Agro-morphological Variability Study of Barley *(Hordeum vulgare* L.) Landraces in Jumla, Nepal

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ABSTRACT

Barley is an important winter cereal crop in Jumla (2240-3000 masl), Nepal. It is grown in different cropping patterns in both *Khet* and *Bari* land conditions. A total of 207 accessions of barley landraces collected from various locations of Jumla were studied for agro-morphological characteristics in Khumaltar and Jumla. Data on eight qualitative and five quantitative traits in 2-m row plot were recorded to assess diversity among the landraces. *Bhuwali, Chawali, Lekali* and *Pawai* were four farmer-named traditional barley varieties under cultivation in Jumla. A range of variability was observed among the accessions of barley landraces. All accessions are six-row covered barley possessing rough awns and whitish-brown grains. These landraces exhibit a range of variation in growth class, spike density and rachilla hair length. *Lekali* and *Pawai* are adapted to the high-altitude area of Jumla. Cluster analysis of measured data under on-farm and on-station conditions indicated five distinct clusters. Three principal components explained 84.3% and 60.2% of the total variation from on-station and on-farm, respectively.

Key words: *Hordeum vulgare*, landraces, morphological variation, on-farm, on-station

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the old and an important winter cereal crop for the people living in high mountain areas of Nepal. High level of barley diversity is observed in the Nepalese high lands and the region is considered a center of diversity for barley (Witcombe and Gilani 1979). Barley is cultivated in a wide range of environments in Nepal (Baniya et al 1997). Although, the acreage of barley in Nepal is limited, it is very important crop in remote and food deficit areas. Jumla is a transition zone between lower elevations, where a summer crop follow a winter cereal, and higher elevations where only one crop (crop is grown in summer season only) can be grown. Barley is the second cereal crop to rice in Jumla. It is utilized as food, beverages and livestock feed and also served as an indicator of well-being in the community of remote areas as the crop tolerates cold climate.

Morphological characterization is the foundation of genetic diversity research at any taxonomic level (Chandran and Pandya 2000). It is still an important tool for the management of crop germplasm collections (Ariyo 1993, Polignano et al 1993, Annicchiarico and Pecetti 1994) having been used to identify duplicates, to discriminate among material from different geographic areas, to establish core collections, to investigate relationships between landraces and their wild, and to prioritize material for use in breeding programmes.

Pradhanang and Sthapit (1995), Witcombe and Murphy (1986) and Konishi and Matsuura (1991) reported that high level of variability was observed within and among populations. In Jumla, farmers classify their land according to its utilization and ecological conditions. The major land types are *Khetland*[1] (*Kholapane*[8], *Sim*[7], and *Gadkule*[6]), *Bariland*[2] (*Gharbari*[5] and *Pakhobari*[4]) and *Lekhland*[3]. Barley is cultivated in *Khet*, *Bari* and *Lekh.* The amount of farmyard manure applied is normally between 17 and 27 t ha^{-1} for *Khet* and *Bari*. In *Kehtland*, fertilization is done through *in situ* manuring by the animal herds (Rana et al 2000). A more intensive cropping pattern was observed in *Pakhobari*. *Gharbari* is suitable for residence, kitchen garden and fruit orchards whereas mono cropping is practiced in *Lekhland*. The land types of the study site were 40% *Khetland* and 60% *Bariland* (Paudel et al 1998). The cropping patterns were observed in different land types. Rice–barley is the major cropping pattern in both *Kholapane* and *Gadkul*e *khet* whereas rice–fallow is the major pattern in *Simkhet*. Barley–fallow cropping pattern is usually practiced in *Lekhland.* Similarly, barley–beans in *Gharbari* and barley–buckwheat, barley–beans, barley–proso millet cropping pattern is common in *Pakhobari* and it is considered as the most productive and very important land type with respect to food security.

