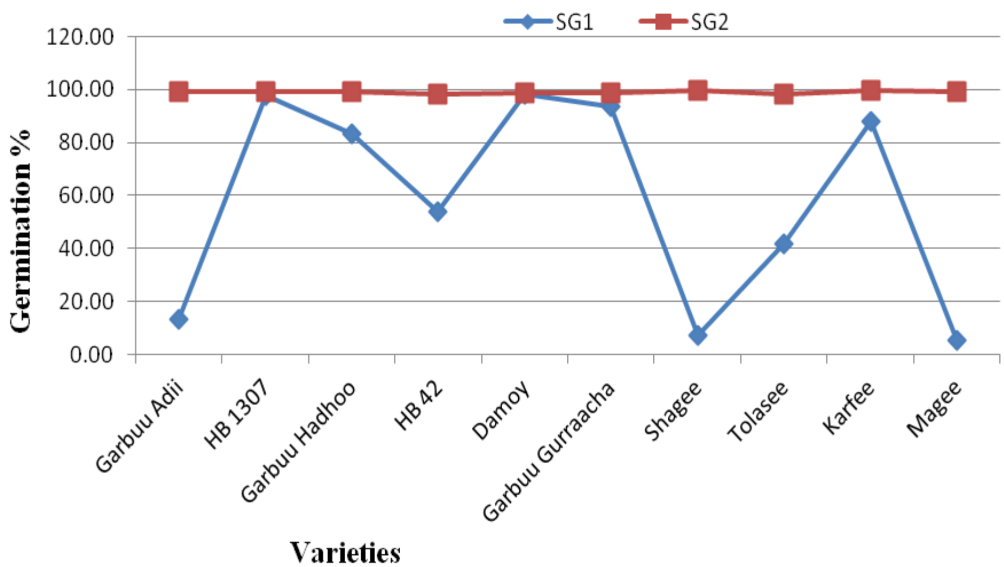

Figure 2. Standard germination after one and four months after harvest. SG1=Standard germination after one month of harvest; SG2=Standard germination after four month of harvest.

closely associated with field emergence than the standard germination test (Elias et al., 2006).

Mycological evaluation

The presence and type of fungi were determined according to their development on seed, which had been incubated on Potato Dextrose Agar (PDA) medium. Accordingly, sixteen different fungi genera were identified. Their importance, in relation to their occurrence were *Helmithosporium sativum, Helminthosporum teres, Fusarium graminarum, Fusarium oxysporum, Fusarium avenacerum, Cladosporium* spp.*, Alternaria* spp.*, Botryodiplodia* spp.*, Phoma* sp.*,* and *Stemphylium* sp.. In addition, storage fungi associated to barley seed were also identified, which include *Penicillium* spp.*, Trichoderma* sp.*, Aspergillus* spp. and *Chaetomium funicola* (Table 12).

The result indicated that high incidence of facultative fungal such as*, Fusarium avenacerum* and *Phoma* spp*.* and low incidence of field fungi like *Botryodiplodia, Aspergillus, and Trichoderma. Fusarium* spp were commonly occurring as seedborne fungi and responsible for causing seed decay and seedling mortality. Likewise, some diseases were also observed in large number on different varieties. This showed that there was differential occurrence of some fungi on varieties tested. The mean difference between varieties showed that *karfee* (3.52%) was highly infected followed by *Damoy* (2.44%) while *G/adii* (0.98%) was the least affected (Table 12). HB-1307, HB-42, *Damoy* and *G/gurracha* were more infected by *H. sativum,* while *Shagee, G/gurracha* and *Magee* were more infected by *F. oxysporum. Damoy, Hadhoo, Tolasee* and *Magee* were more infected by *F. avenacerum* (Table 12). In general significant different was observed between varieties for different seed-borne fungi. Similarly, Bekele et al. (2005) reported that most of the FV's were found susceptible to scald (*Rhynchosporium secalis* Oud.), net blotch (*Helminthosporium teres* Sacc.), spot blotch (*H. sativum* Pum.), leaf rust (*Puccinia hordei* Otth.) and lodging. Novak et al. (2001) also reported that difference in disease incidence were due to the ability of saprophytes to colonize, rapid germination of spores, quick hyphal invasion, high competitive nature, their ability to utilize a wide variety of substrates and their nutrient composition.

