Effects of climate and soil properties on phytochemical characteristics of *Ferulago angulate* (Schltdl.) Boiss

Khodabakhsh Safari, Mehrab Yadegari*, Behzad Hamedi

Department of Agronomy and Medicinal Plants, Faculty of Agriculture, Shahrekord Branch, Islamic Azad University, Shahrekord, Iran. PO. Box: 166

Abstract

This research investigated the effects of climate and soil on the content and components of essential oils in *Ferulago angulate* (Schltdl.) Boiss, belonging to the Apiaceae family. Aerial parts of plants were collected from three elevations (2500, 3000, and 3500 m above sea level) and three regions (Kallar Mountain from Boroujen, Mili Mountain from Koohrang, and Saldaran Mountain in Farsan, Chaharmahal and Bakhtiari province) with three replications. Results suggested that soil and climatic conditions had significant effects on the quantitative and qualitative properties of essential oils. The highest (0.65%) and the lowest (0.15%) levels of essential oils were obtained from elevation of Mountain Kallar (3000 m) and Mili Mountain (3500 m), respectively. Forty-four compounds were detected most of them being alpha-pinene, alpha-thujene, alpha-phellandrene, cis-ocimene, beta-phellandrene, beta ocimene, and nonadecane. As for regional variations, most of alpha-pinene (20.88%), beta ocimene (6.8%), cis-ocimene (23.6%) were recorded in the elevation of 3000 m from Saldaran Mountain and alpha-thujene (10.14%), alpha-phellandrene (3.49%), nonadecane (5.01%), and beta-phellandrene (7.57%) were obtained in the elevation of 3000 m from Kallar Mountain in clay loam soil texture. The lowest values were obtained from elevations of 3500 m in each region especially in sandy clay soil texture in Mili Mountain. It seems that the greater amount of nutrients was due to the presence of clay-loam texture, and the less environmental stresses and desirable soil enrichment in this elevation led to an increase in the essential oils content and components of this plant.

Keywords: elevation; environmental properties, essential oil, clay loam.

Safari, Kh. M. Yadegari and B. Hamedi.2019. 'Effects of climate and soil properties on phytochemical characteristics of *Ferulago angulate* (Schltdl.) Boiss. *Iranian Journal of Plant Physiology* 9 (2), 2719- 2726.

Introduction

The genus *Ferulago* belongs to Apiaceae family. *Ferulago* species are used in folk medicine for their sedative, tonic, digestive, and anti-parasitic effects (Özkan et al., 2008). Growth and development, quantitative and qualitative changes of the active ingredients of medicinal plants are guided by genetic processes, but the environmental factors of the growth region play a major role in this, causing significant changes in the growth of medicinal plants and active ingredients such as alkaloids, glycosides and essential oils (Yadegari et al., 2017). *Ferulago angulate* (Schltdl.) Boiss, locally noun as Chavill, belongs to the Apiaceae family and is one of the

*Corresponding author
E-mail address: mehrabyadegari@gmail.com
Received: May, 2018
Accepted: Julay, 2018

most valuable indigenous plants in west of Iran which is also distributed in Turkey, Syria, Lebanon, Iraq. The genus *Ferulago* is widely spread, with about 35 species in southern Europe and the Balkans. There are seven species of this plant in Iran (Mozaffarian, 2008). Most of these species are considered to be valuable plants. The species is morphologically herbaceous, persistent, and non-cracked. The stems are at an elevation of 60-150 cm, the grooves are generally canal, and the leaves are 50 to 100 cm long and 50 to 75 cm wide, with yellow petals, glabrous, inflorescence cluster and panicle, elliptical, and without fluff (Mozaffarian, 2008). *Ferulago angulate* is generally featured in mountainous regions, especially high mountains with rocky arenas and in pitches such as the rocky clefts. Growth of *Ferulago angulate* begins with melting of snow in the spring when the smell of its perfume can be perceived a few s away (Özkan et al., 2008).

In one study, 33 compounds that comprised 89.7% of the essential oil contents were identified, 77.1% of which being monoterpene and 12.6% sesquiterpenoids (Rustaiyan and Sedaghat, 2002) where the main compounds identified were alpha-pinene (17.3%), boronilate (14.5%) and cis-ocimene (14.4%). In another study, in the 24 identified compounds, the main components of the essential oil were cis-beta-ocimene (41.35%), alpha-pinene (18.2%), gama-terpinene (15.61%), and para-cymene (3.123%) (Özkan et al., 2008).

