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Qualitative traits variation in barley (*Hordeum vulgare* L.) landraces from the Southern highlands of Ethiopia

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Thirty six barley landraces were collected from three districts of the southern highlands of Ethiopia and evaluated for 11 morphological traits to assess the extent of qualitative trait variations based on morphological traits. The results showed that 42% of the 36 barley landraces were found to have six kernel row numbers for the three collection districts. The distribution of four kernel raw number was found to be very low among the different landraces. Phenotypic diversity index (H') was analyzed and the result indicated that all characters revealed intermediate to high diversity ranging from 0.78 for kernel row number to 0.34 for glume color in all districts. Individual characters showed different levels of diversity index in different districts. The results clearly showed that there is high diversity of barley landraces in the southern highlands; this can be used for the conservation of these germplasm resources and future improvement work on barley crops.

Key words: Diversity index, conservation, barley landraces, agro morphology.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the earliest cultivated cereal crops in Ethiopia and it is the fifth most important cereal crop both in area coverage and production, with around 1,013,623.72 ha and 18,155,830.29 qt, respectively (CSA, 2012). Ethiopia is considered to be a center of diversity for food barley crop production (Firdissa et al., 2010). The diversity in altitude, soils, climate and topography together with geographical isolation for long periods, are considered as the main factors influencing the large diversity in the country (Mekonnon et al., 2015). The wide cultural diversity in the country also plays an important part in the diversification of the landraces. Lack of improved varieties, disease, insect and pest problems, weed competition, and poor soil fertility have been indicated as major constraints in barley improvement (Lakew and Alemayehu, 2011).

Ethiopian barley landraces are a precious source of genes that control important agronomic traits, such as resistance to disease (for example powdery mildew, barley yellow dwarf virus, net blotch, scald and loose smut), to insect attack (Yitbarek et al., 1998), high lysine and protein quality and content (Munck et al., 1970), and

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Table 1. List of barley landraces used in the experiment and their collection site.

Number	Local name	Collection site	Altitude (m.a.s.l.)[1]	Number	Local name	Collection site	Altitude (m.a.s.l.)[1]
1	Duhe I	Chencha	2983	19	Solga II	Dita	2764
2	Locha I	Chencha	2992	20	Morka	Dita	2771
3	Maleno I	Chencha	2986	21	Chega IV	Dita	2867
4	Locha II	Chencha	2984	22	Osaha	Dita	2870
5	Chega I	Chencha	2968	23	NK 1	Dita	2871
6	Chentic	Chencha	2971	24	Maleno III	Dita	2888
7	Wolate	Chencha	2932	25	Locha II	Dita	2948
8	Kawbanga I	Chencha	2931	26	Losha	Dita	2950
9	Bote I	Chencha	2939	27	Bote II	Dita	2950
10	Maleno II	Chencha	2872	28	Kaobanga II	Dita	2904
11	Bote 2	Chencha	2886	29	Chega V	Dita	2762
12	Ye gibirina	Chencha	2885	30	Murka	Bonke	2384
13	Karsa Ocho	Chencha	2895	31	Shilash	Bonke	2365
14	Giso	Chencha	2810	32	Geze Banga	Bonke	2559
15	Bote 3	Chencha	2809	33	Wolkiie	Bonke	2557
16	Chega II	Dita	2536	34	Lealo	Bonke	2372
17	Solga I	Dita	2542	35	Mirichicho	Bonke	2379
18	Chega III	Dita	2636	36	NK II	Bonke	2354

[1]Expressed as metres above sea level (m.a.s.l.).

malting and brewing quality (Lance and Nilan, 1980). For these important aspects, characterization of genetic variability of a population is required; because genetic variation within a population, and between populations, determines the rate of adaptive evolution and response to traditional crop improvement (Hunter, 1996).

Furthermore, the high variability of the environmental conditions in Ethiopia that promote adaptive selection, and the cultivation of barley in two growing seasons per year (Tanto et al., 2009), have probably driven the structure of these landrace variations. Furthermore, utilization of barley for home consumption can contribute to some variation in the type of landraces maintained in a particular geographic location. Continuous efforts to understand the genetic diversity of Ethiopian landraces, as well as the nature and extent of their variations, would be useful for the efficient conservation and use of the existing plant materials.

