

## INFRASPECIFIC MORPHOLOGICAL VARIATIONS IN *ACINOS GRAVEOLENS* (M.B.) LINK

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**Abstract.** This study compares the effect of ecological factors on phenotype plasticity in the natural populations of *Acinos graveolens* in Iran. In total, twenty six quantitative and qualitative morphological traits were examined in the sixteen populations at two sections: inter- and intrapopulation. In the interpopulation section, averages amounts of morphological characteristics of populations were examined, while in the intrapopulation, morphological features of the seventy six plant samples of the populations were investigated. The obtained data showed that these characteristics differed between and within the populations and the analysis of variance test and one-sample test have shown significant differences of all quantitative characteristics. The biplot Principal Correspondence Analysis (PCA-biplot) of traits showed some populations had indicator morphological characteristic(s) which were useful in detecting of these populations. Significant correlations were found between some quantitative characteristics with ecological factors. The studied populations were separated from each other in the PCA and Principal Coordinate Analysis (PCO) plots and the Unweighted Paired Group using Average method (UPGMA) tree. The PCA plot of morphological features showed that some characteristics separated from others and the rest ones were together and had overlapping. The individuals of the studied populations were separated from others in the PCA and PCO plots and the UPGMA tree of the morphological characteristics. Individuals of some populations arranged separately and placed far from others, but this condition was reverse in the rest populations and most of individuals placed near each other. The obtained data confirmed high variations within some populations.

**Key words:** *Acinos graveolens*, ecology, interpopulation, intrapopulation, Iran, phenotype plasticity

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### Introduction

Investigation of difference within widespread species at large spatial scales offers unique opportunities to observe evolution in progress, and is the first step to identify and determine the relative importance of different factors that promote phenotypic differentiation (e.g. BOYD 2002; HERRERA *et al.* 2002; MASCÓ *et al.* 2004; HERRERA 2005). Different studies (e.g. SLATKIN 1983; GRANT 1991) showed that there are two main evolutionary forces that promote geographical and morphological variations at infraspecific levels: one of them is natural selection which exerted by geographically patterned abiotic or biotic factors and the other are random events such as genetic drift. On the contrary, gene flow has the inverse effect, linking populations through interbreeding and intercepting differentiation and speciation in the long term.

The other mechanism is phenotypic plasticity which definite is the ability of one genotype to express various phenotypes depending on ecological conditions and can permit a genotype to be present in different environments (BRADSHAW 1965; PIGLIUCCI 2001; DE WIT & SCHEINER 2004). Conversely phenotypic plasticity does not require genetic variation and allows a more flexible and quicker response to change in environmental condition, but is usually considered as unsuitable to support extreme phenotypic changes (PIGLIUCCI 2001; VALLADARES *et al.* 2007).

*Acinos* Miller belongs to Lamiaceae family which has 10 species that distributed over Mediterranean regions toward Central Asia (MABBERLEY 1990). This genus comprises of two species in Iran (RECHINGER 1982; JAMZAD 2012). Some species of this genus were employed in folk medicine as antiseptic, stimulant, tonic and antispasmodic due to their beneficial effects on melancholy,

**Tab. 1.** Habitat adders of the studied populations.

Population	Locality address
Ivanaki	Semnan province, Ivanaki, 1810 m a.s.l.
Avaj	Tehran to Hamadan road, Avaj mountain, 2237 m a.s.l.
Fasham	Tehran province, Fasham mountain, 1990 m a.s.l.
Darakeh	Tehran province, Evin, Darakeh mountain, 2252 m a.s.l.
Abegarm	Markazi province, Mahallat, Abegarm, 1700 m a.s.l.
Rahjerd	Qom province, Salafchegan, Rahjerd village, 1647 m a.s.l.
Peyghambar	Markazi province, Zarandiyeh, Peyghambar village, 1846 m a.s.l.
Razeghan	Markazi province, Zarandiyeh, Razeghan village, 2046 m a.s.l.
Sangak	Markazi province, Saveh, Ghargh Abad, Sangak village, 2237 m a.s.l.
Arak	Markazi province, Arak, Hussein Abad mountain, 1777 m a.s.l.
Varameh	Markazi province, Zarandiyeh, Varameh village, 1900 m a.s.l.
Mazid Abad	Zanjan province, Mazid Abad, 1839 m a.s.l.
Bijar	Zanjan province, Bijar, 1785 m a.s.l.
Hasan Abad	Zanjan province, Hasan Abad, 2006 m a.s.l.
Sero	West Azerbaijan province, Urmia, Sero mountain, 1680 m a.s.l.
N	West Azerbaijan province, Mianboab, 1700 m a.s.l.

coughs, toothache, sciatica, neuralgia and gastrointestinal disorders; in addition, this genus has mucilaginous nutlets (DAVIS *et al.* 1982).

The pollen morphology of six taxa of the genus *Acinos* had been examined under scanning electron microscopy (SEM). The results revealed rather uniform morphological features, however found details were characteristic to differentiate the pollen taxa. *Acinos* pollen also shares some common morphological features with the other Lamiaceae pollen (Kaya & Kutluk 2007).

*Acinos graveolens* (M.B.) Link is one of them which naturally found in Iran and has a wide range of distribution and occurred in different regions of western, north-western and central parts of the country (RECHINGER 1982).

TALEBI & SHAYESTEHFAR (2014) investigated trichomes morphology in different populations of *A. graveolens* in Iran. Results of this study showed that types and frequency of trichomes as well as the kinds of dominant trichomes varied between populations. This confirms the effect of various ecological factors on trichomes plasticity in this species.

Due to absence of morphological investigation of this species, the present study

aimed to present a comparative study of inter and intra-population variation in different vegetative and reproductive morphological characteristics of *A. graveolens*. A specific aim of this research project was to quantify and contribute to the body of knowledge of the phenotypic variability and allocation pattern for an individual species and its interactions with its environment. To achieve these aims, data were collected from naturally growing populations across a wide geographic range.

