MORPHOLOGICAL DIVERSITY OF WILD ORIGANUM VULGARE (LAMIACEAE) IN IRAN

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Received 12.10.2010. Accepted for publication 02.03.2011.

Andi, S. A., Nazeri, V., Zamani, Z. & Hadian, J. 2011 06 30: Morphological diversity of wild *Origanum vulgare* (*Lamiaceae*) in Iran. -*Iran. J. Bot. 17 (1): 88-97.* Tehran.

Evaluation of morphological diversity in 144 genotypes of twenty-four populations of *Origanum vulgare* grown in North line of Iran including two subspecies (subsp. *viride* & subsp. *vulgare*) was studied for determining valuable characters for future breeding programs and medicinal purposes. In this investigation, 32 quantitative and qualitative characters were evaluated. The results showed great diversity of important characters among populations. Results of simple correlation revealed significant correlations among some important characters. Principal Component Analysis (PCA) explained about 86% of the variation related to main effective characters such as second internode length, leaf, inflorescence and peduncle length, average number of inflorescence per stem, bract, calyx and corolla color, state of calyx and bract hairs, length and width of bract and calyx and petiole length. Cluster analysis at similarity coefficient distance of about 13 divided populations in two main groups. The first main group consisted of 21 populations and the second main group included three populations. All of the specimens located in the latter group and one population from the first group belonged to *Origanum vulgare* subsp. *vulgare*, whereas the others were included in *Origanum vulgare* subsp. *viride.*

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Key words. Populations, *Origanum vulgare*, *Lamiaceae*, variation, morphology, breeding programs, cluster analysis, medicinal plant.

تنوع مورفولوژیکی گیاه مرزنجوش (Origanum vulgare) در ایران

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در این مطالعه، تنوع مورفولوژیکی ۱٤٤ ژنوتیپ از ۲٤ جمعیت گیاه مرزنجوش (*Origanum vulgare*)، که شامل دو زیرگونه (subsp. *viride* و subsp. *vulgare*) بودند، برای تعیین صفات ارزشمند به منظور انجام برنامه های اصلاحی آینده و اهداف دارویی مورد ارزیابی قرار گرفت. در این بررسی، ۳۲ صفت مورفولوژیکی کمی و کیفی مطالعه شدند. نتایج، تنوع بالایی از صفات مهم را در بین جمعیت های آنالیز شده نشان داد. نتایج همبستگی ساده حاکی از روابط معنی داری در میان برخی از فاکتور های اندازه گیری شده مهم بود. آنالیز عوامل اصلی (PCA) تقریبا ۸٦ درصد از تغییرات مربوط به صفات تاثیر گذار مهم را توجیه کرد که برخی از این صفات عبارت بودند از: طول میانگره دوم، طول برگ، گل آذین و دم گل آذین، متوسط تعداد گل آذین هر ساقه، رنگ براکته، کاسه و جام گل، تراکم کرک های براکته و کاسه، طول و عرض کاسه و براکته و طول دمبرگ. آنالیز کلاستر در فاصله تقریبا ۱۳ جمعیت ها را به دو بخش اصلی تقسیم کرد. اولین گروه ۲۱ جمعیت و دومین گروه اصلی ۳ جمعیت را شامل شدند. تمام نمونه های مربوط به

گروه دوم و یک جمعیت از گروه اول متعلق به زیر گونه subsp. *vulgare* بودند در حالی که بقیه جمعیت ها زیر گونه دیگر را شامل می‌شدند.

INTRODUCTION

The genus *Origanum* belongs to *Lamiaceae* family with the great morphological and phytochemical variations, distributed around the Mediterranean region (Kokkini, 1997). The genus has been classified in 10 sections including 42 species. One of the sections is *Origanum*. This section has only one species *i.e. Origanum vulgare* L. and six subspecies including subsp. *hirtum* (Link) Ietswaart, subsp. *vulgare* L., subsp. *virens* (Hoffmannsegg et Link) Ietswaart, subsp. *viride* (Boissier) Hayek, subsp. *gracile* (Kock) Ietswaart and subsp. *glandulosum* (Destontaines) (Ietswaart, 1980; Carlström, 1984; Danin, 1990; Danin and Kϋnne, 1996).

Origanum species are annual and perennial herbs growing on stony slopes at a wide range of altitudes (Aligiannis, et al., 2001; Snogerup, 1971). The aerial parts of the plant are widely used in spice industry while their essential oils show antimicrobial, cytotoxic and antioxidant activities (Lagouri, et al., 1993; Sivropoulou, et al., 1996).

The previous works have shown that high morphological and phytochemical diversity exists among *O. vulgare* populations (D'Antuono, et al., 2000; Chalchat and Pasquier, 1998), which may be used in planning the breeding and conservation of this important economic plant (Azizi, et al., 2009).

The *Origanum* species are herbs with several stems, ascending or erect, subsessile or petiolate leaves and flowers in verticillasters aggregated in dense or loose spikes, which are arranged in a paniculate or corymbiform inflorescence. The plants of *O. vulgare* have dense spikes, and tubular 5-toothed calyces, never becoming turbinate in fruit (Ietswaart, 1980).

O. vulgare contains three subspecies (subsp. *viride*, subsp. *vulgare* and subsp. *gracile*) in Iran (Mozaffarian, 1996), and grow mainly in northern parts of the country. The subspecies are distinguished from each other by some morphological characteristics, for example compact inflorescences, green color bracts and white corolla in subsp. *viride*, compact inflorescences and purple color bracts and corolla in subsp. *vulgare* and lax inflorescences, glaucous color leaves and very slender branches in subsp. *gracile*. Information on morphological characters of *O. vulgare* grown in Iran is mostly from descriptions given in Flora Iranica (Rechinger, 1982). No investigation have been done on morphological diversity of populations of this species in Iran, therefore present study can be very useful for breeding programs and medicinal purposes of this plant.