The effects of climate and topography on the quantity and quality of essential oils of medicinal plants are reported in several studies. There is a direct correlation between elevation and phenolic and flavonoids contents (Mozaffarian, 2008). The highest levels of growth and essential oil occur when the plant is in its flowering stage (Kizil and Toncer, 2006). Elevation and ecotype also has significant effects on morphological and biochemical characteristics. The amount of phenolic compounds and flavonoids, chlorogenic acid and caffeic acid in the nettle leaves increase with increasing elevation (Kremer et al., 2016). A significant relationship was also found between altitude and essential oil contents (Özkan et al., 2008; Rustaiyan and Sedaghat, 2002). In fact, the influence of environmental factors is reported on the essential oils of *Stachys* (Yadegari and Mohmmadian, 2015) and mint (Viljoen et al., 2006). This may be explained by the idea that with increasing altitude, there are major changes in rainfall, evaporation, and temperature. Therefore, the effect of elevation on soil texture causes numerous physiological changes in different plants (Omer, 2008).

The aim of this study was to evaluate the quantitative and qualitative changes of essential oils in *Ferulago angulate* under influence of climatic and soil type conditions and also at elevations of 2500, 3000, and 3500 meters in the mountains of Saldaran in Farsan, Mili in Koohrang and Kallar in Boroujen, all located in Chaharmahal and Bakhtiari province, southwest Iran.

Material and Methods

To account for the effects of environmental variations on growth of *F. angulate* in three mountainous areas, namely, Mili (Koohrang), Saldaran (Farsan), and Kallar (Borujen), shoots were collected from plants found at three elevations (2500, 3000, and 3500 meters above sea level) in Chaharmahal and Bakhtiari Province, southwest Iran during April-July 2016-2017, using a randomized complete design with three replicates per region.

Plant material were collected from natural populations at the end of vegetative stage in each region. The climatic and soil characteristics of the sampling regions are listed in Tables 1 and 2. Fresh aerial *F. angulate* tissues (20 plant in each region) were dried for 10 days at room temperature (25 ± 5 °C). Essential oils were extracted by heating 50 g of plant material in a 2 L flask containing 1 L water using a heating jacket at 100 °C for 3 h in a Clevenger-type apparatus according to the procedures outlined by the British Pharmacopoeia. Voucher specimens (FH No.1/99) were those described by Mozaffarian (2008), and were deposited in the Herbarium of the Center of Agricultural and Natural Resources of Chaharmahal and Bakhtiari Province, Shahrekord, Iran. The essential oil content (150 g dry matter in each sample) was estimated by the Clevenger apparatus and the active compounds were assayed using gas chromatography/mass spectrometry (GC / MS). The gas chromatograph

Table 1
Geographic and climatic properties in experimental site

Region	Average Minimum Temperature	Average Maximum Temperature	Average Annual Temperature	Average Annual Rainfall	Geographic Properties
	Centigrade			mm	
Saldaran Mountain	-1.4	24.5	12.1	516.9	32010/N-50030/E
Mili Mountain	-4.5	17.5	9.5	875.5	320 5/N-16051/E
Kallar Mountain	4	27.8	18.4	500	31, 82 N-50, 96 E

Table 2
Soil properties in the experimental sites

Elevation	Regions	Texture	pH	O.C	EC	B	Mn	Fe	Cu	Zn	N	K	P
				%	ds/m					mg/lit			
2500	Saldaran Mountain	Clay Loam	7.76	1.65	0.361	1.12	8.37	3.62	0.94	0.81	0.1	254	12.
3000		Clay Loam	7.2	1.5	0.21	1.3	7.7	2.12	0.97	0.92	0.3	259	13.
3500		Sandy Loam	7.1	1.4	0.11	1.2	5.6	1.3	0.45	0.55	0.1	148	9.9
2500	Mili Mountain	Clay	7.12	2.2	0.38	1.3	11.1	3.8	0.55	0.52	0.3	355	19.
3000		Sandy Clay	7.61	3.4	0.688	2.46	12.4	4.91	0.86	0.66	0.43	401	20.
3500		Sandy Clay	7.5	1.4	0.55	1.1	8.8	3.3	0.56	0.55	0.24	322	18.
2500	Kallar Mountain	Clay Loam	7.93	2.85	0.481	1.23	9.38	5.32	1.02	0.77	0.311	291	34.
3000		Clay Loam	7.7	4.4	0.33	1.4	9.7	5.6	1.4	0.85	0.44	312	37.
3500		Sandy Loam	7.1	1.9	0.35	0.92	8.2	4.8	1.1	0.79	0.27	255	25.

