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Original Article

Diversity in Essential Oil Compounds in Relation to Different Geographic Origins and Plant Organs of *Salvia sharifii*

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ABSTRACT

Medicinal and aromatic plants are rich in active substances that represent many medicines. Climatic factors and ontogenetic growth stages affect the quantity and quality of these costly materials. The present study aimed to investigate the effects of the geographic origins and the different plant organs (leaves, flowers and stalks) of *Salvia sharifii* Rech. f. & Esfand., an endemic aromatic herb in the south of Iran, essential oil in three different natural habitats. The essential oil was extracted by hydro-distillation using Clevenger type apparatus and analyzed by GC and GC-MS. The highest essential oil content was obtained in flower (1.2%) and stalk (0.7%) of *S. sharifii* in Sirmand population. Also, in the latter plant organ, the highest essential oil content was observed in Abmah population (1.1%). Essential oils were characterized by the domination of sesquiterpenes (37.92–84.40%), followed by monoterpenes (13.42–58.86%). Quantitative and qualitative analyses of the essential oil identified 58 constituents that varied with plant origin and organ. Results revealed that the main essential oil constituents in *S. sharifii* were linalool, hexyl-2-methyl butyrate, caryophyllene, sclareol oxide, agarospirol and hexyl caprylate in different plant organs and natural habitats. The variations among natural populations of *S. sharifii* showed that add to the impact of plant inheritance, it conjointly encompasses a high adaptation potential so that a variety of climatic conditions like temperature, altitude and rainfall are among different populations.

INTRODUCTION

As essential compounds of human life, plants have been used for various purposes and in many fields such as medicine, the food industry, perfumery, beverages, cosmetics, and the dyeing industry. From ancient times, plants have been mainly used to treat various diseases. More than 40% of the world's medicines have plant origin, and more than 50% of the medications prescribed in Europe and the United States have a natural source [1]. Different types of herbal products and raw extracts are used in traditional medicine. Medicinal plants have long played an important role in health care and the protection of human health. According to the World Health Organization (WHO), medicinal plants will be the best source for preparing various medicines containing various compounds derived from medicinal plants. New herbal medicines are currently being used worldwide despite many developments in medicinal plants and plant-derived products [2]. Medicine phytochemical standards are used to identify counterfeit herbal medicines. Besides, phytochemical evaluation plays a critical role in the possibility of counterfeiting [3].

Salvia sp. is one of the most common and largest genus in the Lamiaceae family. It is native to the Mediterranean region and contains more than 1000 species worldwide [4]. *Salvia* species exist in 3 specific areas: Central and South America with 500 species, Central Asia and the Mediterranean with 250 species, and East Asia with 90 species. Iran is particularly one of the centers of the genus *Salvia*.

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The genus consists of 58 perennial and herbaceous species, of which 17 species are native to Iran and are scattered in the southern and southeastern provinces of Iran, especially Hormozgan province [5].

Salvia means treatment. This plant is used to treat more than 60 different diseases, mainly colds, bronchitis, tuberculosis, bleeding, menstrual, and digestive disorders. It is also used in traditional medicine as an antibacterial, antitumor, diabetes treatment and antioxidant activity. It is also used in food preparation, herbal tea, the pharmaceutical industry, perfumery, flavoring, cosmetics, and disinfectant. *Salvia* species produce terpenoids, steroids, flavonoids, and polyphenol compounds [6, 7]. The plant also contains several active compounds such as thujone, cineole, borneol, pinene, saponin, vitamin C, vitamin E, tannins, and gums. In addition, *Saliva* species are mainly aromatic plants [8]. Among some of these aromatic species observed in Iran, *S. sharifii* Rech. f. & Esfand. has been studied as a medicinal plant with significant essential oil potential. This plant, which is endemic to Iran, is found only in the country's southern regions and is widely used as a medicinal plant. The height of this plant is about 70-100 cm. *S. sharifii* is a perennial plant with a yellowish-green color. The plant is slightly covered with dense non-granular trichrome, has short stems and elliptical and ovate leaves with serrated leaf margins and short petioles. The inflorescence is panicle-shaped, consisting of spaced cycles, bracts shorter than the calyx, a regular tubular calyx, Trichrome-free tubular corolla, and the white or light purple flowers [9].

