Phenotypic Diversity for Qualitative Characters of Barley (*Hordeum Vulgare* (L.)) Landrace Collections from Southern Ethiopia

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Abstract: ***Barley is one of the most important traditional crops in Ethiopia which is a major center of genetic diversity for barley along with other crop plants species. Two hundred seven accessions and 18 released varieties were laid down in 15*15 simple lattice design and planted in 2008 main cropping season (June to Nov) at Kokate. The objective of the study was to conduct the morphological characterization and to determine the nature and degree of variability in morpho- agronomic traits of landrace of barley in southern Ethiopia collections. The proportion of genotypes in kernel row number were 26.6, 15.3, 16.6, 41.5 and 0.4% for two rowed with lateral floret, two rowed deficient, irregular, six rowed with awns on lateral floret and branched heads, respectively. Genotypes with white kernel color (57.5%) and amber (normal) lemma color (50%) were dominant. The highest diversity indices pooled over the characters within zones/ special woredas were recorded for accessions sampled from Dawro (H'= 0.75 ± 0.05) followed by Sheka (H'=0.74 ± 0.07), Gamgofa (H' =0.70 ± 0.05) and Keffa (H'= 0.70 ± 0.08). These zones can be used for in situ conservation for barley landraces as representatives of southern Ethiopian high lands. The barley genotypes were clustered into five distinct groups of various sizes based on 8 qualitative traits. The estimates of diversity index (H') for each trait in each of the three altitudinal class has shown that polymorphism was common in varying degrees for most traits, implying the existence of a wide range of variation in the materials.***

Keywords: Hordeum vulgare, Landrace, Diversity, Morphological Characterization

1. Introduction

Ethiopia is a major center of genetic diversity for barley along with other crop plant species such as sorghum, teff, chickpeas and coffee (Worede *et al*., 2000). The large diversity in the Ethiopian barley landraces could be due to the diversity in soils, climate, altitude and topography together with geographical isolation for long periods (Harlan, 1968). The long history of barley cultivation and the diverse agro-ecological zones and the diverse cultural practices have resulted in a country renowned for its large number of farmers' varieties (landraces) and traditional agricultural practices (Bekele *et al*., 2005).

Barley is one of the most important traditional Ethiopian crops. It occupies about 948,107.0 hectares of land with total production of 1,585,286.9 tones (CSA, 2011). This gives a productivity of about 1.67 tones / ha almost half of the world productivity. It is used in many traditional foods such as injera, genfo (porridge), dabo (bread), kitta, kinche, atmit/muk, eshet, kollo, beso, chicko, zurbegone and making local beverages (tella, bequre, borde, areki). The straw is used for animal feed during the dry season and it is also a useful material for thatching roofs of houses and for use as bedding (Kerssie and Goitom, 1996; Bekele *et al*., 2005).

Landraces are still the backbone of agricultural systems in many developing countries, mainly in marginal environments and are characterized by high genetic heterogeneity, good adaptation to local environment conditions and by low productivity (Ceccarelli and Grando, 1996) important in marginal areas or seasons where the production of other cereal is limited (Abay *et al*., 2009). These landraces have developed abundant patterns of variation and would represent a largely untapped reservoir of useful genes for adaptation to biotic and abiotic stresses (Nevo, 1992; Brush, 1995). Therefore, characterization of landraces and knowledge on the pattern of variation for important morpho-agronomic traits is needed for a proper management and a better exploitation of this gene pool (Jain *et al*., 1975; Gebrekidane, 1982; Assefa 2003).

The existence of genetic diversity has special significance for the maintenance and enhancement of productivity in agricultural crops in a country like Ethiopia, which is characterized by highly varied agro-climates and diverse growing conditions (Worede, 1993; Worede et *al*., 2000; Brush 2000).

Asfaw (2000) stated that within the general barley growing areas and the optimal agro-ecologic range, there are pockets in which some morphological and chemical groups are concentrated that can guide future conservation strategies. The southern and southeastern highlands of Ethiopia harbor more morphotypes than the central highlands (Asfaw 2000). Moreover, some individual localities within the study zones (e.g. Kembata, Galessa- Tululencha, Chencha) are recognized as pockets of higher number of morphotypes per field (Asfaw, 1990).