Table 3
Analysis of variation for the effects of elevations and regions on essential oil content and main essential oil components of *F. angulate*.

Source of Variation	Degree of freedom	Mean of Squares							
		Essential oil content	Alpha-Thujene	Alpha-Pinene	Alpha-Phellandrene	Beta-Phellandrene	Cis-Ocimene	Beta Ocimene	Nonadecane
Elevation	2	52455**	89.65**	127.54**	178.9**	28.09**	169.67**	18.45**	867.54**
Region	2	38795**	97.69**	145.9**	211.7**	34.56**	156.99**	22.89**	772.54**
Elevation× Region	4	67342**	43.67*	91.1*	72.2^{ns}	7.65*	88.34*	8.2*	112.3^{ns}
Error	18	797	15.21	23.1	41.6	2.68	19.4	2.2	80.1
Coefficient of Variation		23.1	14.05	21.12	14.4	19.8	21.3	22.74	17.7

ns,*, and ** : Non-significant, significant at 5%, and significant at 1% levels of probability, respectively

was of the Agilent type A7890, the type of HP-5 MS column with a length of 30 m, an inner diameter of 0.25 mm and a thickness of 0.25 µm. The initial temperature of the column was 60 °C and the final temperature was 280° C with helium gas at 0.8 ml / min. An increase in the temperature was set at 4 °C / min. Isolation ratio was set to 40: 1. The inlet temperature was 300° C. The gas carrying the column, helium with a purity of 99.9999%, was used for injection of 0.1 µl essential oil, using a Hamilton syringe. The ionization energy was selected in a mass spectrometer of 70 electron volts (Adams, 2007). Data analysis was performed using SAS ver.8 software and the means were analyzed using the least significant difference (L.S.D) method at 1% and 5% probability levels.

Results

Effects of area and elevation on quantitative and qualitative value of essential oil were significant at p<0.01 and 0.05 levels (Table 3). Forty-four compounds accounted for 69.41-95.15% of the total oil content (Table 4). The seven

Table 4
Chemical composition (%) of the essential oils of *F. angulate* in various climatic and soil conditions