Chawali, Bhuwali, Lekali and *Pawai* are four farmers' varieties of barley that are under cultivation in these land conditions for their preferred traits and different use values (Paudel et al 1998, Rana et al 2000). Among them, *Chawali* and *Lekali* are two very common landraces grown in large areas and by many farmers. Field study and household survey, indicates that *Chawali* was commonly cultivated in rice fields in winter where as *Lekali* is grown in diverse conditions from lowlands in rice field to *Bari* (upland) on hill tops and terraces under rainfed conditions. These varieties constitute a range of variability in agro-morphological traits and farmers use these traits as descriptors to identify and distinguish the varieties that have been maintained by them on-farm. The study was therefore aimed to measure the range of variation in agro-morphological characteristics among the barley accessions with distinct farmer units of diversity being maintained on-farm.

MATERIALS AND METHODS

A total of 207 accessions of barley landraces were collected from various locations of Jumla ranging from 2260 to 2530 m elevation. Collection was carried out from farmers' fields. Three to five ears from each hill were collected from field at the time of harvest. Each collection was considered as an accession and consisted of bulk of seeds of a particular population from farmers' plots (Table 1). These materials were evaluated on-station for morphological and agronomical variability under Khumaltar conditions (1350 m). Among 207 barley landrace populations only 96 were evaluated on-farm for their agro-morphological traits in farmers' fields by farmers' group in Jumla due to loss of other 111 accessions by insect damage during storage in the farmer's house. One set of these

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[1]*Khetland* – bunded and irrigated land mainly for puddle rice.
[2]*Bariland* – unbunded and unirrigated upland.
[3]L*ekhland* – upland situated at high altitude far from village.
[4]*Pakhobari* – marginal and sloppy land located far from homestead devoted to neglected crops, grass and fodder.
[5]*Gharbari* – unbunded and unirrigated land around homestead with kitchen garden and orchard.
[6]*Gadkule – Khet* land irrigated from snow-melted river.
[7]*Simkhet* – water logged marshy land with poor drainage.
[8]*Kholapane – Khet* land irrigated by stream.

materials with their passport information was supplied to Agriculture Botany Division for *ex situ* conservation.

Samples were planted in 2-m long, 2-row plots, with 25 cm spacing from row to row. The study was carried out under rainfed conditions with 30:30:0 NPK kg/ha fertilization before sowing and 15 kg/ha of N_2 was top-dressed at 2 months after planting. Data on quantitative traits (days to 50% heading, days to maturity, plant height, spikelet groups per spike, spike length, tiller number, effective tiller number and filled grains per head), and qualitative traits (growth class, row number, hoodedness, awn roughness, rachilla hair length, kernel covering and lemma colour) were recorded in five individual plants selected randomly using the IPGRI descriptors for barley (IPGRI 1994). Morphological traits were measured on 10 randomly selected plants of each accession in on-farm study in Jumla.

Descriptive statistics of both quantitative and qualitative traits were calculated by using the MS EXCEL program. In addition, Principal Component Analysis (PCA) and clustering methods using Unweighted Pair Group Method Analysis (UPGMA) were carried for quantitative traits on both sites and diversity indices using Shannon Weaver Index were calculated for qualitative traits. PCA allows reduction of a dimension problem. The techniques consist of reducing the structure and data matrix starting from a linear method and setting new variables called principal components. PCA and cluster analyses allowed identification of groups of objects or variables that are important in determining the amount of variability accounted by each of the axes. Both PCA and cluster analysis were performed using MINITAB-12 software.

Table 1. Number of accessions and collecting sites

Collecting site	Altitude, m	Number of accessions			
		Bhuwali	Chawali	Lekali	Pawai
Bayalkatiya	2500-2530	5	8	-	-
Damaibada	2300-2320	-	4	-	-
Dhaulabada	2320-2380	1	13	1	-
Kartikswami-8	2530	-	1	-	-
Khalla	2530	1	3	1	-
Kotila	2410-2480	2	13	-	-
Rokayabada	2320	2	3	-	-
Seridhuska	2480-2500	7	27	-	1
Silam	2530	1	4	1	-
Talebhir	2480-2520	15	17	-	-
Talium 1, 3-6, 8 and 9	2260-2500	4	53	13	-
Umgad	2500	1	2	-	-
Total		42	148	16	1

