Taiwania 63(1): 41-48 , 2018
DOI: 10.6165/tai.2018.63.41

Morphological variation of some *Lepidium draba* and *L. latifolium* populations

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(Manuscript received 13 August 2017; accepted 12 February 2018; online published 26 February 2018)

ABSTRACT: Hoary cress (*Lepidium draba* L.) and pepperweed (*L. latifolium* L.) are herb plants grown in a wild form across Iran, which considered as vegetable or medicinal crop. The evaluation of the *Lepidium* germplasm collections under field conditions is recognized as a general method to estimate phenetic variability. In the present study, phenetic diversity among five populations of hoary cress and eight populations of pepperweed was assessed using 12 agro-morphological traits. Multivariate analysis with principal component analysis (PCA) was done and a cluster dendrogram was generated based on Ward's method. In *L. draba*, variation was observed among 3 out of 12 quantitative characters, whereas in *L. latifolium* significant differences were observed for all evaluated traits except leaf number. The populations Asadabad and Razan belonging to the *L. latifolium* species, showed major values for shoot fresh and dry weight, and leaf length and width, these should be used to improve these traits in a *Lepidium* breeding program. Based on cluster analysis, *L. draba* populations were classified in three groups, while for *L. latifolium*, two groups were obtained with few subgroups. The principal component analysis showed great dispersion of the populations. The first three principal component axes accounted for 94.8% and 90.6% of total variation observed among *L. draba* and *L. latifolium* populations, respectively. The phenetic diverse identified in this study show that some populations are featured with several agro-morphological characteristics and could be appropriate as promising material for the creation of new varieties.

KEY WORDS: Brassicaceae, Clustering, Germplasm, *Lepidium*, Morpho-agronomical traits, Phenetic diversity, Score plot.

INTRODUCTION

Lepidium draba L. (syn. *Cardaria draba* L.) and *L. latifolium* L., commonly known as 'hoary cress' and 'pepperweed', respectively, are perennial plants belong to Brassicaceae family. *L. draba* is indigenous of western Asia, including Iran, Turkey, Armenia, central Asia, and the European coastal regions of the Mediterranean and Black Sea. It was first collected in North America on the east coast in 1862 and is now found in most US states, most Canadian provinces, and Mexico. *L. latifolium* is native to southern Europe and Asia (Francis and Warwick, 2008; Kaur *et al*., 2013).

These wild *Lepidium* species have been used for different purposes by native people. Hoary cress can be found in most parts of Iran in a wide diversity of soil types where moisture is adequate and a wide range of disturbed habitats. It could be used in rice as cooked in traditional foods (Miri *et al*., 2013; Shahrokhi *et al*., 2014) and applied as chemoprotective, dietry and pharmacological agents, whereas Pepperweed is used as phytofood, garnish and beverage so as a local vegetable (Rana *et al*., 2012; Kaur *et al*., 2013). Leaf and seed extracts of hoary cress have phenolic compounds with potential of antibacterial, antioxidant and scolicidal activities (Sharifi rad *et al*., 2015). Hoary cress contains two major types of Glucosinolates: Glucoraphanin and Glucosinalbin. Hence, it could serve as a source of glucoraphanin extraction, as the precursor of SFN(4-(methylsulfinyl) butyl isothiocyanate) that has antioxident properties, antibacterial effects on both Gram-positive and Gram-negative bacteria and fungi. Sulforaphane (SF) is a phytochemical that displays both anticarcinogenic and anticancer activity in *L. draba* (Zhang and Tang, 2007; Radonić *et al*., 2011; Mohammadi *et al*., 2014).

Knowledge of the genetic diversity in the germplasm populations is important for the efficient germplasm management and long-term breeding programs (Garzón-Martínez *et al*., 2015; Roughani *et al.,* 2018). The morphological characterization of the germplasms is necessary to make the collection useful for breeders (Miri *et al.,* 2009). The objective of this study was to evaluation of agro-morphological variation of *L. draba* and *L. latifolium* in Iran.

MATERIALS AND METHODS

Seeds of five hoary cress (*Lepidium draba*) and eight pepperweed (*L. latifolium*) landrace populations were provided from Research Institute of Forests and Rangelands (RIFR), Tehran, Iran. These wild materials

Table 1. List of thirteen populations of ***L. draba*** and ***L. latifolium*** used in this study and their origin, code and altitude site.

