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Original Article

Comparing Essential Oil Composition of Cultivated and Wild Samples of *Achillea biebersteinii* Afan. in Kurdistan Province

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Abstract

The composition of essential oils in six accessions of *Achillea biebersteinii* Afan., transferred from the natural habitats in various townships of Kurdistan province, Iran to the cultivated conditions, were analyzed by GC/MS. Twenty-nine components were identified, of which the main constituents of the essential oil of *A. biebersteinii* Afan. contained 1,8-cineole (17-34%), Bornyl acetate (0.7-39%), and *p*-cymene (2.2-19.2%). The cultivated accessions produced more 1,8-cineole and bornyl acetate than those of the natural habitats, while the highest amount of *p*-cymene was found in *A. biebersteinii* Afan., collected from natural habitats. The essential oils were characterized by the highest amount of 1,8-cineole (24.9-37.9%), bornyl acetate (13.7-26.9%), and *p*-cymene (2.7-9%) in all cultivated accessions. When transferred to the field conditions, the accession Khan gorge of Baneh City was demonstrated as the best in terms of 1,8-cineole, and the accession Booein village of Baneh produced the largest amount of bornyl acetate. The accessions from Janevareh village and Ney village in Marivan city had the largest amount of *p*-cymene in both fields and in both years of cultivation. The results of the study of the pharmaceutical ingredients, extracted from cultivated conditions and natural habitats, could be very important for the next stages of cultivation and domestication of *A. biebersteinii* Afan..

Keywords: *Achillea biebersteinii* Afan., Essential oil compositions, Gas chromatography, Cultivated field, Kurdistan.

Introduction

The genus *Achillea* (Yarrow), belonging to the *Asteraceae (Compositae)* family, includes more than 130 species in the world and possesses multiple biologically effective compounds in essential oils and extracts. Their extract is used in pharmaceutical and food industry. *Achillea* species have a wide distribution range, and the differences in oil composition may be affected by different environmental factors such as soil mineral fertilization, climate conditions, and the characteristics of the cultivation site [1-4]. The *Achillea* genus belongs to a group whose difficulty is to identify its species and subspecies. However, some researches revealed the composition of the oils as additional characteristics of the identification [5]. At present, this species is the synonym of *Achillea arabica* Kotschy [6].

Some researchers have been able to extract essential oils by water distillation from aerial parts of *Achillea biebersteinii* Afan., collected from different locations in Turkey [7,8]. Bader *et al.* [9] reported that *A. biebersteinii* Afan. oil contained cis-ascaridole, *p*-cymene, carvenone oxide, and camphor among its principal constituents. Baris *et al.* [10] using GC-MS analysis of the essential oil, identified 64 components, representing 92.24% of the oil, of which piperitone, camphor, and 1,8-cineole (Eucalyptol) were the main constituents. In

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samples from Iran, caridole, piperitone and camphor have been reported to be the most important essential oil components of *A. biebersteinii* Afan. [11]. In a study conducted by Mirahmadi *et al.* [12], the chemical composition of essential oils from twenty-three wild populations of *A. biebersteinii* Afan., growing wild in different parts of Iran, was determined. They reported that 1,8-cineole was the principal component of most essential oils. Rahimmalek *et al.* [13] collected various species of *Achillea* from natural habitats and cultivated these species under field conditions with the aim of studying their essential oil compositions. Their study indicated that the content of essential oil among *Achillea* species varied based upon the genetic and environmental factors and even their interaction. Similarly, Toncer *et al*. [14] reported that the chemical composition of *Achillea* essential oils was highly variable, which may be due to the differences in their chemical polymorphic structure and environmental conditions. The compounds that make up the essential oils of *A. biebersteinii* Afan show a lot of phytochemical variations. According to chemical studies, the main components of *A. biebersteinii* Afan essential oil are oxygenated monoterpenes [9,13]. *Achillea* plants have been cultivated since ancient times as medicinal herbs. In recent years, however, new medicinal functions of *Achillea* including spasmolytic, choleretic, treatment of wounds, and anti-inflammatory activities have made the herb more important for medicinal purposes [15-17]. Many of *Achillea* species have a much less leaf area which causes them to produce less essential oil over time, resulting in time-consuming and noneconomic extraction of leaves essential oils. Therefore, it would be noticeable to select other species such as *A. biebersteinii* Afan. with a higher leaf area (around 36cm^2), possessing a higher essential oil yield [13,18,19]. In the flora of Iran, the genus *Achillea* contains 19 species, of which seven are native. One of these species, namely, *A. bieberstenii* Afan., is found in many parts of the country, including the center, north, northwest, west, and northeast with the local name of 'Bumadarane Zard'. *A. biebersteinii* Afan., is a perennial herb, stems erect, simple or branched from the base; 30-60 cm high; leaves up to 10 cm, oblong-lanceolate, the heads are radiate, in large dense compound corymbs; involucre 4-5 mm, flowering period, April-May [20,21]. The major problems in the cultivation of wild medicinal species, associated with their chemical composition, are the effect of domestication on biological activities. Therefore, the biochemical indices of plants can change with altered environmental conditions [22].