Previous studies on morphological variability of Ethiopian barley landraces concentrated on random samples and failed to assess variability of landraces within specific localities in terms of economically important traits that pave the way for further evaluation and utilization (Lakew and Alemayehu, 2011). Hence, this study was conducted with the objective to assess the extent of qualitative trait variations based on morphological traits of barley landraces from the southern highlands of Ethiopia, and select potential genotypes for variety improvement program.

MATERIALS AND METHODS

Experimental materials

A total of 36 barley landraces were collected from southern highlands of Ethiopia. Twenty accessions per landraces were collected from each site. The landraces were collected based on their diverse agroecology, origin, and altitude (Table 1). The accessions were collected from farmers' fields, by using a random sampling technique (Hawkes, 1976).

Experimental site

The experiment was conducted at Arba Minch University field Enset Park at Chencha, during the main cropping season of 2014 under rain fed conditions. Altitude of the experimental site is 2537 m.a.s.l and the annual rainfall ranges between 1201 to 1600 mm and mean maximum and minimum temperatures are 22 and 12.7°C, respectively (Table 2). The site is selected based on its barley crop production potential, during the rainy season, which occurs from June to October.

Experimental procedure

The experiment was laid out in a randomized complete block design with three replications. The experimental plots consisted of six rows of 2.5 m length with 30 cm spaces, and seeds were sown by hand. The plant density of 300 plants per m^2 and recommended

Table 2. Metrological data of the study area during the study period (July to December, 2014).

Parameter	July	August	September	October	November	December	Total/average
Total monthly rainfall (mm)	41.2	113	193.6	234.8	121	14.8	718.4
Minimum temperature (°C)	11.5	11.4	11.6	12.6	12.5	12.0	11.9
Maximum temperature (°C)	18.8	18.3	20.4	21.4	21.7	23.5	20.7

[1]Source: Arba Minch University, Dorze Metrological Station.

Table 3. Phenotypic classes of the qualitative characters used for diversity study.

Trait	Type
Kernel row number (KRN)	Two rowed ; Two rowed, deficient; Irregular, variable lateral florets; six rowed, awnless or awnlete; Six rowed, long awns; Others
Spike density (SD)[b]	Lax; Intermediate ;Dense
Lemma awn barb (LAB)	Smooth; Intermediate (small barbs) ;Rough
Glume color (GC)	White; Yellow; Brown; Black
Lemma type (LT)	No lemma teeth; Lemma teeth; Lemma hair
Length of rachila hair (LRH)	Short; Long
Kernel covering (KC)	Naked grain; Semi-covered grain; Covered grain
Lemma/Kernel color (LC)	Yellow; Tan/red; Purple; Black/grey
Growth habit (GH)	Prostrate; Intermediate; Erect
Stem Pigmentation (SP)	Green; Purple (basal only); Purple (half or more)
Awn color (AC)	White; Yellow; Brown; Reddish; Black

dose of fertilizer (100:70:50, NPK) kg per ha were applied. Plots were kept free from weeds.

Data collection

Based on the IPGRI descriptor list (IPGRI, 1994), 11 qualitative characters were recorded (Table 3). For each landrace, 20 randomly selected individual plants were used for recording qualitative traits. Color traits were recorded using the Eagle Sprit Ministry Color Chart, which was developed by Kohe't (1996).

Statistical analysis

Phenotypic frequencies distributions of the characters were calculated for all the barley landraces. Shannon-Weaver diversity index (H') (Poole, 1974) was computed using the phenotypic frequencies to assess the phenotypic diversity of each character for all landraces:

$$H' = \sum_{i=1}^{s} p_i \log_e p_i$$

Where, s represents the number of phenotypic classes of a given character, and P_i the proportion of the total number of accessions consisting of the i^{th} class. Each value of H' was divided by ln s, in order to keep the values of H' between zero and one (Goodwin et al., 1992). To study the patterns of diversity among the sampled populations, a dendrogram was made based on Nei's (1978) unweighted, pairwise distance matrix between populations. This showed the relationships among all of the 36 landrace populations. For this analysis, the Pop Gene version 1.32 (Yah et al., 2000) computer software was also used.