Species	Population	Population code	Altitude(m)	Species	Population	Population code	Altitude(m)
L. latifolium	Tabas	33780	1366	*L.draba*	Saveh-1	35378	1000
L. latifolium	Hamedan	21895	1732	*L. draba*	Saveh-2	35418	1620
L. latifolium	Shahreza	27262	1765	*L. draba*	Nir	36834	1732
L. latifolium	Asadabad	21922	1990	*L. draba*	Saveh-3	35877	2113
L. latifolium	Razan	35901	2113	*L. draba*	Kohgiluyeh & Boyer-Ahmad-5	31202	2360
L. latifolium	Mehriz	33813	2189				
L. latifolium	Taft	10425	2493				
L. latifolium	Khatam	10428	1570				

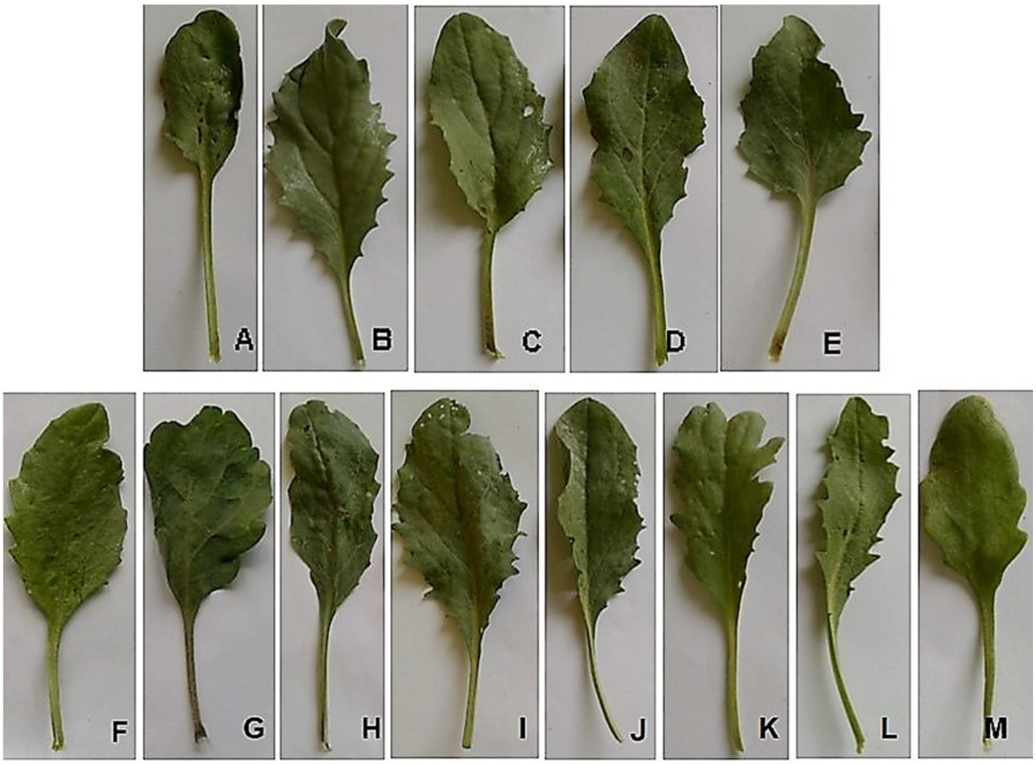

Fig. 1. Variation in leaves form of ***L. draba*** (top) and ***L. latifolium*** (below) populations. **A**: Saveh-1. **B**: Saveh-2. **C**: Saveh-3. **D**: Nir, **E**: Kohgilouyeh & Boyerahmd-5. **F**: Tabas. **G**: Hamedan. **H:** Shahreza. **I**: Asadabad. **J**: Razan. **K**: Mehriz. **L**: Taft. **M**: Khatam.

were distributed in a wide range of climatic conditions with various site altitudes (Table 1).

The field experiment for agro-morphological study was conducted at Research Field of Islamic Azad University, Karaj Branch, is located Karaj, Iran (35°73´N, 50°73´E, 1313 m) in 2015-2016. The location has a semi-arid climate. During the crop growth period, average temperature and humidity were 16°C and 29%, respectively. The soil was clay-loam with a pH of 7.4 and its salinity in 0 to 30 cm of soil profile was 3.33 dS m^{-1}.