However, there are no comprehensive researches in the evaluation of essential oil variations in *A. biebersteinii* Afan. in the natural habitats and field conditions of Kurdistan Province; therefore, the aim of this study was (1) to extract the essential oils from aerial parts of *A. biebersteinii* Afan., grown in natural habitats and field conditions, (2) to analyze the qualitative and quantitative chemical composition of essential oils from wild and cultivated *A. biebersteinii* Afan., (3) to compare the essential oils variation among different accessions in two different conditions.

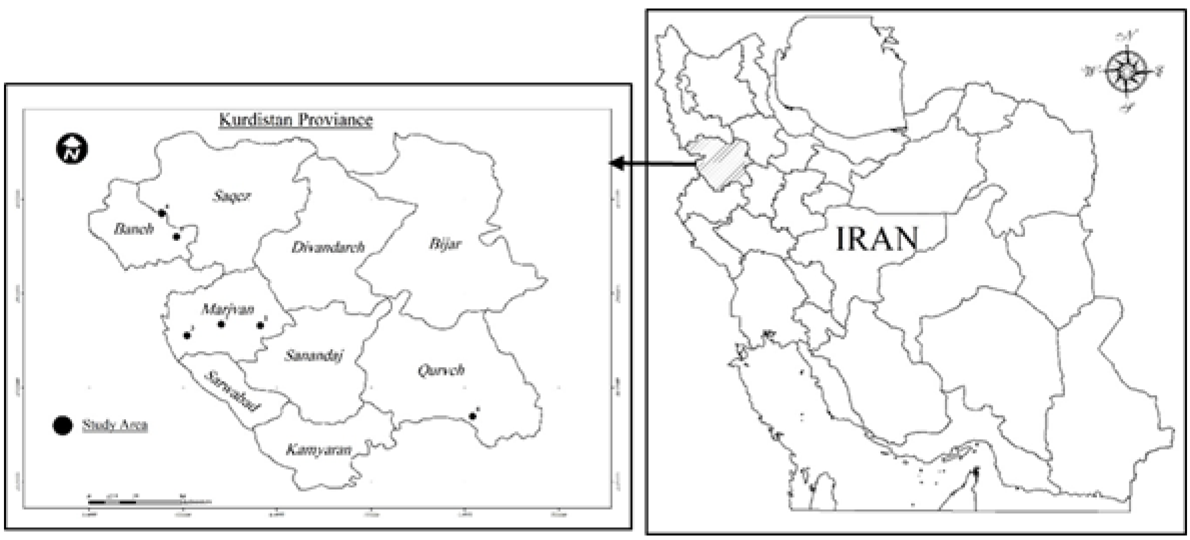

Fig. 1 The map of collection area

Material and Methods

Plant Material

First of all, in the spring, six accessions of *Achillea biebersteinii* Afan in the province were identified and at the proper time, the seeds of this species were collected. The study of phenological stages of the species, morphological traits, and the essential oil yield of *A. biebersteinii* Afan in field conditions were carried out by planting the seeds in an experimental area located at the Saral Research Station (35 ^{o}31' to 35 ^{o}41'N, 47 ^{o}07' to 47 ^{o}09'E and 1700 m above sea level). The experimental area is characterized with a cold bioclimate with an average temperature of 37 ^{o}C, in the warmest month, and an average temperature of -30 ^{o}C in the coldest month, and a mean rainfall of 500 mm year.
The planting method of *A. biebersteinii* Afan seeds, collected from the province, was indirect cultivation. Therefore, the seeds were cultivated in the first half of March in the greenhouse of the Kurdistan Agricultural Research Center (Fig. 2A). At the end of April, at the Saral station land, 20 plots of 5 × 2 were prepared in three replications with a distance of one meter (Fig. 2B). After 50 days intervals, the seedlings were planted in a randomized complete design at 40 cm spacing per plot. In order to level out the conditions of the field and the habitat, the irrigations were performed only until the establishment of the seedlings and in the first year of planting. The crops were irrigated in four times (two cases for 15 days and the two others for one month). *A. biebersteinii* Afan seedlings were ready to flower in the next spring (Fig. 2C). To extract, evaluate, and comparison of essential oils in populations of natural habitats as well as cultivated *A. biebersteinii* Afan accessions during the flowering period, the aerial parts of cultivated and wild *A. biebersteinii* Afan were harvested. The wild plants were collected from six natural habits of Kurdistan province.
The plant samples, collected from the flowering headers of *A. biebersteinii* Afan (Fig. 2D), with 15 cm leafy stem leading to inflorescence, were air-dried under room temperature (20- 27 ^{o}C) in shade for a week. Then, 100 g of each of the milled samples were subsequently subjected to hydro-distillation for 2h using Clevenger-type apparatus preparation method to extract the essential oils until total recovery of oil.
Due to the complexity of essential oil compounds in *A. biebersteinii* Afan, gas chromatography is the most suitable fragmentation method.

