



The Impact of Morpho- and Onto-Genetic Variation on Essential Oil Profile of *Hypericum heterophyllum* Vent., an Endemic Species in Turkey's Flora

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ABSTRACT

The objectives of this research were to determine the variations in the amount and chemical composition of the herbage essential oil according to different harvesting periods, and the amount and composition of the dry capsule essential oil in *Hypericum heterophyllum*. The samples of herbage in four different growth stages as before flowering, beginning flowering, 50% of flowering, and full flowering and dry capsule in full maturity stage were taken from plants in a natural environment. The highest essential oil rate (0.09%) in the aerial parts was recorded before the flowering stage. Also, germacrene-D, δ -cadinene, spathulenol, and α -guaiene in herbage and germacrene-D, caryophyllene oxide, and α -guaiene in the dry capsule were determined as main components. The essential oil content and the components showed variations depending on the developmental stages of the plant and the part used.

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Türkiye Florasında Endemik Bir Tür Olan *Hypericum heterophyllum* Vent.'in Uçucu Yağ Kompozisyonuna Morfogenetik ve Ontogenetik Varyasyonun Etkisi

ÖZET

Bu araştırmanın amacı, farklı hasat dönemlerine göre herba uçucu yağın miktar ve kompozisyonundaki değişimi ve *Hypericum heterophyllum*'da kuru kapsül uçucu yağın miktar ve kompozisyonunu belirlemektir. Bitkilerden çiçeklenme öncesi, çiçeklenme başlangıcı, %50 çiçeklenme ve tam çiçeklenme dönemi olmak üzere dört farklı büyüme dönemindeki herba, tam olgunluk döneminde ise kuru kapsül doğal ortamdaki bitkilerden toplanmıştır. Toprak üstü kısımlarda en yüksek uçucu yağ oranı (%0.09) çiçeklenme öncesi dönemde kaydedilmiştir. Ayrıca herbada germakren-D, δ -kadinen, spathulenol ve α -guaien, kuru kapsülde germakren-D, karyofillen oksit ve α -guaien ana bileşenler olarak belirlenmiştir. Uçucu yağ içeriği ve bileşenleri bitkinin gelişim evrelerine ve kullanılan kısma bağlı olarak değişiklik göstermektedir.

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INTRODUCTION

There are 482 *Hypericum* species distributed in different geographies of the world from the equatorial zone to the Nordic countries in the north (Mártonfi, 2006; Crockett & Robson, 2011; Cırak & Kurt, 2014). *Hypericum* species have been used in many parts of the world for many years because of their healing, bactericidal, diuretic, anti-inflammatory, and sedative effects (Cırak & Kurt, 2014). Especially, several extracts from *H. perforatum* L. are used as a drug in Europe (Brutovska et al., 2001). Turkey is an

important gene center in terms of *Hypericum* species and 49 of the 119 taxa are endemic (Guner et al., 2012). One of these endemics is *H. heterophyllum* Vent. which is a perennial, shrub form, and blooming in August. Its habitat is reported as *Pinus* woodlands (1200-1600 m altitude) (Anonymous, 2021). This species is known locally as "Yaraotu" in Turkey (Guner et al., 2012).

Secondary metabolites (essential oils, alkaloids, glycosides, steroids, saponins, resins, etc.) are invaluable effects phytochemicals (Baydar, 2013).

Hypericum species contain a large number of secondary metabolites of at least 11 different classes, including bisantraquinones, phloroglucinol derivatives, flavonoids, organic acids, essential oils, amino acids, xanthenes, tannins, procyanidins, and other water-soluble components (Greenson et al., 2001; Tanaka & Takaishi, 2006; Bal et al., 2022). However, Patocka (2003) refers to the pharmacological effects of *Hypericum* extracts to hypericin, flavonoids, and essential oils, which are hypericin and pseudohypericin, and phloroglucinol derivatives, with naphthodianthrones pigments. Hypericin and pseudohypericin are the naphthodianthrones derivatives, they are not phloroglucinol derivatives. Essential oils secreted by aromatic plants are stored in droplets in some specific metabolic cells and tissues such as secretion hairs, secretion channels, and resin channels (Baydar, 2013). They are obtained from different organs of plants such as leaves, flowers, and stalks. It is known that essential oils have various biological activities. The essential oil isolated from *H. heterophyllum* exhibited antifungal activity (Cakir et al., 2004). The aqueous extracts prepared from aerial parts of this species showed clastogenic and genotoxic effects in human lymphocytes cultures (Ocal & Eroglu, 2012). Furthermore, it was observed that *H. heterophyllum* had significant impact on several bacteria (*Bacillus* sp., *Esherichia coli*, *Klebsiella* sp., *Pseudomonas* sp., *Staphylococcus* sp., and *Salmonella* sp.) (Tanker et al., 1980; Akgoz, 2015). The contents of bioactive substances composed of secondary metabolites vary significantly depending on the plant's organs (morphogenetic variability), life cycles of the plant (ontogenetic variability), and harvest/collection time of the plant (ontogenetic variability) (Ramakrishna and Ravishankar, 2011; Baydar, 2013; Saha et al., 2016).