### Material and methods

In present study, sixteen different geographical populations of *A. graveolens* were collected from different regions of central and north-western of Iran (Tab. 1) during spring 2013. Plant samples were identified on the basis of provided descriptions in Flora Iranica (RECHINGER 1982) and Flora of Iran (JAMZAD 2012). From each population, 3 to 6 samples were collected randomly and totally twenty six qualitative and quantitative morphological traits from the both reproductive and vegetative organs such as stem height and its branches number, shape, length and width of

basal and floral leaves, the shape of apex, margin and base of basal and floral leaf blade, as well as calyx dimensions were examined between and within the populations.

For study the effect of different environmental factors on the morphological traits of *A. graveolens* populations, three environmental factors such as: longitude ( $E^\circ$ ), latitude ( $N^\circ$ ) and altitude (in m a.s.l.) were examined. These factors were obtained with Garmin GPS map76CSx.

The mean and standard deviation of the studied quantitative morphological features were determined. In order to group the studied populations and individuals on the basis of morphological characteristics, data were standardized (mean = 0, variance = 1) and used for multivariate analyses, including Unweighted Paired Group using Average method (UPGMA) and Principal Coordinate Analysis (PCO) (PODANI 2000).

One-way analysis of variance test (ANOVA) was employed to assess the significant quantitative morphological differences among the studied populations, and Pearson's coefficient of correlation was used to determine the quantitative morphological characteristics in relation to ecological factors as well as longitude, latitude, altitude of the habitats, so as to show relationship between populations. MVSP ver. 3.1 (2004) and SPSS ver. 9 (1998) softwares were used in the statistical analyses.

Morphological features of sixteen populations of *A. graveolens* were investigated. This study was conducted in two levels: inter- (between) and intra- (within) populations. In the interpopulation section, averages amounts of morphological characteristics of each population were examined, while in the intrapopulation, morphological features of the seventy six plant samples of the studied populations were investigated.

## Results

### *Interpopulation study*

*A. graveolens* is the widespread species and naturally grows in different regions of Iran. In order to determine the degrees of morphological

variations between different populations of this species, sixteen geographical populations of *A. graveolens* were collected from different habitats and their morphological features of the both vegetative and reproductive organs were examined. In total, eighteen quantitative and eight qualitative morphological traits were identified and evaluated (Tab. 2). Most of these characteristics differed between the populations and the ANOVA test has shown significant differences ( $p < 0.05$ ) of all the studied quantitative morphological features (Tab. 3). The PCA biplot of morphological traits showed some studied populations had distinct morphological characteristic(s) which were useful in distinction of populations. For example, in Darakeh and Vardeh populations, the calyx length as well as basal leaf shape was prominent morphological characteristics, respectively. In Sero population, floral leaf shape was distinct trait (Fig. 1).

Significant positive/ negative correlations were found between some quantitative characteristics of vegetative and reproductive organs, for example a significant positive correlation ( $p < 0.01$ ,  $r = 0.80$ ) occurred between stem height and inflorescence length. Basal leaf petiole as well as basal leaf width had significant positive correlations ( $p < 0.05$ ,  $r = 0.50$ ) with inflorescence length. Significant positive correlations ( $p < 0.01$ ) seen between calyx length and basal and floral leaf length. A significant negative correlation ( $p < 0.01$ ,  $r = -0.50$ ) occurred between calyx width with basal leaf length/ width ratio.

In addition significant correlations occurred between morphological characteristics in relation to ecological factors of habitat. For example a significant positive correlation ( $p < 0.01$ ,  $r = 0.44$ ) found between stem height with northern distribution, but this trait had a significant correlation ( $p < 0.05$ ,  $r = -0.26$ ) with habitat elevation. Inflorescence length had a significant positive correlation ( $p < 0.01$ ,  $r = 0.35$ ) with northern distribution, but two significant negative correlations ( $p < 0.01$ ) were recorded between the mentioned features with eastern distribution as well as habitat elevation. A significant negative correlation ( $p < 0.05$ ,

**Tab. 2.** Some of the morphological features of the studied populations (all values are in cm).

Population	Stem height	Inflorescence Length	Branch	Basal Leaf Petiole Length	Ba.Pet	Basal Leaf Width	Floral Leaf Petiole Length	Fl.Pet	Floral Leaf Width	Calyx Length	Calyx Width
Ivanaki	Mean	39.00	1.00	8.00	6.50	5.00	7.50	3.75	4.50	7.25	2.00
	N	4	4	4	4	4	4	4	4	4	4
	SD	19.63	1.19	1.15	.816	2.38	.00	1.73	.95	.50	.00
Bijar	Mean	74.00	.40	5.60	4.40	4.20	6.40	2.20	4.80	6.80	1.90
	N	5	5	5	5	5	5	5	5	5	5
	SD	16.73	1.23	.89	.89	1.14	.83	.54	.83	.44	.22
Hasan Abad	Mean	46.75	19.25	.75	6.25	4.25	6.00	2.75	4.00	6.25	2.00
	N	4	4	4	4	4	4	4	4	4	4
	SD	12.60	1.05	1.50	2.50	1.89	1.29	2.00	1.25	1.41	.95
Mazid Abad	Mean	96.00	31.00	4.40	10.20	6.60	9.40	2.60	7.60	6.60	1.90
	N	5	5	5	5	5	5	5	5	5	5
	SD	27.57	6.44	2.70	.44	1.51	1.30	1.81	.89	.54	.22
Abegarm	Mean	66.20	24.60	.40	9.20	9.20	9.00	4.80	6.60	7.80	1.80
	N	5	5	5	5	5	5	5	5	5	5
	SD	11.49	4.56	.89	3.11	.83	1.81	1.58	.44	1.09	.44
Arak	Mean	34.66	16.16	.33	5.50	4.00	4.83	2.50	1.46	6.50	2.00
	N	6	6	6	6	6	6	6	6	6	6
	SD	6.47	2.63	.81	.83	1.09	.83	.40	.21	.83	.00
Avaj	Mean	44.40	15.20	.00	6.00	5.20	6.40	3.60	5.60	7.40	2.00
	N	5	5	5	5	5	5	5	5	5	5
	SD	10.92	3.03	.00	1.00	.44	.89	.89	1.14	.89	.00

