



ISSN Print: 2394-7500
 ISSN Online: 2394-5869
 Impact Factor: 8.4
 IJAR 2020; 6(12): 216-221
www.allresearchjournal.com
 Received: 08-10-2020
 Accepted: 10-11-2020

Shalini Singh
 Department of Chemistry,
 Uttarakhand Open University
 Vishwavidhyalaya Marg,
 Haldwani (Nainital),
 Uttarakhand, India

Correlation studies among soil properties, climatic conditions and essential oil constituents of *Origanum vulgare* L. from Central Himalaya, India

Shalini Singh

DOI: <https://doi.org/10.22271/allresearch.2020.v6.i12d.8086>

Abstract

Environmental conditions and soil properties plays important role to regulate the plant metabolism. Considering the importance of essential oil of *Origanum vulgare* L., this study was done to understand the oil profile with microclimatic conditions and soil properties in wild conditions. The plant materials were collected from ten sites of Uttarakhand, India with their soil samples. Correlation was established among essential oil major constituents, micro and macronutrients, microclimatic conditions, physical properties of soil by using Microsoft Excel XP. Available nitrogen in soil was positively correlated with linalool, bornyl acetate, (*E*)-caryophyllene, germacrene D and β -bisabolene while negatively correlated with thymol. Thymol and caryophyllene oxide were found to be positively correlated with available potassium. Available Zn was positively correlated with β -bisabolene. Total iron (Fe) present in the soil was found to be positively correlated with total p-cymene and γ -terpinene in the oils. pH of soil was found to be negatively correlated with thymol and positively correlated with elemol. Percent organic carbon (OC%) was negatively correlated with p-cymene, (*E*)-ocimene and caryophyllene oxide. In our study water holding capacity is positively correlated with caryophyllene oxide. The results of present study indicate the significant role of macro and micronutrients and other soil properties on the essential oil composition.

Keywords: Essential oil, microclimatic conditions, macronutrients, micronutrients, *Origanum vulgare* L.

Introduction

Origanum vulgare L. (family Labiateae; Lamiaceae), is a multipurpose medicinal plant commonly known as Bantulsi, oregano or Himalayan marjoram in India [1]. It is widely distributed in the mild and temperate climate of Eurasia, North Africa and America from 7000 to 12,000 ft. [2-3]. It is 20-80 cm high, erect, perennial and aromatic herb with ovate, entire, stalked leaves 1-4 cm and small pale pink flowers [4]. *Origanum vulgare* L. is the only species of the genus *Origanum* which is found in India [3]. *Origanum* is used as herbal tea spices salads, sausages olives in meat by local people. Since ancient times, *O. vulgare* L. has been used as stimulant, stomachic, analgesic, expectorant, sedative, antiparasitic, carminative and diaphoretic [5-6]. A number of reports have been published on the antimicrobial, antifungal, antiviral, analgesic, antioxidant and anti-inflammatory activities of *Origanum vulgare* L. [7-13]. The essential oil of *O. vulgare* has been widely studied from many countries [14-16].

The most important biologically active compounds reported to be present in *O. vulgare* are carvacrol and thymol followed by γ -terpinene, p-cymene, linalool and terpinen-4-ol. Among these, γ -terpinene and p-cymene are supposed to be the biological precursors of the phenolic monoterpenes [1]. Four chemotypes carvacrol, (*Z*)- α -bisabolene, linalyl acetate and caryophyllene oxide/germacrene D/(*E*)- β -caryophyllene were investigated from Iranian *Origanum vulgare* L. grown under similar conditions [17]. De Martino *et al.* in 2009 reported three chemotypes of *O. vulgare* L. growing wild in Campania (Southern Italy) which were rich in carvacrol/thymol, thymol/ α -terpineol and linalyl acetate/linalool [18]. The essential oil composition of aromatic plants depends upon various environmental factors like nature of soil, climatic conditions, altitude, temperature, moisture and harvesting conditions [19-20]. The content of macro and micronutrients in the soil as well as in the plants are the one of the

Corresponding Author:
Shalini Singh
 Department of Chemistry,
 Uttarakhand Open University
 Vishwavidhyalaya Marg,
 Haldwani (Nainital),
 Uttarakhand, India

important factors, which affects the essential oil composition of aromatic and medicinal plants. They play a very important role in the biogenetic pathways of different secondary metabolites of the oil. Kaniyas *et al.* (1998) [21] reported that iron, chromium, and scandium showed a negative significant correlation with carvacrol and positive one with thymol. Application of phosphorus in nutrient solution was found to increase the percentage of p-cymene accompanied by a decrease in the percentage of carvacrol in the case of leaves of *O. dictamnus* [22]. Effect of nitrogen fertilization on the essential oil of *O. vulgare* L. has been reported by Said-Al Ahl *et al.* (2009) [23].