According to Asfaw (2000) there exists barley diversity at higher level in southern Ethiopia, but, this was not well studied and documented. In this regard, a considerable number of characterization and diversity studies have been conducted and documented on barley landrace collections from northern and central Ethiopia barley (Asfaw, 1988, 1989; Demissie, 1996; Kebebew *et al*., 2001; Assefa, 2003). However, barley collections from southern Ethiopia have not been extensively studied and characterized and hence the diversity within this material is not known. Hence, this work

was done with the objectives to conduct the morphological characterization and to determine the extent and nature of variability in morpho- agronomic traits of the barley landrace collections of southern Ethiopia.

2. Materials and Methods

2.1 Description of the Experimental Area

The experiment was conducted at Kokate sub center located in Soddo Zuria Woreda of Wolaita Zone. Kokate is located at the coordinates of 6^0 52'43. 9''N and 37^0 48'22.1''E. and has an elevation of 2161 meters above sea level. The ten years (1999- 2008) mean annual rainfall of the area is 1352.11 mm. The ten years (1999- 2008) mean minimum and maximum annual temperatures are 14.5^0c and 25.3^0c, respectively. The soils of the site are classified as dystric nitosols (EMA, 1988), which are formed from basaltic parent materials. The soils are highly weathered, well drained, deep, highly leached and acidic with low organic carbon, nitrogen and phosphorus content (Kena, *et al*., 1996). The pH of the soil is 5.1 to 5.6 (strong to moderately acidic); CEC is 24.1 to 26.65 cmol (+) / kg soil (medium to high); organic matter content is 0.764 to 3.47 % (very low to medium) and total N ranges from 0.056 to 0.182 % (low to medium) (Esayas and Ali, 2006).

2.2 Genotypes Studied

The materials for this study consisted of a total of 225 genotypes of which 207 are landraces (accessions) collected from various agro-ecological zones in southern Ethiopia (Figure 1) and 18 released varieties. The landraces were collected and maintained by Awassa Agricultural Research Center. The original samples were collected from farmers' stock and village markets.

Figure 1: Map of Southern Nation and Nationality Peoples Regional State (SNNPR) showing barley landrace collection areas

3. Experimental Design and Cultural Practices

The 207 accessions and 18 released varieties were laid down in 15 by 15 simple lattice design and were planted in 2008 main cropping season at Kokate. A plot size of two rows each 2.5m long and spaced 0.2m apart was used. At planting the seeds were drilled in the rows at the rate of 85 kg ha $^{-1}$. Nitrogen and phosphorous fertilizers were applied at the rate of 78.56 kg/ha Urea and 54.76 kg/ ha DAP at planting (i.e N= 46 kg/ ha and P_20_5= 25.19). To control broad leaf weeds, 2, 4-D herbicide was applied four weeks after planting at the rate of 1 liter per 200 liter of water per hectare followed by two hand weedings.

3.1 Data collected on single plant basis

Data were taken according to the International Plant Genetic Resources Institute (IPGRI, 1994) descriptor for barley. The color (awn, lemma) was recorded using color chart at the dough stage of the crop (Sarkar *et al*., 2002) and kernel color or pericarp color was recorded at harvest. Data were collected on qualitative traits `viz` kernel row number, awn color, awn roughness, kernel covering, lemma color, kernel color, spike density, hoodedness / awnedness (Table 1).Ten plants (spikes) were selected randomly at the time of heading (five plants from each row) and tagged with thread and all the necessary plant based qualitative data was collected from these plants.