Plant essential oils are composed of hundreds of complex phytochemicals such as monoterpenes, diterpenes, sesquiterpene, and benzene derivatives that mostly have antioxidant potential. In addition to increasing shelf life, these compounds play a beneficial role in the sensory properties of food (taste, smell, and color) [10,11]. The chemical composition of the essential oil is strongly influenced by genetic and environmental factors, organ age, and harvest time [12]. So far, several studies have been performed on chemical diversity on different species of *Saliva*. Studying volatile compounds in the aerial part of *S. sharifii*, 17 chemical compounds were identified in essential oil. The most important compounds of these species include germacrene-D (30.3%), bicyclo germacrene (15.7%) and trans-beta-caryophyllene (12.3%) [13]. In an experiment on the chemical compounds of 11 species of *Saliva*, 58 compounds were identified. The most important of these compounds were alpha-pinene, beta-pinene, 1, 8-cineol, beta-caryophyllene, and sclareol [14]. Examining *S. hydrangea* on the composition of essential oils in leaf and flower organs revealed that the highest essential oil composition in flowers is caryophyllene oxide (35.47%) and the highest essential oil composition in leaf is spathulenol (16.07%) [15].

A review of scientific sources showed that this study was conducted for the first time on the chemical diversity of essential oil compounds of different *Salvia* organs collected from different natural habitats. Considering the importance of *S. sharifii* in terms of therapeutic and economic characteristics, the drought of the past few years, and uncontrolled harvesting from nature, the present study aimed to determine the yield of essential oil. Also, it was tried to identify critical oil compounds in different parts of the plant such that the target organ can be used following different parts of the industry and the breeding objectives of breeders.

MATERIAL AND METHODS

Plant Material

The plant material of *S. sharifii*, collected at the flowering stage from three natural habitats. Each population was represented with 30 individuals. The collected materials were dried at room temperature in shade for six days. 30 *S. sharifii* genotypes were divided into 3 groups containing 10 genotypes. The plant parts including flowers, leaves and stalks were separated and stored inside paper bags in a dark place until analysis. Information about the plant material is given in Table 1. The plants were identified by Flora Iranica [9]. Voucher specimens are kept at the Herbarium of Agriculture and Natural Resources Research Center of Hormozgan, Iran (Herbarium number: 71).

Essential Oil Isolation

The essential oils of air-dried samples (100 g) were extracted by hydro-distillation for 3 h with three replications for each sample, using a Clevenger-type apparatus (Shot, Germany) according to the method recommended in British Pharmacopoeia [16]. The essential oils were obtained in different yields,

shown in Table 3. The oils were dried over anhydrous sodium sulfate and kept in tightly closed dark glass vials at 4 °C until GC-FID and GC-MS analysis.

GC-FID and GC-MS analysis

Gas chromatography-mass spectrometry (GC-MS) analysis was conducted using a Shimadzu (GC-17A, Kyoto, Japan) gas chromatograph coupled with a Shimadzu Quadruple-MS (model QP5050) mass spectrometer. Compounds were separated on a 30 m × 0.22 mm i.d. fused-silica capillary column coated with 0.25 µm film of BP-5. The oven temperature was programmed to increase from 40 to 280 °C at a rate of 4 °C /min and finally held isothermal at 280 °C for 10 min. Ion source and transfer-line temperature were 250 °C, respectively. Ultra-pure helium was used as carrier gas. Injector and interface temperatures were set at 280 °C and 260 °C, respectively. The mass spectrum was acquired over the mass range of 35–450 a.m.u. The split ratio was 1/50. The GC-FID analysis of the essential oils was conducted using a Thermoquest Finnigan apparatus equipped with a flame ionization detector (FID) and a BP-5 fused-silica capillary column (30 m × 0.25 mm i.d., film thickness 0.25 mm). The oven temperature was programmed the same as above mentioned for the GC-MS; detector temperature, 300; injector temperature, 250 °C; carrier gas Helium with a flow rate of 1 ml min^{-1}; split ratio, 1:10 [17].

Identification of components

Identification of the essential oil compounds was based mainly on comparing retention indices (RIs) with published data and mass spectra with authentic references compounds and a MS computer library [18,19].

Soil sample

To determine some characters of soils of studied sites, three-soil samples of each site were collected from 0–30 cm depth and transferred to the laboratory of Soil Sciences Department at the Faculty of Agriculture and Natural Resources, University of Hormozgan, BandarAbbas, Iran for further analyses. Information about soil characters are given in Table 2.