To the best of our knowledge no work has been reported on the effect of soil and geographic conditions on the essential oil composition of the wild *O. vulgare* L. in Uttarakhand. Therefore, the aim of present study is to explore the effect of soil and microclimatic conditions on this important genus.

Materials and methods

1. Plant material and soil samples

Collection of plant material (at full blooming stage) along with its soil samples (0-20 cm) were done from ten sites of Kumaun Himalayan region. The plants specimens were authenticated at Botany Department, Kumaun University, Nainital (Voucher no.-2036). The geographical and climatic conditions are given in Table 1.

2. Determination of physicochemical properties of soil

Soil texture was determined by using International hydrometer method using sodium meta phosphate (5%) as dispersing agent (Kilmer and Alexander, 1949) [24]. Measurement of the soil pH and electrical conductivity (EC) of the soil suspension (1:2 soil and water ratio) was done by using pH meter and EC meter (Jackson, 1958) [25]. Soil organic-carbon (%OC) content was determined by using Walkley and Black method described by Jackson (1958) [25]. Cation exchange capacity (CEC) was determined by the NH₄⁺ saturation method given by Chapman. Water holding capacity (WHC) of the soils was determined by using Hilgard apparatus (Black, 1965) [26]. Total nitrogen (N), available phosphorus (P₂O₅) and available potassium (K) were determined by using Kjeldahl method, Olsen's method and flame photometer respectively.

3. Soil sample preparation for micronutrient analysis.

Sample for the analysis of total metal content (Piper, 1942) [27] in soil were prepared by digestion with HClO₄-HF method. 1.0g of soil wetted with 5ml distilled water. 2ml of HClO₄ and 12 mL of HF added and heated till dryness. Now 2 mL of HClO₄ and 5 mL of distilled water were added and heated to dryness residue was dissolved in 8 mL of HCl and 20 mL of water and distilled water was added to make up the volume 50 mL.

The procedure developed by Lindsay and Norvell (1978) [28] was followed to prepare soil samples for available metal content. 20 mL extracting solution (0.005M DTPA + 0.1M triethanolamine + 0.01M CaCl₂) was added to 10g soil taken in a conical flask. Suspension in flasks was shaken for two hours at a speed of 120 cycles per minute on a horizontal shaker. After shaking, the suspension was filtered through a Whatman no. 42 filter paper.

4. Heavy metal analysis in soil samples

Atomic absorption spectrophotometer (GBC-902 and Avanta sigma Models) was used to analyze the Zn, Cu, Mn, and Fe.

5. Statistical analysis

Experimental data were processed using Microsoft Excel XP. Correlation coefficients were calculated among oil major constituents, micro and macronutrients, microclimatic conditions and physical properties of soil. Significance level of correlation coefficient was checked on probability level of p<0.05 and p<0.01.

Results and discussion

1. Physicochemical parameters of the soil samples

The soil samples were analysed for their physicochemical properties (Table 2). The analysis was done in triplicate and represented as the mean value ± standard deviation (±SD). The soils were loamy sand and sandy loam. They were acidic to neutral in nature (pH 5.31 to 7.41). The EC, OC %, CEC and WHC values of most of the soil samples were observed to be within the limits. Furthermore, macro and micronutrients content also falls within the permissible limits.