RESULTS AND DISCUSSION

The frequency distribution for the 11 qualitative traits tabulated by source of the landraces is shown in Table 4. Forty two percent of the barley landraces were found to have six kernel row numbers and the distribution of four kernel row number was very low. The variation in spike density revealed the predominance of the intermediate spike density type in all of the districts with overall frequency of 83% followed by dense type; whereas lax type was found to concentrate in Bonke with overall

Table 4. Frequency distribution (%) of different phenotypic classes for 11 qualitative characters in Barley landraces by location of collection.

Location	KRN						SD			LAB			GC				LT		
	1	2	3	4	5	6	3	5	7	3	5	7	1	2	3	4	1	2	3
Chencha	33	0	27	0	0	40	13	53	33	27	20	53	33	53	0	13	60	33	7
Dita	29	7	21	7	0	36	21	36	43	36	21	43	79	14	0	7	21	57	21
Bonke	14	14	14	0	0	57	14	43	43	0	43	57	86	14	0	0	14	14	71
All	28	6	22	3	0	42	17	44	39	25	25	50	61	31	0	8	36	39	25

	LRH		KC			LC/KC				GH			SP			AC				
	1	2	1	2	3	1	2	3	4	3	5	7	1	2	3	1	2	3	4	5
Chencha	87	13	0	87	13	7	7	53	13	20	0	20	80	7	7	87	13	53	13	7
Dita	71	29	0	71	29	29	0	57	7	7	7	7	86	7	50	43	50	36	14	0
Bonke	86	14	0	86	14	57	14	29	0	0	0	57	43	0	43	57	71	14	0	14
All	81	19	0	81	19	33	8	50	8	49	15	36	58	10	32	39	28	22	6	5

frequency of 17%. This suggests preference of farmers for barley landraces with intermediate or dense spike density types, which may be due to the fact that such landraces types are less susceptible to bird damage (Derbew et al., 2013).

Various lemma types were observed in all of the districts. The lemma teeth type was concentrated in Dita and Chencha with 57 and 33%, respectively. This result is generally in agreement with the findings of Tenaw and Tanto (2014) who reported high frequency for lemma teeth type in Dita and Chencha. With respect to growth habit the prostate type was more predominantly followed by erect type with a frequency of 49 and 36%, respectively.

Kernel color is one of the most important characters that determine the quality and acceptance of landraces. It has an economic value because it constitutes the basis for farmers' variety identification and commercial classification of different varieties of crops (Tsehaye and Kebebew, 2002). Purple kernel color was found to be the dominant color followed by yellow kernel color with a frequency of 50 and 33%, respectively, in the present study. Farmers prefer barley with purple kernel color with high yield and hardiness, even though it fetches fewer market prices compared to a black or red color.

Diversity index analysis

Table 5 shows the estimates of diversity index for each of the character. Overall, all characters revealed intermediate to high diversity ranging from 0.34 for glume color to 0.78 for kernel row number in all districts. Individual characters showed different levels of diversity index in different districts. Kernel row number exhibited higher diversity index in most districts than other characters with more than two phenotypic classes. A higher phenotypic diversity index for characters with less number of phenotypic classes was also reported by Mekonnon et al. (2015) in barley landraces. Kemelew and Alemayehu (2011) also reported a high diversity index among 181 barley landraces, using collections from Shewa and Wollo for the eight qualitative characters considered. The result revealed a diversity ranging from 0.32 for kernel covering to 0.90 for spike density.

Phenotypic diversity index across districts

The H' pooled across characters by districts of collection showed high phenotypic diversity among the 11 qualitative characters (Table 6). The mean H' varied from 0.49 for Bonke to 0.53 to Dita. The low H' from Bonke district were not necessarily associated with lack of adequate sample size. This diversity reflects the wide range of ecological and human influences under which the crop has evolved.

Altitudinal diversity index

Most of the qualitative characters showed significant

Table 5. Phenotypic diversity index (H') for the 11 qualitative traits.