Darakeh	Mean	57.75	25.25	3.75	12.25	6.25	5.50	14.25	3.75	7.25	9.50	1.75
	N	4	4	4	4	4	4	4	4	4	4	4
	SD	3.30	4.57	.95	5.85	.50	1.00	4.50	.95	1.25	1.00	.50
Fasham	Mean	76.60	20.80	2.80	8.40	7.80	6.00	8.00	3.40	7.00	6.60	1.70
	N	5	5	5	5	5	5	5	5	5	5	5
	SD	20.77	3.70	1.09	1.67	2.16	.70	1.58	1.51	1.58	1.14	.44
Rahjerd	Mean	72.33	32.50	1.83	8.16	6.00	7.33	7.50	4.16	5.83	8.33	2.00
	N	6	6	6	6	6	6	6	6	6	6	6
	SD	14.51	9.93	1.94	.98	.89	1.21	.83	.75	1.16	.81	.00
Peyghambar	Mean	75.40	46.00	5.60	10.40	10.40	7.20	9.80	3.60	6.20	7.80	2.10
	N	5	5	5	5	5	5	5	5	5	5	5
	SD	21.68	1.41	2.30	1.14	3.04	1.48	.83	.89	1.09	.83	.22
N	Mean	86.00	32.20	1.60	9.40	6.60	6.20	7.20	3.60	4.80	7.80	2.40
	N	5	5	5	5	5	5	5	5	5	5	5
	SD	26.07	5.01	1.67	1.94	1.51	1.78	2.58	1.14	1.64	1.30	.41
Razeghan	Mean	52.00	17.20	.00	8.00	7.20	7.00	8.00	3.60	6.20	7.80	1.80
	N	5	5	5	5	5	5	5	5	5	5	5
	SD	6.67	3.11	.00	1.22	.83	1.22	2.00	.89	.83	.83	.44
Sangak	Mean	88.66	54.66	.33	8.16	6.00	6.33	7.00	3.66	5.00	7.83	2.63
	N	3	3	3	3	3	3	3	3	3	3	3
	SD	4.72	8.08	.57	1.60	1.00	1.15	1.00	.57	2.00	.28	.32
Sero	Mean	107.00	57.60	2.00	13.60	10.40	7.80	10.20	5.40	7.40	7.80	1.90
	N	5	5	5	5	5	5	5	5	5	5	5
	SD	35.10	2.40	1.22	4.50	5.12	1.92	3.49	2.88	3.50	.83	.22
Varameh	Mean	73.60	32.20	.40	16.20	5.60	6.60	11.80	4.60	4.80	10.80	1.40
	N	5	5	5	5	5	5	5	5	5	5	5
	SD	11.41	6.72	.89	2.38	2.19	1.81	1.92	1.34	1.09	.83	.54

**Tab. 3.** ANOVA test of some studied morphological traits.

Character		Sum of Squares	df	Mean Square	F	Sig.
Stem Height	Between Groups	28602.099	15	1906.807	5.787	.000
	Within Groups	20099.433	61	329.499		
	Total	48701.532	76			
Inflorescence Length	Between Groups	11522.430	15	768.162	7.994	.000
	Within Groups	5861.700	61	96.093		
	Total	17384.130	76			
Branch No.	Between Groups	211.978	15	14.132	7.285	.000
	Within Groups	118.333	61	1.940		
	Total	330.312	76			
Basal Leaf Length	Between Groups	648.587	15	43.239	8.106	.000
	Within Groups	325.400	61	5.334		
	Total	973.987	76			
Basal Leaf Petiole	Between Groups	292.321	15	19.488	4.738	.000
	Within Groups	250.900	61	4.113		
	Total	543.221	76			
Basal Leaf Petiole	Between Groups	20.596	15	1.373	3.422	.000
	Within Groups	24.473	61	.401		
	Total	45.068	76			
Basal Leaf Width	Between Groups	106.692	15	7.113	4.128	.000
	Within Groups	105.100	61	1.723		
	Total	211.792	76			
Basal Leaf Length/ Width Ratio	Between Groups	10.732	15	.715	4.969	.000
	Within Groups	8.784	61	.144		
	Total	19.516	76			
Floral Leaf Petiole	Between Groups	55.628	15	3.709	2.679	.003
	Within Groups	84.450	61	1.384		
	Total	140.078	76			
Floral Leaf Petiole	Between Groups	30.523	15	2.035	3.863	.000
	Within Groups	32.131	61	.527		
	Total	62.654	76			
Floral Leaf Width	Between Groups	193.750	15	12.917	5.644	.000
	Within Groups	139.608	61	2.289		
	Total	333.358	76			
Calyx Length	Between Groups	98.105	15	6.540	8.543	.000
	Within Groups	46.700	61	.766		
	Total	144.805	76			
Calyx Width	Between Groups	4.829	15	.322	2.995	.001
	Within Groups	6.557	61	.107		
	Total	11.385	76			
Calyx Length/Width Ratio	Between Groups	132.433	15	8.829	8.564	.000
	Within Groups	62.887	61	1.031		
	Total	195.320	76			

$r = -0.26$ ) found between basal leaf width with stand altitude. Significant positive correlations were seen between northern distribution with basal leaf length ( $p < 0.05$ ) and floral leaf width ( $p < 0.01$ ).

The studied populations were separated from each other in the PCA (Fig. 2) and PCO (Fig. 3) plots as well as the UPGMA tree (Fig. 4). In the UPGMA tree, two main clades were seen. In one clade population Sero and in secondary the rest of populations were found. In this clade population Arak, Hasan Abad, Razeghan, Avaj and Darakeh placed separately. This condition was confirmed by the PCA and PCO plots. This subject was the verification about the presence of high morphological variations between the populations.