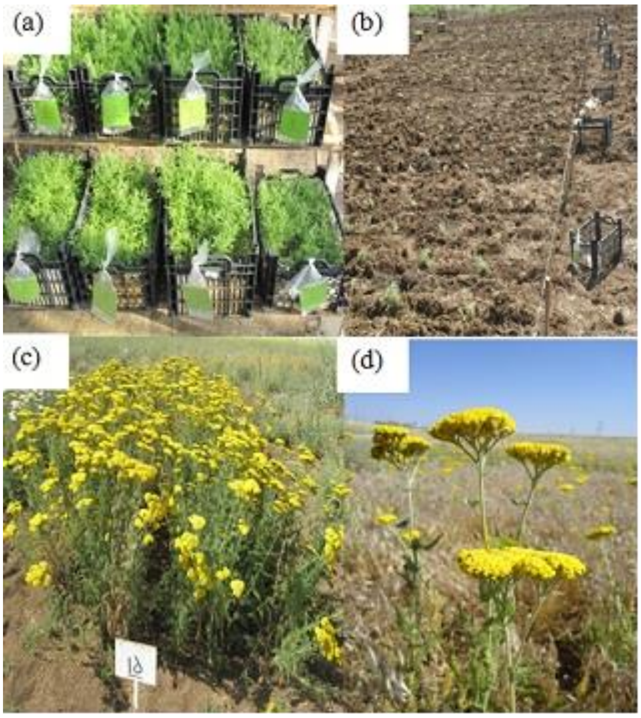

Fig. 2 *A. biebersteinii* Afan. growing steps. (A) seedlings (B) plots (C) and (D) aerial parts and inflorescences

Extraction and Study of Essential Oils

Gas chromatography (GC) is the physical method to separate the essential oil components based on the propagation between the stationary phase (liquid) and the mobile phase (gas). The sample is removed from the mobile phase after the release between the two stationary and mobile phases, and since the solvent has different absorption properties for different objects, therefore, the gas, containing various compounds, is recorded.

Gas Chromatography

GC analyses were performed using a gas chromatography, Ultra-Fast Module –GC, made in Italia. Profile column machine brand Ph-5 capillary column, manufactured by Shimadzu with Length of 30 mm and an inner diameter of 1.0 mm and 25.0 mm thick. The inner surface of the stationary phase material is covered with Phenyl Dimethyl Siloxane 5%. Column temperature program: initial temperature of 60 °C to start the final temperature of 210°C. The initial 3 °C per minute to be added and then injected into the chamber to a temperature of 280°C. The carrier gas inlet pressure to the column: helium with a purity of 99.99% of the inlet pressure to the column equal to 5.1 kg per square centimeter is set.

Gas Chromatography-Mass Spectrometry

The GC/MS unit consisted of a Varian Model 3400 gas chromatograph coupled to a Saturn II ion trap detector was used. The column was same as GC, and the GC conditions were as above. Mass spectrometer conditions were: ionization potential 70 eV; electron multiplier energy 2000 V.
The identity of the oil components was established from their GC retention indices (RI), relative to C7-C25 n-alkanes, by comparison of their MS spectra with those reported in the literature [3], and by computer matching with the Wiley 5 mass spectra library, whenever possible, by co-injection with standards available in the laboratories.

Statistical Analysis

The quantitative differences among the means ± SD of essential oil compounds in natural habitats and cultivated conditions, containing three replicates (n=3), were statically analyzed by ANOVA, and the mean comparison was done using Duncan test at $P<0.05$. Analyses were performed by SAS computer software.