Among sixteen seed fungi observed, eight of them were known to be seed transmitted (Table 13). Seed transmitted pathogens are pathogen that can affect the yield in next production season and transmit pathogen to disease free environment. Therefore, to increase the planting values of the seed, treatment is important to produce healthy seed for the next planting season.

Significant different in seed infection was observed on varieties. High *H. sativum* was observed on *G/gurracha*, HB-1307, HB-42, and Damoy respectively.

H. teres was more observed on *Damoy* followed by HB-42. More *F. graminarum* seed infection was observed on *Shagee* followed by *Magee* and HB-1307and *F. oxysporum* was observed on *Sahgee*, *Magee* and *Tolesee*. *Fusarium avenacerum* was more observed on *Hadhoo*, HB- 42 and *Magee* (Table 13).

On the other hand, seven of the fungi were seed deteriorating pathogen (Table 14). These seed deteriorating fungi were affecting the planting value of the seed due to their deteriorating action. Seed infection was significant at ($p<0.001$) except for *Penicillium,* and

Table 12. Fungi detected on food barley seed collected from Degem wereda in 2010.

Fungi	Percentage of pathogen observed on different varieties										
	G/Adii	**HB 1307**	***Hadhoo***	**HB 42**	***Damoy***	***G/gurraacha***	***Shagee***	***Tolasee***	***Karfee***	***Magee***	**Mean**
HS	0.00	2.00	0.00	1.80	1.80	2.00	0.30	0.80	0.50	0.30	0.93
HT	0.30	0.00	0.30	0.80	1.00	0.00	0.00	0.30	0.00	0.00	0.25
FG	1.00	2.30	1.80	0.30	0.50	3.30	5.30	2.00	0.00	2.50	1.88
FO	0.30	0.50	2.00	1.00	0.80	0.80	1.00	0.50	0.30	1.80	0.88
FA	0.00	0.00	9.50	1.00	28.80	2.00	0.80	8.50	0.00	7.30	5.78
Fus	6.50	8.00	6.00	0.80	0.50	4.00	3.00	4.30	1.50	5.30	3.98
CL	0.50	0.30	1.00	0.30	0.80	1.30	0.00	0.50	0.00	1.30	0.58
AL	0.00	1.80	0.00	5.80	0.80	1.00	3.30	0.00	0.00	0.00	1.25
AS	0.50	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
CH	4.50	0.30	0.00	3.30	0.30	0.00	8.50	0.00	0.80	0.00	1.75
PE	1.50	8.30	3.50	4.00	1.80	6.50	0.00	3.00	0.30	7.00	3.58
TR	0.30	0.00	1.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.15
PH	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	51.50	0.00	20.70
BO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.03
RH	0.00	0.00	0.00	1.00	0.30	0.00	0.00	2.30	0.00	1.00	0.45
ST	0.30	1.00	0.30	1.00	1.80	0.30	0.50	0.30	1.50	0.00	0.68
Mean	0.98	1.52	1.61	1.30	2.44	1.31	1.41	1.39	3.52	1.66	2.68

HS=*Helmithosporium sativum*; HT=*Helminthosporum teres*; FG=*Fusarium graminarum*; FO=*Fusarium oxysporum*; FA=*Fusarium avenacerum*; *CL=Cladosporium*; *AL=Alternaria; BO=Botryodiplodia*; *PH=Phoma;* ST= *Stemphylium*; *PE=Penicillium*; *TR=Trichoderma*; *AS=Aspergillus*; CH=*Chaetomium*; Rh=*Rhinchosporium scalis*; Fus= *Fusarium* spp.

Alternaria.

Hence, appropriate seed handling should be made during pre-harvest and post-harvest operations to ensure quality seed system.

Heleminthosporium spp, *H. teres, Rhynchosporium, Ustilago nuda, U. hordi, H. graminea* are common barley seedborne disease in Ethiopia. Semeane et al. (1996) reported that net blotch, scald and leaf rust are the most three important barley diseases targeted for control. Of those, net blotch was an endemic disease in most highlands of the country where barley is important. Similarly, Hundie et al. (2001) also reported that on farm average yield loss of 28 to 29% was accounted for net blotch and leaf rust infection.