Some previous reports of *Ocimum gratisimum* (Vieria, et al., 2001) and *Thymus baeticus* (Saez, 1999) have shown correlations between chemical and morphological traits. In a study of *Tanacetum vulgare* was found that the camphor and artemisia ketone chemotypes have the greatest plant height and flower numbers, respectively (Keskitalo, et al., 2001). In addition, a positive correlation between essential oil yield and dry weight of *Satureja hortensis* different populations has been shown by Hadian, et al. (2009).

In this study, twenty-four populations of *O. vulgare* growing in Iran have been compared morphologically. The objective of this work was a more thorough assessment of morphological diversity of wild genotypes of *O. vulgare* from different geographical points of Iran and the evaluation of their potential in breeding, conservation and exploitation of genetic resources.

MATERIALS AND METHODS

Plant materials

One hundred and forty four oregano genotypes collected from twenty-four populations in north part of Iran including Golestan, Mazandaran, Gilan, Ardabil and East Azerbaijan provinces were used for this study. The populations studied represent two of the three subspecies recorded in Iran, including *O. vulgare* subsp. *viride* and *O. vulgare* subsp. *vulgare*.

Plant specimens were collected during the full flowering period from their natural habitats specified in Flora Iranica (Rechinger, 1982, Table 1 and Fig. 1).

Taxonomic identification of plants

Plants growing in 4 populations of South Chalus, Sabalan, Meshkin Shahr and Kaleybar were identified as *O. vulgare* subsp. *vulgare*, whereas the plants of the other populations were identified as *O. vulgare* subsp. *viride* (Table 1). Voucher specimens have been deposited in the Herbarium of Horticulture department, Faculty of Agriculture and Natural Resources, University of Tehran, Iran.

Six specimens were selected from each population to study morphological characters. In present study, 32 quantitative and qualitative characters were evaluated (Table 2 & 3). To measure the characters five replicates were evaluated from each plant.

Table 1. Localities of the *Origanum vulgare* populations.

No.	Locations	Provinces	Subspecies
1.	Golestan National Park	Golestan	subsp. *viride*
2.	Galikesh	Golestan	subsp. *viride*
3.	Minoodasht	Golestan	subsp. *viride*
4.	Aliabad (Katul)	Golestan	subsp. *viride*
5.	Behshahr	Mazandaran	subsp. *viride*
6.	Qaem Shahr	Mazandaran	subsp. *viride*
7.	Pol-e Sefid	Mazandaran	subsp. *viride*
8.	Babol	Mazandaran	subsp. *viride*
9.	Amol	Mazandaran	subsp. *viride*
10.	Nur	Mazandaran	subsp. *viride*
11.	Nowshahr	Mazandaran	subsp. *viride*
12.	Kandlus	Mazandaran	subsp. *viride*
13.	Siah Bishe	Mazandaran	subsp. *viride*
14.	Kalar Dasht	Mazandaran	subsp. *viride*
15.	18 km South Chalus	Mazandaran	subsp. *vulgare*
16.	Chalus	Mazandaran	subsp. *viride*
17.	Ramsar	Mazandaran	subsp. *viride*
18.	Lahijan	Gilan	subsp. *viride*
19.	Asalem	Gilan	subsp. *viride*
20.	Rudbar	Gilan	subsp. *viride*
21.	Sabalan	Ardabil	subsp. *vulgare*
22.	Meshkin Shahr	Ardabil	subsp. *vulgare*
23.	Heiran defile	Ardabil	subsp. *viride*
24.	Kaleybar	East Azerbaijan	subsp. *vulgare*

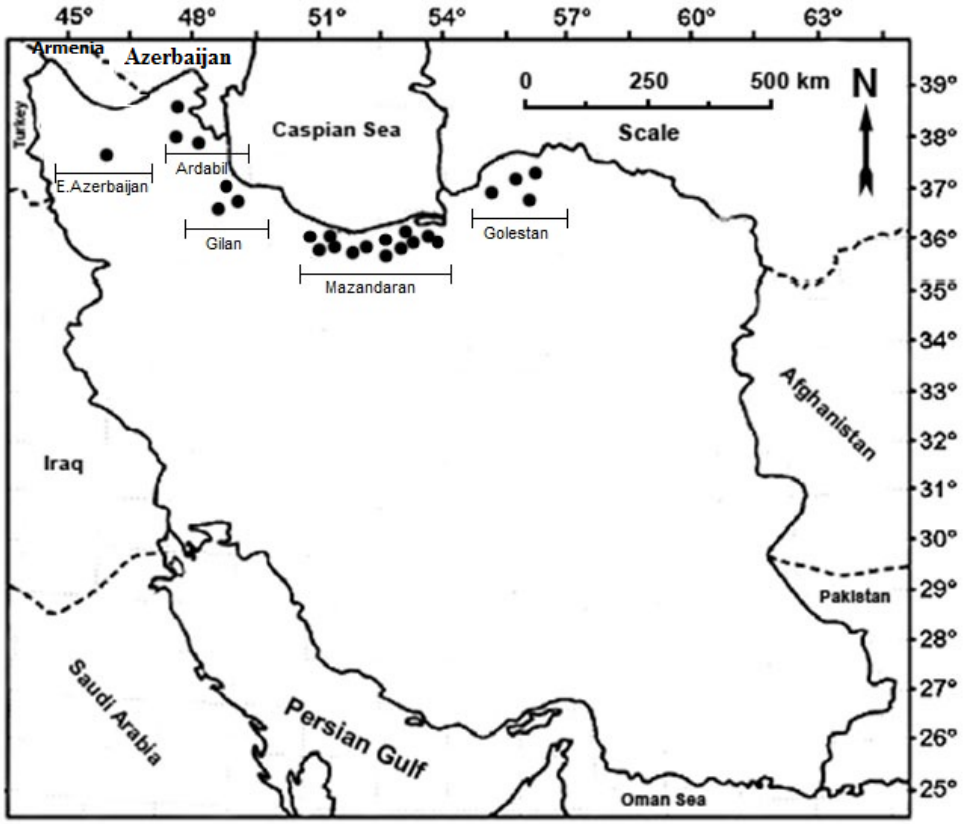

Fig. 1 Locations of *Origanum* populations.