Table 1: Phenotypic classes of the qualitative characters used for diversity study

Characters	*No. Class*	*Code*	*Classes*
Kernel row number	6	1	Two- rowed, with lateral florets
		2	Two- rowed, deficient
		3	Irregular,
		4	Six rowed, awnless or awnleted
		5	Six rowed with awns
		6	Branched heads
Awn color	6	1	White
		3	Yellow
		5	Brown
		7	Reddish
		9	Black
		10	Elivated hooded
Awn roughness	3	1	Smooth
		2	Rough
		3	Elevated hoods
Kernel covering	3	1	Naked grains
		2	Semi-covered grain
		3	Covered grains
Lemma color	5	1	Amber (= normal)
		2	Tan/red;
		3	Purple to white
		4	Black/grey
		5	Other
Kernel color	6	1	White
		2	Blue
		3	Black
		4	Brown
		5	Purple
		10	Mixture
Spike density	3	1	Lax
		2	Intermediate
		3	Dense
Hoodedness/ awnedness	5	1	Awn less
		2	Awnleted
		3	Awned
		4	Sessile hoods
		5	Elevatedhoods

4. Analysis of Qualitative Data

Frequency distribution of the various categories of qualitative traits was studied in to the zones and altitude from which the accessions were collected. Deviation of the frequency distribution from the theoretical distribution was tested by χ^2. Proc Freq of SAS (SAS, 1994) used for the χ^2 test.

5. The Shannon- Weaver Diversity index

The Shannon-Weaver diversity index (H') was computed using the phenotypic frequencies to assess the overall phenotypic diversity for each character by zones and altitude ranges. The altitude was arbitrarily classified in to three altitude classes, viz., <2000, 2001- 2500, 2501-3000 masl based on the altitudes from which the accession were collected. The Shannon-Weaver diversity index as described by Hutchenson (1970) was used to calculate phenotypic diversity for j^{th} trait with n sub classes:

$$h_{sj} = \sum_{i=1}^{n} pi \ln pi$$

Where pi is the relative frequency in the i^{th} category of the j^{th} trait. To keep Shannon-Weaver diversity index between 0 and 1 the formula suggested by Hennink and Zeven (1991) was used as:

$$H' = \frac{-\sum Pi \ln Pi}{\ln n}$$

Where Pi is the relative frequency in the i^{th} category of the j^{th} trait. H' of 0 indicates that is monomorphic, i.e all individual belong to one and the same category (clan), where as H' of 1 indicates maximum diversity i.e individuals are equally dispersed among the n class.

6. Results and Discussion

Eight qualitative traits, namely, kernel row number**,** awn color, awn roughness, kernel covering, lemma color, kernel color or pericarp color, spike density and hooded ness/ awned ness were recorded for the landraces studied.

7. Kernel Row Number

The proportion of genotypes in kernel row number were 26.2, 15.3, 16.6, 41.5 and 0.4% for two rowed with lateral floret, two rowed deficient, irregular, six rowed with long wns on lateral floret and branched heads, respectively (Table 2)

Generally two rowed with lateral floret and a deficient type comprises 41.9% while the six rowed was 41.5%. The frequency of six-row type's increase with increasing altitude (Asfaw, 2000) while the two- rowed types are frequently found at low and intermediate altitudes. Unlike Demissie and Bjørstad (1996) who reported the prevalence of six-rowed type in all geographical regions of the country, the distribution of six and two row types along with altitudinal range was somewhat balanced in this study. The more common botanical forms of Ethiopian barley are *Deficiens (*Asfaw, *2000)*. In this study only 15.3% of the total genotypes were deficient types.

7.1 Awn Color

Most of the genotypes were white in awn color (57.1%) followed by red (24.6%), yellow (14.1%) and brown (3.8%) but an accession collected from Sheka zone did not have awn color because it was elevated hooded types and consisted of 0.4% (Table 2).