RESULTS AND DISCUSSION

The average Yield of Essential Oils of Different Organs

The average yield of essential oil obtained from leaves, stalks, and flowers of *S. sharifii* in Abmah population was 1.1, 0.6, and 0.8% (w/w), respectively. In Sirmand population, they were 0.8, 0.7, and 1.2% (w/w), respectively. Finally, in GhotbAbad population, they were 0.6, 0.6, and 0.9% (w/w), respectively (Table 3). As can be seen, in the Abmah population, the essential oil yield of leaf was higher than other organs. The lowest amount of essential oil yield was related to the stalk. In Sirmand population, the flower essential oil yield was higher than other organs, and the lowest essential oil yield was related to the stalk.

Table 1 Some characteristics of the collected *S. sharifii* Rech.f. & Esfand. natural habitats

Collection places	Altitude (m.a.s.l *)	Longitude (E)	Latitude (N)	Mean annual temp. (°C)	Maximal temp. (°C)	Minimal temp. (°C)	Rainfall (mm/year)
Abmah	761	56° 01'	27° 47'	+27.2	+47.2	+4.0	125.6
Sirmand	1210	56° 05'	27° 59'	+24.9	+46.8	-3.6	167.6
Ghotbabad	908	55° 58'	28° 50'	+29.9	+50.5	+5.0	133.4

*meter above sea level

Table 2 Soil characters of the studied *S. sharifii* Rech.f. & Esfand. samples

Character	Abmah	Sirmand	Ghotbabad
Soil texture	Sandy Loam	Silt Loam	Silt Loam
pH (1:2 H_2O)	7.9	8.1	7.9
Ec (dS/m)	0.51	0.74	0.55
Organic matter (%)	2.62	1.81	1.00
Total N (%)	0.12	0.08	0.05
P exchangeable (mg/kg)	11.19	12.16	13.05
K^+ exchangeable (mg/kg)	170.12	193.65	184.23

In GhotbAbad population, flower essential oil yield was higher than other organs while the essential oil yields of leaf and stalk were equal.

Our results also are consistent with those of other studies. In various genera of this family, different organs of plants have a significant variation in terms of quantitative and qualitative yield of essential oil [20-23]. These results show that in addition to producing secondary metabolites such as essential oils, they have a long evolutionary and genetic background, environmental (biological and non-biological), and genetic factors. Moreover, different organs of the plant and the developmental stage of the plant are very influential in the production and quantitative and qualitative diversity of the compounds of *S. sharifii* essential oil collected from different habitats and regions. Since various organs of aromatic plants have a different power to produce essential oils, to reach the maximum effect of essential oil, it is necessary to have plant organs with a high essential oil percentage [24]. Medicinal plants breeders can consider this issue as breeding objectives in the dry matter yield and for use in pharmaceuticals, food, and cosmetics [25]. The *S. sharifii* is covered with secretory trichrome, and these trichomes in the *Saliva* are among the prominent places of essential oil accumulation [26]. In the Abmah population, the high amount of leaf essential oil compared to other organs of this plant can be attributed to the high concentration of secretory trichrome per unit leaf unit in the *S. sharifii*. Therefore, in this population, one of the breeding objectives to increase the maximum yield of essential oil in this plant is to increase the number and area of leaves, which breeders should consider. In other populations, the high amount of flower essential oil compared to other plant organs can be attributed to the high number of flowers and inflorescences in this species. Consequently, a large number of secretory trichrome exist in the reproductive organs of *S. sharifii*.

Therefore, one of the breeding objectives to increase the maximum essential oil yield in this plant is to increase the number of flowers and inflorescences. These issues also should be considered by breeders. Since *S. sharifii* is a perennial plant. The stalk lignin of the plant increases during puberty. Also, the development of this organ of the plant can cause a change in the structure of external secretory trichrome, probably leading to rupture of secretory trichrome and loss of accumulated essential oil [27]. Therefore, it can justify the low percentage of essential oil in the stem compared to other plant organs.