Locus	H'	I*
KRN	0.78	1.60
SD	0.52	0.88
LAB	0.51	0.87
GC	0.35	0.70
LT	0.55	0.92
LRH	0.49	0.69
KC	0.53	0.82
LC	0.71	1.36
GH	0.49	0.83
SP	0.46	0.65
AC	0.67	1.27
Mean	0.55	0.96
St. Dev	0.12	0.31

Table 6. Estimation of the diversity index (H') of the 36 barley landraces for the three districts of origin.

District	KRN	SD	LAB	GC	LT	LRH	KC	LC/KC	GH	SP	AC
Chencha	0.77**	0.45**	0.48**	0.49**	0.26*	0.48**	0.52**	0.74**	0.39**	0.39**	0.64**
Dita	0.75**	0.57**	0.56**	0.29*	0.56**	0.49*	0.49**	0.64*	0.44**	0.48*	0.56*
Bonke	0.71**	0.48**	0.41**	0.00*	0.64**	0.39	0.56**	0.66**	0.48**	0.49*	0.61**
Mean H'	0.74	0.50	0.48	0.26	0.49	0.45	0.52	0.68	0.44	0.45	0.60
Overall	0.78	0.52	0.51	0.35	0.55	0.49	0.53	0.71	0.49	0.46	0.67

Table 7. Estimates of the diversity index (H') for the three altitude classes.

Altitude (m.a.s.l)	KRN	SD	LAB	GC	LT	LRH	KC	LC/KC	GH	SP	AC	Mean
2,000-2,400	0.71*	0.41**	0.51*	0.04	0.64	0.49	0.53**	0.65	0.61**	0.47	0.48*	0.50
2,401-2,800	0.75*	0.53*	0.46*	0.30*	0.39*	0.49*	0.42*	0.69*	0.46*	0.50*	0.73*	0.52
2,801-3,000	0.73	0.57**	0.52*	0.55*	0.37*	0.42	0.51**	0.74*	0.26**	0.35*	0.58	0.51
Average H'	0.73	0.50	0.50	0.30	0.47	0.47	0.49	0.69	0.44	0.44	0.60	0.51

variation among altitude groups. The estimates of H' for each of the characters and altitude class are presented in Table 7. In altitude group I (2,000 to 2,400) and group III (2,801 to 3,000) spike density, kernel covering and growth habit showed highly significant variation. The altitude group II (2,401 to 2,800) showed significant variation for all characters measured. Mekonnon et al. (2015) also reported a significant variation among different altitude groups for 102 barley landraces among six qualitative characters.

Cluster analysis

All of the 36 barley landraces were grouped into five clusters (Table 8) and among these four clusters had different compositions in terms of collection districts. The number of landrace populations per cluster varied from 11 landraces in cluster II and IV to four landraces in cluster I (Figure 1) in which 71.4 % of landraces from Dita are grouped in cluster III and IV, and most of them have predominant white glume color, lemma teeth and green stem pigmentation.

Furthermore, cluster I was the only cluster without landraces from Dita and Bonke districts; and Clusters II, II and IV contain landraces from all districts with the following percentages: Chencha (41.67%), Bonke (38.89%) and Dita (19.4%). Landraces, which were grouped in cluster IV, were mainly characterized by the

Table 8. The total number of landraces by cluster.

District	Number of landraces by clusters				Total
	I	II	III	IV	
Chencha	4	4	4	3	15
Dita	0	5	4	5	14
Bonke	0	2	2	3	7
Total	4	11	10	11	36