2. Essential oil components

The major components in the essential oils of the *O. vulgare* L. collected from ten sites have already been reported in our previous studies (Pande *et al.*, 2012; Singh *et al.*, 2013) [29-30] Mukteshwer, Rushi village and Kilbury, Nainital, Mussoorie collections were found to be rich in linalool (5.1%-9.7%), germacrene D (6.3%-18.00%), (*E*)-caryophyllene (9.2%-16%) and bornyl acetate (12.6-18.6%). Thymol (5.1%), germacrene D (5.7%), carvacrol (7.5%), α-cadinol (9.3%), (*E*)-caryophyllene (10.4%) and linalool (10.9%) were the major components obtained from the oil of Ramgarh. The oil collected from Dhoulchina and Champawat were rich in p-cymene (6.7-9.8%), γ-terpinene (12.4-14.0%), carvacrol (12.4%-20.9%) and thymol (29.7-35.1%). The composition of oil from Dharchula and Munsiyari showed the remarkable presence of thymol (30.2-55.1%) followed by aliphatic hydrocarbons (12.8-35.1%) and caryophyllene oxide (7.5-7.6%).

3. Correlation of soil properties with essential oil components

Simple correlation coefficients (r²) shown in Table 3 the soil pH was found to be negatively correlated with thymol (r²= -0.671, P<0.05) and positively correlated with elemole (r²= 0.647, P<0.05). Percent organic carbon represent negative correlation with p-cymene (r²= -0.759, P<0.05), γ-terpinene (r²= -0.692, P<0.05) and caryophyllene oxide (r²= -0.698, P<0.05). The study done by Dunford Vazquez (2005) [31] to correlate the effect of moisture on Mexican oregano showed that amount of water received by the plant did not have any significant effect on thymol and carvacrol of the oil. In our study, water holding capacity was positively correlated with caryophyllene oxide (r²=0.633, P<0.05).

4. Correlation of macronutrients with essential oil components

According to simple correlation coefficients (r²) shown in Table 4 the available nitrogen was positively correlated with linalool (r²=0.672, P<0.05), bornyl acetate (r²=0.642, P<0.05), (*E*)-caryophyllene (r²=0.684, P<0.05), germacrene D (r²=0.674, P<0.05) and β-bisabolene (r²=0.649, P<0.05) while negatively correlated with thymol (r²= -0.842, P<0.01). Arabaci *et al.* (2007) [32] reported that nitrogen fertilizer increased the linalool content in the essential oil of

Lavandula hybrid which also support our result in natural conditions. Omer (1999) [33] reported that nitrogen fertilization increased the biosynthesis of thymol and carvacrol while in our result, natural nitrogen concentration was negatively correlated with thymol. Available potassium was found to be positively correlated with thymol ($r^2=0.709$, $P<0.05$) and caryophyllene oxide ($r^2=0.642$, $P<0.05$) (Table 4).

5. Correlation of micronutrients with essential oil components

Available Zn in soil was positively correlated with β -bisabolene ($r^2=0.644$, $P<0.05$). (Table 5). Kaniyas, *et al.* (1998) [21] reported that chromium, iron and zinc are responsible for variation of the concentration of thymol, carvacrol and δ -cadinene. As zinc participates in photosynthesis and saccharide metabolism, and as CO₂ and glucose is the most likely sources of carbon utilized in terpene biosynthesis, the role of zinc becomes very important in the terpenoid biosynthesis [34]. Total iron (Fe)

present in the soil was found to be positively correlated with total p-cymene ($r^2=0.693$, $P<0.05$) and γ -terpinene ($r^2=0.736$, $P<0.05$). (Table 6). Kaniyas *et al.* (1998) [21] found positive correlation between iron and carvacrol in *O. vulgare* collected from Greece. Available Iron is positively correlated with germacrene D ($r=0.636$, $P\leq 0.05$) and elemol ($r=0.759$, $P\leq 0.05$) (Table 7). Iron plays a very important role in plant metabolism [35]. It activates catalase enzymes associated with superoxide dismutase, photorespiration and the glycolate pathway. Role of micronutrients, altitude on essential oil composition has been studied by Singh *et al.* (2013) In this study essential oil of *Craniotome furcata* altitude seems one of the important factors influencing the percent variation of germacrene D [36]. Under warm conditions the percentage of (*E*)-caryophyllene found more in essential oil composition of *Ocimum ammericanum* [37]. In present study, no significant correlations were found between concentration of Mn (Table 7), Cu (Table 8), altitude of site and temperature (Table 9) with essential oil components.