RESULTS

Simple statistical analysis of the observed data showed a range of variability among the accessions of barley landraces. These landraces showed variability in spike and grain morphological characters both on-farm and on-station. The differences with high range and diversity indices were observed in plant height (40-74 cm), spike characters such as row numbers (17.59), well filled grains per spike (18-50) and 50% of flowering days (92-117) in quantitative traits. The landraces also showed variability in spike and grain morphological traits both on-farm and on-station (Table 2). The landraces were winter (9.5% *Bhuwali*, 95.3% *Chawali* and 18.8% *Lekali*) and facultative types (78.6% *Bhuwali*, 4.4% *Chawali* and 81.3% *Lekali*) except five samples (11.9%) of *Bhuwali,* which has spring growth habit (Table 3). No variation was observed in row number, hoodedness, awn roughness, kernel covering and lemma colour. However, variation was observed in spike density and rachilla hair length. The *Pawai* landrace of barley had only one accession so its variability could not be measured.

Table 2a. Statistical parameters for quantitative traits of barley from on-station (Khumaltar)

Characters	On-station (Khumaltar)					
	Bhuwali		*Chawali*		*Lekali*	
	Range	X ± SD†	Range	X ± SD†	Range	X ± SD†
Phenological						
50% heading, d	95-117	111.7±7.7	92-117	96.35±4.7	93-117	109.6±9.1
Maturity, d	139-149	147.1±3.1	139-149	144.7±3.8	145-150	148.3±1.4
Morphological						
Plant height, cm	40-72	56.1±6.7	36-74	50.92±6.2	45-70	55.94±7.7
Spike length, cm	-	-	-	-	-	-
Spikelet/spike, n	20-59	44.9±7.8	17-58	38.18±7.5	28-56	45.12±7.1
Tiller, n	-	-	-	-	-	-
Effective tiller, n	-	-	-	-	-	-
Filled grain/head, n	-	-	-	-	-	-
Grain						
1000-grain wt, g	36.4-46	41.1±2.3	24.8-479	38.19±3.1	36.8-46	39.8±2.2

† *X ± SD = Mean ± Standard deviation.*

Table 2b. Statistical parameters for quantitative traits of barley from on-farm trial (Jumla)

Characters	On-farm (Jumla)					
	Bhuwali		*Chawali*		*Lekali*	
	Range	X ± SD†	Range	X ± SD†	Range	X ± SD†
Maturity, d	-	-	-	-	-	-
Morphological						
Plant height, cm	55-61	57.5±2.3	37.5-83	60.8±10	42.9-60	53.4±9.2
Spike length, cm	4-5.4	4.7±0.6	2.6-7.1	4.4±0.7	2.2-4.8	3.6±1.3
Spikelet/spike, n	-	-	-	-	-	-
Tiller, n	2.6-4	3.4±0.5	1.8-8.5	3.8±1.1	2.4-3.9	3.3±0.8
Effective tiller, n	1.6-3.2	2.6±0.6	1.1-6.1	2.9±0.9	1.9-2.7	2.3±0.4
Filled grain/head, n	23-48	37±10	18.2-50	33.1±7.2	26.6-37	30.9±5.7
Grain						
1000-grain wt, g	33-43	39.1±4.2	27-47.2	38.6±3.4	36-43.4	40.7±4.1

† *X ± SD = Mean ± Standard deviation.*

A pairwise association among landraces of barley (on-station and on-farm) was measured from the observed agro-morphological traits using Ward and Euclidean distance and revealed a clear clustering into different morphological groups (Table 4). The resulting dendrograms depicted in Figures 1 and 2 show the relationship between populations of barley landraces and grouped all populations into five distinct clusters for both on-station and on-farm characterizations respectively. In both clusterings, *Chawali* landraces were found to be most diverse and represented in all the clusters (Table 5). However, *Bhuwali* and *Lekali* landrace populations predominantly represented cluster II. The study showed the distribution of landraces in different clusters irrespective of farmers' given name and their descriptions.