The seeds of each population were sown on 3 rows with 150×20 cm spacing. All crop management practices were implemented and weeds were controlled manually during the vegetative phase of the culture. The irrigation was done as regular intervals. Three weeks after planting, seedlings were fertigated once with a liquid fertilizer (Grow More; 20-20-20 NPK plus micronutrients).

The field layout experiment was a randomized complete block design (RCBD) with 3 replications. Data was collected from fifteen random plants from each replicate of each population for twelve agro-morphological traits. These traits were leaf number, shoot height, shoot fresh and dry weight, leaf length, width and thick, petiole length and thick, root length, root fresh and dry weight. Harvesting time for vegetative data was one month after planting, which vegetative growth of most herbs were as usual for local people (native consumption). The Homogeneity test of quantitative data and principal component analysis (PCA) were done by Minitab statistical package (ver. 16.0). SPSS software (ver. 21) was used for Pearson correlation coefficients, analysis of variance and cluster analysis. Compare mean was carried out using Duncan multiple range test at 5% probability level. Before statistical analysis, all data were passed normality test.

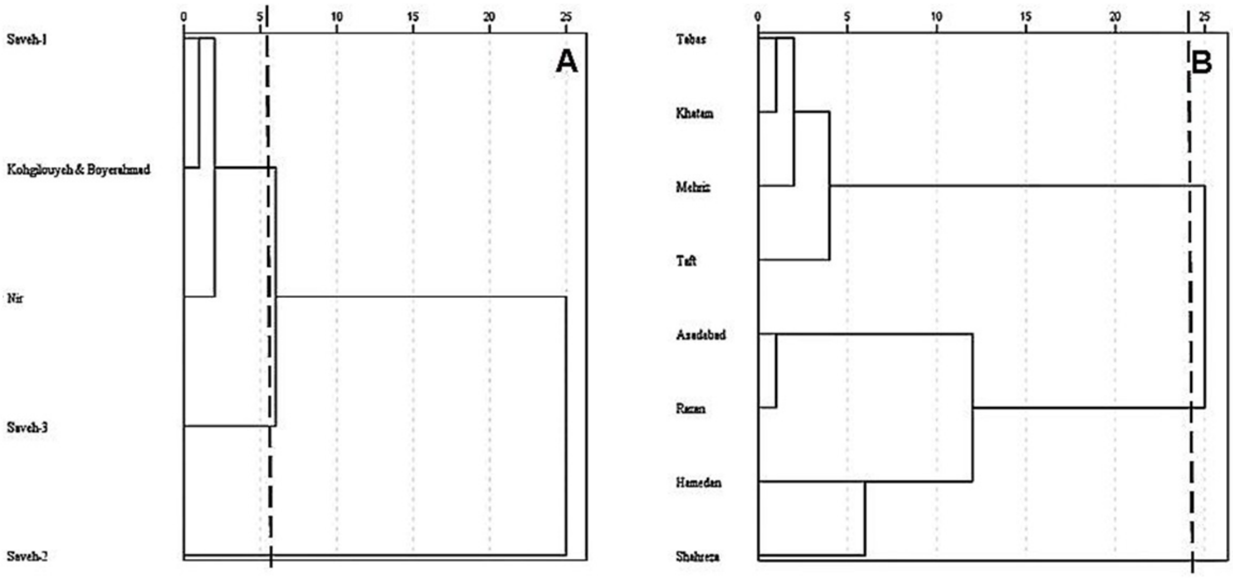

Fig. 2. Clustering by Ward's method based on agro-morphological data of five ***L. draba*** (**A**) and eight ***L. latifolium*** populations (**B**).