#### ***Intrapopulation study***

In the intrapopulation sections, the morphological polymorphisms of randomly selected individuals of the studied populations were investigated. In populations Ivanaki, Abegarm, Rahjerd, Arak, Bijar and Hasan Abad, floral leaf shape unchanged within populations, but in other populations its shape varied between samples of each population so that there were two to three different shapes of floral leaf. This condition was true about the basal leaf shape and its shape fixed within the studied samples of Rahjerd, Razeghan, Sangak and Bijar populations. In contrast, in others basal leaf shape varied within populations. In addition, quantitative morphological characteristics of these individuals varied and one-sample test showed significant difference for all of the studied traits, but the rate of changes in morphological features varied. Maximum variations in the morphological characteristics belong to the stem height with standard deviation about 25.13 while the minimum difference were occurred in calyx width with standard deviation about 0.38, the standard deviation of others were reposed between these amounts (Tab. 4).

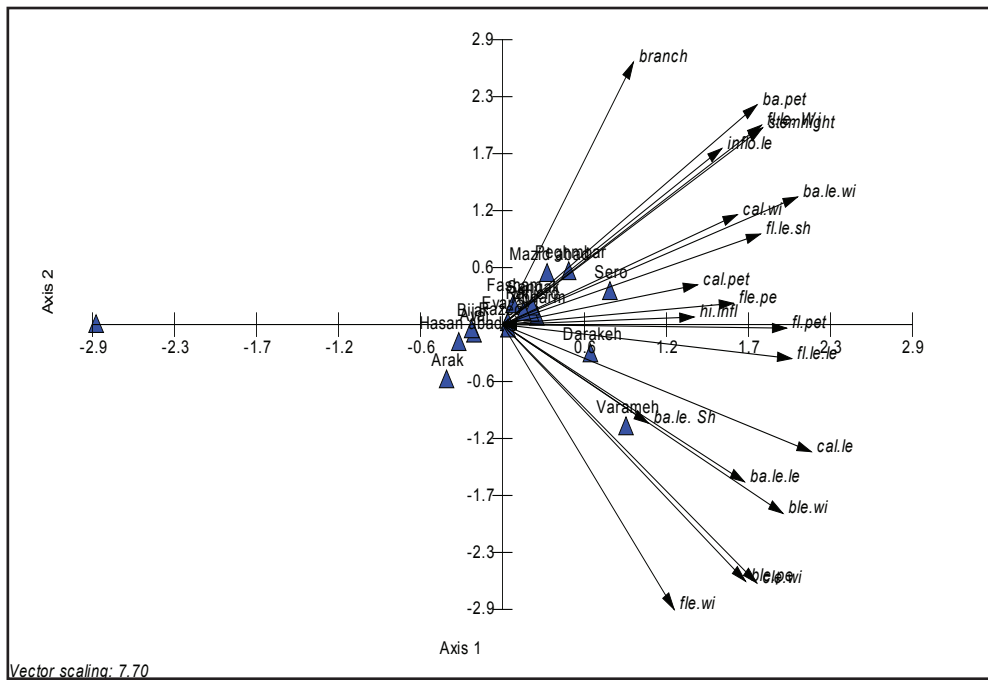
In order to presentation and comparing quantitative morphological characteristics between individuals, box and whisker plots were used. These plots were ideal for comparing traits distributions because the centre, spread and

overall range were immediately apparent. These graphs were plotted for all the quantitative morphological characteristics. The patterns of traits distribution showed that, in some individuals, some of morphological features had abnormal distribution and separated from others, for detail investigation see Fig. 5. The PCA plot of morphological features showed that some characteristics, such as stem height, inflorescence length and basal leaf length, separated from others and the rest ones placed near each other and overlapped (Fig. 6). The individuals of the studied populations were separated from others in the PCA and PCO plot (Figs. 7, 8) as well as the UPGMA tree of the morphological characteristics (Fig. 9). The pattern of individual's arrangement varied between the populations. In some cases such as Bijar, Sangak and N populations, individuals of each population arranged separately and placed far from others, but this condition was reverse in Arak population and most of individuals placed near each other.