Chemical compositions of essential oils of various plant organs

Comparing different studied organs of *S. sharifii* in terms of type and percentage of chemical compounds identified in the essential oil reveals a significant difference between them (Table 3). In this study, 58 chemical compounds were observed in different organs of the plant, of which 32 compounds were common in Abmah population. In this habitat, the highest and lowest identified compounds were observed in stalks (49 compounds) and flowers (44 compounds), respectively. Also, the number of chemical compounds in the leaf was 45. In the Abmah population, the identified flower compounds contain 97.29% of the total essential oil. The main constituents of *S. sharifii* flower essential oil were linalool (21.44%), sclareol oxide (15.14 %), hexyl-2-methyl butyrate (6.01%), germacrene B (5.39%), hexyl caprylate (5.27%), caryophyllene (4.01%) and dibutyl phthalate (3.34%). Other compounds made up less than 3% of the essential oil compounds (Table 3). The compounds identified from the leaves accounted for 96.69% of the essential oil compounds. The main constituents of leaf essential oil were β-pinene (9.28 %), caryophyllene (7.77%), α-pinene (7.36 %), (Z) -β-Farnesene (4.98%), dibutyl phthalate (4.91%), linalool (4.55%), caryophyllene oxide (4.39%), phthalic acid diisobutyl ester (3.93 %), octadecane (3.45%), α-terpineol (3.2%), nootkatone (3.12%), and hexyl caprylate (3.09%). Other compounds created less than 3 % of the essential oil compounds (Table 3). The compounds identified from the stalk accounted for 97.43 % of the essential oil compositions. The main constituents of stalk essential oil were agarospirol (13.54%), hexyl caprylate (13.29%), linalool (3.12%), octadecane (8.45%), caryophyllene (8.26%), iso-bornyl acetate (7.05%), sclareol oxide (10.5%), diisobutyl ester phthalic acid (4.58%), α-bisabolol (3.8%), junipercamphor (3.72%), germacrene-D (3.56%), and 7-epi-α-selinene (3.47%). Other compounds composed less than 3% of the essential oil constituents (Table 3).

Table 3 Identified compounds in the essential oils of *S. sharifii* Rech.f. & Esfand. plant organs from different habitats