Therefore, the objectives of this research were to determine the variation in the amount and chemical composition of the herbage essential oil according to different harvesting periods, and the amount and composition of the dry capsule essential oil in *H. heterophyllum*, an endemic species. The data obtained from this research was determined for the first time for this species.

MATERIALS and METHODS

The aerial parts and dry capsules of *H. heterophyllum* were collected from the natural area (Study Area: Inside the Yozgat Bozok University Campus Area; Altitude: 1340 m; Locality: 9°46'48,04'' N-34°48'02,34'' E) in Yozgat/Turkey). According to the climate data of the area where plant samples were collected for many years, total precipitation was 562.5 mm, the average temperature was 9.1 °C, the average highest temperature was 14.6 °C, the average lowest temperature was 4 °C, average sunshine time was 82.0 h and the average number of rainy days was 113.5

(Anonymous, 2020). Identification of the plant sample (Herbarium number: BCF-1/2014) was performed in Biology Laboratory at Yozgat Bozok University/Turkey. Herbarium samples are kept in the Field Crops Department of the Faculty of Agriculture.

Plant Material

The aerial parts were collected in four different stages as before flowering (BF1, in May), beginning flowering (BF2, in June), 50% of flowering (50% F, in July), and full flowering (FF, in July). Dry capsules were collected in October. In the laboratory, seeds were removed from dry capsules. The samples weighed as 2 g were determined by moisture analyzers (MA 210.R, Radwag, Radom, Poland) for 15 min at 160 °C.

Capsule and Herbage Essential Oil Contents and Chemical Compositions

The amount of essential oil in herbage and dry capsule were determined by hydro-distillation method in the Clevenger device. An 100 g of sample for herbage and 50 g of sample for dry capsule were used. The samples were ground in the blender and 10 times distilled water was added and hydro-distilled for 3 h. The amounts of the essential oils (% v/w) were determined by volume over dry matter. The essential oils were taken into dark-coloured flasks and stocked at 4 °C in a refrigerator until they were analysed (Damyanova et al., 2016).

The chemical components of the essential oils from four collection times were defined by gas chromatography (GC) and gas chromatography-mass spectrometry (GC/MS) analyses (GC/MS-QP2010 Ultra, Shimadzu, Japan). The 0.1 mL oil sample was dissolved in 10 mL *n*-hexane and shaken vigorously. It was kept in the dark for 1-2 h. The sample was taken into vials and given to the device. The information about the chromatographic method is given below:

Column: RXI-5MS (0.25µm x 30m x 0.25mm); Scan range: 35-600 m/z; Split ratio: 30; Oven temperature: 60 °C for 1 min followed by a temperature rise at a 4 °C min rate to 250 °C (held for 4 min); Flow rate: 1.50 mL/min. The essential oil components were identified by comparing their mass spectra, retention indices, and relative to C₅-C₄₀ *n*-alkanes, the FFNSC 1.2 and W9N11.1 mass spectral library, and the literature (Babushok et al., 2011).

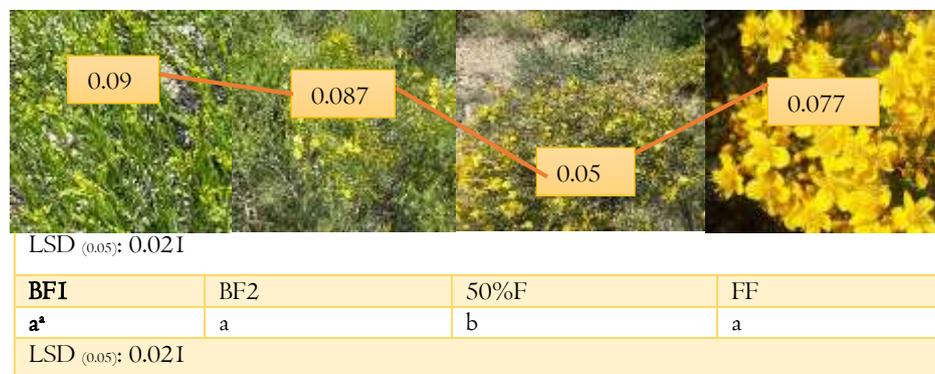
Statistical Interpretation

The numerical data were stated as means ± standard error of the mean. The amount of essential oil was made with three replications. Analysis of variance was performed using TARIST package program, and the means were compared using LSD test (p<0.05) (Acikgoz et al., 2004).