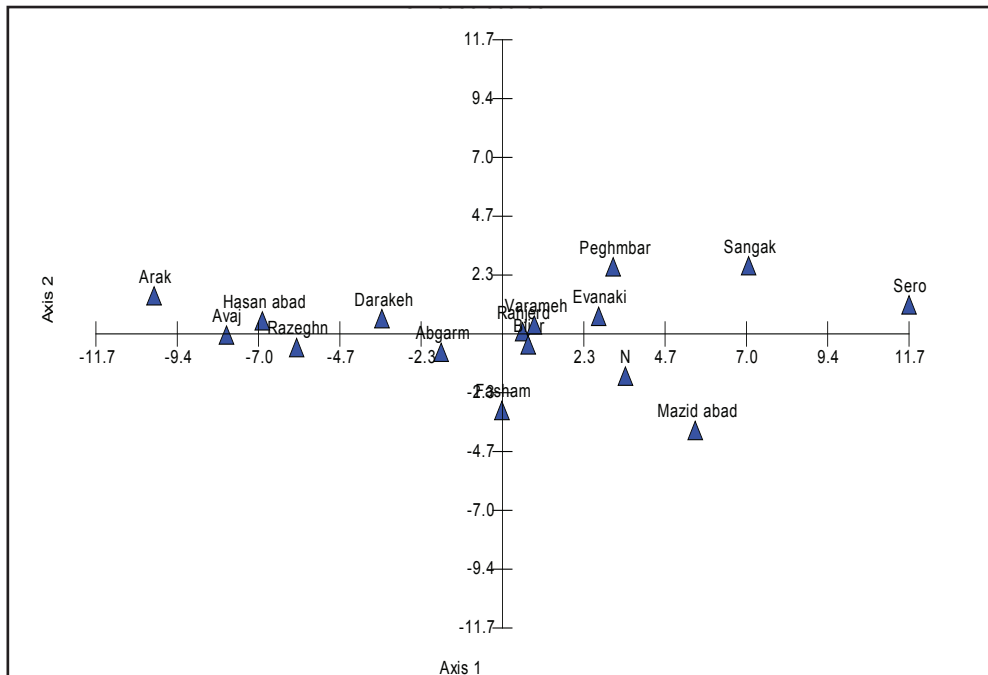
#### **Discussion**

Results of this study showed that *A. graveolens* has a wide distribution range and grows in various regions of the western, north-western and central parts of Iran on the slopes of mountains and hills. Iran is a large country with a surface area more than of 1.6 million km<sup>2</sup>. This country is considered as geographical meeting grounds of the Mediterranean region and Indian subcontinent. Two mountains run parallel to its northern and western borders, joining each other in the northwestern tip of the country. Surrounded by the above mountainous fence, the country is marked by remarkable natural contrast; within the distance of a few miles one can experience major changes in landscape and vegetation (MOBAYEN 1996). For these reasons, this species facing with various environmental factors in its natural habitat.

To understand how to adapt of such species to the wide ranges of habitat conditions, two well-known different adaptive mechanisms which improve the survival and the dispersal of invasive species are phenotypic plasticity and



**Fig. 1.** PCA biplot of the studied populations with their morphological characteristics. Abbreviations: **branch** – branch number; **ba.pet** – basal leaf petiole; **ba.le.sh** – basal leaf shape; **ba.le.le** – basal leaf length; **ba.le.wi** – basal leaf length/wide ratio; **fle.wi** – floral leaf width; **fl.le.le** – floral leaf length; **fl.le.sh** – floral leaf shape; **fl.pet** – floral leaf petiole; **info le.** – inflorescence length; **cal. wi.** – calyx width; **cal.pet** – calyx petiole; **cal. le** – calyx length.



**Fig. 2.** PCA plot of the studied populations on the basis of morphological characteristics.



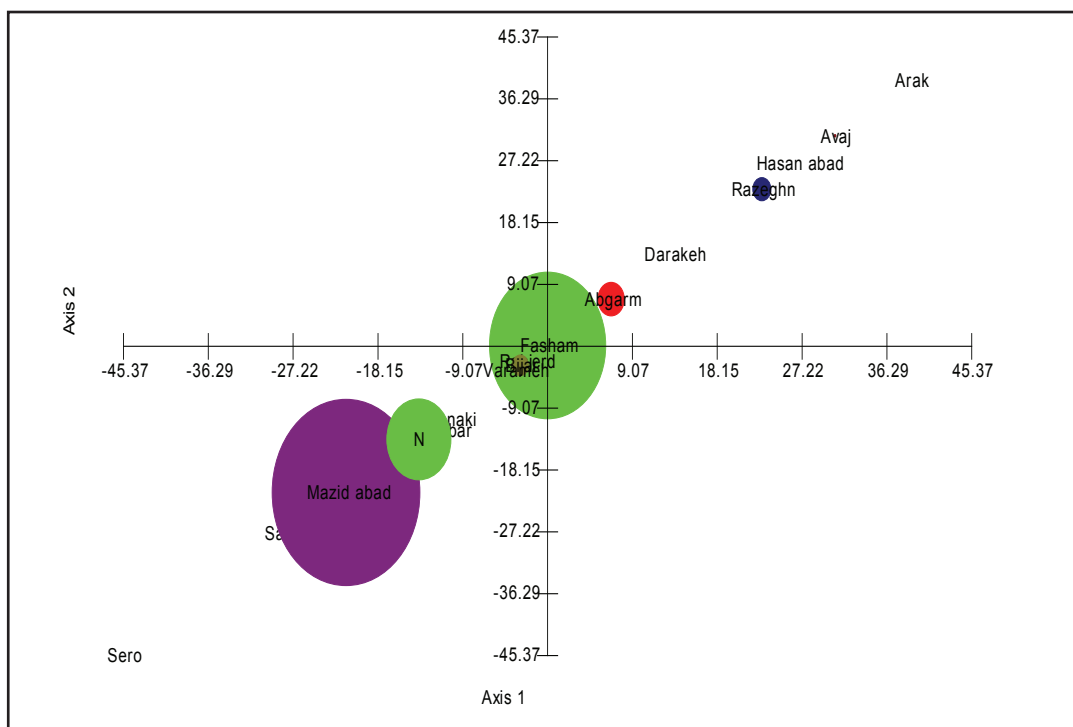


Fig. 3. PCO plot of the studied populations based on morphological traits.