Table 1: Geographic and climatic conditions of collection sites

Districts	Dehradun	Nainital					Pithoragarh		Almora	Champawat
Geographic and climatic conditions	Mussoorie	Mukteshwar	Kilbury	Nainital	Ramgarh	Rushi	Munsiyari	Dharchula	Dhoulchina	Champawat
Altitude (m)	2333	2286	2134	2100	1789	1600	2235	2183	1800	1650
Temperature (°C)	20	18	23	22	23	28	25	22	24	26
Latitude/longitude	30° 27' N: 78° 06' E	29°28'N: 79°39'E	29°23'N: 79°30'E	29°23'N: 79°30'E	29°23'N: 79°30'E	29°23'N: 79°30'E	30°04'37"N: 80°23'04"E	29°51'00"N: 80°31'60"E	29°37'N:79°4 0'E	29°36'N:79° 30'E
Sun/Shady side	Sunny	Shady	Sunny	Sunny	Shady	Shady	Sunny	Sunny	Shady	Sunny

Table 2: Physicochemical properties of collected soil samples

Districts	Dehradun	Nainital					Pithoragarh		Almora	Champawat
Soil Properties	Mussoorie	Mukteshwar	Kilbury	Nainital	Ramgarh	Rushi	Munsiyari	Dharchula	Dhoulchina	Champawat
Soil Texture	Sandy loam	Loamy sand	Loamy sand	Loamy sand	Sandy loam	Loamy sand	Sandy loam	Sandy loam	Sandy loam	Loamy sand
Soil pH (1:2)	7.40±0.11	7.41±0.10	7.32±0.11	5.60±0.61	6.62±1.00	6.22±0.61	5.41±0.20	5.31±0.40	5.81±0.20	6.30±0.30
Organic carbon (%)	3.00±0.70	2.65±0.35	1.21±0.30	3.23±0.07	3.15±0.04	3.90±0.61	4.20±0.40	4.10±0.71	1.70±0.40	0.60±0.30
Electrical conductivity (dS cm ⁻¹)	0.18±0.01	0.34±0.02	0.10±0.00	0.07±0.00	0.19±0.01	0.10±0.00	0.11±0.02	0.20±0.00	0.12±0.02	0.05
Cation exchange capacity (c mol kg ⁻¹)	18.11±0.21	38.11±0.30	19.72±0.20	25.83±0.51	15.12±1.38	16.31±1.21	27.30±2.01	10.30±0.20	10.31±0.29	27.36±0.79
Water holding capacity (%)	58.31±0.60	46.10±1.50	49.71±2.19	39.61±1.56	35.10±0.19	38.21±1.65	54.59±1.68	56.00±2.50	37.87±2.26	39.69±0.47
Available nitrogen(kg/hc)	0.012±0.29	0.0138±0.03	0.011±0.09	0.009±0.25	0.012±1.54	0.012±0.67	0.008±0.50	0.004±0.01	0.005±1.34	0.009±0.78
Total nitrogen(kg/hc)	0.250±0.01	0.350±0.03	0.210±0.01	0.180±0.02	0.300±0.03	0.240±0.05	0.280±0.06	0.300±0.05	0.200±0.00	0.280±0.01
Available phosphorus(kg/hc)	0.0009±0.00	0.0024±0.00	0.0037±0.00	0.0014±0.00	0.0033±0.00	0.0007±0.00	0.0011±0.00	0.0030±0.00	0.0026±0.00	0.0009±0.00
Available potassium(kg/hc)	0.02±0.001	0.010±0.001	0.03±0.010	0.01±0.001	0.020±0.010	0.00±0.002	0.02±0.010	0.24±0.030	0.02±0.020	0.020±0.001
Total Zn content (mg kg ⁻¹)	54.280±0.57	91.680±0.43	45.280±1.42	40.500±2.13	35.280±0.67	26.880±1.17	38.670±0.88	35.050±0.91	32.150±0.48	43.620±0.63
Total Fe content (mg kg ⁻¹)	522.060±1.79	559.250±2.94	528.870±6.99	536.480±0.49	526.470±8.85	516.860±4.09	519.330±1.03	525.630±5.03	543.640±14.00	564.450±12.87
Total Mn content (mg kg ⁻¹)	220.900±0.59	348.020±1.42	252.010±0.62	264.400±0.59	219.350±0.04	84.150±1.82	165.000±0.85	160.100±1.63	194.620±0.50	185.810±2.18
Total Cu content (mg kg ⁻¹)	19.830±0.88	15.550±0.22	34.680±0.27	15.300±0.59	10.830±0.88	10.700±1.75	24.630±0.68	23.400±0.35	15.500±1.15	12.900±0.71
Available Zn content (mg kg ⁻¹)	4.980±2.35	10.260±0.67	9.450±1.18	7.370±0.99	0.800±0.40	0.650±0.24	0.950±0.32	0.780±0.05	0.610±0.32	1.240±0.28
Available Fe content (mg kg ⁻¹)	91.700±1.39	57.980±0.37	29.940±0.81	28.770±2.42	33.280±0.7	29.000±0.4	30.000±0.95	36.680±2.35	22.650±1.98	35.380±0.55
Available Mn content (mg kg ⁻¹)	17.110±0.42	17.400±0.08	14.560±0.51	15.430±0.42	10.000±0.11	3.000±0.91	6.200±0.63	14.280±0.48	7.080±0.43	6.680±0.23
Available Cu content (mg kg ⁻¹)	1.820±0.01	7.330±0.25	2.260±0.01	1.830±0.60	0.400±0.28	0.320±0.02	0.900±0.06	1.120±0.01	0.150±0.09	0.530±0.50