No	Compound	R.I†	Kallar Mountain ×2500 m	Kallar Mountain × 3000 m	Kallar Mountain × 3500 m	Saldaran Mountain ×2500 m	Saldaran Mountain × 3000 m	Saldaran Mountain × 3500 m	Mili Mountain ×2500 m	Mili Mountain × 3000 m	Mili Mountain ×3500 m
1	Alpha-Thujene††	926	0.57	10.14	0.11	0.24	0.35	0.47	0.16	1.1	0.08
2	Alpha-Pinene	937	11.69	17.33	10.21	20.15	20.88	9.94	16.3	13.53	12.77
3	Beta-Pinene	977	1.13	1.87	1.4	2.08	1.61	1.91	1.84	1.15	1.74
4	Beta-Myrcene	986	2.32	1.12	1.45	2.67	2.68	2.94	2.55	2.08	2.75
5	Alpha-Phellandrene	1003	3.25	3.49	2.78	2.29	2.83	2.91	1.32	2.21	3.04
6	Beta-Phellandrene	1027	5.86	7.57	6.1	1.1	2.5	6.61	4.28	4.65	1.45
7	P-Cymene	1020	0.01	0.04	1.14	0.03	0.05	0.06	0.06	0.08	0.1
8	Delta 3-Carene	1025	1.75	1.6	0.19	0.37	1.75	0.01	1.1	1.93	1.03
9	Limonene	1030	0.91	7.1	0.12	2.38	2.19	2.2	1.73	1.81	1.97
10	Cis-Ocimene	1031	11.83	4.46	2.2	22.65	23.6	19.54	16.29	14.92	11.84
11	Thujene, 4	1041	4.75	3.84	1.21	3.11	3.2	4.31	4.12	5.01	3.44
12	Beta Ocimene	1053	1.64	2.56	0.18	4.41	6.8	3.9	0.22	3.58	3.33
13	Alpha-Terpinolene	1063	0.44	1.18	1.79	0.87	0.91	1.25	1.01	0.13	0.7
14	Terpinolene	1083	0.02	0.06	0.01	0.66	0.08	0.01	1.49	0.06	0.54
15	Linalyl Alcohol	1087	0.22	0.55	0.65	0.85	1.19	1.1	1.69	2.31	1.09
16	Camphene Bicyclo[2.2.1]Heptane	1095	1.13	0.77	0.59	1.25	0.83	1.14	1.16	1.22	1.47
17	2-Beta-Pinene	1120	1.13	1.01	0.99	2.08	2.01	1.91	1.84	1.15	1.17
18	Alloocimene Cis-Ocimene	1127	0.21	0.02	1.34	0.5	0.5	0.32	0.29	0.29	0.01
19	Cis-Verbenol	1131	1.16	0.02	1.01	0.39	0.52	0.33	0.67	0.4	0.81
20	Trans-Verbenol	1135	0.81	1.12	0.41	1.66	2.27	1.43	4.04	2.71	4.07
21	P-Mentha-1,5-Dien-8-Ol	1151	0.01	0.01	0.01	0.24	0.21	0.1	0.34	0.09	0.01
22	Sabinene $$ Bicyclo[3.1.0]Hexane	1192	3.6	2.5	2.83	1.02	1.17	2.99	1.09	1.11	1.02
23	Verbenone	1204	2.5	3.51	2.1	0.79	0.3	0.23	0.31	0.97	0.33
24	Beta-Citronellol	1210	0.77	0.82	0.55	0.8	0.8	0.53	1.58	1.12	1.05
25	Bornyl Acetate	1219	3.49	2.01	1.28	2.22	2.42	2.11	8.02	6.85	6.01
26	Z-Citral	1238	1.13	0.01	0.001	0.04	0.06	0.05	0.17	0.01	0.001
27	Borneol acetate	1267	3.49	4.11	3.87	2.22	2.42	2.69	4.79	5.13	4.93
28	Benzene, 1-Methyl-4-Methylethyl	1295	0.85	2.85	1.88	0.96	1.19	1.6	0.6	1.56	0.4
29	Alpha-Copaene	1366	0.81	1.23	1.32	1.06	0.1	0.86	0.1	0.2	0.01
30	Methyl eugenol	1401	0.87	0.01	0.01	0.4	0.67	0.62	0.6	0.93	0.74
31	Trans-Caryophyllene	1418	0.27	0.01	0.01	0.19	0.16	0.12	0.02	0.01	0.01
32	2-Naphthalenemethanol	1468	2.59	0.01	2.01	0.22	0.07	0.05	0.05	0.1	0.01
33	Germacrene D	1480	0.01	2.26	1.002	0.15	0.09	0.25	0.01	0.12	0.01
34	Bicyclogermacrene	1491	2.72	1.35	1.56	2.63	3.01	2.88	1.87	1.29	1.54
35	Delta-Cadinene	1506	0.62	0.65	1.31	0.72	0.75	1.38	0.3	0.27	0.1
36	Elemol	1543	0.01	0.01	0.84	0.26	0.23	0.17	0.58	0.29	0.37
37	Spathulenol	1580	0.91	0.01	0.01	0.32	0.82	1.33	0.5	0.31	0.01
38	Beta-Eudesmol	1652	0.01	0.01	1.01	0.22	0.07	1.13	0.07	0.17	0.34
39	Gamma-Curcumene	1785	0.01	0.02	1.01	0.39	0.28	0.25	0.05	0.15	0.51
40	Nonadecane	1900	2.42	5.01	4.01	0.18	3.03	0.11	1.02	2.01	0.001
41	Cis-Jasmone	1969	0.31	0.01	0.95	0.17	0.32	0.12	0.11	0.4	0.36
42	Ledol	2057	0.1	1.14	1.47	0.12	0.21	0.01	0.38	0.08	0.33
43	Heneicosane	2109	2.87	0.01	2.001	0.1	0.01	0.09	0.01	0.001	0.001
44	Heneicosane - Heneicosane	2115	2.87	0.31	2.49	0.1	0.01	0.09	0.01	0.001	0.001
Total			84.07	93.72	69.41	85.26	95.15	82.05	84.74	83.49	71.49
Essential oil content (w/w%, g/100g fresh weight basis)			%0.39	%0.65	%0.55	%0.38	%0.42	%0.39	%0.31	%0.25	%0.15