CONCLUSIONS AND RECOMMENDATION

The presence of significant ($p<0.01$) variation among FVs' and improved varieties for most characters implies that there is high variability among genotypes tested. This result showed that variability were existed among FVs' and improved varieties tested for important quantitative traits indicating high potential for effective barley enhancement and/or for further manipulation of the genetic resources through mass selection as FVs' are good sources of genes for many desirable traits. *Damoy* is the earliest in heading, maturity and grain filling period followed by *G/gurracha*. These traits are advantageous to escape terminal moisture stress and good character to cope up with the rainfall variability. *G/gurracha* gave highest grain yield (3573.6 kg ha^{-1}) which showed the possibility of improvement of FVs' through mass selection. In general, the study revealed that mass selection scheme would be more promising and encouraging for improving barley yield. This could be the nature of FVs' because of their better adaptive traits to variable environmental conditions which have important

Table 13. Mean difference seed transmitted pathogen observed on seed collected from field experiment at Degem 2010.

Varieties	HS(Ω)	HT(Ω)	FG(Ω)	FO(Ω)	FA(Ω)	PH(Ω)	RH(Ω)	F.sp(Ω)
G/adii	0.48^{b}	0.65^{bc}	1.00^{a}	1.0^{cdef}	0.66^{b}	1.42^{c}	0.66^{b}	0.48^{b}
HB1307	1.58^{a}	0.48^{c}	2.3^{bcd}	1.5^{abcd}	0.83^{ab}	2.68^{a}	0.48^{b}	0.48^{b}
Hadhoo	0.48^{b}	0.65^{bc}	1.8^{bcd}	1.4^{bcde}	1.56^{a}	1.99^{abc}	0.48^{b}	0.48^{b}
HB42	1.53^{a}	1.01^{ab}	0.25^{cd}	0.65^{ef}	1.13^{ab}	1.83^{bc}	0.48^{b}	0.48^{b}
Damoy	1.53^{a}	1.12^{a}	0.5^{cd}	0.83^{def}	0.95^{ab}	1.50^{c}	0.48^{b}	0.48^{b}
G/gurracha	1.62^{a}	0.48^{c}	3.25^{ab}	1.98^{ab}	0.95^{ab}	2.52^{ab}	0.48^{b}	0.48^{b}
Shagee	0.65^{b}	0.48^{c}	5.25^{a}	2.27^{a}	1.03^{ab}	0.48^{d}	0.48^{b}	0.48^{b}
Tolasee	0.95^{b}	0.65^{bc}	2.0^{bcd}	1.6^{abcd}	0.77^{b}	1.95^{abc}	0.48^{b}	0.48^{b}
Karfee	0.83^{b}	0.48^{c}	0.00^{d}	0.48^{f}	0.66^{b}	0.66^{d}	4.62^{a}	0.48^{b}
Magee	0.65^{b}	0.48^{c}	2.5^{bc}	1.76^{abc}	1.38^{ab}	2.67^{a}	0.48^{b}	0.66^{a}
Mean	1.03	0.65	1.87	1.35	0.99	1.76	0.91	0.49
CV%	33	41.7	85.86	40.59	54.56	28.64	16	22.55
Signficance	<0.0001	0.0105	0.0023	0.0007	0.3279	<0.0001	<0.0001	0.4612

(Ω)=Data was transformed by arc sine; HS=*Helmithosporium sativum*, HT=*Helminthosporum teres*; FG=*Fusarium graminarum*; FO=*Fusarium oxysporum*; FA=*Fusarium avenacerum*; *PH=Phoma*; *F.sp=Fusarium* sp.

Table 14. Mean difference seed deteriorating pathogen observed on seed collected from field experiment at Degem 2010.

Varieties	CH#	PE#	TR#	BO#	RH#	CL#	AL#
G/adii	0.48^{e}	0.77^{ab}	2.29^{a}	0.66^{b}	0.66^{b}	0.48^{d}	0.83^{ab}
HB1307	1.5^{bc}	0.48^{b}	0.65^{b}	0.48^{b}	0.48^{b}	0.48^{d}	0.66^{ab}
Hadhoo	0.48^{e}	0.83^{a}	0.48^{b}	1.13^{a}	0.48^{b}	2.99^{b}	1.13^{ab}
HB42	2.51^{a}	0.48^{b}	1.18^{b}	0.48^{b}	0.48^{b}	1.13^{b}	0.66^{ab}
Damoy	1.01^{d}	0.48^{b}	0.65^{b}	0.65^{b}	0.48^{b}	3.81^{a}	0.95^{ab}
G/gurracha	1.13^{cd}	0.48^{b}	0.48^{b}	0.48^{b}	0.48^{b}	1.33^{c}	1.14^{ab}
Shagee	1.92^{b}	0.48^{b}	2.87^{a}	0.48^{b}	0.48^{b}	0.95^{cd}	0.48^{b}
Tolasee	0.48e	0.48^{b}	0.48^{b}	0.48^{b}	0.48^{b}	2.84^{b}	0.77^{ab}
Karfee	0.48e	0.48^{b}	0.85^{b}	0.48^{b}	4.62^{a}	0.48^{d}	0.48^{b}
Magee	0.48e	0.48^{b}	0.48^{b}	0.48^{b}	0.48^{b}	2.72^{b}	1.24^{a}
Mean	1.04	0.54	1.04	0.58	0.75	1.72	0.83
CV%	28.15	41.47	56	39.97	26.64	29	56.67
Signficance	<0.0001	0.2013	<0.0001	0.005	<0.0001	<0.0001	0.2539