No.	Compound*	RI**	Leaf			Stalk			Flower		
			Abmah	Sirmand	GhotbAbad	Abmah	Sirmand	GhotbAbad	Abmah	Sirmand	GhotbAbad
1	Hexanol	862	0.89	0.02	-	-	-	-	0.26	0.02	0.02
2	α-pinene	937	7.36	0.57	5.74	0.01	-	-	1.12	0.49	1.21
3	β-pinene	986	9.28	1.20	6.45	0.15	-	0.25	1.20	0.59	0.71
4	Myrcene	991	0.24	0.16	0.37	-	-	-	0.52	0.37	0.86
5	*p*-cymene	1032	1.18	0.54	-	0.15	-	0.18	-	0.51	0.15
6	Limonene	1035	1.70	0.64	2.12	0.12	-	-	-	0.33	0.86
7	*Cis*-β-ocumene	1046	1.03	0.32	0.78	0.15	0.26	0.15	-	0.64	0.27
8	Linalool	1103	4.55	6.77	5.78	3.12	6.74	3.15	21.44	24.04	5.90
9	*Trans*-pinocarveol	1135	-	-	-	0.16	-	0.06	0.12	0.62	0.03
10	Hexyl isobutyrate	1151	2.28	0.21	1.86	0.54	1.15	0.54	1.28	3.84	0.78
11	Isoborneol	1159	0.96	-	0.33	0.16	0.79	0.16	0.47	0.62	-
12	Dihydro-α-terpineol	1163	1.51	0.09	-	0.23	-	-	-	0.44	-
13	Pinocarvone	1170	0.92	0.94	1.81	0.28	0.63	0.20	1.75	0.86	-
14	α-terpineol	1188	3.20	0.33	1.77	0.62	0.64	0.42	2.48	3.06	0.32
15	Dodecane	1206	-	0.80	-	0.26	-	0.16	0.99	-	0.41
16	Carveol	1217	0.38	1.17	-	0.28	0.18	0.18	-	0.11	-
17	Hexyl-2-methyl butanoate	1237	0.36	0.08	-	0.14	0.42	-	-	5.79	-
18	Hexyl-2-methyl butyrate	1240	1.03	33.25	2.35	1.47	1.39	1.37	6.01	2.49	1.90
19	Hexyl isovalerate	1247	2.28	11.35	0.17	0.55	0.49	0.75	1.77	2.76	3.20
20	Geraniol	1257	-	0.02	-	0.21	0.04	-	2.49	4.53	-
21	Iso-bornyl acetate	1292	1.30	0.36	4.19	7.05	1.24	5.85	2.84	0.53	0.46
22	δ-Elemene	1341	1.94	-	-	-	-	-	-	2.89	-
23	Copaene	1384	2.85	0.57	0.86	0.52	1.41	0.57	2.26	4.80	1.11
24	*n*-Hexyl hexanoate	1388	-	0.53	0.68	0.19	1.19	0.19	1.33	2.07	1.35
25	*β*-Bourbonene	1390	-	0.38	-	0.63	-	-	-	-	-
26	*β*-Elemene	1396	-	0.13	0.23	0.11	0.41	0.19	0.07	1.11	-
27	Aristolene	1428	-	-	-	0.44	-	0.44	-	-	0.10
28	Caryophyllene	1435	7.77	3.84	6.77	8.26	18.73	6.66	4.01	6.33	10.51
29	*Trans*-α-Bergamotene	1438	0.12	0.01	-	0.01	0.31	-	0.48	1.17	0.58
30	*α*-Guaiene	1441	0.65	0.76	0.49	0.21	1.82	0.21	0.05	0.45	0.88
31	(Z)-*β*-Farnesene	1450	4.98	0.31	-	0.02	-	-	0.03	0.08	0.45
32	*α*-Humulene	1458	0.71	1.67	3.32	1.36	12.23	3.36	1.95	2.22	0.69
33	δ-Hlmachalene	1482	0.41	0.31	0.19	0.38	0.20	0.38	0.41	0.71	1.01
34	Germacrene-D	1490	0.75	1.32	0.32	3.56	2.48	1.26	0.83	1	2.04
35	*α*-Seliene	1498	0.99	0.24	1.02	-	0.63	-	0.03	0.46	1.20
36	*α*-Bulnesene	1505	-	0.71	-	1.55	0.38	1.05	-	0.54	0.10
37	*β*-Bisabolene	1515	-	-	0.65	0.01	-	-	0.01	0.06	0.11
38	7-epi-α-Selinene	1518	2.05	0.46	0.80	3.47	1.37	2.67	0.65	0.40	4.82
39	Elemol	1559	1.85	0.20	1.55	0.79	1.91	1.58	-	0.26	21.99
40	Germacrene B	1567	-	-	-	-	0.69	-	5.39	-	-
41	Hexyl caprylate	1584	3.09	11.09	10.95	13.29	11.20	11.29	5.27	8.19	2.14
42	Veridiflorol	1590	-	0.34	-	-	-	-	0.05	-	0.09
43	Spathulenol	1579	1.56	-	0.11	-	-	-	-	0.26	-
44	Caryophyllene oxide	1596	4.39	0.43	0.89	0.54	1.50	0.84	1.07	1.07	1.50
45	10-epi-δ-Eudesmol	1618	2.07	0.28	0.12	0.34	1.38	0.39	0.06	0.36	0.22
46	δ -Eudesmol	1637	0.81	-	0.97	2.12	0.54	1.12	0.79	0.67	0.71
47	Bulnesol	1656	0.80	0.81	1.31	0.33	2.68	0.31	1.12	0.76	5.22
48	Alloaromadendrene oxide	1661	0.54	0.30	-	-	-	-	0.05	0.40	-
49	Agarospirol	1682	1.29	0.48	0.94	13.54	2.07	11.45	0.81	0.39	15.77
50	Junipercamphor	1695	1.99	0.87	0.12	3.72	3.59	3.72	0.09	-	-
51	α-Bisabolol	1693	-	0.60	4.90	3.80	0.14	3.73	-	-	0.17
52	Aristolone	1729	-	1.30	0.98	-	0.19	-	-	0.62	0.41
53	Nootkatone	1778	3.12	0.28	-	0.79	0.93	0.64	1.80	1.72	0.86