†RI: Retention Indices, as determined by FID and HP-5MS 5% capillary column using a series of the standards of C7-C30 saturated n-alkanes
††Values are means of triplicates

most abundant components comprising 25.59-59.99% of the essential oil content were cis-ocimene, alpha-pinene, alpha-thujene, alpha and beta- phellandrene, beta-ocimene, and nonadecane. Furthermore, based on dry weight, the yield (w/w) of the obtained essential oils ranged from 0.15-0.65% (Table 4). Meanwhile, the least abundant components were P-Cymene, P-Mentha-1,5-Dien-8-Ol, Germacrene D, Elemol, Beta-Eudesmol, and Gamma-Curcumene (5.012-0.93%). The highest levels of cis-ocimene (23.6%), alpha-pinene (20.88%) and beta-ocimene (6.8%) were obtained at the altitude of 3000 m in the Saldaran Mountain while the highest levels of alpha-thujene (10.41%), beta-phellandrene (7.57%), nonadecane (5.01%), and alpha-phellandrene (3.49%) were obtained from an elevation of 3000 m in the Kallar Mountain. The highest level of essential oil (0.65%) obtained at 3000 m from Kallar Mountain and the lowest

(0.15%) obtained at 3500 m in Mili Mountain (Table 4). The lowest values of cis-ocimene (2.2%), beta-ocimene (0.18%), and alpha-thujene (0.11%) were obtained at elevation of 3500 m above sea level (Kallar Mountain), alpha-pinene (9.94%) at 3500 m above sea level (Saldaran Mountain), beta-phellandrene (1.1%) at 2500 m (Saldaran Mountain), nonadecane (0.001%) at 3500 m above sea level (Mili Mountain) and alpha-phellandrene (1.32%) at 2500 m above sea level (Mili Mountain) (Table 4).

There were significant correlations between essential oil content with alpha-thujene, alpha-pinene, beta-pinene, p-cymene, delta-3-carene, limonene, terpinolene, cis-verbenol, verbenol, verbenone, beta-citronellol, and nonadecane at 99% probability level and with beta-myrcene and cis-ocimene at 95% probability level (Table 5). There were significant relationships between the amount of cis-ocimene and beta-thujene, alpha-terpinolene, terpinolene, beta-pinenen, cis- verbenol, verbenone, and nonadecane, and also between beta-phellandrene and beta-pinene and nonadecane. Significant relationships were also found between beta-ocimene and alpha- terpinolene, terpinolene, beta-pinene, cis- verbenol, verbenone, and nonadecane (at 99% probability level). Moreover, relationship between other essential oil components were also significant as shown in Table 5.

Table 5
Results of simple correlation between essential oil content and composition in *F. angulate* in various climatic and soil conditions