RESULTS and DISCUSSION

The aerial parts of *H. heterophyllum* were recorded to contain 0.090±0.01% (v/w), 0.087±0.006% (v/w), 0.050±0.00% (v/w), and 0.077±0.02% (v/w) essential oil for BF1, BF2, 50% F, and FF stages, respectively (Figure 1). The highest and lowest essential oil content

was obtained from BF1 and 50% F stage, respectively. According to Cirak et al. (2022) stated that component accumulation in essential oils is higher in *Hypericum androsaemum* and *Hypericum xylosteifolium* species during the before flowering and full flowering stages and these periods are the most suitable period for harvesting.



* Means followed by the same letter are not significantly different

Figure 1. The impact of different growth stages on the essential oil content of *H. heterophyllum* (%)

Şekil 1. Farklı büyüme aşamalarının *H. heterophyllum*'un uçucu yağ miktarına etkisi (%)

In term of essential oil contents, in the previous study, it was stated that hydrodistillation of the dried aerial parts of *H. heterophyllum* yielded 0.09% of the essential oil (Cakir et al., 2004). The amount of the essential oil from aerial parts of *H. aucheri* Jaub.&Spach, *H. montbretii* Spach, and *H. perforatum* L. was 0.28%, 0.22%, and 0.23% in the before flowering, 0.27%, 0.20%, and 0.33% in the beginning of flowering, 0.33%, 0.23%, and 0.37% in the full flowering, 0.02%, 0.03%, and 0.05% in the capsule during, respectively (Pasa, 2013). In the four *Hypericum* species, the highest essential oil ratio was obtained from the plants harvested in the full flowering period. In our study, the highest rate of essential oil was recorded in BF1, followed by BF2 and FF. It has been observed that the amount and composition of essential oil in *Hypericum* species show a wide variation according to the harvest time and the developmental periods of the plant (Guedes et al. 2004; Bertoli et al., 2011).

The chemical components of the essential oils of *H. heterophyllum* collected at four different developmental stages were given in Table 1. A total of 14, 12, 11, and 10 components representing 91.50%, 73.40%, 82.67%, and 71.61% of the total essential oils were detected in the BF1, BF2, 50%F, and FF stages, respectively.

In this study, germacrene-D, bicyclogermacrene, δ -cadinene, spathulenol, α -guaiene, and α -muurolene having significant biological activities were found to be the main components of essential oils obtained from different ontogenetic stages of *H. heterophyllum*. The highest concentrations of germacrene-D were recorded in the BF1, 50% F, and BF2 stages, respectively. This component showed a significant decrease by average 3

times in the FF stage. Bicyclogermacrene reached the maximum concentration in the BF1 stage. The amount of this compound reduced approximately to half in the 50% F and BF2 stages, and it was not detected in the FF stage. Although the highest amount of δ -cadinene was recorded in the FF period, similar rates were obtained in BF1 and 50%F stages. But a decrease of about 7% was observed in the BF2 stage. The highest ratio of spathulenol was recorded in the 50% F stage, followed by the BF2 stage. The lowest ratio was obtained from BF1 stage. The amount of α -muurolene being among the minor components in the BF1, BF2, and 50%F stages was found to be 9.76 % in the FF stage. α -Guaiene was detected only in the essential oil in the FF stage. Significant differences in the concentrations of the main components of *H. heterophyllum* essential oils were determined according to the developmental stages. A similar situation was observed in the minor components of the essential oil such as β -caryophyllene, α -humulene, aromadendrene, viridiflorol, globulol, salvial-4(14)-en-1-one, isospathulenol, t-muurolol, α -amorphene, and α -cadinol.

In the dry capsules, 0.087±0.015% (v/w) essential oil was acquired. In the obtained essential oil, 23 components were determined, and Germacrene-D had the highest value with 33.81% among these components. This component was followed by caryophyllene oxide (18.08%), β -caryophyllene (9.45%), α -cadinol (6.05%), and α -pinene (5.53%), respectively. Also, cadalene, phytol, phytone, α -bisabolol, β -pinene, and *n*-pentadecanol have been recorded as other important components (Table 1). No studies on the capsule essential oil content and composition of *H.*

heterophyllum have been found in the literature review. However, the essential oil obtained from immature and mature fruits of *H. androsaemum* L.

were 0.3% and 0.1%, respectively. A decrease in the amount of essential oil was recorded with the ripening of the fruits (Caprioli et al., 2016).