Table 3. Correlation matrix (r^2) between physical properties of soil and major constituents of essential oil

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
pH	EC	OC %	CEC	Moisture content	p-Cymene	γ -Terpinene	Linalol	Bornyl acetate	Thymol	Carvacrol	(E)-Caryophyllene	Germacrene D	Bicyclic germacrene	β -Bisabolene	Elemol	Caryophyllene oxide	Aliphatic hydrocarbons
1.00	0.398	-0.422	0.311	0.094	-0.100	-0.116	0.544	0.509	-0.671*	-0.233	0.470	0.578	0.045	0.521	0.647*	-0.541	-0.562
	1.00	0.406	0.137	0.305	-0.611	-0.524	0.218	0.259	-0.241	-0.377	0.177	0.391	0.167	0.283	0.472	0.254	-0.058
		1.00	-0.151	0.299	-0.759*	-0.692*	-0.097	0.048	0.047	-0.527	0.023	0.190	0.212	0.108	0.159	0.698*	0.542
			1.00	0.036	-0.001	0.031	-0.017	0.370	-0.313	-0.348	0.180	0.180	0.093	0.347	0.253	0.006	0.077
				1.00	-0.392	-0.546	-0.482	-0.070	0.233	-0.508	-0.308	0.067	-0.283	0.025	0.259	0.633*	0.528
					0.151	0.130	0.406	0.614	-0.446	-0.279	0.541	0.184	0.010	0.499	0.135	-0.449	-0.369
					-0.209	-0.304	-0.440	-0.508	0.325	0.033	-0.575	-0.100	-0.228	-0.412	0.085	0.495	0.558
					-0.035	0.037	-0.393	-0.510	0.586	0.392	-0.480	-0.372	-0.066	-0.483	-0.369	0.441	0.269

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level.

Table 4. Correlation matrix (r^2) between macronutrients and major constituents of essential oil

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
N (av)	N (total) %	P ₂ O ₅ % (av)	K ₂ O % (av)	p-Cymene	γ -Terpinene	Linalol	Bornyl acetate	Thymol	Carvacrol	(E)-Caryophyllene	Germacrene D	Bicyclic germacrene	β -Bisabolene	Elemol	Caryophyllene oxide	Aliphatic hydrocarbons
1.00	0.270	-0.146	0.626	-0.329	-0.275	0.672*	0.642*	-0.842**	-0.488	0.684*	0.674*	0.344	0.649*	0.628	-0.424	-0.389
	1.00	0.097	0.260	-0.117	-0.189	-0.233	-0.068	0.217	-0.167	-0.341	-0.159	-0.291	-0.160	0.140	0.378	0.245
		1.00	0.368	-0.158	-0.218	0.323	-0.121	0.067	0.133	0.040	-0.320	-0.068	-0.267	-0.381	0.021	-0.143
			1.00	-0.158	-0.262	-0.488	-0.359	0.709*	-0.089	-0.470	-0.425	-0.267	-0.383	-0.304	0.642*	0.314

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level.