No	Essential oil (1)	Alpha-Thujene (2)	Alpha-Pinene (3)	Beta-Myrcene (4)	Beta-Pinene (5)	Alpha-Phellandrene (6)	P-Cymene (7)	Delta 3-Carene (8)	Limonene (9)	Cis-Ocimene (10)	Thujene, 4 (11)	Beta-Ocimene (12)	Alpha-Terpinolene (13)	Terpinolene (14)	Beta-Phellandrene (15)	2-Beta-Pinene (16)	Cis-Verbenol (17)	Trans-Verbenol (18)	Verbenone (19)	Beta-Citronellol (20)	Bornyl Acetate (21)	Nonadecane (22)
1	-																					
2	0.9**	-																				
3	0.9**	0.1	-																			
4	0.5*	0.1	0.2	-																		
5	0.9**	0.1	0.5*	0.11	-																	
6	0.2	0.2	0.4	0.3	0.2	-																
7	0.8**	0.2	0.5*	0.2	0.8**	0.9**	-															
8	0.9**	0.2	0.42	0.15	0.9**	0.9**	0.9**	-														
9	0.9**	0.3	0.41	0.17	0.4	0.4	0.88**	0.9**	-													
10	0.5*	0.6**	0.6**	0.2	0.3	0.3	0.84**	0.8**	0.9**	-												
11	0.3	0.6**	0.37	0.2	0.4	0.4	0.9**	0.9**	0.8**	0.9**	-											
12	0.2	0.7**	0.7**	0.2	0.4	0.9**	0.8**	0.3	0.9**	0.4	0.9**	-										
13	0.2	0.6**	0.3	0.2	0.4	0.3	0.9**	0.9**	0.77**	0.9**	0.9**	0.9**	-									
14	0.7**	0.3	0.37	0.7**	0.6**	0.9**	0.3	0.9**	0.9**	0.9**	0.8**	0.9**	0.9**	-								
15	0.2	0.1	0.7**	0.1	0.2	0.2	0.3	0.2	0.3	0.3	0.9**	-0.2	0.3	0.2	-							
16	0.2	0.6**	0.2	0.6**	0.4	0.8**	0.8**	0.8**	0.8**	0.8**	0.8**	0.8**	0.9**	0.8**	0.6**	-						
17	0.6**	0.2	0.7**	0.8**	0.6**	0.9**	0.3	0.6**	0.9**	0.9**	0.9**	0.9**	0.9**	0.9**	0.2	0.8**	-					
18	0.3	0.6**	0.37	0.65**	0.2	0.5*	0.5*	0.6**	0.8**	0.5*	-0.4	-0.5*	0.4	0.5*	0.3	0.1	0.5*	-				
19	0.7**	0.3	0.36	0.7**	0.7**	0.8**	0.7**	0.8**	0.7**	0.7**	0.6**	0.8**	0.6**	0.8**	0.4	0.3	0.8**	0.8**	-			
20	0.6**	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-		
21	0.3	0.1	0.1	0.6**	0.4	0.7**	0.5*	0.5*	0.5*	0.1	0.1	0.5*	0.5*	0.5*	0.2	0.4	0.5*	0.1	0.7**	0.4	-	
22	0.6**	0.7**	0.8**	0.6**	0.8**	0.3	0.6**	0.6**	0.2	0.6**	0.2	0.7**	0.2	0.6**	0.7**	0.35	0.6**	0.3	0.2	0.1	0.4	

ns: Not Significant; *and**: Significant at P≤0.05 and P≤0.01, respectively

Discussion

The quantity and quality of essential oil compounds can be influenced by climatic conditions, soil texture, plant organs, and plant growth stages. Various environmental factors such as the amount of nutrients in the soil, climatic conditions of the planting area, including elevation, temperature, and rainfall, and also harvest time are among the important factors affecting the amount of secondary metabolites of the plant (Mozaffarian, 2008; Maxwell and Jones, 2007). Conditions of growth caused a significant difference in plant essential oil yield. Quantitative and qualitative differences in essential oil components might result from differences in ecological characteristics of areas such as humidity, altitude, soil, and geographic factors (Yadegari et al., 2017). In a similar study on the varieties of artichoke and chicory, a direct relationship was found between elevation and the consequent effect of ecological stresses on the amount of phenolic and flavonoids. Most importantly, the enhancement of free radical and anti-free radicals and oxidation of the extract of these plants' genetic abilities led to changes in the quality and quantity of essential oils (Yadegari et al., 2018). In general, ecological factors, soil conditions, genetic factors, management factors, essential oil extraction methods, and plant traits are the most important factors affecting the quantity and quality of essential oils (Ghasemi Pirbaloti and Mohammadi, 2013). The highest and lowest values of essential oil of thyme was obtained at 1800 and 3000 meters, respectively, and a significant relationship was found between altitude and essential oil content (Yadegari et al., 2018). With increasing altitude, major changes occur in rainfall, evaporation, and temperature. The effect of elevation on soil texture leads to many physiological changes in different plants, such as the content of artemisin in *Artemisia annua* (Omer, 2008), the amount of antioxidants in vegetables (Kalt, 2005), the amount of phenolic substances in *Stachys* (Baczek et al., 2016; Ghasemi Pirbalouti and Mohammadi, 2013; Kremer et al., 2016; Yadegari et al., 2017), the composition of essential oils and antioxidant properties of mint (Viljoen et al., 2006) and oregano (Vokou et al., 1993). In medicinal plants, the quantity and quality of active ingredients are largely controlled by genetic factors. But environmental factors also play an important role (Kremer et al., 2016). In most cases, the role of habitat as an effective factor in the accumulation of secondary metabolites has been emphasized (Baczek et al., 2016). With an increase in elevation, increasing rainfall and the enrichment of nutrients in soil, the amount of essential oil and essential oil composition were more than other conditions that were similar to findings of the previous studies on mint (Viljoen et al., 2006), *Artemisia annua* (Omer, 2008), *Stachys* (Ghasemi Pirbalouti and Mohammadi, 2013; Kremer et al., 2016; Yadegari et al., 2017), *Cynara scolymus* (Yadegari and Yousefi, 2016), *Cirsium arvense* (Yadegari et al., 2018), and oregano (Vokou, 1993).