54	Octadecane	1801	3.45	-	0.12	8.45	4.38	6.35	1.75	-	-
55	Phthalic acid, Diisobutyl ester	1880	3.93	-	4.84	4.58	2.22	4.58	2.39	0.98	0.89
56	Sclareol oxide	1914	0.33	6.63	17.55	5.10	5.86	15.10	15.14	0.59	3.83
57	Dibutyl phthalate	1978	4.91	1.33	0.69	1.87	1.65	3.89	3.34	0.54	1.03
58	Epimanoyl oxide	2015	0.88	2.18	2.79	2.34	1.08	2.43	1.32	2.03	0.82
Monoterpene hydrocarbons			23.99	5.19	19.31	1.12	2.04	1.48	6.86	7.63	5.25
Oxygenated monoterpens			16.46	53.67	14.59	13.99	11.93	11.94	37.88	45.01	11.83
Sesquiterpene hydrocarbons			34.72	13.02	16.76	33.49	51.25	28.34	20.93	26.03	26.37
Oxygenated sesquiterpenes			21.52	24.90	48.29	48.83	31.92	56.06	31.62	17.10	54.23
Total identified			96.69	96.78	98.77	97.43	97.14	97.82	97.29	95.77	97.68
Essential oil content (w/w %)			1.1	0.8	0.6	0.6	0.7	0.6	0.8	1.2	0.9

*) Mode of identification: retention index (RI), mass spectrometery (MS), and co-injection (CoI) with some available authentic compounds.
**) RI: retention indices determined in the present work relative to C_6–C_{24} *n*-alkanes on the BP-5 column.

In the Sirmand population, 34 common compounds were detected. In this population, the highest and lowest identified compositions were detected in flower (50 compounds) and stalk essential oils (41 compounds), respectively. Also, the number of chemical compounds present in the leaf was 48. In the Sirmand population, the compounds identified from the flower accounted for 95.77% of the essential oil compounds. The main constituents of the essential oil of *S. sharifii* were linalool (24.04%), hexyl caprylate (8.19%), caryophyllene (6.33%), hexyl-2-methyl butanoate (79.5%), copaene (4.8%), geraniol (4.53%), hexyl isobutyrate (3.84%) and α-terpineol (3.06%). Other compounds made up less than 3% of the essential oil compounds (Table 3). The compounds detected from the leaves accounted for 96.78% of the essential oil compounds. The main constituents of leaf essential oil are hexyl-2-methyl-butyrate (33.25%), hexyl isovalerate (11.35%), hexyl caprylate (11.09%), linalool (6.77%), sclareol oxide (6.63%) and caryophyllene (3.84%). Other compounds created less than 3% of the essential oil compounds (Table 3). The compounds identified from the stalk accounted for 97.14% of the essential oil compounds. The main constituents of stalk essential oil were caryophyllene (18.73%), α-humulene (12.23%), hexyl caprylate (11.2%), linalool (6.74%), sclareol oxide (5.86%), octadecane (4.38%) and junipercamphor (3.59%). Other compounds composed less than 3% of the essential oil constituents (Table 3).

In the GhotbAbad population, 30 common compounds were identified, with the highest number of compounds observed in flower essential oil (44 compounds) while the number of chemical compounds in leaves and stems was equal (40 compounds). In the GhotbAbad population, the identified flower compounds contained 97.68% of the total essential oil. The main constituents of the essential oil of *S. sharifii* were elemol (21.99%), agarospirol (15.77%), caryophyllene (10.51%), linalool (5.9%), bulnesol (5.22%), 7-epi-α-selinene (4.82%), sclareol oxide (3.83%) and hexyl isovalerate (3.2%). Other compounds made up less than 3 % of the essential oil compounds (Table 3). The compounds identified from the leaves accounted for 98.77% of the essential oil compositions. The main constituents of leaf essential oil were sclareol oxide (17.55%), hexyl caprylate (10.95%), caryophyllene (6.77%), β-pinene (6.45%), linalool (78.5%), α-pinene (5.74%), α-bisabolol (4.9%), phthalic acid, diisobutyl ester (4.84%), iso-bornyl acetate (4.19%) and α-humulene (3.32%). Other compounds composed less than 3% of the essential oil constituents (Table 3). The compounds detected from the stalk accounted for 97.82% of the essential oil compositions. The main constituents of stalk essential oil are sclareol oxide (15.10%), agarospirol (11.45%), hexyl caprylate (11.29%), caryophyllene (6.66%), octadecane (6.35%), iso-bornyl acetate (5.85%), phthalic acid, diisobutyl ester (4.58 %), dibutyl phthalate (3.89%), α-bisabolol (3.73%), junipercamphor (3.72%), α-humulene (3.36%) and linalool (3.15%). other compositions created less than 3 % of the essential oil compounds (Table 3).