#=Data was transformed by arc-sine transformation, *CH=Chaetomium, PE=Penicillium, TR=Trichoderma BO=Botrytis , RH=Rinchosporium, CL=Cladosporium AL=Alternaria.*

implications for sustainable crop production. The maximum yield was obtained from *G/Gurracha*. This indicates that minimum improvement should be vital for barley yield and yield related traits improvement. *Damoy* has been selected as the sole variety for *belg* season production in the study area for its early in heading, maturity and grain-filling period and require low moisture. Improvement should be vital for adopting this variety in an area of short rainfall so as to attain food security. Varieties differ in dormancy duration. Hence, dormancy behavior of the genotypes needs to be studied. Seed is the basic input of crop production. Therefore, seed treatment and quarantine measure should have to be undertaken prior to seed delivery for the end-users to improve field planting value of the seed lots. Attention should be given to exploit variability of FVs' for for varietal improvement and enhancement to attain food security. In general, Ethiopian barley FVs' is contributing as major sources of variability for selection and enhancement which has many advantages than improved varieties. Therefore, the available variability is useful to design better selection strategies in FVs'.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENTS

The author's thanks go to Fitche Soil Research Center and Local Seed Business Project (LSBP) of Haramaya

University for financing the research expense and farmers of Degem Woreda for their willingness to share their experience and contracting their farm land for experimental plot. Mr. Wondimu Fikadu for his expertise assistance on statistical data analysis and Mrs. Simegn Techane for her excellent technical support during seed laboratory analysis are acknowledged in this work.

REFERENCES

Almekinders CJM, Thiele G, Dabial DL (2006). Can cultivars from participatory plant breeding improve seed provision to small scale farmers? Euphytica DOI 10.1007/s106881-006-9201-9

Ahmad I (2004). Genetic Diversity for Agro-Morphological and High Molecular Weight Glutenin Sub-unit in Wheat (Triticum aestivum L.) Landraces. PhD. Dissertation. University of Arid Agriculture, Rawalpindi-Pakistan, 182 pp.

Anonymous (1996). International rules for seed testing. Seed Sci. Technol. 21:1-259.

AOSA (Association of Official Seed Analysts) (1981). Rules for testing seeds. J. Seed Technol. 6(2):162.

Austin RB (1999). Yield of Wheat in United Kingdom: Recent advances and prospects. Crop Sci. 39:1604-1610. http://dx.doi.org/10.2135/cropsci1999.3961604x

Barry MB, Pham JL, Courtois B, Billot C, Ahmadi A (2007). Rice genetic diversity at farm and village levels and genetic structure of local varieties reveal need for in situ conservation. Genet. Resour. Crop Evol, 54:1675-1690. http://dx.doi.org/10.1007/s10722-006-9176-3

Bekele B, Alemayehu F, Lakew B (2005). Food barley in Ethiopia. In: S. Grando and H. Gomez Macpherson (Eds). Food Barley: Importance, uses and local knowledge. ICARDA, Aleppo, pp. 53-82.

Bensemane L, Bouzerzour H, Benmahammed A, Mimouni H (2011). Assessment of the Phenotypic Variation within Two- And Six-rowed Barley (Hordeum Vulgare L.) Breeding Lines Grown Under Semi-Arid Conditions. Adv. Environ. Biol. 5(7):1454-1460.