RESULTS

The summary of 12 morpho-agronomic traits recorded from the 5 hoary cress and 8 pepperweed populations are presented in Table 2 and 3. In *L. draba*, variation was found in 3 of the 12 quantitative traits including leaf number, petiole length and thick. Saveh-2 population has more leaf number (31.00) than Kohgiluyeh and Boyer-Ahmad-5 (12.50). Also, petiole length in Saveh-3 had significant increase compared to Kohgiluyeh and Boyer-Ahmad-5, while there has been a reverse in the petiole thick. The leaf number, shoot fresh weight and leaf length values ranged 11 to 44, 2.58 to 17.59 g and 3.93 to 10.58 cm, respectively. The analysis of variance showed significant variations among the 8 populations of *L. latifolium* for all the 12 traits studied, except leaf number. The population Asadabad showed major values for the following parameters: shoot height, shoot fresh and dry weight, leaf length, width and thick, petiole length and thick and, root dry weight. On the other hand, Taft population had the least value for all characteristics, except leaf number. However, these two populations did not differ statistically with other populations. In early spring, *L. latifolium* developed as a rosette of basal leaves (Leininger and Foin, 2009), and in this study, the mean of shoot height was 10.71 cm. As regards this is serving as an edible vegetable, the results emphasized on leaf number, shoot fresh and dry weight and leaf length and width. The range of leaf number was 8 to 38 and the populations Asadabad and Razan showed the highest of the latter four traits among the studied populations. Diversity in leaf morphology of *Lepidium* species are shown in Figure 1.

Phenotypic correlations between 12 agro-morphological traits are shown in Table 4 and 5. There was a significant positive correlation between leaf number with shoot fresh and dry weight, also between shoot fresh weight with shoot dry weight, leaf length and width, root length and root dry weight in both species.

Cluster analysis of morphological traits using mean values of 12 characteristics by Ward's method in *L. draba* divided populations into three main groups at distance level of 6 (Fig. 2-a). The first cluster composed of Saveh-1, Kohgilouyeh and Boyerahmad-5 and Nir. The second and third cluster consisted of Saveh-3 and Saveh-2, respectively. *L. latifolium* dendogram based on morpho-agronomic characteristics divided genotypes into two main groups at distance level of 25 (Fig. 2-b). In the first cluster, Tabas, Khatam, Mehriz and Taft were placed, while Asadabad, Razan, Hamedan and Shahreza formed the second cluster. The populations Asadabad and Razan showed the highest values for the shoot fresh and dry weight and leaf length, forming a separated sub-group.

The principal components analysis (PCA) performed with morphological data for *L. draba* and *L. latifolium* (Tables 6-a and 6-b). The first three principal components of *L. draba* accounted for 94.8% of the total variation and having Eigen values of 6.18, 2.69 and 2.49% with variance of 51.6, 22.5 and 20.8%, respectively. In hoary cress, shoot fresh weight, root length, leaf thick and length as PC1 had more effects on the genotype grouping. The PC2 had a positive correlation with shoot dry weight and negative correlations to petiole length and root fresh weight. The PC3 included shoot height, leaf width, petiole thick and root dry weight with positive correlation and negative to leaf number. The first three PCA of *L. latifolium* accounted for 90.6% of total variation and having Eigen

Table 2. Mean ± SE comparison for 12 morpho-agronomic traits of five ***L. draba*** populations.

Population	Leaf number	Shoot height (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Leaf length (cm)	Leaf width (cm)	Leaf thick (cm)	Petiole length (cm)	Petiole thick (mm)	Root length (cm)	Root fresh weight (g)	Root dry weight (g)
Saveh-1	14.66±2.6^{ab}	9.50±0.8^{a}	4.27±0.3^{a}	0.49±0.0^{a}	5.34±0.3^{a}	2.80±0.2^{a}	0.04±0.0^{a}	4.12±0.6^{ab}	0.27±0.0^{ab}	12.50±1.0^{a}	0.19±0.0^{a}	0.03±0.0^{a}
Saveh-2	31.00±13.0^{a}	9.75±1.2^{a}	11.09±6.5^{a}	1.56±0.8^{a}	6.63±1.5^{a}	3.59±0.5^{a}	0.05±0.0^{a}	3.47±0.2^{ab}	0.26±0.0^{ab}	13.75±5.7^{a}	0.45±0.2^{a}	0.09±0.0^{a}
Saveh-3	20.66±3.1^{ab}	12.66±0.1^{a}	8.10±1.7^{a}	0.85±0.0^{a}	6.87±0.0^{a}	3.58±0.0^{a}	0.04±0.0^{a}	7.23±2.8^{a}	0.24±0.0^{b}	13.33±4.4^{a}	1.15±0.8^{a}	0.14±0.1^{a}
Nir	15.33±2.1^{ab}	12.50±1.8^{a}	8.58±3.5^{a}	1.30±0.6^{a}	7.67±1.5^{a}	4.03±0.7^{a}	0.05±0.0^{a}	3.52±0.1^{ab}	0.30±0.0^{ab}	13.33±6.3^{a}	0.45±0.2^{a}	0.12±0.1^{a}
Kohgilouyeh& Boyerahmd-5	12.50±0.5^{b}	10.00±2.5^{a}	6.23±3.6^{a}	0.74±0.4^{a}	6.05±2.1^{a}	3.64±0.9^{a}	0.04±0.0^{a}	2.80±0.1^{b}	0.33±0.0^{a}	10.25±2.7^{a}	0.30±0.1^{a}	0.05±0.0^{a}
Mean	18.38	11.03	7.50	0.96	6.54	3.52	0.04	4.39	0.28	12.73	0.53	0.09
Range	11–44	7.50–16.00	2.58–17.59	0.30–2.53	3.93–10.58	2.38–5.48	0.04–0.06	2.62–12.96	0.22–0.37	6.00–26.00	0.14–2.9	0.01–0.36
S.E	2.45	0.65	1.31	0.19	0.48	0.23	0.00	0.74	0.01	1.73	0.21	0.03
F. value	2.00*	1.35	0.62	0.87	0.63	0.73	1.00	1.27*	2.11*	0.07	0.63	0.29