Statistical analyses

The cluster analysis (without the use of the key characters between two subspecies), correlations between morphological traits at *P*= 0.05, 0.01 and Principal Component Analysis (PCA) were performed using the SPSS software, version 9.0 and Ward method (Norusis, 1998). For quantitative characters, the data was computed for each trait and subspecies and mean values were used for comparisons. The data was analyzed by one-way ANOVA model and Dunkan's procedure at 0.05 level was used to test for significant differences between the subspecies via SAS software.

RESULTS AND DISCUSSION

Evaluation of qualitative characters

A number of 13 qualitative traits were evaluated in the 24 individual populations by recording the predominant character-state for each trait. Average values are shown in Table 4. Most of populations had dark red stems. The amount of hairs on stem were intermediate in all of the populations, except for Sabalan, Kaleybar, Heiran defile and Babol having very dense hairs. Siah Bishe and Meshkin Shahr populations exhibited dentate leaf margine, whereas the others had entire leaf margins. Most of the populations showed dense hairs on their leaves and calyxes, whereas they had bracts with intermediate density of hairs (but no hair was seen on bracts of Kaleybar specimens). The populations of Golestan National Park, Behshahr, Qaem Shahr, Babol and Minoodasht had tomentose bracts. According to Rechinger, specimens related to *O. vulgare* subsp. *vulgare* have lower hair density on bract in comparison with the other subspecies, that confirmed by our observations. Leaf apex was acute in all of the populations. Leaf color was light green in the majority of the populations and among these populations, Lahijan population had the darkest leaves. Leaf shape was ovate in all of the populations surveyed, except for Behshahr population having elliptical leaf shape.

The populations studied differed in the number of flowers per inflorescence, therefore the inflorescence contained dense, intermediate and sparse flowers. Corolla color was white in all of the populations, except for 18 km South Chalus, Sabalan, Meshkin Shahr and Kaleybar populations having purple color flowers. In addition, calyx and bract colors were green-purple and purple in the latter populations, respectively, while, the other populations had green color calyx and bracts, as also reported by Rechinger (1982).

Differences observed in morphological characteristics among populations studied may be due to ecological or genetical factors. Therefore, a molecular study using DNA markers is needed to distinguish these differences and to explain classification between subspecies of *O. vulgare* in Iran.

Quantitative characters

Seventeen quantitative traits were scored in 24 oregano populations (Tables 2, 5 and 6) and analyzed by ANOVA test. Only, the mean of second internode length, leaf and inflorescence length and the mean number of inflorescence per stem were significantly different between the two subspecies of *vulgare* and *viride* and are of taxonomic value. The results obtained agree in majority of measured characteristics with previous report (Rechinger, 1982).

For the majority of the measured characters, among specimens related to subsp. *vulgare*, Meshkin Shahr population had the longest measurements, except for a few characters including peduncle length, average number of inflorescence per stem, number of stem nodes and corolla length that 18 km South Chalus had the highest values. Meshkin Shahr population was found to have higher second internode length and the leaf length and width than those of subsp. *viride*, whereas the latter subspecies had the longest mean values in some of the characters such as plant height, inflorescence length, mean number of inflorescence per stem, number of stem nodes and the bract length and width. Therefore, the morphological differences observed among wild populations of *O. vulgare* are probably due to genetic as well as environmental conditions that have classified the Iranian specimens in two distinct subspecies. These results indicate that morphological characterization of the *Origanum* germplasm must be done in the wild.

Correlations between the characters

The correlation between pair of traits was tested in this study. Plant height was significantly correlated with stem diameter, inflorescence and peduncle length, the mean number of inflorescence per stem and the number of stem nodes. These characters are important in secondary metabolites production and can be used in breeding programs. Inflorescence and peduncle length, peduncle diameter, mean number of inflorescence per stem, number of stem nodes and the bract length and width were significantly correlated with stem diameter. The second internode length showed significant positive correlations with the leaf length ($r= 0.65$, $p< 0.01$) and width and inflorescence width ($r=0.44$, $p< 0.05$). Both leaves and inflorescences are the main parts of essential oil accumulation in *O. vulgare* (Mockute, et al., 2003). In addition, the second internode length had shown significant negative correlations with average number of inflorescence per stem and number of nodes

Table 2. Measuered morphological characteristics in 144 *Origanum* genotypes.