Table 3. Frequency distribution and Shannon Weaver indices of qualitative traits of barley (on-station)

Character	*Bhuwali*			*Chawali*			*Lekali*			*Pawai*	
	No. of acc.	Freq. %	H	No. of acc.	Freq. %	H	No. of acc.	Freq. %	H	No. of acc.	Freq. %
Growth class											
Winter	4	9.5		141	95.3		3	18.8		1	100
Facultative	33	78.6	0.67	7	4.7	0.19	13	81.3	0.48	0	0
Spring	5	11.9		0	0		0	0		0	0
Row number											
Six row	42	100	0	148	100	0	16	100	0	1	100
Two row	0	0		0	0		0	0		0	0
Spike density											
Lax	38	90.5		95	64.2		14	87.5		1	100
Intermediate	4	9.5	0.31	53	35.8	0.65	2	12.5	0.38	0	0
Dense	0	0		0	0		0	0		0	0
Hoodedness											
Sessile hoods	0	0		0	0		0	0		0	0
Elevated hoods	0	0	0	0	0	0	0	0	0	0	0
Awnless	0	0		0	0		0	0		0	0
Awned	42	100		148	100		16	100		1	100
Awn roughness											
Smooth	0	0	0	0	0	0	0	0	0	0	0
Rough	42	100		148	100		16	100		1	100
Rachilla hair length											
Short	24	57.1	0.68	125	84.5	0.43	14	87.5	0.69	1	100
Long	18	42.9		23	15.5		2	12.5		0	0
Kernel covering											
Naked grains	0	0	0	0	0	0	0	0	0	0	0
Covered grains	42	100		148	100		16	100		1	100
Lemma colour											
White/brown	42	100		148	100		16	100		1	100
Purple or black	0	0	0	0	0	0	0	0	0	0	0
Pink	0	0		0	0		0	0		0	0

Table 4. Means of relevant quantitative traits for two sites of the clusters formed

Character	Clusters											
	On-station						On-farm					
	I	II	III	IV	V	Mean	I	II	III	IV	V	Mean
50% heading, d	94.8	111.1	95.8	95.2	95.6	100.6	–	–	–	–	–	–
Plant height, cm	50.2	58.2	44.5	55.5	52.4	52.4	56.6	52.6	63.4	61.5	63.4	61.0
Spike length, cm	–	–	–	–	–	–	4.0	4.5	4.3	4.0	4.6	4.3
Spikelet groups/spike, n	46.4	46.5	35.7	37.9	29.3	40.2	–	–	–	–	–	–
Tiller, n	–	–	–	–	–	–	3.2	4.1	3.9	3.6	3.8	3.8
Effective tiller, n	–	–	–	–	–	–	2.5	3.0	2.9	2.7	2.8	2.8
Filled grain/head, n	–	–	–	–	–	–	32.6	30.3	35.0	35.4	33.5	33.8
Unfilled grain/head	–	–	–	–	–	–	2.4	1.9	1.9	1.8	1.8	1.9
Maturity, d	139.0	148.3	144.9	147.1	148.0	145.6	–	–	–	–	–	–
1000-grain weight, g	38.9	41.2	37.4	38.1	38.2	38.9	37.0	37.7	39.1	38.7	39.2	38.7

Table 5. Composition and characteristics of clusters based on observed traits for two locations

Cluster	On-station				On-farm			
	No. of acc.	Landrace name	Total no. types	Cumulative characteristics of landraces in cluster	No. of acc.	Landrace name	Total no. types	Cumulative characteristics of landraces in cluster
I	39	*Bhuwali* (4) and *Chawali* (35)	2	Early heading & maturity, medium plant height & more no. of spikelet groups per spike	8	*Bhuwali* (1), and *Chawali* (7)	2	Medium plant height, short spike, low tillering and low 1000-seed wt.
II	55	*Bhuwali* (34), *Chawali* (8), *Lekali* (12) and *Pawai* (1)	4	Late heading & maturity, taller plant and high number of spikelet groups/spike and 1000-grain weight	14	*Bhuwali* (11), *Chawali* (2) and Unknown (1)	2	Dwarf plant, long spike, high tillering and medium 1000-seed wt.
III	45	*Bhuwali* (3), *Chawali* (40) and *Lekali* (2)	3	Dwarf plant, medium maturity & heading and low seed weight	36	*Bhuwali* (2), *Chawali* (33) and Unknown (1)	2	Tall plant, medium tiller & spike length, moderately high number of grain per head
IV	40	*Chawali* (38) and *Lekali* (2)	2	Medium heading, plant height, maturity & 1000-seed weight	15	*Chawali* (15)	1	Medium plant, short spike, with medium tillering and high number of filled grain/head.
V	28	*Bhuwali* (2), *Chawali* (26)	2	Low seed weight & number of spikelet groups/spike and medium plant height & maturity.	23	*Bhuwali* (1), *Chawali* (21) and Unknown (1)	2	Tall plant, long spike, medium tiller number but higher 1000-seed wt.