Table 2: Percentage of phenotypic classes of each character

Characters	*Code*	*Classes*	*Frequency Distribution*
Kernel row number	1	Two- rowed, with lateral florets	26.2
	2	Two- rowed, deficient	15.3
	3	Irregular, variable lateral floret development	16.6
	4	Six rowed, awnless or awnleted	0
	5	Six rowed with awns	41.5
	6	Branched heads	0.4
Awn color	1	White	57.1
	3	Yellow	14.1
	5	Brown	0.8
	7	Reddish	24.6
	9	Black	0
	10	Elivated hooded	0.4
Awn roughness	1	Smooth	67.2
	2	Rough	32.3
	3	Elevated hoods	0.5
Kernel covering	1	Naked grains (grain without glumes)	2
	2	Semi-covered grain	11
	3	Covered grains	87
Lemma color	1	Amber (= normal)	2
	2	Tan/red;	24.1
	3	Purple to white	25.3
	4	Black/grey	0.58
	5	Other	0.02
Kernel color	1	White	57.5
	2	Blue	0.7
	3	Black	10.3
	4	Brown	10.3
	5	Purple	7.7
	10	Mixture	13.5
Spike density	1	Lax	36.3
	2	Intermediate	18.9
	3	Dense	44.7
Hooded-ness /awned-ness	1	Awn less	0
	2	Awnleted	0
	3	Awned	99.5
	4	Sessile hoods	0
	5	Elevatedhoods	0.5

7.2 Awn Roughness

The proportions of genotypes in awn roughness were 67.2% and 32.3% for rough and smooth awn, respectively. While the elevated hood types (no awns) comprised of 0.5% of the genotypes (Table 2). Similarly, Tadesse and Mekibib (1996) reported that the proportion of rough awn was greater than the smooth awn.

7.3 Kernel Covering

The genotypes in the current study comprised of 87% covered, 11% semi- covered and 2 % naked grain of the total landraces (Table 2).

7.4 Lemma Color

In the present study, frequency of the genotypes with lemma color show a trend of decrease order were amber (=normal) (50%), white to purple (25.3%), red (24.1), black (0.58%) and others (0.02%) respectively (Table 2). The amber or white (normal) color was the dominant one which is in agreement with the finding of Demissie and Bjørstad (1996) where white lemma color was the predominant in all zones despite the presence of highly significant deviation between black and white lemma colors.

7.5 Kernel Color or Pericarp Color

White kernel color was the dominant (57.5%) followed by mixture of different color (13.5%), black (10.3%), brown (10.3%), purple (7.7%) and blue (0.7%) (Table 2). This could be the result of conscious artificial selection that favored the white caryopsis genotypes by discriminating the other caryopsis colors. Similarly, Demissie and Bjørstad (1996) in barley and Legesse (2007) in sorghum observed that white kernel color predominates in regions where the accessions were sampled. This could be associated with high market value that farmers fetch from white grains.

7.6 Spike Density

In this study, spike density was 44.7%, 36.4% and 18.9% for dense type, lax and intermediate, respectively (Table 2). In disagreement with this result, Tadesse and Mekibib (1996) reported that the highest spike density was 58.63%, 28.82%, 12.43% for intermediate, lax and dense, respectively.

8. Hoodedness/ Awnedness

Except one genotype, which has elevated hoods (0.5%), almost all genotypes were awned (99.5%) (Table 2). Tadesse and Mekibib (1996) reported that 0.57% of their accessions were awnless. In this study awnless genotypes were not observed but some genotypes shaded their awns before physiological maturity because of the blowing winds.

8.1 Estimates of diversity for each zones/ special woredas

Table 3 shows the estimates of Shannon-Weaver diversity index for 7 discrete characters by zones / woredas. Table 4 summarizes the result of chi-square test for zones/ special woredas. This index was previously used to determine the range of variation in several crop species including wheat (Jain *et al*., 1975; Belay *et al*., 1997), barley (Kebebew et al, 2001; Demisse and Bjornstad, 1996) and finger millet (Bezawletaw, 2007). Over all, all characters revealed a diversity ranging from 0.32 for kernel covering to 0.90 for spike density. Monomorphism (H'< 0.10) was observed in accessions collected from Bench, Silitie and Wolaita Zones for trait of kernel covering (Table 3). For all zones / special woredas almost all genotypes are awned except for Sheka zone, which has one genotype with elevated hooded type, but all the rest have awn which is monomorphism (H'=0) and omitted from calculating the mean diversity index. Monomorphism was seen in some genotypes and in some zones which could be either drift or loss of genetic integrity caused by selection forces (Hammer *et al*., 1996).