Table 5. Correlation matrix (r^2) among zinc (Zn) in soil with major constituents in oil

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Zn total	Zn DTPA	p-Cymene	γ -Terpinene	Linalool	Bornyl acetate	Thymol	Carvacrol	(E)-Caryophyllene	Germacrene D	Bicyclic germacrene	β -Bisabolene	Elemol	Caryophyllene oxide	Aliphatic hydrocarbons
1.00	0.732*	-0.122	-0.073	0.075	0.416	-0.335	-0.301	0.173	0.353	0.012	0.418	0.516	-0.045	-0.177
	1.00	-0.305	-0.247	0.429	0.630	-0.609	-0.493	0.610	0.494	0.283	0.644*	0.410	-0.211	-0.341
		-0.136	-0.200	-0.097	0.187	-0.197	-0.424	0.033	0.205	0.019	0.228	0.337	0.118	0.059

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level.

Table 6. Correlations matrix (r^2) among iron (Fe) in soil with major constituents in oil

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fe total	Fe DTPA	p-Cymene	γ -Terpinene	Linalool	Bornyl acetate	Thymol	Carvacrol	(E)-Caryophyllene	Germacrene D	Bicyclic germacrene	β -Bisabolene	Elemol	Caryophyllene oxide	Aliphatic hydrocarbons
1.00	-0.011	0.693*	0.736*	-0.157	-0.034	0.121	0.449	-0.163	-0.223	-0.119	-0.094	-0.111	-0.387	-0.380
	1.00	-0.244	-0.236	-0.027	0.180	-0.300	-0.352	0.090	0.636*	0.140	0.382	0.759*	-0.055	-0.176
		0.538	0.621	-0.059	0.040	-0.136	0.319	0.036	0.157	0.142	0.134	0.162	-0.514	-0.502

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level.

Table 7. Correlation matrix (r^2) among manganese (Mn) in soil with major constituents in oil

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mn total	Mn DTPA	p-Cymene	γ -Terpinene	Linalool	Bornyl acetate	Thymol	Carvacrol	(E)-Caryophyllene	Germacrene D	Bicyclic germacrene	β -Bisabolene	Elemol	Caryophyllene oxide	Aliphatic hydrocarbons
1.00	0.772*	-0.118	-0.40	0.300	0.229	-0.405	-0.143	0.329	0.255	0.356	0.258	0.167	-0.204	-0.308
	1.00	-0.420	-0.381	0.176	0.216	-0.280	-0.446	0.319	0.418	0.398	0.343	0.328	0.056	-0.237
		-0.328	-0.258	0.424	0.618	-0.619	-0.598	0.659*	0.523	0.450	0.656*	0.392	-0.188	-0.330

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level.

Table 8. Correlation matrix (r) among copper (Cu) in soil with major constituents in oil

1	2	4	5	6	7	8	9	10	11	12	13	14	15	16
Cu total	Cu DTPA	p-Cymene	γ -Terpinene	Linalol	Bornyl acetate	Thymol	Carvacrol	(E)-Caryophyllene	Germacrene D	Bicyclic germacrene	β -Bisabolene	Elemol	Caryophyllene oxide	Aliphatic hydrocarbons
1	1.00	-0.236	-0.284	-0.061	0.021	-0.232	-0.284	0.047	0.548	0.110	0.255	0.582	-0.043	0.059
2		1.00	-0.278	-0.201	0.170	0.559	-0.375	-0.419	0.301	0.366	0.040	0.521	0.492	0.040
3			-0.217	-0.349	0.049	0.115	-0.204	-0.274	0.087	-0.005	-0.176	0.091	-0.023	0.133

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level.

Table 9. Correlation matrix (r^2) between microclimatic conditions and major constituents of essential oil

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Altitude	Temp	p-Cymene	γ -Terpinene	Linalol	Bornyl acetate	Thymol	Carvacrol	(E)-Caryophyllene	Germacrene D	Bicyclic germacrene	β -Bisabolene	Elemol	Caryophyllene oxide	Aliphatic hydrocarbons
1	1.00	0.774*	-0.577	-0.626	-0.058	0.152	-0.077	-0.567	0.153	0.321	0.066	0.271	0.251	0.397
2		1.00	-0.194	-0.336	-0.692*	-0.533	0.706*	-0.085	-0.693*	-0.607	-0.388	-0.583	-0.458	0.915**
3			1.00	0.393	0.345	-0.286	-0.233	0.238	0.290	-0.379	-0.471	-0.252	-0.319	0.074
4				1.00	0.054	0.516	0.496	-0.623	-0.223	0.644*	0.704*	0.540	0.627	0.562

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level.