Results

As shown in Table 2, the three main essential oil components of *Achillea biebersteinii* Afan accessions in the province's habitats are 1,8-cineole (17-34%), bornyl acetate (0.7-39%), and *p*-cymene (2.2-19.2%), the highest of which are recorded in accessions A3 (Nei-Marivan), A5 (Booein-Baneh), and A6 (Khanan-Abad-Qurveh). In the first year of cultivation in the field, the essential oil of the accession A2 was not obtained due to the small amount isolated . In Table 3, the main components of the essential oils of *Achillea* were 1,8-cineole (26.8-45.1%), *p*-cymene (0.9-6.3%), and Boronyl acetate (0.5-1%), from accessions A6 (Khanan-Abad-Qurveh), A1 (Janevareh-Marivan), and A3 (Nei-Marivan), respectively.
However, in these accessions, two other chemical compositions (compounds) including piperitone (1.1-28.7%) and camphor (3.5-12.5%) showed a high percentage in accessions A5 (Booein-Baneh) and A6 (Khanan-Abad-Qurveh). Noticeably, in the second year of cultivation of *A. biebersteinii* Afan accessions in the field, the essential oil of the accession A6 was not obtained. In Table 4, showing the results of the evaluation of the essential oils in the two-year cultivated *A. biebersteinii* Afan, 1,8-cineole (24.9-37.9%), Bornyl acetate (13.7-26.9%) and *p*-cymene (2.7-9%), as the main components, had the highest values in accessions A4 (Khan-Baneh), A5 (Booein-Baneh), and A3 (Nei-Marivan).
Our finding also revealed that the domestication had significant effect on essential oil production in terms of 1,8-cineole, bornyl acetate, and *p*-cymene, so that the accessions cultivated in the field conditions produced significantly more 1,8-cineole and bornyl acetate than those of the natural habitats (Table 5). However, the amount of *p*-cymene obtained from *A biebersteinii* Afan plants, collected from the natural habitats showed the higher amount as compared with field conditions (Table 5).

Discussion

First, the results of previous research must be divided into two parts. One is the study of the essential oils of *Achillea biebersteinii* Afan flowering shoots in the natural habitat, and the other is the study of essential oil in the field.

Table 1 Environmental data of 6 wild populations of *Achillea biebersteinii* Afan., in Kurdistan province

	Name	Longitude	Latitude	Altitude	Tmin	Tmax	$P_{av\text{-}annal}$
1	Janevareh- Marivan	641271	3932953	1674	5	20	550
2	Garan- Marivan	620432	3933618	1442	7	20	650
3	Nei- Marivan	602173	3927659	1357	6	22	800
4	Khan- Baneh	588614	3992201	2036	6	21	600
5	Boein- Baneh	596455	3979907	1760	5	21	650
6	KhananAbad-Qurveh	754175	3884675	2355	5	18	400

Table 2 Essential oil compositions (%) of *Achillea biebersteinii* Afan. at different locations in Kurdistan province

Component	A1	A2	A3	A4	A5	A6	RI
α-pinene	0.4	0.6	1.0	0.6	1.3	1.0	932
Camphene	-	0.4	0.8	-	1.0	0.8	946
Sabinene	-	-	-	-	0.2	-	969
β-pinene	-	-	0.3	-	-	-	974
Myrcene	-	0.4	-	0.4	0.9	0.6	988
α-phellandrene	0.5	-	0.4	-	-	-	1002
α-terpinene	-	0.5	-	1.3	0.2	0.3	1014
p-Cymene	8.3	5.0	19.2	9.3	2.5	2.2	1020
1,8-Cineole	21.1	19.9	30.9	17.0	34.0	25.2	1026
γ-terpinene	-	0.4	-	0.4	0.3	0.4	1054
Terpinolene	-	2.0	-	1.8	2.0	2.1	1085
1-Terpineol	-	4.7	-	-	-	-	1130
Trans Pinocarveol	0.4	-	0.4	-	-	-	1140
Camphor	1.9	0.3	3.7	1.9	5.4	7.1	1145
Borneol	-	1.1	-	0.6	1.5	1.3	1170
Terpinen-4- ol	-	2.7	-	0.3	0.5	0.3	1177
α-Terpineol	0.9	-	0.7	1.0	1.2	1.1	1189
γ-Terpineol	1.9	0.7	0.8	-	0.5	0.4	1199
Cis Carveol	0.5	-	2.3	-	-	-	1229
Carvone	-	11.8	2.3	-	-	1.7	1243
Piperitone	19.6	-	7.4	-	-	-	1249
Bornyl acetate	1.5	21.9	0.7	19.0	34.5	39.0	1284
Carvacrol	-	12.8	-	19.2	1.1	2.1	1300
Dihydro Carveol acetate	20.8	0.4	13.0	0.3	0.3	0.5	1307
Spathulenol	-	-	-	-	-	0.2	1580
Caryophyllene oxide	-	0.6	-	-	-	-	1585
Globulol	-	-	-	-	0.3	0.3	1590
γ-eduesmol	-	-	-	-	-	1.4	1631
α-eduesmol	-	0.3	-	-	-	-	1655
Total (%)	77	87	84	73	88	88	-

Table 3 Essential oil compositions (%) of *Achillea biebersteinii* Afan. cultivated under field conditions (in the first year)