Bezancon G, Pham J, Deu M, Vigouroux Y, Sagnard F, Mariac C, Kapran I, Mamadou A, Ge'rard B, Ndjeunga J, Chantereau J (2009). Changes in the diversity and geographic distribution of cultivated millet (Pennisetum glaucum (L.) R. Br.) and sorghum (Sorghum bicolor (L.) Moench) varieties in Niger between 1976 and 2003. Genet. Resour. Crop Evol. 56:223-236. http://dx.doi.org/10.1007/s10722-008-9357-3

Bellon MR, Berthaud J, Smale M, Aguire JA, Taba S, Aragon F, Diaz J, Castro H (2003). Participatory landrace selection for on-farm conservation: An example from the central valleys of Oaxaca, Mexico. Genet. Resour. Crop Evol. 50:401-416. http://dx.doi.org/10.1023/A:1023967611495

Booth C (1971). The genus Fusarium. Common Wealth Mycological Institute, Kew, Surry, England, 237 p.

Bradford KJ, Roberto L, Arnold B, Come D, Corbineau F (2008). Quantifying the sensitivity of barley seed germination to oxygen, abscisic acid, and gibberellin using a population-based threshold model. J. Exp. Bot, 59(2):335-347. http://dx.doi.org/10.1093/jxb/erm315

Briggs DE (1978). Barley. London: Chapman and Hall. http://www.answers.com/topic/barley. Accessed on 19 September 2011. http://dx.doi.org/10.1007/978-94-009-5715-2

Brush S, Kesselli R, Ortega R, Cisneros P, Zimmerer K, Quiros C (1995). Potato diversity in the Andean Center of Crop Domestication. Conserv. Biol. 9(5):1189-1198. http://dx.doi.org/10.1046/j.1523-1739.1995.9051189.x

Brush S, Meng E (1998). Farmers' valuation and conservation of crop genetic resources. Genet. Resour. Crop Evol. 45: 139-150. http://dx.doi.org/10.1023/A:1008650819946

Brush SB (2000). Genes in the Fields: On Farm Conservation of Crop Diversity. Rome, Italy and International Development Research Centre, International Plant Genetic Resources Institute Ottawa, Canada. Lewis Publishers, Boca Raton London New York Washington, D.C. 288 p.

Brush SB (2004). Farmers' Bounty: Locating Crop Diversity in the Contemporary World. Yale University Press, New Haven. http://dx.doi.org/10.12987/yale/9780300100495.001.0001

Ceccarelli S, Gando S, Tutwiler R, Baha J, Martini AM, Salahieh H, Goodchild A, Michael M (2000). A methodological study on participatory barley breeding I. Selection phase. Euphytica 111:91-104. http://dx.doi.org/10.1023/A:1003717303869

CIMMYT (1998). Practical Guide to the Identification of Selected Diseases of Wheat and Barley 2nd (eds.) Mexico.

Cox TS, Shroyer JP, Liu B-H, Sears RG, Martin TJ (1988). Genetic improvement in agronomic traits of hard red winter wheat cultivars from 1919 to 1987. Crop Sci. 28:756-760. http://dx.doi.org/10.2135/cropsci1988.0011183X002800050006x

Dawson JC, Murphy KM, Jones SS (2008). Decentralized selection and participatory approaches in plant breeding for low-input systems. Euphytica 160:143-154. http://dx.doi.org/10.1007/s10681-007-9533-0

Donmez E, Sears RG, Shroyer JP, Paulesen GM (2001). Genetic gain in yield attributes of winter wheat in the Great Plains. Crop Sci. 41:1412-1419. http://dx.doi.org/10.2135/cropsci2001.4151412x

Duvick DN (1984). Genetic diversity in major farm crops on the farm and in reserve. Eco. Bot. 38(2):161-178. http://dx.doi.org/10.1007/BF02858829

Ellis MB (1976). More Dematiaceous Hyphomycetes. CMI, Kew, Surrey England. 505 p.

Elias S, Garay A, Schweitzer L, Hanning S (2006). Seed quality testing of native species. Native Plants J. 7(1):15-19. http://dx.doi.org/10.2979/NPJ.2006.7.1.15

Elias S, Garay A, Gatch E (2010). Seed quality testing and certification: Resources useful in organic seed production. Organic seed resource guide. Website http://www.extension.org/ accessed 12 October 2011.

FAO (1998). The state of the world's plant genetic resources for food and agriculture, FAO, Rome.

FAO (2010). Second report on the world's plant genetic resources for food and agriculture. Food and Agriculture Organization, Rome, Italy [in press] – Electronic version (ftp://ftp.fao.org/docrep/fao/meeting/017/ak528e.pdf).