Number in parenthesis indicates total number of accessions.

Principal component analysis also showed a marked variation among landraces with great influence of the morphological traits of plant, spikes and grains along the first three axes (Table 6). Figure 3 shows the distribution of barley populations by landrace names under the on-station characterization. Three PCs accounted 84.3% of the total variance of five quantitative characters measured from on-station, and 60.2% of total variance of seven quantitative characters measured from the on-farm trial (Table 6). The first principal component explained 46.4% and 29.5% of the total variance on-station and on-farm, respectively. Eigen values and eigenvectors were different between on-farm and on-station trials. The variation shown between two locations may be due not only to the location difference, but probably also to the differences in number of traits and accessions.

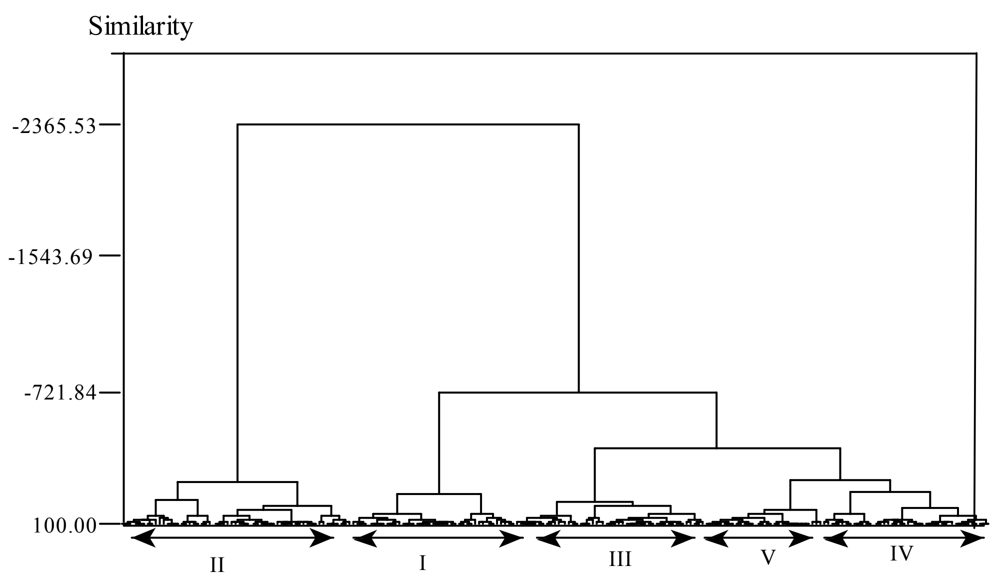

Figure 1. Dendrogram of 207 barley accessions revealed by UPGMA cluster analysis (on-station).