Component	A1	A3	A4	A5	A6	RI
α-pinene	1.7	1.0	1.3	1.2	2.9	932
Camphene	1.3	0.8	0.5	0.4	2.7	946
α-phellandrene	0.9	0.6	0.7	0.9	2.1	1002
p-Cymene	6.3	0.9	5.6	2.1	2.0	1020
1,8-Cineole	29.7	26.8	34.7	37	45.1	1026
z-β-Ocimene	0.7	-	1.9	-	2.0	1050
γ-Terpinene	0.5	0.4	0.5	0.4	0.9	1054
p-Mentha 3, 8 diene	0.3	-	2.1	-	1.3	1073
Terpinolene	0.3	0.3	0.5	0.8	0.6	1085
Trans pinene hydrate	2.2	1.9	2.0	2.2	0.4	1123
Trans Rose oxide	0.4	0.3	0.5	0.4	0.6	1126
Camphor	9.8	5.5	6.5	3.5	12.5	1148
Trans pino carveol	1.1	1.6	1.1	1.7	-	1163
Borneol	0.8	0.7	1.1	1.0	1.2	1170
Terpinen-4-ol	1.9	1.9	3.1	2.0	4.9	1178
α-Terpineol	2.5	2.0	2.9	3.0	3.6	1190
γ-Terpineol	0.4	0.3	0.5	0.5	0.4	1199
Cis- piperitol	0.4	0.4	0.6	0.5	0.5	1200
Trans piperitol	1.5	1.2	1.5	1.4	0.6	1210
Cis-Carveol	-	6.4	5.0	1.7	-	1230
Carvone	5.9	5.9	3.2	1.0	-	1243
Piperitone	15.7	16.2	11.9	28.7	1.1	1249
Geraniol	2.5	4.7	3.0	0.8	1.6	1267
Bornyl acetate	0.6	1.0	0.9	0.9	0.5	1284
Terpinen-4-ol-acetate	7.5	9.6	5.4	0.7	-	1300
Dihydro-Carveol acetate	0.4	0.3	0.4	0.3	0.6	1308
Germacrene D	-	-	0.5	4.7	-	1485
Total (%)	94	94	92	93	88	-

Table 4 Essential oil compositions (%) of *Achillea biebersteinii* Afan. cultivated under field conditions (in the twice year)

Component	A1	A2	A3	A4	A5	RI
α-pinene	1.3	1.5	1.5	1.6	1.6	932
Camphene	0.8	1.0	0.9	0.7	0.9	946
Sabinene	-	-	-	-	0.3	969
Myrcene	0.8	0.9	0.9	1.0	0.9	988
α- terpinene	0.5	0.4	0.6	0.4	0.4	1014
p-Cymene	8.0	7.1	9.0	6.6	2.7	1020
1,8-Cineole	24.9	33.5	28.3	37.9	32.8	1026

γ-Terpinene	0.5	0.4	0.4	0.5	0.5	1054
Terpinolene	2.1	2.2	1.9	1.6	2.4	1085
1-Terpineol	-	-	5.2	-	-	1130
Camphor	6.5	6.2	-	4.4	5.9	1145
Borneol	1.8	2.1	2.6	1.8	3.0	1170
Terpinen-4-ol	2.8	0.4	0.4	0.4	0.5	1177
α-Terpineol	1.6	1.4	1.3	1.1	1.4	1189
γ-Terpineol	0.8	0.7	2.6	0.8	0.6	1199
Carvone	7.5	5.2	6.7	4.5	1.7	1243
Bornyl acetate	17.0	16.0	16.9	13.7	26.9	1284
Carvacrol	8.6	6.3	8.3	4.9	2.4	1300
Dihydro Carveol acetate	0.6	0.5	-	0.6	0.4	1307
Spathulenol	0.5	0.3	-	-	-	1580
Caryophyllene oxide	0.8	0.6	-	0.6	0.3	1585
Total (%)	87	87	88	83	86	-

Table 5 Mean comparision of *Achillea biebersteinii* Afan. essential oil compounds in natural habitats and field conditions

Compound	(%)	
	Cultivated conditions	Natural habitats
p-Cymene	5.03 e	7.75 d
1,8-Cineole	33.07 a	24.68 b
γ-Terpinene	0.5 g	0.38 g
Terpinolene	1.27 e	-
Borneol	1.61 ef	1.13 ef
4-Terpinenol	1.83 f	-
α-Terpineol	2.08 f	-
Carvone	4.62 e	-
Bornyl acetate	9.44 c	-
α -Pinene	-	0.82 g
Comphene	-	0.75 g
Comphor	-	3.38 ef
α-Terpinene	-	0.98 fg

Means followed by the same letter are not significantly different by Duncan's Multiple Range Test (MRT) at $P \leq 0.05$.