No.	Character	Abb.	Unit	Mean	Min.	Max.
1.	Plant height	PH	cm	62.02	34.50	91.67
2.	Stem diameter	SD	mm	2.21	1.37	2.78
3.	Stem color	SC	Code*	4.19	3.00	5.00
4.	State of stem hairs	SSH	Code	3.39	1.00	3.00
5.	Second internode length	SIL	mm	34.72	25.59	61.52
6.	Leaf length	LL	mm	20.09	12.59	34.24
7.	Leaf width	LW	mm	11.73	7.03	15.11
8.	Leaf length/width ratio	LLWR	Ratio	1.75	1.46	2.13
9.	Petiole length	PetL	mm	4.77	2.98	6.92
10.	State of leaf margin	SLM	Code	1.17	1.00	3.00
11.	State of leaf hairs	SLH	Code	4.42	1.00	5.00
12.	State of leaf apex	SLA	Code	3.03	1.00	3.00
13.	Leaf color	LC	Code	1.44	5.00	1.00
14.	Leaf shape	LS	Code	1.08	3.00	1.00
15.	Inflorescence length	IL	mm	51.43	27.54	70.71
16.	Peduncle length	PedL	mm	31.54	14.31	52.52
17.	State of inflorescence compaction	SIC	Code	2.82	5.00	1.00
18.	Peduncle diameter	PedD	mm	0.55	0.33	0.79
19.	Average number of inflorescence per stem	ANIS	-	11.37	7.00	14.00
20.	Inflorescence width	IW	mm	14.55	10.23	22.46
21.	Node number before the first inflorescence	NNFI	-	11.77	7.00	17.00
22.	Bract length	BL	mm	10.29	5.27	14.46
23.	Bract width	BW	mm	5.43	2.61	7.68
24.	Bract length/width ratio	BLWR	Ratio	2.02	1.56	2.61
25.	Bract color	BC	Code	1.67	3.00	1.00
26.	Calyx length	CL	mm	2.33	1.91	2.62
27.	Calyx diameter	CD	mm	1.07	0.85	1.33
28.	Calyx color	CC	Code	1.67	5.00	1.00
29.	State of calyx hairs	SCH	Code	4.50	1.00	5.00
30.	Corolla length	CoL	mm	4.20	3.44	5.25
31.	Corolla color	CoC	Code	1.67	3.00	1.00
32.	State of bract hairs	SBH	Code	5.08	1.00	5.00

Codes description has been shown in Table 3.

Table 3. Qualitative traits, their character states and related codes.

Traits	Characters							
Codes	1		3		5		7	
Stem color	light red	LR	red	R	dark red	DR	-	-
State of stem hairs	sparse	S	intermediate	M	dense	D	-	-
State of leaf margin	entire	En	dentate	Dt	-	-	-	-
State of leaf hairs	sparse	S	intermediate	M	dense	D	-	-
State of leaf apex	obtuse	Ob	acute	Ac	-	-	-	-
Leaf color	light green	LG	green	G	dark green	DG	-	-
Leaf shape	ovate	Ov	semi-circular	SC	elliptical	El	-	-
State of inflorescence compaction	sparse	S	intermediate	M	dense	D	-	-
Bract color	green	G	green-purple	GP	purple	P	-	-
Calyx color	green	G	green-purple	GP	purple	P	-	-
State of calyx hairs	sparse	S	intermediate	M	dense	D	-	-
Corolla color	white	W	white-purple	WP	purple	P	-	-
State of bract hairs	absent	Ab	sparse	S	intermediate	M	dense	D

Table 4. Characteristics of 24 oregano populations based on qualitative traits.*

No.	Populations	Stem color	State of stem hairs	State of leaf margin	State of leaf hairs	State of leaf apex	Leaf color	Leaf shape	State of inflorescence compaction	Bract color	Calyx color	State of calyx hairs	Corolla color	State of bract hairs
1.	Golestan National Park	DR	M	En	D	Ac	LG	Ov	S	G	G	D	W	D
2.	Galikesh	DR	M	En	D	Ac	LG	Ov	M	G	G	D	W	M
3.	Minoodasht	DR	M	En	D	Ac	LG	Ov	M	G	G	D	W	D
4.	Aliabad (Katul)	DR	M	En	M	Ac	LG	Ov	M	G	G	D	W	M
5.	Behshahr	DR	M	En	M	Ac	LG	El	S	G	G	D	W	D
6.	Qaem Shahr	DR	M	En	M	Ac	LG	Ov	S	G	G	D	W	D
7.	Pol-e Sefid	R	M	En	D	Ac	G	Ov	S	G	G	D	W	M
8.	Babol	DR	D	En	D	Ac	LG	Ov	M	G	G	D	W	D
9.	Amol	DR	M	En	D	Ac	G	Ov	S	G	G	D	W	M
10.	Nur	DR	M	En	D	Ac	G	Ov	D	G	G	D	W	M
11.	Nowshahr	R	M	En	D	Ac	LG	Ov	M	G	G	D	W	M
12.	Kandlus	DR	M	En	D	Ac	LG	Ov	S	G	G	D	W	M
13.	Siah Bishe	LR	M	Dt	D	Ac	LG	Ov	S	G	G	D	W	M
14.	Kalar Dasht	DR	M	En	D	Ac	LG	Ov	M	G	G	D	W	M
15.	18 km South chalus	DR	M	En	D	Ac	LG	Ov	M	P	M	M	P	M
16.	Chalus	DR	M	En	D	Ac	LG	Ov	M	G	G	D	W	M
17.	Ramsar	DR	M	En	D	Ac	LG	Ov	D	G	G	D	W	M
18.	Lahijan	DR	M	En	D	Ac	DG	Ov	D	G	G	D	W	M
19.	Asalem	R	M	En	M	Ac	LG	Ov	D	G	G	D	W	M
20.	Rudbar	DR	M	En	D	Ac	LG	Ov	D	G	G	D	W	M
21.	Sabalan	LR	D	En	M	Ac	LG	Ov	D	P	M	W	P	W
22.	Meshkin Shahr	LR	M	Dt	M	Ac	LG	Ov	D	P	M	M	P	W
23.	Heiran defile	DR	D	En	D	Ac	LG	Ov	D	G	G	D	W	M
24.	Kaleybar	LR	D	En	M	Ac	LG	Ov	D	P	M	W	P	Ab