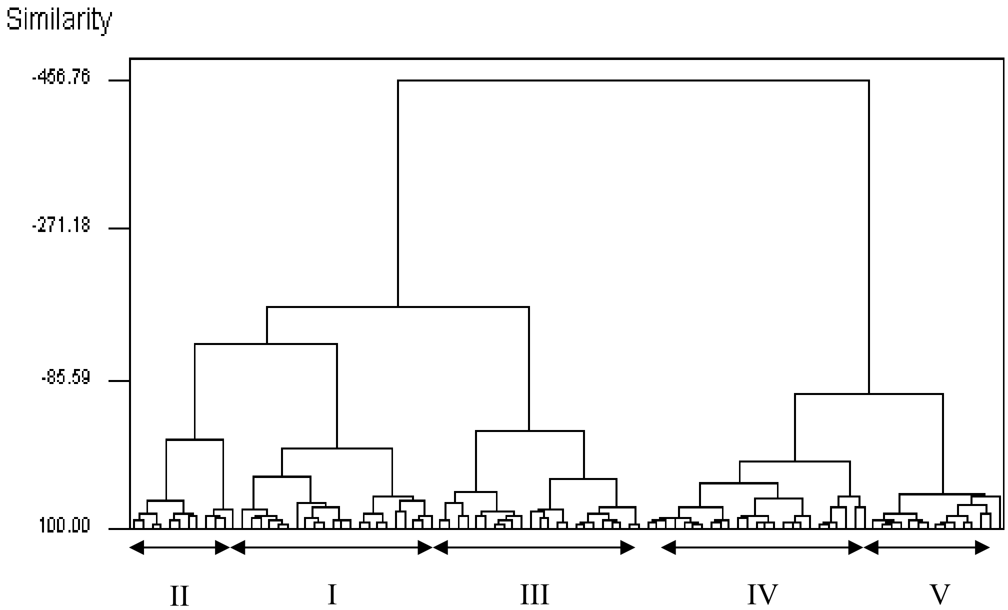

Figure 2. Dendrogram of 96 barley accessions revealed by UPGMA cluster analysis (on-farm).

Table 6. Eigenvectors, eigen values, total variance and cumulative variance for quantitative traits in barley landraces over two sites

Character	On-station (Khumaltar)			On-farm (Jumla)		
	PC1	PC2	PC3	PC1	PC2	PC3
50% heading, d	-0.577	0.013	0.139	-	-	-
Plant height, cm	-0.482	-0.122	0.529	3.94	-0.234	-0.173
Spike length, cm	-	-	-	0.379	0.070	0.372
Spikelet groups/spike, n	-0.327	0.712	0.172	-	-	-
Tiller number	-	-	-	0.505	0.264	-0.281
Effective tiller, n	-	-	-	0.495	0.262	-0.355
Filled grain/head, n	-	-	-	0.230	-0.564	-0.030
Unfilled grain/head	-	-	-	-0.131	-0.371	-0.183
Maturity, d	-0.355	-0.679	-0.070	-	-	-
1000-grain weight, g	-0.449	0.131	-0.816	0.239	-0.379	0.278
Eigen values	2.320	1.221	0.673	2.653	1.662	1.098
% of total variance	46.4	24.4	13.5	29.5	18.5	12.2
% of cumulative variance	46.4	70.8	84.3	29.5	48.0	60.2

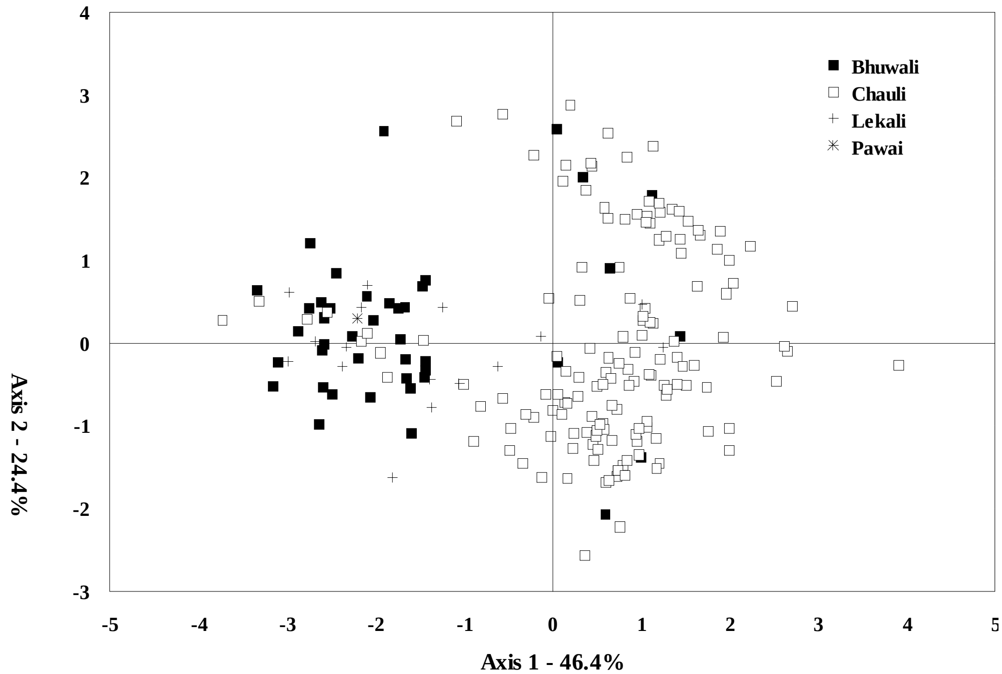

Figure 3. Distribution plot of barley landraces along with the first and second principal components (PCs).