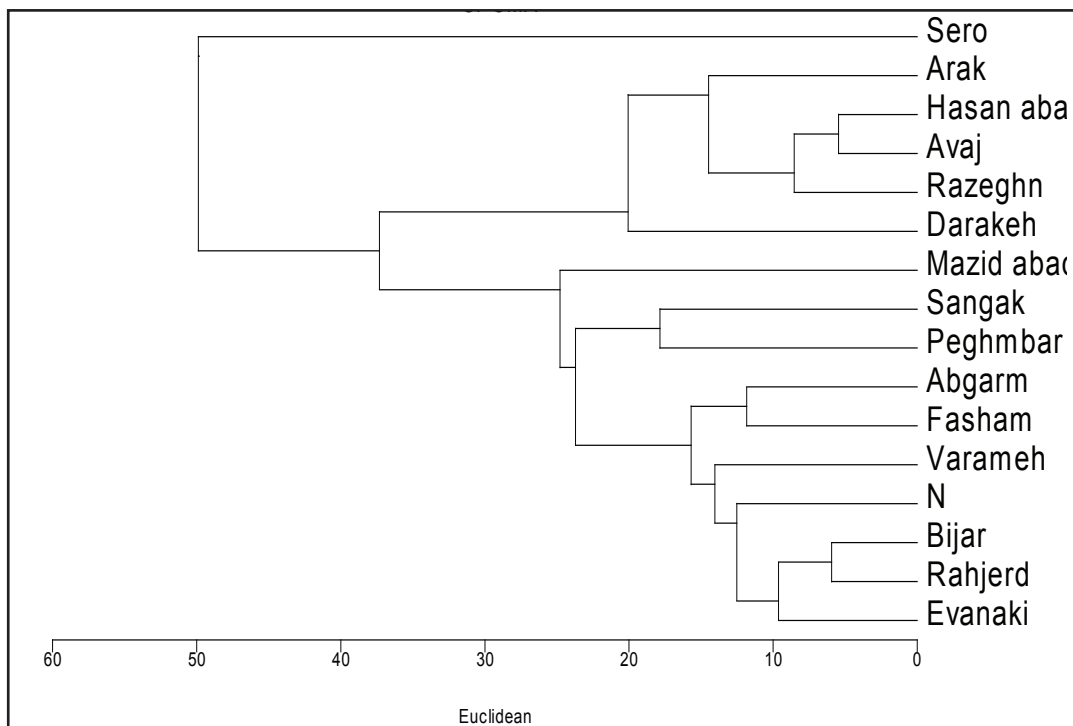


Fig. 4. UPGMA tree of the studied populations on the basis of morphological features.

**Tab. 4.** One-Sample T-Test of quantitative morphological traits.

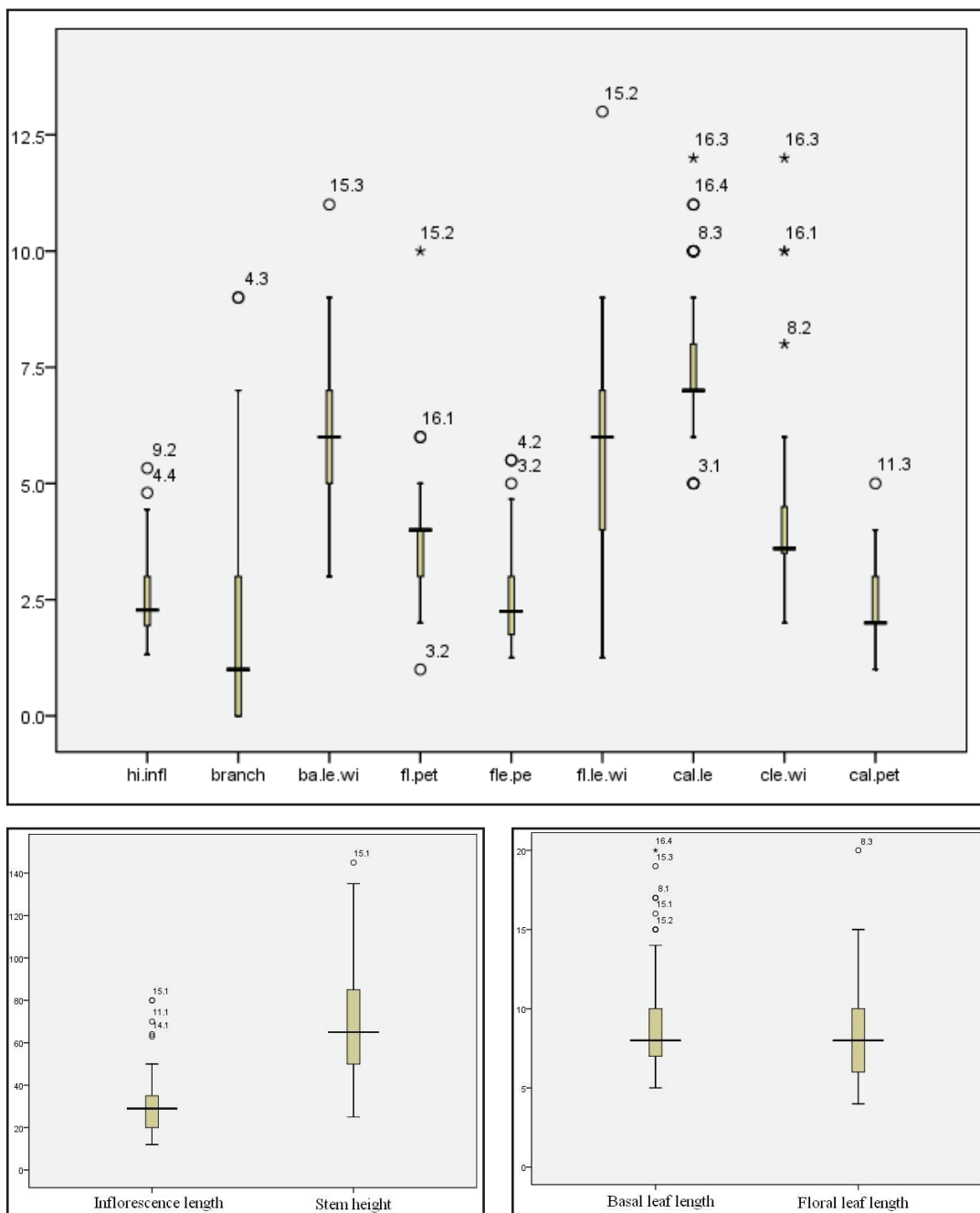
Character	Test Value = 0					
	t	df	Sig. (2-tailed)	SD	95% Confidence Interval of the Difference Lower	Upper
Stem Height	24.292	76	.000	25.31422	64.3323	75.8235
Inflorescence Length	17.579	76	.000	15.12410	26.8660	33.7315
Branch No.	6.778	76	.000	2.08476	1.1372	2.0836
Basal Leaf Length	22.204	76	.000	3.57989	8.2459	9.8710
Basal Leaf Petiole	21.867	76	.000	2.67351	6.0555	7.2691
Basal Leaf Petiole	16.983	76	.000	0.77007	1.3156	1.6652
Basal Leaf Width	31.812	76	.000	1.66935	5.6731	6.4308
Basal Leaf Length/Width Ratio	26.128	76	.000	0.50674	1.3938	1.6238
Floral Leaf Length	25.349	76	.000	2.86373	7.6227	8.9227
Floral Leaf Petiole	23.420	76	.000	1.35762	3.3152	3.9315
Floral Leaf Petiole	23.685	76	.000	0.90796	2.2447	2.6569
Floral Leaf Width	23.224	76	.000	2.09435	5.0676	6.0183
Floral Leaf Length Width/Ratio	21.745	76	.000	0.66474	1.4964	1.7981
Calyx Length	48.752	76	.000	1.38034	7.3555	7.9821
Calyx Width	43.989	76	.000	0.38705	1.8524	2.0281
Calyx Length/Width Ratio	22.907	76	.000	1.60312	3.8211	4.5488
Calyx Petiole	21.887	76	.000	0.96327	2.1840	2.6212