* Abbreviations according to table 3.

per stem. Leaf length was significantly correlated with leaf width and petiole length but this had significant negative correlations with peduncle length and average number of inflorescence per stem. Leaf width exhibited significant positive correlations with petiole length and inflorescence width, whereas this explained significant negative correlations with peduncle length and average number of inflorescence per stem. Petiole length was significantly correlated ($r = 0.42$, $p < 0.05$) with bract length. The bract length and width, the peduncle length and diameter and average number of inflorescence per stem were significantly correlated with inflorescence length. Average number of inflorescence per stem, number of stem nodes and bract width showed significant correlations with peduncle length. Peduncle diameter was significantly correlated with the bract length and width. Therefore, the important relationships exist between peduncle and bract characteristics. According to the correlations, the more the length and diameter of peduncle, the higher was the length and width of bract. The number of inflorescence per stem exhibited significant correlations with number of stem nodes and bract width. However, higher number of nodes, correlated with the lower inflorescence width. Correlation between the bract length and width was significant at the 0.01 level. These characters were significantly correlated with calyx length at the 0.05 level ($r= 0.51$ & 0.44, respectively). Finally, calyx length indicated significant correlations with calyx diameter and corolla length. These correlations suggest that many of the associations between morphological traits vary among these populations that can be used for domestication programs and medicinal purposes in order to increase the secondary metabolites level in *O. vulgare*.

Principal Components Analysis

The first eight PCs of the populations showed 86.07% of the total variance among them. The greatest portions of the variance were observed in PC1, PC2 and PC3 with 30.48, 15.06 and 10.76 percent, respectively. In the first PCA factor (PC1) morphological characters such as second internode length, leaf, inflorescence and peduncle length, mean number of inflorescence per stem, bract, calyx and corolla color and state of calyx and bract hairs showed the highest positive correlation ($r >0.64$, Table 7), while in PC2 the bract length and width, and in PC3 petiole length showed the highest positive correlation (Table 7).

Cluster analysis

Cluster analysis at distance of about 13 for similarity coefficient divided populations in 2 main groups (Fig. 2). The first main group (A) consisted of 21 populations including 20 populations of *O. vulgare* subsp. *viride* and one population of *O. vulgare* subsp. *vulgare*. The latter was collected from 18 km South

Chalus in Mazandaran province. The second main group (B) was comprised of 3 populations, all belonging to *O. vulgare* subsp. *vulgare* that were collected from Sabalan and Meshkin Shahr in Ardabil province and Kaleybar in East Azerbaijan province. As shown in Fig. 2, Sabalan, Meshkin Shahr and Kaleybar populations are separated from the other populations. However, South Chalus population belonging to the same subspecies (subsp. *vulgare*), is placed among the specimens of *O. vulgare* subsp. *viride*. This could be explained by different climatic and geographic conditions of the latter population, which can affect on some morphological characters. Specimens of South Chalus are separated from the other specimens related to subspecies *vulgare* due to lower mean values in many characters such as second internode length, the bract length and width, the leaf length and width, inflorescence width and petiole length, whereas it had the higher means on peduncle length, mean number of inflorescence per stem, number of stem nodes and corolla length. Also, this population has been located at distance of 18 km from Chalus, where a population of subsp. *viride* is located. In addition, cross-pollination among *Origanum* species is unavoidable. Therefore, this may be a hybrid between *O. vulgare* subsp. *viride* and *O. vulgare* subsp. *vulgare* because of intermediate characters such as plant height, stem diameter, petiole, inflorescence and peduncle length, mean number of inflorescence per stem, bract width and calyx diameter. While, all of the specimens belonging to subsp. *viride* were placed in a one group. Among populations of Sabalan, Kaleybar and Meshkin Shahr, specimens related to Meshkin Shahr clustered, separately. This could be due to higher mean values in many characters, for example plant height, second internode length, petiole and leaf length, stem diameter, inflorescence and leaf width, bract length to width ratio and the length of the inflorescence. *O. vulgare* is a species that little work has been done so far on conservation and exploitation of its genetic resources. In conclusion, we have shown that *O. vulgare*, which distributes in North line of Iran, is a species with variation among populations. Therefore, it is possible to distinguish populations with valuable traits that can be useful in breeding programs and medicine. We found that population of Meshkin Shahr from *O. vulgare* subsp. *vulgare* has valuable characters for above purposes.

Table 5. Mean values and standard deviation of quantitative characters for 24 oregano populations.