Conclusion

The results of correlation analysis favor that essential oil composition of plants growing in wild conditions are affected by variation in soil and environmental conditions. Nitrogen and zinc in soil positively affect biosynthesis of β -bisabolene while potassium increases the amount of thymol and caryophyllene oxide and iron p-cymene and γ -terpinene in the collected plant material. Acidic soils, will be more favorable for the synthesis of elemol as compared to other essential oil constituents. Organically poor soil, the plant synthesized more p-cymene, (E)-ocimene and caryophyllene oxide.

References

- Ashfaquallah S, Tamta S. Studies on high value medicinal plant- *Origanum vulgare* LA, review International Journal of Research and Analytical reviews 2018;6(1):39-44.
- Ietswaart JH. A taxonomic revision of the genus *Origanum* (Labiataea), Leiden Botanical series, Lei University Press, The Hague, Leiden, Vol. 4 (1980).
- Chishti S, Kaloo ZA, Sultan P. Medicinal importance of genus *Origanum*: A review Journal of Pharmacognosy and Phytotherapy 2013;5(10):70-177.
- Chalchat JC, Pasquier B. Morphological and chemical studies of *Origanum* Clones: *Origanum vulgare* L. ssp. *vulgare* Journal of. Essential Oil Research 1998;10(2):119-125.
- Vokou D, Kokkini S, Bessiere JM, Geographic variation of Greek oregano (*Origanum vulgare* ssp. *hirtum*) essential oils Biochemical Systematics and Ecology 1993;21(2):287-295.
- Werker E. Function of essential oil-secreting glandular hair in aromatic plants of Lamiacea-A review Flavour and Fragrance Journal 1993;8(5),249-255.
- Brdanin S, Bogdanovic N, Kolundzic M, Milenkovic M, Golic N, Kojic M, Kundakovic T. Antimicrobial activity of oregano (*Origanum vulgare* L.) and basil (*Ocimum basilicum* L.) extract Advanced Technologies 2015;4(2):05-10.
- Simirgiotis MJ, Felipe Parra DB, Lopez J, Munoz P, Escobar H, Parra C. Antioxidant and antibacterial capacities of *Origanum vulgare* L. essential oil from the arid Andean region of Chile and its chemical characterization Metabolites 2020;10:0414 (1-12).
- Marques JD, Volcao LM, Funck GD, Kroning IS, De Silva WP, Fiorentini AM, Rebeiro GA, Antimicrobial activity of essential oils of *Origanum vulgare* L. and *Origanum majorana* L. against staphylococcus aureus isolated from poultry meat Industrial Crops and Products 2015;77:444-450.
- Elshafie HS, Mancini E, Sakr S, Martino LD, Mattia CA, Feo VD *et al.*, antifungal activity of some constituents of *Origanum vulgare* L. essential oil against postharvest disease of peach fruit Journal of Medicinal Food 2015;18(8):929-934.
- Blank D, Hubner S, Alves G, Cardoso C Freitag R, Cleff M. Chemical composition and antiviral effect of extract of *Origanum vulgare* Advances in Bioscience and Biotechnology 2019;10(7):188-196.
- Raveendran S, Rajadnya RK, Tilak AV, Das S, Bhalsinge R. A study to evaluate the analgesic activity of *Origanum vulgare* in mice using tail flick method International Journal of Basic & Clinical Pharmacology 2019;8(10):2254-2257.
- Han X, Parker TL. Anti-inflammatory, tissue remodeling, immunomodulatory and anticancer activity of Oregano (*Origanum vulgare*) essential oil in the human skin disease model Biochimie Open 2017;4:73-77.
- Khan M, Khan ST, Khan NA, Mahmood A, Al-Kedhairi A, Alkhatlanh ZH. The composition of the essential oil and aqueous distillate of *Origanum vulgare* L. growing in Saudi Arabia and evaluation of their antibacterial activity Arabian Journal of Chemistry 2018;11:1189-1200.