*, $p \leq 0.05$; SE, standard error.

Table 3. Mean ± SE comparison for 12 morpho-agronomic traits of eight ***L. latifolium*** populations.

Population	Leaf number	Shoot height (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Leaf length (cm)	Leaf width (cm)	Leaf thick (cm)	Petiole length (cm)	Petiole thick (cm)	Root length (cm)	Root fresh weight (g)	Root dry weight (g)
Tabas	18.00±3.5^{a}	8.83±0.7^{ab}	4.32±0.2^{bc}	0.50±0.0^{bc}	4.85±0.2^{cd}	2.68±0.0^{cd}	0.05±0.0^{a}	3.49±0.2^{ab}	0.27±0.0^{ab}	8.90±2.5^{b}	0.24±0.0^{ab}	0.04±0.0^{ab}
Hamedan	16.00±4.3^{a}	12.00±2.0^{ab}	7.81±3.3^{abc}	0.77±0.3^{bc}	6.70±0.8^{bc}	3.71±0.2^{ab}	0.05±0.0^{a}	3.98±1.0^{ab}	0.26±0.0^{ab}	18.66±2.9^{a}	1.86±0.9^{a}	0.24±0.1^{a}
Shahreza	19.00±5.7^{a}	13.00±1.0^{a}	10.16±3.8^{ab}	1.40±0.4^{ab}	7.62±0.6^{ab}	3.81±0.2^{ab}	0.04±0.0^{ab}	4.13±0.1^{ab}	0.28±0.0^{ab}	11.16±2.8^{ab}	0.41±0.1^{ab}	0.10±0.0^{ab}
Asadabad	23.33±6.1^{a}	13.66±2.1^{a}	17.04±7.1^{a}	2.24±0.6^{a}	8.82±0.4^{a}	4.34±0.2^{a}	0.04±0.0^{a}	5.21±0.8^{a}	0.29±0.0^{a}	11.00±3.6^{ab}	2.41±2.0^{ab}	0.44±0.3^{a}
Razan	24.00±14.0^{a}	13.50±0.5^{a}	15.38±6.0^{a}	2.00±0.7^{a}	8.54±0.1^{a}	4.40±0.0^{a}	0.04±0.0^{ab}	3.82±0.3^{ab}	0.26±0.0^{ab}	13.85±1.6^{ab}	0.55±0.2^{ab}	0.11±0.0^{ab}
Mehriz	19.66±5.6^{a}	10.16±1.0^{ab}	6.18±1.1^{abc}	0.68±0.1b^{c}	6.72±0.6^{bc}	3.19±0.2^{bc}	0.04±0.0^{a}	3.69±0.5^{ab}	0.26±0.0^{ab}	11.66±1.1^{ab}	0.27±0.0^{ab}	0.04±0.0^{ab}
Taft	17.33±2.6^{a}	7.50±0.2^{b}	2.55±0.3^{c}	0.24±0.0^{c}	4.52±0.1^{d}	2.24±0.0^{d}	0.04±0.0^{b}	3.10±0.2^{b}	0.23±0.0^{b}	5.43±0.6^{b}	0.10±0.0^{b}	0.01±0.0^{b}
Khatam	24.50±4.3^{a}	7.50±1.5^{b}	4.16±1.0^{bc}	0.42±0.1^{c}	5.10±1.1^{cd}	2.06±0.3^{d}	0.05±0.0^{a}	2.75±0.5^{b}	0.23±0.0^{b}	10.50±2.2^{ab}	0.22±0.0^{ab}	0.03±0.0^{ab}
Mean	19.6	10.71	8.16	0.99	6.63	3.26	0.04	3.85	0.26	11.00	0.76	0.12
Range	9–38	5.00–18.00	2.01–31.30	0.22–3.44	3.74–9.37	1.53–4.56	0.04–0.06	2.27–6.37	0.19–0.33	4.00–23.00	0.09–6.60	0.01–1.15
S.E	1.72	0.64	1.47	0.18	0.36	0.18	0.00	0.21	0.00	1.07	0.30	0.05
F. value	0.23	3.19*	2.12*	4.17*	5.88*	16.33*	3.28*	1.23*	1.48*	2.56*	1.06*	1.06*