It has been reported earlier that phenolic compounds in vegetables are both quantitatively and qualitatively dependent on environmental factors such as temperature, and soil, in addition to factors such as harvest time and genetics (Kalt, 2005). Climate affects the growth and secondary metabolites of these plants (Maxwell and Jones, 2007). Various environmental factors such as the amount of nutrients in the soil, climatic conditions of the region such as elevation, temperature, and rainfall along with the harvest time are among the important factors affecting the amount of secondary metabolites in plants (Kremer et al., 2016).

In this research, with increasing altitude, a significant increase was observed in most of the major components of the essential oil up to 3000 meters in the Kallar Mountain although this increase was greatly influenced by the climate of this region. After this elevation in Kallar and Saldaran regions, significant reduction was observed in essential oils content and composition. In the mountain climate area with cold weather, a slight increase was observed in essential oil compounds up to 3000 meters, but the quantity decreased with a decrease in the elevation of the area. In addition to lowering the temperature in the three areas with the increase in the altitude, it was observed that the amount of soil available for planting decreased, which can be considered as the presence of higher environmental stresses due to elevation, including increase in wind severity, and wind and water erosion. In general, vegetative conditions cause a significant difference in the essential oil yield of the plant. Quantitative and qualitative differences in essential oil components can be due to the differences in the ecological characteristics of areas such as humidity and altitude from the sea surface or other soil and geographic factors (Yadegari et al., 2017, 2018). In medicinal plants, the quantity and quality of active ingredients are largely controlled by genetic factors. In most cases, the role of habitat as an effective factor in the accumulation of secondary metabolites has been emphasized (Figuieredo et al., 2008). The environment influences the type and severity of chemical reactions through the production of metabolites and factors associated with the production process (Baczek et al., 2016). Both climate and elevation affect the yield of essential oils obtained from medicinal plants. In this study, the percentages of organic matter, phosphorus, potassium, manganese, iron, copper, and zinc increased with increasing altitude and soil texture difference. At higher elevation, greater precipitation also increased plant growth (Tables 1 and 2). There were significant differences among the essential oil compositions of various samples, and there was a positive correlation between the essential oil content and components contained in each of the analyzed plant in various elevations. Contents of the main essential oil components (cis-ocimene, alpha-pinene, alpha-thujene, alpha and beta- phellandrene, beta-ocimene, and nonadecane) significantly correlated with the essential oil content of each plant in different elevation. The essential oil composition had a positive effect on the essential oil content (Table 5).

There was a positive and significant relationship between essential oil content and compositions in different regions and elevations. In this research, the most abundant essential oil components were alpha-thujene, alpha-pinene, cis-ocimene, and beta-phellandrene accounting for an average 25.59-59.99% of the total essential oil. The highest amount of essential oil (0.65%) was obtained at 3000 m in Kallar Mountain with clay loam soil texture and the lowest (0.15%) was at 3500 m in Mili Mountain with sandy clay soil texture. The highest amount (10.41%) of the main component (alpha-thujene) of the essential oils was obtained at 3000 m in Kallar Mountain. It seems that the reason for this was an accumulation of more nutrients in clay-loam soils, lack of environmental stresses and better growth temperatures during plant growth. Often in areas where the percentage of elements were higher, essential oil and active ingredients were also higher. This study provides useful information regarding the way elevation and regional variations and the content and composition of essential oil in *F. angulate* are related.