local adaptation. SULTAN (2000) defined the phenomenon of phenotypic plasticity as the capacity of a given genotype to express various phenotypes in different ecological conditions. If phenotypic plasticity is the main adaptive mechanism for plants to distribute into a range of habitats, plants are able to rapidly alter their phenotypic features and the change is caused by ecological conditions in the habitat. WARD *et al.* (2008) stated that local adaptation is the capacity of a species to rapidly adapt genetically by virtue of a diverse gene pool. If local adaptation is the primitive adaptive mechanism in plants, variations in their traits and domination in different habitats between populations are due to local natural selection resulting in local genotypes that have a higher comparative fitness in their local habitat than genotypes originating from other habitats (KAWECKI & EBERT 2004).

The studied populations separated from each other and arranged separately. This subject

represents the difference between populations that was induced by morphological variations. Some characteristics such as stem height differed between populations and various statistical analyses such as trait PCA as well as std.deviation confirmed it. A probable reason for the stem length variation could be related to competition with neighboring plants. In competition with other plants, stem length is one of the main traits which varied in different habitat. Due to the nature of species, especially the dominant plants, differed in various stands, therefore members of different species, in order to increase the absorption of sunlight, changes their stem length (TALEBI *et al.* 2014). Plasticity for morphological characters, for example plant height or biomass, may play a role in competitive interactions (NAVAS & MOREAU-RICHARD 2005).

Some responses in plants, such as stem-elongation, provide an example of adaptive



**Fig. 5.** Box and whisker plots of the studied morphological traits of individuals. Populations abbreviations: 3 – Hasan Abad; 4 – Mazid Abad; 8 – Darakeh; 9 – Fasham; 11 – Peyghambar; 14 – Sangak; 15 – Sero; 16 – Varameh.

plasticity that could involve an opportunity cost. Increased stem elongation is beneficial between plants growing in dense stands because taller plants overtop their neighbors and have higher

lifetime light interception (WEINIG 2000) and fitness (SCHMITT *et al.* 1995; DUDLEY & SCHMITT 1996; WEINIG 2000). Elongation responses early in the life history may limit the duration

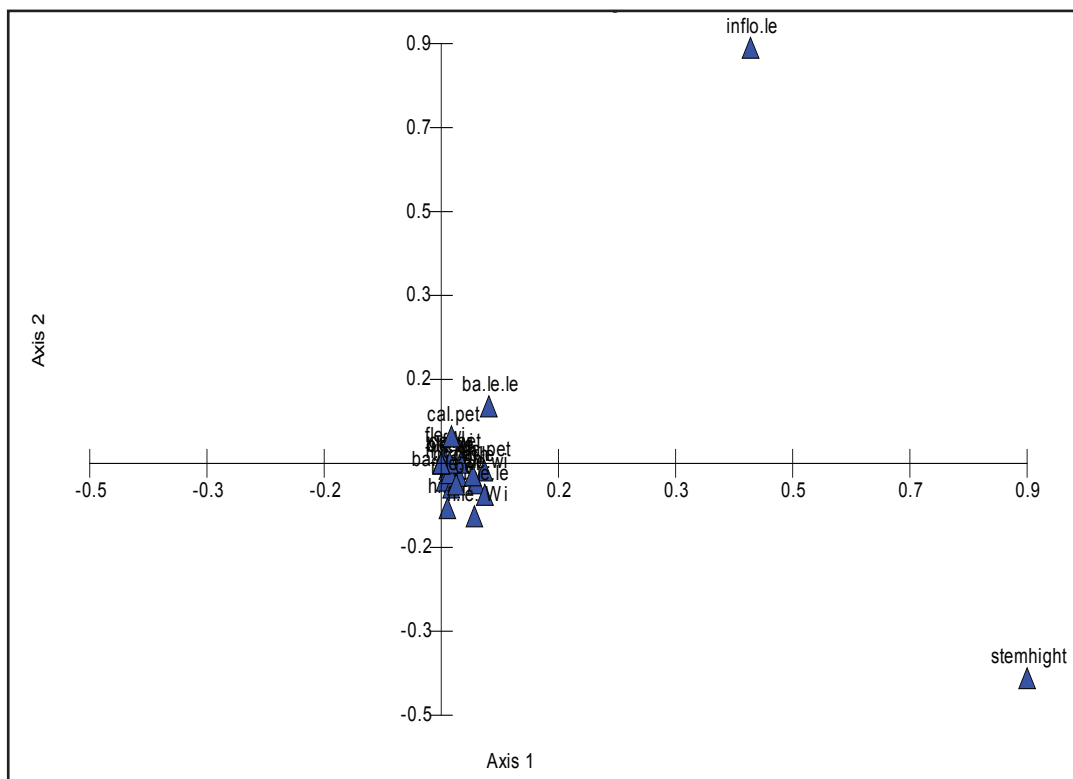


Fig. 6. PCA plot of the studied morphological traits.

of elongation or subsequent responsiveness because elongation lowers structural stability (SCHMITT *et al.* 1995) and reduces resource acquisition by decreasing allocation to resource-harvesting organs such as leaves (BALLARÉ *et al.* 1991; CIPOLLINI & SCHULTZ 1999) and roots (MALIAKAL *et al.* 1999).