15. Kilic O, Ozdemir FA. Variability of essential oil composition of *Origanum vulgare* L. Subsp. gracile population from Turkey Journal of essential oil bearing Plants 2016;19(8):2083-2090.
16. Kula J, Majda T, Stoyanova A, Georgiev. Chemical composition of *Origanum vulgare* L. essential oil from Bulgaria. Journal of essential oilbearing Plants 2007; 10(3):215-220.
17. Morshedloo MR, Salami SA, Nazeri FM, Craker L. Essential oil profile of oregano (*Origanum vulgare* L.) populations grown under similar soil and climate conditions Industrial Crops and Products 2018;119:183-190.
18. Martino LD, Feo VD, Formisano C, Mignola E, Senatore F. Chemical composition and antimicrobial activity of the essential oil from three chemotype of *Origanum vulgare* L.ssp. hirtum(Link) Ietswaart growing wild in Campania(Southern Italy) Molecules 2009;14(8):2735-2746.
19. Sampaio BL, Batista Da Costa F. Influence of abiotic environmental factors on the main constituents of the volatile oils of *Tithonia diversifolia* Revista Brasileira de Farmacognosia 2018;28(2):135-144.
20. Tucker AO, Maciarello MJ, In: (Charalambous, G Ed.) Spices, Herbs and edible fungi. Elsevier Sciences B.V., Oxford, UK 1994.
21. Kanas GD, Souleles C, Loukis A, Philotheou-Panou E. Trace elements and essential oil composition in chemotype of the aromatic plant *Origanum vulgare* Journal of Radioanalytical and Nuclear Chemistry 1998;227:23-29.
22. Economakis C, Skaltsa H, Demetzos C, Sokovic M, Thanos CA. Effect of phosphorus concentrations of the nutrient solution on the volatile constituents of leaves and bract of *Origanum dictamnus* Journal of Agricultural and Food Chemistry 2002;50:6276-628.
23. Said-Al Ahl HAH, Omer EA, Naguib NY. Effect of water stress and nitrogen fertilizer on herb and essential oil of oregano International Agrophysics 2009;23:269-275.
24. Kilmer J, Alexander L T. Method of making mechanical analysis of soils Soil Science 1949;68:15-24.
25. Jackson ML, Soil Chemical Analysis. Prentice Hall Inc., New Jersey, USA. 1958, pp. 38-226.
26. Black CA, Methods of Soil Analysis, Part I. ASA, Inc. Madison, Wisconsin, U.S.A 1965.
27. Piper CS. Soil and Plant Analysis. The University of Adelaide, Adelaide, Australia 1942.
28. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Science Society of America Journal 1978;42:421-428.
29. Pande C, Tewari G, Singh S, Singh C. Chemical markers in *Origanum vulgare* L. from Kumaun Himalayas: a chemosystematic study Natural Product Research 2012;26(2):140-145.
30. Singh S, Tewari G, Pande C, Singh C. Chemotaxonomy of Wild *Origanum vulgare* L. from Kumaun Himalayas, In: (Eds. D.R. Khanna, A.K. Chopra, Gagan Matta, Vikas Singh and Rakesh Bhutiani) Impact of global climate change on earth ecosystems, Biotech Books, New Delhi, 2013, 103-114.
31. Dunford NT, Vazquez RS Effect of water stress on plant growth and thymol and carvacrol concentrations in Mexican oregano grown under controlled conditions Journal of applied Horticulture 2005;7(1):20-22.
32. Arabaci O, Bayram E, Baydar H, Savran AF, Karagodan T, Ozay N. Chemical composition, yield and contents of essential oil of *Lavandula hybrid* Reverchon grown under different nitrogen fertilizer, plant density and location Asian Journal of Chemistry 2007;19:2184-2192.
33. Omer, EA Response of wild Egyptian oregano to nitrogen fertilization in a sandy soil Journal of plant Nutrition 1999;22(1):103-114.
34. Srivastava NK, Misra A, Sharma S. Effect of Zn deficiency on net photosynthetic rate, ¹⁴C partitioning, and oil accumulation in leaves of peppermint Photosynthetica 1997;33:71-79.
35. Marschner, H Mineral nutrient of higher plants. Second Ed., Academic Press Limited. Harcourt Brace and Company, Publishers, London, 1995, 347-364.
36. Singh S, Tewari G, Pande C, Singh C. Chemical variation in volatiles of *Craniotome furcata*: Correlation with soil properties Record of Natural Products 2013;7(4):332-345.
37. Singh S, Tewari G, Pande C, Singh C. Variation in essential oil composition of *Ocimum americanum* L. from north-western Himalayan region Journal of essential oil Research 2013;25(4):278-290.