References

Adams, R.P., 2007. Quadruple Mass Spectra of Compounds Listed in Order of Their Retention Time on DB-5. In Identification of Essential Oil Components by Gas Chromatography/ Mass Spectroscopy'. 4th ed. IL 60188-2787. Allured publishing Corp, Carol Stream, USA.

Baczek, K., O. Kosavowska., L. Jaroslaw and **Z. Przibil.** 2016. 'Accumulation of phenolic compounds in the purple betony herb (*Stachys officinalis* L.) originated from cultivation'. *Herbal Botanica,* 62: 7-16.

Figuieredo, A.C., J.G. Barroso., L.G. Pedro and **J.C. Scheffer.** 2008. 'Factors affecting secondary metabolite production in plants volatile components and essential oils'. *Flavour and Fragrance Journal*, 23: 213-226.

Ghasemi Pirbalouti, A and **M. Mohammadi,** 2013. 'Phytochemical composition of the essential oil of different populations of *Stachys lavandula* folia'. *Asian Pacific Journal Tropical Biomedical,* 3:123-128.

Kalt, W. 2005. 'Effects of production and processing factors and major fruit and vegetables antioxidants'. *Journal of Food Science,* 70: 11-19.

Kizil, S and **O. Toncer,** 2006. 'Influence of different harvest times on the yield and oil composition of spearmint (*Mentha spicatal* Spicata)'. *Food Agricultural Environmental,* 4:135-137.

Kremer, D., V. Matevski and **V. Dunkic.** 2016. 'Essential oil contents and micro-morphological traits of *Stachys iva* and *S. horvaticii* Micevski (Lamiaceae)'. *Records of Natural Products,* 10: 228-39.

Maxwell, A and **P. Jones,** 2007. 'Factors affecting the growth and secondary metabolism of medicinal plants'. Mississippi State, North Mississippi Research and Extension Center. 5421 S Hwy 145, Verona, MS 38879.

Mozaffarian, V. 2008. A Pictorial Dictionary of Botany Botanical Taxonomy Latin-English-French-Germany-Persian, Germany: Koeltz Scientific Books.

Omer, A. 2008.' Effect of soil type and seasonal variation on growth, yield, essential oil and artemisin content of *Artemisia annua* L.' *International Research Journal of Horticulture,* 1: 15-27.

Özkan, A.M.G., B. Demirci., F. Demirci and **K.H.C. Baser.** 2008. 'Composition and antimicrobial activity of essential oil of *Ferulago longistylis* Boiss. *Journal of Essential Oil Research,* 20: 569-73.

Rustaiyan, A and **S. Sedaghat.** 2002. '*Ferulago angolata* (Schlecht) Boiss. from Iran'. *Journal of Essential Oil Research,* 146: 447-510.

Viljoen, A.M., S. Petkar and **S.F.A. Van Vuuren.** 2006. 'Chemo geographical variation in essential oil composition and the antimicrobial properties of *Mentha longifolia* sub sp. polyadena in southern Africa'. *Journal of Essential Oil Research,* 18: 60-65.

Vokou, D., S. Kokkini and **J.M. Bessiere.** 1993. 'Geographic variation of Greek oregano (*Origanum vulgare* ssp) essential oils'. *Biochemistry System Ecology,* 21: 287–295.

Yadegari, M and **F. Mohmmadian.** 2015. 'Ecological diversity and phytochemical properties medicinal plant (*Stachys pilifera*) in Kohgiluyeh and Boyer-Ahmad province'. *International Journal of Biology Pharmacy Allied Science,* 4: 182-188.

Yadegari, M and **S. Yousefi.** 2016. 'Effects of environmental conditions on morphological and physiological characters of *Cynara scolymus'. Bangladesh Journal of Botany,* 45:605-10.

Yadegari, M., M. Alimohammadi and **H.A. Shirmardi.** 2017. 'Effect of elevation and phenological stages on essential oil composition of *Stachys*'. *Turkish Journal of Biochemistry,* 42:647-656.

Yadegari, M., N. Amiri and **B. Hamedi.** 2018. 'Essential oil composition of *Cirsium arvense* L. produced in different climate and soil properties'. *Record of Natural Products,* 12:251-62.