The results also demonstrated that in the Abmah population, the predominant and common compositions in flower, leaf and stalk essential oils were linalool (21.44%), caryophyllene (7.77%), and hexyl caprylate (13.29%), respectively. In the Sirmand population, the predominant and common compounds in flower, leaf, and stalk essential oils were linalool (24.04%), hexyl caprylate (11.09%), and caryophyllene (18.73%), respectively. In the GhotbAbad population, the predominant and common constituents in flower essential oil was

caryophyllene (10.51%) and in leaf and stalk were sclareol oxide (17.55% and 15.10%, respectively).

The compounds of essential oils of different organs of *S. sharifii* were grouped according to their chemical formula (Table 3). Regarding various compositions identified in these three samples' essential oils, there was a high diversity among the constituents of the essential oils of flowers, leaves and stalks in all three populations. In the Abmah population, oxygenated monoterpenes (37.88%) and oxygenated sesquiterpenes (31.62%) were the main compounds of flower essential oil compositions. Sesquiterpene hydrocarbons (34.72%) and oxygenated sesquiterpenes (48.83%) were essential oil compounds in the leaf and stalk of this population, respectively. In flower, the compounds of sesquiterpene hydrocarbons compounds (20.93 %) formed the third-largest group. Finally, monoterpene hydrocarbons (6.86%) had a smaller share. On the other hand, monoterpene hydrocarbons (23.99%) in leaves and sesquiterpene hydrocarbons (33.49%) in the stalk were the second largest group. Also, oxygenated sesquiterpenes and oxygenated monoterpenes had a smaller share in leaves (21.52%) and stalks (13.99%), respectively. In the Abmah population, sesquiterpene compounds were the predominant compounds in flowers (52.55 %), leaves (56.24%) and stalks (82.32%).

In the Sirmand population, oxygenated monoterpenes in flower (52.64%) and leaf (53.67 %) were the main constituents of essential oil compounds. Sesquiterpene hydrocarbons in the stalk (51.25%) were the main constituents of essential oils. Furthermore, oxygenated sesquiterpene in stalk (31.92 %) and leaf (24.90%) and sesquiterpene hydrocarbons (26.03 %) in the flower formed the second largest group. Finally, oxygenated sesquiterpenes (17.10%) and monoterpene hydrocarbons (7.63%) in flower, sesquiterpene hydrocarbons (13.02%), and monoterpene hydrocarbons (5.19%) in leaf and oxygenated monoterpenes (11.93%) and monoterpene hydrocarbons (2.04%) were the compounds with lower shares. In this population, the percentage of monoterpene compounds in flower and leaf (52.64 % and 58.86 %, respectively) was higher than that of sesquiterpene compounds (43.13 % and 37.92 %, respectively). In the stalk, the percentage of sesquiterpene compounds (83.17%) was higher than that of monoterpene compounds (13.97%).

In the GhotbAbad population, oxygenated sesquiterpene in flower (54.23%), leaf (48.29%) and stalk (56.06%) were the main constituents of essential oils. Then, the compounds of sesquiterpene hydrocarbons (26.37%) in flower and stalk (28.34%) and monoterpene hydrocarbons (19.31%) in leaf formed the second largest group. Finally, oxygenated monoterpenes (11.83%) and monoterpene hydrocarbons (5.25%) in flower, sesquiterpene hydrocarbons (16.76%) and oxygenated monoterpenes (14.59%) in leaf and oxygenated monoterpenes (11.94%) and monoterpene hydrocarbons (1.48%) in the stalk had a smaller share. In the GhotbAbad population, the percentage of sesquiterpene compounds in flower, leaf and stalk, (80.60, 65.05 and 84.40%, respectively) was higher than that of monoterpene compounds (17.08, 33.72 and 13.42%, respectively).