Table 3: Estimates of the Shannon-Weaver diversity index (H'), for seven qualitative traits and 15 zones / special woredas

Zones/ Sworeda	Row number	Awn color	Awn roughness	Kernel covering	Lemma color	Kernel color	Spike density	**Mean H' ± SE**
Amaro	0.76	0.44	0.56	0.09	0.47	0.47	0.57	0.48 ± 0.07
Bench	0.80	0.58	0.57	0	0.72	0.64	0.94	0.61 ± 0.10
Dawro	0.84	0.51	0.55	0.85	0.75	0.77	0.95	0.75 ± 0.05
Gamogofa	0.78	0.64	0.59	0.45	0.78	0.72	0.96	0.70 ± 0.05
Gedeo	0.76	0.41	0.54	0.82	0.64	0.62	0.85	0.66 ± 0.05
Guji	0.68	0.53	0.62	0.58	0.60	0.48	0.94	0.63 ± 0.05
Gurage	0.81	0.44	0.52	0.46	0.60	0.54	0.94	0.62 ± 0.06
Hadiya	0.75	0.48	0.44	0.29	0.69	0.71	0.94	0.61 ± 0.07
Kambata	0.56	0.43	0.38	0.06	0.53	0.77	0.78	0.50 ± 0.08
Keffa	0.83	0.80	0.61	0.20	0.77	0.75	0.93	0.70 ± 0.08
Sheka	0.81	0.73	0.88	0.33	0.86	0.67	0.90	0.74 ± 0.07
Sidama	0.67	0.64	0.63	0.37	0.66	0.50	0.92	0.63 ± 0.06
Siltie	0.58	0.58	0.52	0	0.71	0.65	0.95	0.57 ± 0.09
Wolaita	0.71	0.45	0.47	0	0.75	0.61	0.96	0.56 ± 0.10
Yem	0.84	0.67	0.61	0.23	0.77	0.74	0.96	0.69 ± 0.08
Over all	**0.75**	**0.56**	**0.57**	**0.32**	**0.69**	**0.64**	**0.90**	0.63 ± 0.06

Table 4: χ^2 – test for dependence of frequency distribution of seven qualitative traits on zones

Trait	df	χ^2
Row number	56	1127.22***
Awn color	56	1867.35***
Awn rough ness	28	765.75***
Kernel covering	28	856.91***
Lemma color	42	735.68***
Kernel color	70	977.97***
Spike density	28	173.15***

***-Significant at 0.1% level

The highest diversity indices pooled over characters within zones/ special woredas were recorded for accessions sampled from Dawro (H'= 0.75 ± 0.05) followed by Sheka (H'=0.74 ± 0.07), Gamgofa (H'=0.70 ± 0.05) and Keffa (H'= 0.70 ± 0.08) where as genotypes from Amaro and Kembata showed relatively lower diversity estimates of H'=0.48± 0.07 and H'= 0.50± 0.08, respectively.

8.2 Cluster Analysis based on Qualitative Traits

The barley genotypes were clustered in to five distinct groups based on 8 qualitative traits. A dendrogram summarizing genetic similarity among 225 barley genotypes based on qualitative characters is given in Figure 2. The traits used for clustering were kernel row number, awn color, awn roughness, kernel covering, lemma color, kernel color, spike density and hoodedness/ awnedness. The number of genotypes belonging to each cluster varied from one in cluster V to 130 in cluster I.

Cluster I was the largest and consisted of 130 genotypes (57.78%). Barley genotypes grouped under this cluster have predominantly six rowed with awns, white and rough awns, amber (normal) lemma color, white kernel cover, dense spike with awns, majority of covered grains, and most of the partial covered grains and all naked types. The 28 genotypes were included in cluster II (12.44%) with six- rowed having awns, rough and reddish awn color, covered grains, tan/ red lemma color, black and mixture of white and black kernel, dense spike with awns. On the other hand the 55 genotypes (24.44 %) grouped under cluster III were two- rowed barley

(both with lateral floret and deficient types), and posses rough and reddish awn color. The majority were covered grains but some partially covered grains, tan/ red and purple to white lemma color, brown and black kernel covering, and lax spike with awns.