As already mentioned, the results obtained from the natural habitat and field demonstrated three main combinations (compounds) including 1,8-cineole, Bornyl acetate, and *p*-cymene. The first study was carried out by Jaimand and Rezaee (2001), where four chemical compounds i.e. piperitone(45/9%), 1,8-cineole(17/6%), limonene(5/6%), and *p*-cymene (5/2%) were detected from *A. biebersteinii* Afan, collected from the Sabalan Mountain in East Azarbaijan province [23]. Except for the difference in the two compounds, 1,8-cineole and *p*-cymene were similar to those identified in our research.

According to a study performed by Esmaeili *et al.* (2006) in the city of Maku, West Azarbaijan province, three compounds, including camphor (36/3%), 1,8-cineole (22/3%), and Borneol (7/3%), were identified in the essential oils of the three parts (shoots, leaves and flowers) of *A. biebersteinii* Afan, among which only camphor was different [24]. In another report, consistent with our findings, Ghani *et al.* (2008) also documented that 1,8-cineole (32/8%), carvacrol (10/9%), and piperitone (7/3%) were the main components of the essential oil isolated from *A. biebersteinii* Afan. collected from Khorasan-Razavi province [25]. Mirahmadi *et al.* (2012) classified 23 populations of *A. biebersteinii* Afan. in the country's natural habitats, in which two populations of Zeribar lakes-

Marivan and Nanur-Baneh were observed among the populations studied. These researchers identified the most important compounds of essential oils in two populations of Kurdistan province: 1,8-cineole (Zeribar, 43.1% and Nanur, 59.9%) and stated that in Zeribar, *p*-cymene(14.2%), and in the Nanur population, camphor (19.6%), at the next level, were important[26]. So far, their data are similar to our experimental results; however, other chemical compounds were reported in their research such as cis-chrysanthenyl acetate and a derivative of nepetalactone, each as much as 14.5% from the Zeribar-Marivan population, which did not exist in our test results. In the latest research, Mirahmadi and Norouzi (2017) collected *A. biebersteinii* Afan from the Karaj habitat in Alborz province and analyzed the essential oils composition in different ways. In the GC/MS method, the dominant chemical compounds were 1,8-cineole(45/2%), *p*-cymene (20/8%), and cis-chrysanthenyl acetate (20.4%), so that the initial two primary combinations are similar to the results of the present study [12].

Azizi *et al.* (2010) studied the essential oils of *A. biebersteinii* Afan samples in four growth stages of the cultivated accessions in Ferdowsi University of Mashhad, and stated that the flowering stems in the fully flowering stage had the main chemical compound 1,8-cineole (35.5%) [27]. This result is in agreement with our results in the present study. According to Farhoudi and Mehrnia (2013), sabinene(18.8%) was reported to be as the main component (compound) in the essential oils from *A. biebersteinii* Afan, collected from Azad University Farm of Shoushtar, Khuzestan province[28], which was absent in the essential oils of cultivated samples of Kurdistan province. However, these researchers reported two compounds including camphor (14.5%) and Borneol (12%), which were similar to our research. Mottaghi *et al.* (2016) identified 26 chemical compounds in the essential oil extracted from the *A. biebersteinii* Afan flowering shoots in the Alborz Research Station of Karaj, among which *p*-cymene (14.6%), piperitone (13.1%), camphor(12.8%), and 1,8-cineole (12%) were the main components (compounds) [3]. The quality and type of chemical compounds obtained from their experiment were similar to those of the first year of our research, and as a result, these researchers were likely to sample from the first year of cultivation. According to the study conducted by Vaez-Shahrestani and Sefidkon (2018) on the accessions of *A. biebersteinii* Afan, belonging to the Golestan province, at the Alborz Research Station of Karaj, 1,8-cineole was identified as the main chemical compound of the essential oils of flower, leaves, shoots and flowering shoots. However, the flowering shoots (shoots) had 1,8-cineole(35.4%), artemisia ketone (30.6%), and camphor (16.2%) [29]. Their results were similar to our findings except for artemisia ketone, not observed in our samples.

The chemical compound 1,8-cineole (known as eucalyptol) is an oxidizing ring-monoterpene with a chemical formula of $C_{10}H_{18}O$, which is found in the essential oils of many Eucalyptus species[32] and several natural sources. It is an important ingredient in many mouthwashes and is also antiseptic and antispasmodic. 1,8-cineole reduces inflammation and pain when it is applied topically. It also eliminates leukemia cells *in vitro* [30]. Santos and Rao (2000) and Sefidkon *et al.* (2007) stated that 1,8-cineole, a terpenoid oxide is present in many plant essential oils, acting as an anti-inflammatory and pain agent due to the effect of inhibition on the formation of prostaglandin and monocyte cytokines [31,32]. Comparison of the amount of this compound in the essential oils shows that the total essential oil of aerial parts contains the highest amount of 1,8-cineole. Bornyl acetate with the molecular formula of $C_{12}H_{20}O_2$ is a monoterpene ester and a sedative compound used to treat respiratory tract infections in the treatment of pulmonary diseases [33,34]. P-cymene [1-methyl-4-(1-methylethyl)-benzene] is a monoterpene found in over 100 plant species used for medicine (as antimicrobial agent) and food purposes [35].