Fekadu W (2010). Assessment of Genetic Improvement in Grain Yield Potential, Malting Quality and Associated Traits of Barley (Hordeum vulgare L.) in Ethiopia. An MSc Thesis, Presented to the School of Graduate Studies Haramya University. 112 pp.

Fikadu A (1987). Barley breeding in Ethiopia. Rachis Barley Wheat Newslett. 6(2): 13-15.

Harlan JR (1975). Our vanishing genetic resources. Science 188:618-621. http://dx.doi.org/10.1126/science.188.4188.617

Hawkes AG (1971). Point Spectra of Some Mutually Exciting Point Process. J. Royal Stat. Soc. Ser. B, 33:438-443.

Hodgkin T, Rana R, Tuxill J, Dibier B, Subedi A, Mar I, Karamura D, Valdivia R, Colledo L, Latournerie L (2007). Seed systems and crop genetic diversity in agroecosystems. In: Jarvis D.I., C. Padoch and D. Cooper, editors. Managing biodiversity in agricultural ecosystems. New York: Columbia University Press pp. 77-116.

Hockett EA (2000). Barley. In: Kulp K, and Joseph, G.P. (eds). Handbook of cereal science and technology 2nd (eds). Marcel Dekker, Inc. New York.

Hundie B, Kumbi S, Lencho A (2001). Barley yield loss due to net blotch and leaf rust in Bale Highlands. Pest Manage. J. Ethiop. 5:45–53.

IAR (Institute of Agricultural Research) (2006). Crop variety registration.

ICARDA, FAO, AAR INENA and CIHEAM (1999). The national agricultural research systems In the West Asia and North Africa region. Casas, J., Solh, M. and Hafez, H., Eds ICARDA, Aleppo, Syria. 278 pp.

ISTA (International Seed Testing Association) (1996). International Rules for Seed Testing. Zurich, Switherland. 335 pp.

ISTA (2005). International Rules for Seed Testing. International Seed Testing Association, Bassersdorf, Switzerland.

Jalata Z (2011). GGE-biplot Analysis of Multi-environment Yield Trials of Barley (Hordeum vulgare L.) Genotypes in Southeastern Ethiopia Highlands. Int. J. Plant Breed. Genet. 5(1):59-75. http://dx.doi.org/10.3923/ijpbg.2011.59.75

Jarvis DI, Padoch C, Cooper D (2008). editors. Managing biodiversity in agricultural ecosystems. New York: Columbia University Press. pp. 77-116.

Johns T, Sthapit BR (2004). Biocultural diversity in the sustainability of developing country food systems. Food Nutr. Bull. 25:143-155. PMid:15214260

Lenoir C, Corbineau F, Come D (1986). Barley (Hordeum vulgare L.) seed dormancy as related to glumella characteristics. Physiologia Plantarum 68:301-307. http://dx.doi.org/10.1111/j.1399-3054.1986.tb01930.x

Maguire JD (1962). Speed of germination-aid in selection and evaluation for seedling emergence and vigor. Crop Sci. 2:176-177. http://dx.doi.org/10.2135/cropsci1962.0011183X000200020033x

Mariac C, Robert T, Allinne C, Remigereau MS, Luxereau A, Tidjani M, Seyni O, Bezancon G, Pham JL, Sarr A (2006). Genetic diversity and gene flow among pearl millet crop/weed complex: A case study. Theor. Appl. Genet. 113(6):1003-1014. http://dx.doi.org/10.1007/s00122-006-0360-9

Metzger DD, Czaplewski SJ, Rasmusson DC (1984). Grain filling duration and yield in spring barley. Crop Sci. 24:1101-1105. http://dx.doi.org/10.2135/cropsci1984.0011183X002400060022x

Nelson PE, Toussoum TA, Marasas WF (1983). Fusarium species. An illustrated manual for identification. State University press, Penn, USA. 203p.

Novak AS, Matic S, Krpan APB, Gracan J (2001). Common oak seed mycosis and protection possibilities. Znanost-u-potrajnom-gospodarenju-hrvatskimsumama. znastvena-knjiga pp. 343-351.