*, $p \leq 0.05$; SE, standard error.

Table 4. Correlation coefficient for 12 morpho-agronomic traits of ***L. draba*** populations.

Characteristic	Shoot height	Leaf number	Shoot fresh weight	Shoot dry weight	Leaf length	Leaf width	Leaf thick	Petiole length	Petiole thick	Root length	Root fresh weight
Leaf number	0.121										
Shoot fresh weight	0.668*	0.736**									
Shoot dry weight	0.641*	0.649*	0.960**								
Leaf length	0.903**	0.330	0.845**	0.859**							
Leaf width	0.875**	0.212	0.793**	0.817**	0.964**						
Leaf thick	-0.187	0.317	0.116	0.136	-0.117	-0.133					
Petiole length	0.270	-0.024	-0.037	-0.088	0.080	0.053	-0.399				
Petiole thick	0.197	-0.614*	-0.100	0.008	0.217	0.416	-0.106	-0.239			
Root length	0.418	0.536	0.715**	0.679*	0.489	0.431	-0.149	-0.018	-0.298		
Root fresh weight	0.483	0.428	0.551	0.354	0.360	0.333	0.017	0.068	-0.297	0.673*	
Root dry weight	0.611*	0.476	0.762**	0.678*	0.608*	0.574*	-0.063	-0.044	-0.188	0.917**	0.859**

*, Correlation is significant at the 0.05 level (2-tailed).
**, Correlation is significant at the 0.01 level (2-tailed).

Table 5. Correlation coefficient for 12 morpho-agronomic traits of ***L. latifolium*** populations.

Characteristic	Shoot height	Leaf number	Shoot fresh weight	Shoot dry weight	Leaf length	Leaf width	Leaf thick	Petiole length	Petiole thick	Root length	Root fresh weight
Leaf number	0.422*										
Shoot fresh weight	0.858**	0.699**									
Shoot dry weight	0.839**	0.654**	0.974**								
Leaf length	0.881**	0.302	0.741**	0.790**							
Leaf width	0.874**	0.232	0.734**	0.794**	0.865**						
Leaf thick	0.304	0.365	0.335	0.278	0.148	0.229					
Petiole length	0.724**	0.106	0.607**	0.585**	0.701**	0.591**	0.233				
Petiole thick	0.727**	0.313	0.633**	0.663**	0.711**	0.687**	0.351	0.585**			
Root length	0.635**	0.435*	0.580**	0.485*	0.390	0.525*	0.666**	0.286	0.294		
Root fresh weight	0.696**	0.456*	0.778**	0.648**	0.453*	0.458*	0.382	0.655**	0.401	0.636**	
Root dry weight	0.702**	0.509*	0.829**	0.718**	0.478*	0.479*	0.345	0.650**	0.422*	0.588**	0.986**

*, Correlation is significant at the 0.05 level (2-tailed).
**, Correlation is significant at the 0.01 level (2-tailed).

Table 6. Principle component analysis of ***L. draba*** for five populations based on 12 morpho-agronomic traits (a). PCA of ***L. latifolium*** for eight populations based on 12 morpho-agronomic traits (b).