In conclusion, our results represented alterations in the qualitative and quantitative composition of the essential oils obtained from *A. biebersteinii* Afan due to the different locations (accessions). Moreover, the chemical profile of *A. biebersteinii* Afan was affected depending on the cultivated conditions or natural growth of Kurdistan province, suggesting its capability and flexibility to be cultivated in the field conditions. The results of the study on the essential oil obtained from cultivated conditions and natural habitats are very important for the next stages of cultivation and domestication of *A. biebersteinii* Afan.

Conclusion

The flowering shoots of the accession obtained from Qurveh region in the first year under field cultivation had a good quality and quantity of essential oil. If harvesting is necessary in the first year of cultivation, further investigation on the accession obtained from the Qurveh area is recommended. Both accessions from Khan and Booein village, belonging to the Baneh county, exhibited the highest amounts of 1,8-cineole and Bornyl acetate in both cultivation conditions and in both years. As a result, most accessions of the Baneh region, which are important for the preparation of these chemical compounds suitable for cold cure medications are recommendable. Accessions from Janevareh village and Nei village in Marivan city had (showed) the highest amount of *p*-cymene in both cultivation conditions and in both years. Therefore, further investigation on the *A. biebersteinii* Afan accessions in the Marivan area is recommended for the preparation of this chemical composition (compound).

References

1. Bocevska M, Sovova H, Supercritical CO2 extraction of essential oil from Yarrow. J Supercritical Fluids. 2007;40:360-367.
2. Ghani A, Azizi M, Hassanzadeh-Khayyat M, Pahlavanpour AA, Comparison of chemical composition of *Achillea eriophora* and *A. wilhelmsii* grown in wild and cultivated conditions in Iran. J Essent Oil-Bearing Plants. 2011;14:617-624.
3. Mottaghi M, Salehi Shanjani P, Jafari AA, Mirza M, Mihamta MR, Essential oil composition of *Achillea filipenulina*, *A. arabica* and *A. eriophora* cultivated under temperate climate in Iran. J Med Plants by-products. 2016;2:153- 158.
4. Siyahlou S, Barzin G, Entezari M, Review and study of *Achillea milefollium* essential oil compounds in various stages of development. Inter Res J Applied Basic Sci. 2016;10:1112-1115.
5. Lawrence BM, Progress in essential oils. Perfume, Flavor. 1998;9:43.
6. Salehi Shanjani P, Mozafarian VA, Genetic Relationships among Three Yarrow Species Based on Phenotypic Traits and Peroxidase Profiling. J Med Plants By-products. 2016;1:75-88.
7. Chialva F, Monguzzi F, Manitto P, Akgul A, Essential oil constituents of *Achillea biebersteinii* Afan. J Essent Oil Res. 1993;7:87-88.
8. Kusmenoglu S, Baser KHC, Ozek T, Hannandar M, Gokalp Z, Constituents of the essential oil of *Achillea biebersteinii* Afan. J Essent Oil Res. 1995;7:527-528.
9. Bader A, Flamini G, Cioni PL, Morelli I, Essential oil composition of *Achillea santolina* L. and *Achillea biebersteinii* Afan. collected in Jordan. Flavour Fragr J 2003;18:36-38.
10. Baris O, Gulluce M, Şahin F, Ozer H, Kilic H, Ozkan H, Sokme M, Ozbek T, Biological activities of the essential oil and methanol extract of *Achillea biebersteinii* Afan. (Asteraceae). Turkish J Biology. 2006;30:65-73.
11. Rustaiyan A, Komeilizadeh H, Sanei Shariatpanahi M, Jassbi AR, Masoudi S, Comparative study of the essential oils of three *Achillea* species from Iran. J Essent Oil Res. 1998;10:207-209.
12. Mirahmadi SF, Norouzi R, Chemical composition, phenolic content, free radical scavenging and antifungal activities of *Achillea biebersteinii*. Food Bioscience. 2017;23.
13. Rahimmalek M, Tabatabaei BE, Etemadi N, Goli SAH, Arzani A, Zeinali H, Essential oil variation among and within six *Achillea* species transferred from different ecological regions in Iran to the field conditions. Industrial Crops and Products. 2009;29:348-355.
14. Toncer O, Basbag S, Karaman S, Diraz E, Basbag M, Chemical composition of the essential oils of some *Achillea* species growing wild in Turkey. Int J Agric. Biol. 2010;12:527-530.
15. Fiume MZ, Final report on the safety assessment of Yarrow (*A. millefolium*) extract. Int. J Toxicol. 2001;20:79-84.
16. Teixeira da Silva JA, Mining the essential oils of the Anthemideae. Afr. J. Biotechnol. 2004;3:706-720.
17. Benedek, B, Kopp B, Melizg MF, *Achillea millefolium* L. Is the anti-inflammatory activity mediated by protease inhibition?. J Ethnopharmacol. 2007;113:312-317.
18. Nemeth E, Essential oil composition of species in the genus *Achillea*. J. Essent. Oil Res. 2005;17:501-512.
19. Gudaityte O, Venskutonis PR, Chemotypes of *Achillea millefolium* transferred from 14 different locations in Lithuania to the controlled environment. Biochem. Syst. Ecol. 2007;35:582–592.
20. Rechinger K.H, Flora Iranica, Akademische Druck U.Vernagsanstalt, Graz–Austria, No.158, 1986.
21. Mozafarian VA, Dictionary of Iranian Plant Names, Farhange Mosavar, Tehran, Iran, p: 11, 1996.
22. Ellenberger A, First International Symposium on the Conservation of Medicinal Plants in Trade in Europe, Ed.TRAFFIC Europe, Kew, UK, p: 127, 1998.
23. Jaimand K, Rezaee MB, Comparative Study of the Essential Oils of Three *Achillea* Species from Iran. J Essent Oil Res. 2001;13:354-356.
24. Esmaeili A, Nematollahi F, Rustaiyan AH, Moazami N, Masoudi SH, Bamaslan SH, Volatile Constituents of *Achillea pachycephala*, *A. oxyodonta* and *A. biebersteinii* From Iran. Flavour Fragr J. 2006;21:253-256.
25. Ghani A, Azizi M, Hassanzadeh-Khayyat M, Pahlavanpour AA, Essential oil composition of *Achillea eriphora*, *A. nobilis*, *A. biebersteinii* and *A. wilhelmsii* from Iran. J Essent Oil-Bearing Plants. 2008;11:460-467.