Ortiz R, Nurminiemi M, Madsen S, Rognli OA, Bjornstad A (2002). Genetic gains in Nordic spring barley breeding over sixty years. Euphytica 126:283-289. http://dx.doi.org/10.1023/A:1016302626527

Perry MW, D'Antuono MF (1989). Yield improvement and associated characteristics of some Australian spring wheat cultivars introduced between 1860 and 1982. Austr. J. Agric. Resour. 40:457-472. http://dx.doi.org/10.1071/AR9890457c

Sahilu Y (1999). Evaluation of status and quality of barley seed used by the northern and central Ethiopian farmers. An MSc thesis. University of Jordan, Amman, Jordan 65p.

Semeane Y, Hundie B, Woldeab G, Tadesse D (1996). Disease surveys and loss assessment studies on barley. in: H. Gebre and J.A.G. van Leur (eds.). Barley Research in Ethiopia: Past Work and Future Prospects. Proceedings of the 1st Barley Research Review Workshop, 16–19 October 1993, Addis Ababa. IAR/ ICARDA, Addis Ababa, Ethiopia. pp. 105-115.

Sinebo W (2002). Yield Relationships of Barleys Grown in a Tropical Highland Environment. Crop Sci. 42:428-437. http://dx.doi.org/10.2135/cropsci2002.0428

Smale M (2006). Valuing crop biodiversity: On-farm genetic resources and economic change. Wallingford, UK: CABI Publishing. http://dx.doi.org/10.1080/14888386.2006.9712810

Smale M, Bellon MR, Jarvis D, Sthapit B (2004). Economic concepts for designing policies to conserve crop genetic resources on-farms. Genet. Resour. Crop Evol. 51:121-135. http://dx.doi.org/10.1023/B:GRES.0000020678.82581.76

Smith ME, Castillo FG, Gomez F (2001). Participatory plant breeding with maize in Mexico and Honduras. Euphytica 122:551-565. http://dx.doi.org/10.1023/A:1017510529440

Sperling L (2008). Moving towards more effective seed aid. J. Dev. Stud. 44(4):573-600. http://dx.doi.org/10.1080/00220380801980954

Sperling L, Ashby JAQ, Smith ME, Weltzien E, McGuire S (2001). A framework for analyzing participatory plant breeding approaches and results. Euphytica 122:439-450. http://dx.doi.org/10.1023/A:1017505323730

Sthapit B, Rana R, Eyzaguirre P, Jarvis D (2008). The value of plant genetic diversity to resource-poor farmers in Nepal and Vietnam. Int. J. Agric. Sustain. 6(2):148-166. http://dx.doi.org/10.3763/ijas.2007.0291

Sthapit BR, Joshi KD, Rana RB, Upadhaya MP, Eyzaguirre P, Jarvis D, (2001). Enhancing biodiversity and production through participatory plant breeding: Setting breeding goals. pp. 29-54.

Sthapit BR, Rao VR (2009). Consolidating Community's Role In Local Crop Development By Promoting Farmer Innovation To Maximise The Use Of Local Crop Diversity For The Well-Being Of People. Acta Horticulture (ISHS), 806: 669-676.

Sutton BC (1980). The coelomycetes. C.M.I. Kew, Surrey England, 696 p.

Tarekegn KA (2009). Agronomic evaluation of Ethiopian barley (Hordeum vulgare L.) landrace populations under drought stress conditions in low rainfall areas of Ethiopia. An M.Sc. thesis. International Master Programme at the Swedish Biodiversity Center. 43 p.

Teshome A, Brown AHD, Hodgkin T (2001). Diversity in landraces of cereal and legume crops. Plant Breed. Rev. 21:221-261. http://dx.doi.org/10.1002/9780470650196.ch6

Tripp R (2001). Seed Provision and Agricultural Development. London: Overseas Development Institute.

Vandermeer J (1995). The ecological basis of alternative agriculture. Ann. Rev. Ecol. Syst. 26:201-224. http://dx.doi.org/10.1146/annurev.es.26.110195.001221

Witcombe JR, Joshi KD, Gyawali S, Musa AM, Johansen C, Virk DS, Sthapit BR (2005). Participatory plant breeding is better described as highly client oriented plant breeding. II. Optional farmer collaboration in the segregating generations. Expl. Agric. 42:79-90. http://dx.doi.org/10.1017/S0014479705003091

Wych RD, Rasmusson DC (1983). Genetic improvement in malting barley since 1920. Crop Sci. 23:1037-1040. http://dx.doi.org/10.2135/cropsci1983.0011183X002300060004x

Zeven AC (2000). Traditional maintenance breeding of landraces: 1. Data by crop. Euphytica 116:65-85. http://dx.doi.org/10.1023/A:1004089816030