Traits	Component (a)			Component (b)		
	1	2	3	1	2	3
Leaf number	0.265	0.191	-0.376	0.197	0.634	0.043
Shoot height	0.266	-0.295	0.337	0.330	-0.001	0.130
Shoot fresh weight	0.343	0.266	-0.025	0.330	0.226	-0.046
Shoot dry weight	0.308	0.389	0.009	0.322	0.283	-0.049
Leaf length	0.335	0.069	0.329	0.326	0.194	0.114
Leaf width	0.247	0.175	0.457	0.327	0.015	0.100
Leaf thick	0.291	0.260	-0.280	0.205	-0.118	0.610
Petiole length	0.178	-0.531	-0.119	0.319	-0.072	-0.270
Petiole thick	-0.204	0.275	0.464	0.287	0.237	0.062
Root length	0.327	-0.011	-0.284	0.211	-0.446	0.403
Root fresh weight	0.272	-0.408	0.046	0.267	-0.340	-0.402
Root dry weight	0.272	-0.408	0.046	0.293	-0.197	-0.425
% of Variance	51.6	22.5	20.8	69.5	12.2	8.9
Cumulative %	51.6	74.1	94.8	69.5	81.7	90.6

values of 8.34, 1.45 and 1.07 with variance of 69.5, 12.2 and 8.9%, respectively. The first component (PC1) had more effects on the population grouping including shoot height, shoot fresh and dry weight, leaf length and width, and petiole thick and length. The PC2 had a positive correlation with leaf number and negative with root

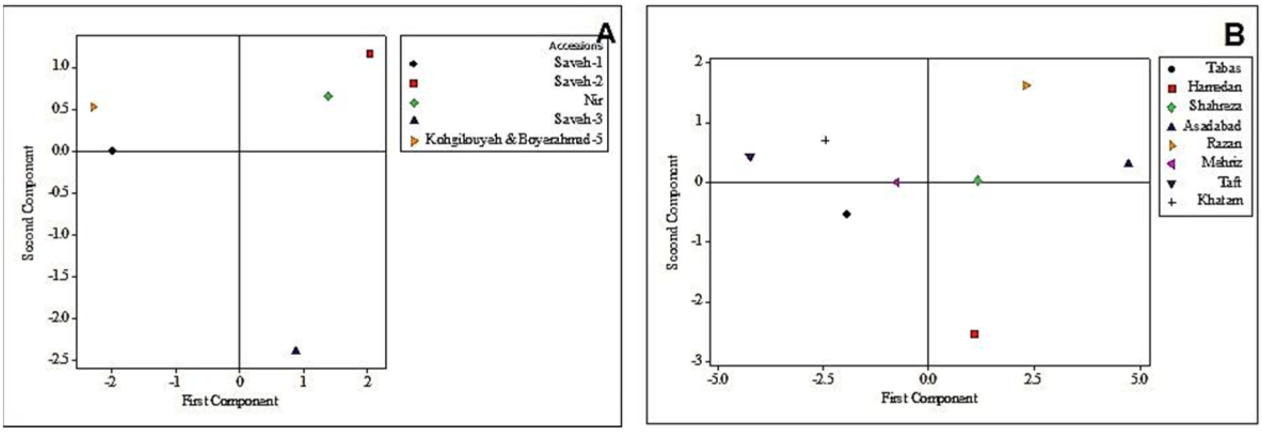

Fig. 3. Score plot graph based on morphological data. of five ***L. draba*** (A) and eight ***L. latifolium*** populations (B).

length. The PC3 had positively correlation with root fresh and dry weight, but negatively with leaf thick.

Score plot grouping of *L. draba* were formed Saveh-2 and the Nir populations distinct groups, whilethe Saveh-1 and Kohgilouyeh and Boyerahmad-5 populations overlap with each other, whereas the most obvious departure is the position of the Saveh-3 (Fig. 3-a). On the basis of score plot grouping of *L. latifolium,* the first group positively correlated to the two axes and gathers Asadabad, Razan and Shahreza populations, which Asadabad and Razan belonging to the Hamedan province. Moreover, Khatam, Mehriz and Taft populations, originated from Yazd province, formed the second group (Fig. 3-b). This set was positively correlated to the PC2 and negatively correlated to the PC1. The third group was composed by Hamedan population. It was positively correlated to the PC1 and negatively correlated to PC2. Tabas population is correlated negatively to the two axes and formed the fourth group. It was collected from lowest altitudes (1366 m) between populations of this study.