26. Mirahmadi SF, Hassandokht MR, Sefidkon F, Hassani ME, Variability of the essential oil content and composition among the wild populations of *Achillea biebersteinii* Afan. From Iran: occurrence of new nepetalactones chemotypes. J Essent Oil Res. 2012;24:523-531.
27. Azizi M, Chizzola R, Ghani A, Oroojalian F, Composition at different development stages of the essential oil of four *Achillea* species grown in Iran. Natural Product Communications. 2010;5:283-290.
28. Farhoudi R, Mehrnia MA, The Essential Oil Composition and Antioxidant Activity of *Achillea* spp. Growing in The Southwest of Iran. J Med Plants By-products. 2013;2:123-130.
29. Vaez Shahrestani AV, Sefidkon F, Essential oil composition in different plant parts of *Achillea biebersteinii* Afan. Iranian J Med Aromatic Plants. 2017;34:40-49.
30. Vojoodi S, Sefidkon F, Salehi P, Salehi Sormaghi M, Essential Oil Content and Composition of Different Parts (Stem, Leaf, Flower and Aerial Part) of *Achillea filipendula* Lam. J Med Plants. 2018;2:91-99
31. Santos FA, Rao VSN, Anti-inflammatory and anti-nociceptive effects of 1,8-cineole a terpenoid oxide present in many plant essential oils. Phytotherapy Res. 2000;14:240-244.
32. Sefidkon F, Assareh MH, Abravesh Z, Barazandeh MM, Chemical composition of the essential oils of four cultivated Eucalyptus in Iran as medicinal plants (E. micratheca, E. spathulata, E. largiflorens and E. torquata). Iranian J Pharmaceutical Res. 2007;6:135-140.
33. De Vincenzi M, Silano M, De Vincenzi A, Maialetti FC, Scazzocchio B, The essential oils. Fitoterapia B. 2002;73:269.
34. Lee NH, Lee SM, Lee TM, Chung N, Lee HS, GC-MS analyses of the essential oils obtained from Pinaceae leaves in Korea. J Essent Oil-Bearing Plants. 2015;18:538-542.
35. Marchese A, Arciola CR, Barbieri R, Silva AS, Nabavi SF, Sokeng AJT, Izadi M, Jafari NJ, Suntar I, Daglia M, Nabavi SM, Update on monoterpenes as antimicrobial agents: a particular focus on *p*- cymene. Materials (Basel). 2017;10:947.