Unlike to the hierarchical clustering, the principal component analysis of quantitative traits revealed a clear grouping of barley populations by landrace names. The accessions of *Bhuwali* and Chawali landraces clustered together and separated by the axis 2 with few outlier accessions (Figure 3). Figure 6 also indicates that these landrace populations were most variable and were encompassed of range of intra-varietal variations for the observed quantitative traits.

DISCUSSION

A large amount of agro-morphological diversity was observed in the barley landraces belonged to four differently named landraces that were under cultivation in Jumla. Morphological diversity of quantitative traits between the three groups of barley landraces under study showed greater variation in both on-farm and on-station (Table 2). *Chawali* and *Bhuwali* landraces is grown in irrigated and well managed conditions and *Lekali* landraces is grown in rainfed and diverse conditions. Similarly, in qualitative traits also variability was observed in growth class, spike density and rachilla hair length (Table 3). The existence of considerable level of diversity in terms of isozyme variability among farmers' barley populations of differently named landraces. *Bhuwali, Chawali*, and *Lekali* consisted greater variation among populations and among farmers named varieties (Bajracharya et al 2001). These landraces can be good source materials for breeding purpose. Hence, it could be a valuable resource to conserve and for utilization with improvement in future.

The analysis of average value of the variables for each group provides information for describing the groups identified. High mean were observed for 50% heading and maturity on on-station and plant height for on-farm indicating that wide variation exists in the population for these traits (Table 4). No variation was observed in grain weight for both on-farm and on-station.

Table 5 gives a general description of each group. The studied populations clustered into five clusters with two sets of observation. In the clustering, *Chawali* landraces were found to be diverse and represented in all the clusters (Table 5). However, *Bhuwali* represented in cluster I and III whereas *Lekali* represented cluster II and IV (Figure 3). It suggests that there is presence of variability in the barley landraces. This study showed the distribution of landraces in different cluster irrespective of farmers' given name and their description. The structure and level of morphological variation revealed in the present study showed a significant level of genetic diversity among the barley accessions of differently named landraces. To an extent, the diverse morphological forms established the genetic identity of the barley landraces.

The studies on landraces have shown the value and importance of agro-morphological characters with direct relevance to local farmers and breeders for conservation, and in estimating diversity of germplasm and in describing the level of discrimination of the varieties (Murphy and Witcombe 1981 have also shown how farmers select preferred maize types from their agro-morphological characters. Similarly, Chu et al (1997) have shown how combining ethno-botanical methods with genetic analysis can give insights into how crop genetic diversity is maintained and managed. These descriptive values of morphological characters are genetically heritable and therefore worthy for the genetic diversity analysis. The first three principal components with eigen value greater than unity explained 84.3% and 60.2% on-station and on-farm of the total variation among the studied landraces for the quantitative traits (Table 6). The first and second principal components accounted for 46.4% and 70.8% on on-station and 29.5% and 48.0% on on-farm respectively of the total variation. 1000-grain weight, grain length and width were the most important traits contributing to the first principal components. Plant height, tiller number, panicle length and grain weight were the important traits contributing to the second and third principal component. Scattered plots of these landraces clearly indicated that there is presence of variability.

Barley landraces were identified according to their group in the dendrogram and graphed in biplots using the first three principal components (Figures 1 and 2). Based on the plots constructed using the first two principal components, groups I, II and III were spatially observed as distinct groups on both the sites while the IV axis was useful for better differentiation of group V.

From the analysis of the groups, the clustering pattern obtained showed an association with the agronomic performance of the accessions. This indicates that the classification can assist in discriminating the groups of material, which can be of future use for plant breeding programme.

This work has been a contribution to increase the knowledge about the barley germplasm conservation in Jumla, Nepal. This better understanding should allow a better conservation and use of the collection in breeding programmes. The research will also assist in the conservation of valuable germplasm, as is the case of local varieties, which hold important local adaptation and are of widespread use by farmers throughout the entire country.

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