In addition, foliar features, such as shape and dimension, varied between populations and ANOVA as well as one-sample T-Test confirmed these differences. Some of these characteristics such as basal and floral leaf shape had diagnostic value and were useful in identifying of some populations. In the studied species, like most plants, leaves are important organ for photosynthesis and food production and any change in their traits can influence all the plant body as well as their biomass. In addition it has a significant effect on seed production and population size. The relationship between the leaves shape and size and ecological factors has been shown for many

of species such as *Oncocyclus* (Siems.) Baker irises (SAPIR *et al.* 2002), *Rhizophora mangle* L. (RICO-GRAY & PALACIOS-RIOS 1996) and *Chuquiraga* Juss. section *Acanthophyllae* (DC.) Ezcurra (EZCURRA *et al.* 1997). For example, it was found that leaves of *Embothrium coccineum* J.R. Forst. et G. Forst. were apparently more influenced by climate, particularly water availability, than flowers. In addition, alternation in leaf morphology of *E. coccineum* has also been reported to reflect adaptive differences associated with specific climatic features across its whole distribution area (SOUTO *et al.* 2009). A common model reported for many species is a decrease in leaf dimension as environmental aridity increases, this condition representing an adaptive strategy because smaller leaves display lower evapotranspiration (PARKHURST & LOUCKS 1972; DUDLEY 1996).

Natural selection can act at different levels, or in different ways, resulting in independent trait evolution when different parts of a plant



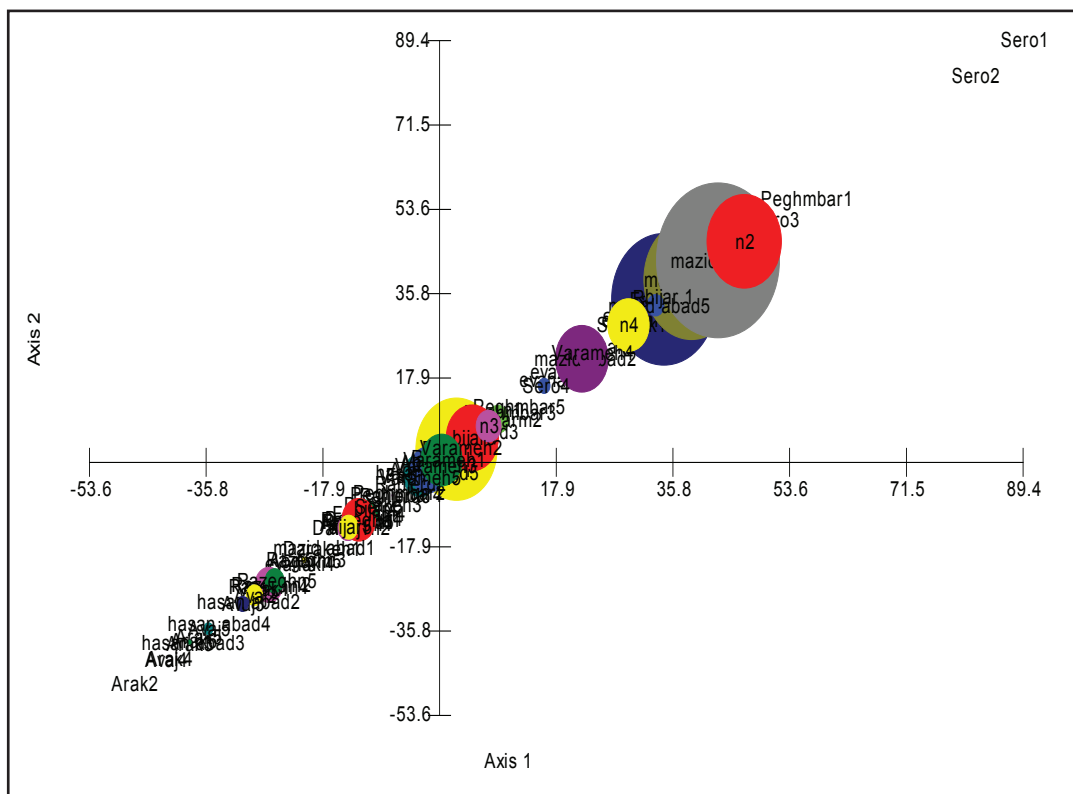


Fig. 8. PC0 plot of the studied individuals of populations based on morphological traits.

responses to environmental variation over small geographical scales. Altitudinal gradients are thus convenient scenarios to investigate such responses and key traits for plant functioning vary in a clinal fashion along elevation gradients. For instance, the reduction in overall plant size is the most conspicuous structural alteration observed along elevational gradients (KORNER *et al.* 1989). Different studies (e.g. KORNER 2003; BARET *et al.* 2004; WILLIS & HULME 2004) suggested that decreasing plant size as an adaptation to increasing altitude is a well-known phenomenon. It results from a slower growth rate as a response to harsher growing conditions and shorter season at high altitude (GRIME 1979; BENNINGTON & MCGRAW 1995). This decrease in plant height along with altitudinal elevation may prove advantageous for the species as the stem shortening allows plants to avoid the damaging effects of the strong

winds blowing at high altitudes and to improve photosynthetic conditions by keeping the leaves closer to the warmer soil surfaces (KORNER & COCHRANE 1983). The results of this study showed that plants growing at lower altitudes had taller inflorescences as compared to plants growing at higher altitudes as also previously revealed by JOHNSON & COOK (1968) as well as HICKMAN (1975).

## Conclusions

The obtained results showed that in the widespread species such as *A. graveolens*, morphological traits were able to change between different populations via phenotype plasticity phenomenon. In these conditions, different phenotypes were become visible between various samples of the same taxon. This was an adaptive response which was created

Fig. 9. UPGMA tree of the studied individuals of populations on the basis of morphological features. ▶



by plants in order to accordance with various environmental conditions that governed in their habitats. Not only these variations were significant between the populations, but also some of them had diagnostic values and were important for identification of populations. In addition, intrapopulation variations occurred in some populations and members of these populations separated from each other. In this condition morphological polymorphisms were seen between individuals. Several factors were involved for these differences. It may be possible that habitat heterogeneity is the most important factor for creation this subject.

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