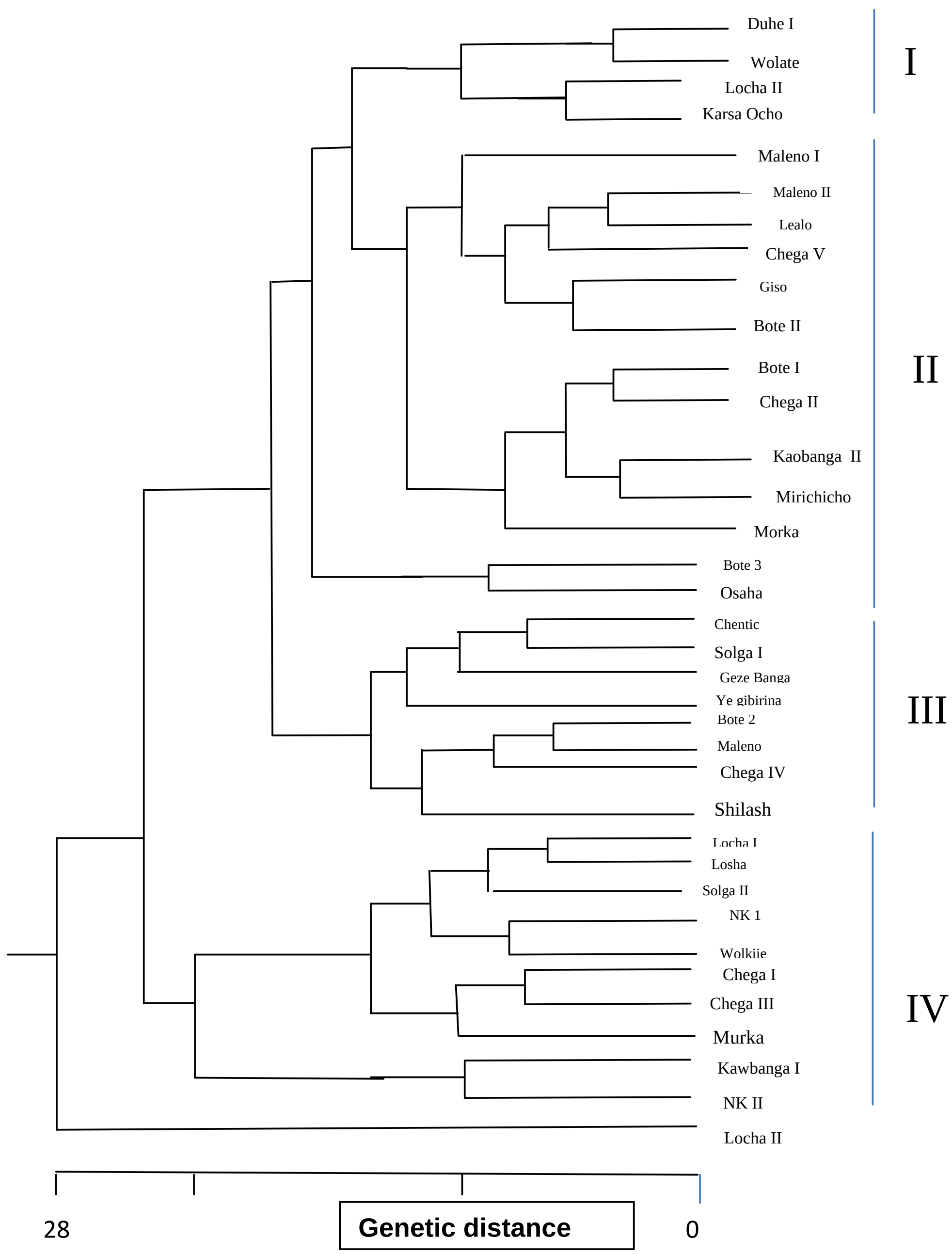

Figure 1. Unweighted pair group method of arithmetic mean (UPGMA) dendrogram based on Nei (1978) genetic distance, showing the relationships among all barley landrace populations.

possession of two row kernel number, short rachila hair, semi covered grain, and white awn color. This result was also in agreement with those of Derbew et al. (2013), who showed that 225 barley genotypes were clustered into five groups based on eight qualitative traits. Their data showed that the number of genotypes belonging to each cluster varied from one in cluster V to 130 in cluster I. Kemelew and Alemayehu (2011) also showed hierarchical clustering analysis using Euclidean distance of 181 barley landraces results in ten clusters, each cluster contained landraces with contrasting expression of agronomic traits. Based on the agronomic merit of each cluster, the ten clusters in turn were re-classified into high and low yielding cluster groups.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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