DISCUSSION

Analysis of the morphological diversity of *L. draba* and *L. latifolium* populations has revealed a variation in quantitative variables. Even though the five *L. draba* populations in this study differed slightly in vegetative characters but the large variation observed for *L. latifolium* indicates a high level of heterogeneity in materials collected from different regions of Iran. This provides opportunity to improve desirable morphological traits of *Lepidium*. Aksakal *et al*. (2010) reported genetic variation within and among populations of six natural populations of *L. draba* L. from Eastern Anatolia using random amplified polymorphic DNA (RAPD) markers. They indicated that most genetic diversity occurs within populations. The major morpho-agronomic variation observed was probably due to multigenic traits and the influence of environmental factors. The genetic variability has been reported in different species of *Lepidium* genus in recent studies (Bansal *et al*., 2012; Bona, 2012; Kumar *et al*., 2012; Sharma *et al*., 2015). Studies carried by Mohammed and Tesfaye (2015) to characterize 86 *L. sativum* genotypes from Ethiopia, found significant differences and high variability for the 12 quantitative morphological characters such as plant height, number of primary branch, number of secondary branch, length of primary branch, leaf length and internode length. Correlation analysis revealed significant correlation among some of the morphological traits suggesting that some traits could be used to predict the other. Traits that show significant positive correlation could be improved simultaneously. Traits that show significant positive correlation could be improved simultaneously (Nyadanu *et al*., 2014). There was a positive correlation between leaf number with shoot fresh and dry weight, and between shoot fresh weight with leaf length in both species. These traits are some of the main components of *Lepidium* production. Mohammed and Tesfaye (2015) on studies with *L. sativum* reported a positive relation between plant height and number of primary and secondary branch, length of primary branch, leaf length and internode length.

In cluster analysis, no relationship was found in phenetic diversity of *L. draba* populations and geographical origin, thus different regions were arranged in the same group. This could be explained by the exchange of varieties that occur among peasants from different localities (Salami *et al*., 2015). Populations in a cluster are more genetically similar than the counterparts in other cluster groups (Nyadanu *et al*., 2014). In contrary of our results, Aksakal *et al*. (2010) found that genetic differentiation is consistent with the geographic distance between *L. draba* populations. On the basis of cluster grouping, crossing between Saveh-1 and Saveh-2 could be recommended to get high heterozygosity. On the other hand, the individual populations of *L. latifolium* collected from the same region tend to form their own grouping. Khatam, Mehriz and Taft were from Yazd province and Asadabad, Razan and Hamedan were located in Hamedan province. In many plant species there is a significant correlation between geographic and genetic distance among populations, which can be explained by the isolation by-distance hypothesis (Aksakal *et al*., 2010).

Information obtained throughout PCA may assist breeders to distinguish the number of highly differentiated population for use in crossing and selection programs (Veronesi and Falcinelli, 1988). Characters with high variability are expected to provide high level of gene transfer during breeding programs (Gana *et al*., 2013). In hoary cress, shoot fresh weight, root length, leaf thick and length and in pepperweed, shoot height, shoot fresh and dry weight, leaf length and width, and petiole thick and length were indicated by principal components analysis to be the most reliable morphological characters that contribute to total variation. These factors could be used as useful marker traits that most effectively discriminate between *L. draba* and *L. latifolium* populations.

The score plot analysis based on two first principal components of 12 morpho-agronomic traits was used to identify the patterns of variation and detecting relationships among genotypes. Applying both methods of clustering and score plot was recommended to extract the maximum amount of information from the matrix data. The populations of Saveh-1, 2 and 3 in both clustering analysis and score plot were placed in separate groups otherwise there were in the same province. Maybe different altitude of their locations (1000, 1620 and 2113 m, respectively) could be affected to distinguishing of populations. Pepperweed populations in our study revealed the moderate agreement between morpho-agronomic classifications and geographic diversity.

CONCLUSION

Considerable agro-morphological diversity was observed among populations (mainly in *L. latifolium*). In *L. latifolium*, the highest shoot fresh and dry weight and leaf length and width were obtained from the populations Asadabad and Razan. These traits are important for breeding *Lepidium* and in order to obtain cultivars for higher yield, these populations are recommended. Clustering by Ward's method was effective in categorizing populations into diverse groups based on twelve agro-morphological traits. PCA could identify the most discriminating traits among the 12 traits evaluated. Therefore, data presented in this study allowed the identification of populations with distinct agro-morphological characteristics that could be used as validate candidate genes responsible for desired agronomic characters in future.

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