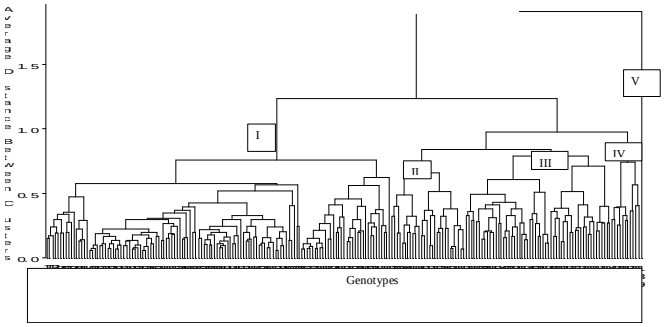

Figure 2: Dendrogram of 225 barley genotypes constructed based on eight qualitative traits

Eleven genotypes (4.89%) were categorized under cluster IV and have predominantly two rowed with lateral floret and two rowed deficient, rough and white awn color, covered grains, tan/ red and white to purple lemma color, a mixture of black and white kernel color, and lax spike with awns. Lastly, cluster V consisted 1 genotype (0.44 %) from Sheka zone and typically posses two rowed deficient, covered grains, black/grey lemma color, black kernel color, dense spike with elevated hoods.

8.3 Altitudinal Trait Distribution

Table 5a, 5b, and 5c summarizes the phenotypic frequencies for individual traits and altitudinal classes as percentages of the number of genotypes from each altitude class. In this study, the frequency of the six row type appears to increase with altitude; this is in agreement with (Demisse and Bjornstad, 1996). Both two-rowed with lateral floret and the irregular types tend to concentrate at lower elevations, in areas below 2500 masl. This is similar with the reports of Demisse and Bjornstad (1996) but in contrast to these authors the frequency of the two rowed-deficient type increases with increasing altitude greater than 2500 masl. In similar trends the frequency of partially covered grains, amber lemma color, and white kernel color increased with increasing altitude while the naked barley (hull less) was frequent in between 2150 masl and 2720 masl but in disagreement with Demisse and Bjornstad (1996) the availability of naked barley was not increased with increasing altitude greater than 2500 masl.

Table 5a: Percentage of phenotypic classes for each altitudinal classes

Alt c	No.	RNO					ACO				
		1	2	3	5	6	1	3	5	7	10
1	280	21.4	34.6	18.2	25.7	58.6	58.6	9.3	2.6	8.6	0.0
2	1940	29.2	14.5	17.1	38.3	53.8	53.8	10.1	3.7	31.4	1.0
3	1920	25.4	16.0	13.3	45.3	58.1	58.1	19.3	1.8	20.8	0.0

Altc = Altitude code , Altitude 1= less than 2000 masl, Altitude 2= between 2000 and 2500 masl, Altitude 3= between 2500 and 3000 masl, RNO = kernel row number, ACO =awn color

Table 5b: Percentage of phenotypic classes for each altitudinal classes

Alt c	No.	ARG			KCV			LCO				
		1	2	3	1	2	3	1	2	3	4	5
1	280	44.3	55.7	0.0	0.0	0.0	100.0	47.1	10.0	42.9	0.0	0.0
2	1940	29.8	69.0	1.2	3.6	8.9	87.5	40.4	31.3	27.3	1.0	0.0
3	1920	34.2	65.8	0.0	1.1	16.8	82.1	57.2	20.3	22.1	0.4	0.1

Altc = Altitude code, Altitude 1= less than 2000 masl, Altitude 2= between 2000 and 2500 masl, Altitude 3= between 2500 and 3000 masl, ARG = awn rough ness, KCV= kernel covering, LCO = lemma color