No.	Populations	PH	SD	SIL	LL	LW	PetL	IL	PedL	PedD	ANIS	IW	NNFl	BL	BW	CL	CD	CoL
1.	Golest National Park	69.83±10.79	2.49±0.39	30.20±2.34	24.02±3.48	12.01±2.19	6.75±1.43	57.72±19.55	36.58±11.61	0.65±0.16	11.00±3.27	10.47±4.07	15.83±2.55	10.55±0.74	4.28±0.25	2.11±0.19	0.94±0.13	3.61±0.51
2.	Galibesh	68.80±14.12	2.15±0.47	30.75±4.41	23.30±3.43	11.50±1.12	6.92±1.27	52.25±20.15	33.84±15.90	0.55±0.14	11.39±2.68	10.68±4.28	13.83±2.26	10.27±2.55	5.55±1.88	2.16±0.05	0.99±0.05	3.54±0.35
3.	Mirordasht	91.67±21.89	2.37±0.59	31.55±5.92	16.26±2.31	7.66 ±1.54	3.17±0.67	52.61±8.49	39.00±7.81	0.49±0.07	13.67±4.61	12.41±1.10	14.72 ±5.90	6.21 ±1.18	2.73±0.64	2.09±0.07	0.85±0.10	3.47±0.19
4.	Alishad (Kant)	69.33±10.55	2.78±0.25	32.39±4.34	12.59±1.77	8.04 ±2.02	3.15±0.76	55.35± 8.22	38.28±6.90	0.62±0.13	14.11±2.97	11.99±1.87	13.61±3.46	9.54 ±1.45	5.79±1.35	2.22±0.15	1.07±0.08	3.72±0.35
5.	Behshahr	63.33±6.50	2.39±0.31	37.61±6.94	12.68±2.44	7.03 ±1.82	2.98±1.16	64.38±13.12	51.38±19.99	0.56±0.10	13.28±3.20	15.91±2.79	8.61 ±2.33	11.62±1.75	6.31±1.25	2.37±0.15	1.33±0.09	4.01±0.34
6.	Qaem Shahr	89.03±12.59	2.19±0.44	28.98±2.69	13.60±2.59	9.63 ±2.74	4.26±1.30	67.35±14.17	52.52±11.60	0.48±0.07	13.87±3.49	13.24±3.72	17.13±4.75	11.04±1.37	6.82±0.59	2.31±0.16	1.24±0.09	3.65±0.15
7.	Pol-e Sefid	57.67±9.57	2.40±0.36	35.35±4.15	16.67±1.78	11.20±1.67	5.45±0.49	65.53±23.67	47.09±17.25	0.65±0.10	13.94±4.71	12.13±2.03	12.67±2.68	12.78±2.51	7.69±1.23	2.62±0.30	1.31±0.11	4.29±0.51
8.	Babol	50.33±4.19	1.37±0.13	28.34±4.06	16.59±1.30	9.95 ±0.84	3.53±0.63	27.54±7.31	14.31±5.39	0.36±0.06	9.61 ±2.12	12.21±1.88	12.22 ±2.05	5.27 ±1.03	2.61±0.61	1.91±0.19	0.98±0.07	3.44±0.43
9.	Amol	67.83±3.98	2.05±0.31	25.59±1.20	17.30±2.41	12.10±2.35	5.25±0.71	52.22±11.30	37.76±8.67	0.53±0.05	14.06±4.07	10.23±1.52	17.00 ±3.52	11.65±1.44	7.57±0.76	2.44±0.16	1.14±0.16	4.45±0.37
10.	Nur	54.33±4.61	2.25±0.06	27.75±2.80	16.44±2.57	10.70±1.99	4.51±0.83	51.17±8.64	32.16±5.57	0.33±0.05	11.00±1.88	10.24±2.57	12.50±1.79	11.05±1.52	6.69±0.68	2.53±0.18	1.13±0.06	5.11±0.22
11.	Nowshahr	62.33±8.88	1.72±0.18	35.11±3.63	22.05±3.14	12.85±1.57	5.14±0.84	32.16±5.57	14.71±4.93	0.63±0.09	11.00±1.88	14.40±1.57	10.56 ±2.78	7.61 ±1.21	3.74±0.67	2.13±0.22	1.01±0.16	3.98±0.48
12.	Kandsilur	46.83±4.98	1.07±0.39	32.16±4.95	18.83±2.71	12.73±1.74	4.72±0.83	47.78±9.06	23.82±3.20	0.64±0.25	11.17±2.65	12.00±2.29	8.67 ±1.62	12.29±1.78	7.05±0.62	2.36±0.21	1.02±0.07	4.30±0.47
13.	Siah Bishe	58.67±5.44	2.09±0.12	37.36±8.38	25.24±1.84	12.79±0.57	6.13±1.36	49.09±7.11	21.03±4.64	0.47±0.09	12.00±0.98	12.37±2.44	9.11 ±2.33	14.46±1.23	5.64±1.13	2.50±0.27	1.03±0.05	3.99±0.54
14.	Kalar Dasht	53.00±7.57	2.48±0.37	34.60±4.93	17.93±3.29	12.15±2.07	4.72±0.58	70.71±14.86	28.52±8.66	0.79±0.15	13.06±0.73	13.67±0.97	7.22 ±2.50	13.69±2.64	7.67±1.05	2.41±0.16	0.99±0.08	3.87±0.50
15.	18 km S Chalus	56.33±15.02	1.75±0.36	29.07±7.89	17.31±3.94	10.59±1.92	3.92±0.57	41.33±8.79	29.47±8.52	0.50±0.07	9.89 ±2.05	12.14±2.14	13.22 ±1.15	6.63 ±1.58	3.15±0.80	2.59±0.22	1.08±0.10	5.25±0.58
16.	Chalus	75.83±10.71	2.73±0.54	33.42±6.06	21.88±3.54	13.48±2.41	5.13±1.01	55.61±15.52	32.40±12.70	0.57±0.10	11.44±1.42	11.62±3.55	15.50 ±2.30	12.40±1.18	6.42±1.17	2.25±0.19	0.99±0.11	4.12±0.46
17.	Ramsar	60.83±14.83	2.32±0.33	31.60±7.04	18.80±2.82	12.09±2.83	4.64±1.17	62.51±16.17	40.81±13.47	0.61±0.10	11.50±2.68	22.46±3.95	10.44 ±3.10	10.89±3.33	6.84±1.25	2.17±0.14	0.85±0.09	3.71±0.48
18.	Lahijan	80.83±23.17	2.76±0.55	45.84±7.62	21.04±3.13	13.07±3.01	5.15±1.02	67.29±22.54	47.36±18.61	0.54±0.14	13.11±4.72	18.68±5.05	13.06 ±2.86	9.96 ±2.56	5.66±0.91	2.37±0.21	1.05±0.13	4.62±0.46
19.	Arasbaran	52.83±4.67	2.02±0.21	29.91±3.21	23.57±4.34	14.61±3.63	5.75±1.87	59.73±13.62	33.89±7.66	0.49±0.11	11.44±2.63	20.30±2.55	10.44 ±3.28	11.01±3.11	5.53±1.28	2.40±0.26	1.06±0.14	4.88±0.70
20.	Ruzbar	66.17±18.52	2.34±0.55	30.44±5.56	20.88±6.74	12.00±2.48	4.88±1.34	50.00±16.24	23.83±11.12	0.60±0.07	10.50±1.20	19.36±3.28	15.39 ±5.39	7.97 ±1.88	4.05±1.03	2.33±0.31	1.11±0.10	4.59±0.43
21.	Sabalan	34.50±2.14	1.87±0.40	40.08±13.21	21.55±4.29	11.59±2.53	4.27±1.22	35.83±6.56	19.63±3.10	0.47±0.11	8.17 ±1.90	14.45±1.76	5.22 ±0.97	11.26±2.00	4.85±0.49	2.37±0.23	1.18±0.10	4.19±0.46
22.	Sabi	61.00±13.47	2.52±0.13	61.52±10.71	34.24±5.44	15.11±3.24	5.06±1.63	38.33±3.77	20.01±2.07	0.57±0.02	8.00 ±0.86	20.03±2.73	8.06 ±1.11	10.82±2.45	4.58±0.88	2.53±0.37	1.12±0.16	4.76±0.75
23.	Heiran deEle	43.67±4.07	2.25±0.12	33.43±4.21	22.83±2.15	13.70±1.88	4.69±1.36	41.11±4.37	19.93±3.29	0.59±0.08	10.22±1.85	20.92±2.46	6.94 ±0.85	9.93 ±0.85	5.21±0.45	2.44± 0.40	1.14±0.10	5.01±0.58
24.	Kaleybar	53.50±8.02	1.87±0.24	50.16±5.07	26.67±2.42	14.94±1.70	4.34±1.33	36.62±14.25	21.46±8.58	0.45±0.10	6.67 ±0.77	17.27±3.92	10.50 ±0.96	7.96 ±1.00	4.16±0.57	2.29±0.17	1.11±0.07	4.27±0.49