Therefore, different compounds identified in the essential oils of these three samples revealed that, there is a high diversity among the constituents of the essential oils of various organs (flower, leaf, and stalk) in different habitats. Studies on essential oil compounds in different European countries are also consistent with our results and show a high diversity among the constituents of *Salvia* essential oil [12, 28]. These differences can be due to the effect of various factors such as ecological and climatic conditions on the composition of essential oils of different populations of a species that grow in different geographical areas [29]. Findings of other studies also show high diversity among the essential oil constituents in *Salvia*. For example, it has been reported that oxygenated monoterpenes, monoterpene hydrocarbons and oxygenated sesquiterpenes compounds contain 85.75%, 10.36%, and 0.62% of *S. officinalis* L. essential oil, respectively [23].

Other studies have also reported that the percentage of monoterpene hydrocarbons in *Salvia* essential oil is higher than that of sesquiterpenes hydrocarbons [20-22]. Several pieces of evidence can justify periodic fluctuations in the composition and yield of plant essential oils. As the plant develops, the structure of its cells and tissues changes, leading to the change in various chemical compounds existing in its organs. These changes can affect the chemical interactions that control the production of essential oils [30]. Differences in the composition of essential

oils of different plant parts may be due to distinct secretory structures that are non-uniformly distributed throughout the plant.

The volatile compounds of the plant are produced and stored in specific secretory structures to minimize the risk of self-toxicity by acting as a defense agent in the plant. However, the presence of different secretory trichomes with the non-uniform distribution in several species that lead to various compounds in their essential oils has been reported [24,31-32]. In addition, growth regulators are other influential factors in various chemical compounds of essential oils in different plant organs. Comparing different stimulating hormones reveals that gibberellin and auxin compounds have the most significant effect on growth stimulation, essential oil content, leaf area, and branches by increasing the biomass production of plants. They also positively impact on the activation of more enzymes involved in the biosynthetic pathway of essential oils [33].

Generally, the existence of diversity in the essential oils of the studied organs can be due to each organ's different developmental and physiological conditions, and the different compositions of essential oils may be different depending on various factors [34]. A study on the aerial part of *S. sharifii* in the full flowering stage in Hormozgan province, Genow region was conducted. They found that among the 39 identified compounds, the predominant essential oil compounds obtained from the dried plant sample were caryophyllene (12.8%), germacrene-D (9.5%), trans-iso lemon (7%), spathulenol (6.9%), bicyclogermacrene (5.6%), caryophyllene oxide (5.5%) and two compounds 1, 8- cineol and limonene (4.2%) [35]. Another study was arranged in the same area on essential oil extracted from fresh vegetative organs of *S. sharifii*. According to results, the main constituents of the essential oil were germacrene-D, bicyclogermacrene, and trans-caryophyllene [13]. Observation of these differences can be due to factors such as ecological and climatic conditions on the composition of essential oils of different populations of a species that grow in other geographical areas [29].

In the studied populations, the common predominant compound in all three organs was linalool, which is an aromatic non-cyclic oxygenated monoterpene with the formula $C_{10}H_{18}O$, 154.25 g. mol^{-1} molar mass, and colorless to light yellow. This compound is produced in many flowering plants and plant species through a class of monoterpene synthase enzymes called linalool synthase (LIS) from Isopentenyl pyrophosphate. Since linalool is aromatic, it is used to manufacture 60-80% of hygienic and cleansing substances such as soaps and lotions. Linalool is also used in the cosmetics industry to treat diseases such as severe skin allergies, leukemia, and breast cancer [36,37]. This compound prevents memory loss due to seizures by protecting the cholinergic system. In addition, linalool is widely used as a flavoring in the food and beverage industries. In industry, linalool is also used as an essential intermediate compound in the production of vitamins E and A, farnesol, and citronellal. It is also used as an insecticide to control parasites on pets' skin [38,39]. According to the applications of linalool, the flower sample, which has more linalool in its essential oil, has a higher quality for use in pharmacy and cosmetics.

Generally, the yield of essential oil extracted from different aerial parts of the *S. sharifii* confirms the existence of diversity in the production of essential oil. In the Abmah population, the leaf and in other populations, the flower can be used as herbal medicine because of having the highest yield of essential oil. The observed variation in the qualitative properties of the essential oil of this plant was also evident. Therefore, accurate identification of quantitative and qualitative indicators of essential oil, followed by introducing the most desirable chemical type, was a practical step toward proper exploitation, providing favorable conditions for domestication and preservation of natural resources. Besides, the necessary conditions are available to correct these valuable resources to the pharmaceutical, food and cosmetic industries.

Conflict of Interest

The authors declare that there is no conflict of interest.

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