Table 5c: Percentage of phenotypic classes for each altitudinal classes

Al tc	No.	KCO						SDE			HA	
		1	2	3	4	5	10	1	2	3	3	5
1	280	42.1	0.0	23.6	93	4.3	20.7	35.4	16.4	48.2	48.2	0.4
2	1940	49.0	0.8	13.6	124	6.2	18.1	40.7	19.7	39.5	39.5	1.0
3	1920	64.4	0.9	5.9	9.7	9.8	9.2	32.9	18.2	48.9	48.9	0.0

Altc = Altitude code, Altitude 1= less than 2000 masl, Altitude 2= between 2000 and 2500 masl, Altitude 3= between 2500 and 3000 masl, KCO =kernel covering, SDE = spike density, HA = hooded ness/ awned ness

9. Diversity Index for Altitudinal Class

The estimates of diversity index (H') for each trait to the three altitudinal class is shown in Table 6. Table 7 summarizes chi-square value for altitudinal class based on eight morphological traits. Polymorphism was common in varying degrees for most traits, this implying the existence of a wide range of variation in the materials. The H' value ranged from 0.0 (monomorphic) for kernel covering and hoodedness/ awnedness to 0.99 (high polymorphic) for awn ruoghness. The diversity index for kernel row number, awn color, awn rough ness, kernel covering increased between 2500 and 3000 masl but traits such as lemma color, kernel color and spike density increased below 2500 masl. Compared with zonal estimates, H' values pooled over all traits for altitudinal classes showed less variation (Table 6).The altitude class with highest diversity index is between 2500 and 3000 masl (Altitude III) in disagreement with the results of Demisse and Bjornstad (1996) who reported the highest diversity index between 2000 and 2500 masl (Altitude II). The diversity of altitude one (<2000 masl) was higher unexpectedly increased this might be associated with small sample size as compared to altitude two and three.

Table 6: Estimates of Shannon- Weaver diversity index (H'), for eight qualitative traits and altitudinal classes

Alt C	RNO	ACO	ARG	KCV	LCO	KCO	SDE	HA	Mean H'±SE
1	0.98	0.78	0.99	0.00	0.86	0.86	0.92	0.03	.68±0.15
2	0.84	0.68	0.61	0.41	0.81	0.78	0.96	0.08	.65±0.10
3	0.92	0.74	0.93	0.46	0.62	0.65	0.93	0.00	.66±0.11

Altc= Altitude code Altitude 1= less than 2000 masl, Altitude 2= between 2000 and 2500 masl, Altitude 3= between 2500 and 3000 masl RNO = kernel row number, ACO =awn color, ARG = awn rough ness, KCV= kernel covering, LCO = lemma color, KCO =kernel covering, SDE = spike density, H.A = hooded ness/ awned ness

Table 7: χ^2- values for altitudinal class based on eight morphological traits

Trait	df	χ^2
Row number	8	127.99***
Awn color	8	448.39***
Awn rough ness	4	50.63***
Kernel covering	4	130.25***
Lemma color	8	182.33***
Kernel color	10	244.73***
Spike density	4	38.46***
Hoodedness/awnedness	2	20.46***

10. Conclusion and Recommendation

There was variation in the qualitative traits of the landraces under study. White kernel color and amber (=normal) lemma color were the dominant kernel colors observed in the present study. The highest diversity indices pooled over characters within zones/ special woredas were recorded for accessions sampled from Dawro (H'= 0.75 ± 0.05) followed by Sheka (H'=0.74 ± 0.07), Gamgofa (H'=0.70 ± 0.05) and Keffa (H'= 0.70 ± 0.08). Altitudinal trait distribution indicated that frequency of six- row type appears to increase with increase in altitude. Both two-rowed with lateral floret and the irregular types tend to concentrate at lower elevations, in areas below 2500 masl. Thus, the existence of wider agro-morphological diversity among the barley collections indicated the potential to improve the crop and the need to conserve the diversity. Future collections of barley germplasm as source of diversity should take into account the distribution of polymorphism. Accordingly, priority of germplasm collection expedition should strategically focus on areas with relatively large variation. From genetic conservation point of view, it appears that Dawro, Sheka, Gamgofa and Keffa zones coupled with appropriate altitudinal focus can be suitable for *in situ* barley germplasm conservation.

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