ACKNOWLEDGEMENT

The authors are grateful to M. Akramian and A. Mehdizadeh, M. H. Lazavi and M. A. Rahimi to help in collection of plant samples.

Table 6. Mean values and standard deviation of quantitative characters for two *O riganum vulgare* subspecies.

Characters	*O. vulgare* subsp. *vulgare*		*O. vulgare* subsp. *viride*	
	Range	Average	Range	Average
Plant height	34.50-61.00	51.33 ± 11.64 a*	43.67-91.67	64.16 ± 13.11 a
Stem diameter	1.75-2.52	2.00 ± 0.35 a	1.37-2.78	2.26 ± 0.34 a
Second internode length	29.07-61.52	45.21 ±13.87 a	25.59-45.84	32.62 ± 4.41 b
Leaf length	17.31-34.24	24.94 ±7.29 a	12.59-25.24	19.12 ± 3.91 b
Leaf width	10.59-15.11	13.05 ±2.31 a	7.03-14.61	11.46 ± 2.06 a
Petiole length	3.92-5.06	4.40 ±0.48 a	2.98-6.92	4.85 ± 1.09 a
Inflorescence length	35.83-41.33	38.03 ± 2.44 b	27.53-70.71	54.11 ± 11.32 a
Peduncle length	19.63-29.47	22.64 ± 4.62 a	14.31-52.52	33.32 ± 11.42 a
Peduncle diameter	0.45-0.57	0.50 ± 0.05 a	0.33-0.79	0.56 ± 0.10 a
Average number of inflorescence per stem	6.67-9.89	8.18 ± 1.32 b	9.61-14.11	12.01 ± 1.49 a
Inflorescence width	12.14-20.03	15.97 ± 3.43 a	10.23-22.46	14.26 ± 3.91 a
Node number before the first inflorescence	5.22-13.22	9.25 ± 3.42 a	6.94-17.13	12.27 ± 3.16 a
Bract length	6.63-11.26	9.17 ±2.24 a	5.27-14.46	10.51 ± 2.34 a
Bract width	3.15-4.85	4.18 ± 0.75 a	2.61-7.68	5.68 ± 1.52 a
Calyx length	2.29-2.59	2.45 ± 0.14 a	1.91-2.61	2.31 ± 0.17 a
Calyx diameter	1.07-1.18	1.12 ± 0.04 a	0.85-1.33	1.05 ± 0.13 a
Corolla length	4.19-5.25	4.62 ± 0.49 a	3.44-5.11	4.12 ± 0.52 a

* Dunkan's test at $P = 0.05$ level.

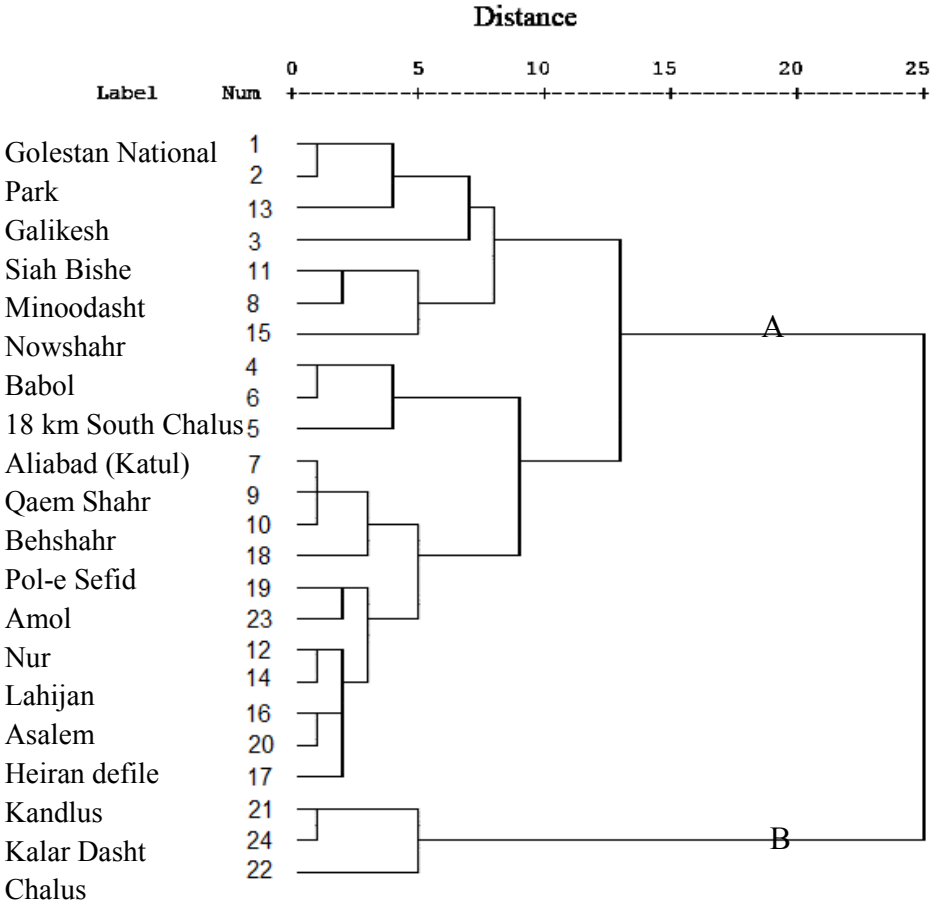

Fig. 2. Dendrogram showing the distance (similarity) among 24 *Origanum* populations based on morphological data.

Table 7. Loading factor of variables in the first eight Principal Components (PCs).

No.	Variable**	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
1	PH	0.57	-0.24	0.17	0.51	0.33	0.31	0.19	-0.19
2	SD	0.41	0.43	0.27	0.48	0.39	-0.10	-0.16	0.06
3	SC	0.61	-0.19	-0.10	-0.12	0.47	-0.06	-0.20	0.15
4	SSH	-0.50	-0.10	-0.38	-0.33	-0.11	-0.15	-0.01	-0.17
5	SIL	-0.65*	0.30	0.13	0.48	0.17	-0.10	0.12	-0.08
6	LL	-0.71*	0.12	0.63	0.07	0.08	-0.02	0.13	-0.07
7	LW	-0.55	0.38	0.52	-0.34	0.17	0.01	0.13	-0.19
8	LLWR	-0.44	-0.37	0.42	0.61	-0.05	-0.09	0.04	0.11
9	PetL	-0.02	0.25	0.77*	-0.20	-0.17	0.21	0.09	-0.22
10	SLM	-0.41	0.17	0.50	0.41	-0.31	0.02	0.19	0.20
11	SLH	0.36	-0.19	0.43	-0.52	0.06	0.20	-0.13	0.37
12	SLT	0.17	-0.55	0.04	0.39	0.24	0.05	-0.13	0.25
13	LC	0.28	0.44	-0.02	-0.16	0.28	0.42	0.28	0.09
14	LS	0.20	0.10	-0.43	0.45	-0.27	-0.38	0.21	0.22
15	IL	0.72*	0.48	0.08	0.29	0.14	-0.06	-0.11	-0.11
16	PedL	0.70*	0.28	-0.23	0.45	0.17	0.13	0.06	-0.17
17	PedD	0.37	0.56	0.18	0.04	0.17	-0.17	-0.57	0.19
18	SIC	0.54	-0.06	-0.01	0.18	-0.67*	0.27	-0.06	-0.05
19	ANIS	0.91*	0.16	-0.02	0.20	-0.05	0.07	0.01	0.04
20	IW	-0.35	0.25	0.03	0.04	0.50	-0.56	0.35	0.09
21	NNFI	0.56	-0.28	0.05	0.04	0.25	0.59	0.12	-0.24
22	BL	0.21	0.77*	0.30	0.09	-0.42	-0.11	-0.17	-0.09
23	BW	0.47	0.79*	0.02	-0.08	-0.17	-0.07	-0.16	-0.19
24	BLWR	-0.40	-0.46	0.50	0.30	-0.33	0.07	-0.08	0.24
25	BC	-0.86*	0.06	-0.26	0.23	0.07	0.26	-0.22	-0.06
26	CL	-0.19	0.79*	-0.09	0.05	-0.09	0.30	0.01	0.42
27	CD	-0.07	0.50	-0.57	0.15	-0.28	0.17	0.38	0.02
28	CC	-0.86*	0.06	-0.26	0.23	0.07	0.26	-0.22	-0.06
29	SCH	0.85*	-0.04	0.32	-0.15	-0.03	-0.17	0.23	0.19
30	CoL	-0.37	0.52	-0.11	-0.25	0.27	0.24	0.22	0.52
31	CoC	-0.86*	0.06	-0.26	0.23	0.07	0.26	-0.22	-0.06
32	SBH	0.77*	-0.40	-0.01	0.08	-0.19	-0.07	0.14	0.22

* Values more than 0.64, that have most loading factor among components are considered as significant.
** For abbreviations see Table 2.

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