Table 1. The chemical components of *H. heterophyllum* essential oils

Çizelge 1. H. heterophyllum uçucu yağının kimyasal bileşenleri

Peak	Compounds	RI ^a	RI ^b lit. data	Area (%)					
				Dry Capsule	BF1	BF2	50%F	FF	
1	α -Pinene	MH	943	934	5.53	- ^c	-	-	-
2	α -Fenchene	MH	944	945	0.33	-	-	-	-
3	Camphene	MH	968	947	0.11	-	-	-	-
4	β -Pinene	MH	982	973	2.69	-	-	-	-
5	Myrcene	MH	990	983	0.23	-	-	-	-
6	Limonene	MH	1020	1023	0.63	-	-	-	-
7	<i>trans</i> - β -ocimene	MH	1035	1038	0.21	-	-	-	-
8	<i>trans</i> -Verbenol	OS	1132	1133	0.36	-	-	-	-
9	α -Copaene	SH	1375	1375	-	0.70	-	-	-
10	β -Cubebene	SH	1386	1383	-	1.04	-	-	0.58
24	δ -Gurjunene	SH	1405	1405	-	1.86	-	4.09	-
11	β -Caryophyllene	SH	1422	1419	9.45	4.07	2.18	3.08	1.77
12	α -Guaiene	SH	1438	1442	-	-	-	-	14.30
13	Aromadendrene	SH	1440	1439	-	-	1.89	2.29	-
14	α -Humulene	SH	1451	1449	1.27	2.04	1.37	1.86	-
15	Germacrene-D	SH	1478	1475	33.81	21.61	12.78	18.35	5.49
16	β -Selinene	SH	1488	1480	-	-	-	-	1.40
17	α -Muurolene	SH	1491	1491	0.79	4.21	4.12	1.70	9.76
18	Bicyclogermacrene	SH	1498	1498	1.11	12.55	6.81	7.66	-
19	δ -Cadinene	SH	1523	1513	-	19.57	12.54	19.21	20.20
20	Spathulenol	OS	1574	1566	1.25	11.08	17.48	18.22	13.17
21	Caryophyllene oxide	OS	1578	1570	18.08	-	-	-	-
22	Globulol	OS	1581	1578	-	-	3.74	-	-
23	Viridiflorol	OS	1590	1579	-	3.31	-	-	-
26	α -Muurolol	OS	1626	1626	1.38	-	-	-	-
25	Isospathulenol	OS	1633	1625	-	1.41	1.94	2.58	2.45
28	T-muurolol	OS	1642	1631	-	3.45	2.85	3.63	2.49
29	β -Eudesmol	OS	1649	1633	0.98	-	-	-	-
30	α -Cadinol	OS	1652	1640	6.05	4.60	5.70	-	-
31	Cadalene	SH	1665	1654	3.99	-	-	-	-
32	α -Bisabolol	OS	1680	1668	2.92	-	-	-	-
33	<i>n</i> -Pentadecanol	A	1770	1773	2.52	-	-	-	-
34	Phytone	D	1835	1840	2.92	-	-	-	-
35	Phytol	D	2098	2099	3.75	-	-	-	-
Monoterpene hydrocarbons (MH), %					9.73	-	-	-	-
Sesquiterpene hydrocarbons (SH), %					50.42	67.65	41.69	58.24	53.5
Oxygenated sesquiterpenes (OS), %					31.02	23.85	31.71	24.43	18.11
Alcohols (A), %					2.52	-	-	-	-
Diterpenes (D), %					6.67	-	-	-	-

^a Retention Index, ^b Retention Index literature data, ^c Not detected

In the study carried out by Cakir et al. (2004), in the essential oil of *H. heterophyllum*, 35 compounds, representing 99.4% of the total essential oil, were determined, and isocaryophyllene (17.1%), α -pinene (11.6%), δ -cadinene (9.5%), γ -muurolene (8.2%), γ -cadinene (5.5%), *n*-decane (5.8%), and β -caryophyllene (4.5%) were recorded as major compounds in this essential oil. Although there is a similarity between these findings and the present study, there are some

differences. Essential oil components have been reported to be affected by many intrinsic (genetic, plant origin, type of plant part, stage of development or seasonal sampling period, etc.) and extrinsic factors (environmental factors such as climate and habitat conditions, sowing date, cultivation conditions, and postharvest techniques such as drying methods and extractions, distillation time, and conditions of analysis) (Moghaddam and Mehdizadeh, 2017).

In terms of the effect of ontogenetic variability on essential oil components, the full flowering stage was more effective in *H. perforatum* L. and *H. aucheri* Jaub.&Spach. species (Pasa, 2013). The amount of essential oil and the changes in its chemical composition during ontogenesis are specific to each taxon (Németh, 2005). The findings from previous studies showed that there may be similarities and differences in its chemical composition and amount of essential oil of various species at different phenological stages of harvesting time in *Mentha aquatic* L. (Andro et al., 2013), *Origanum vulgare* L. (Chauhan et al., 2013), *Ocimum basilicum* L. (Lemberkovics et al., 1998), *Cuminum cyminum* L. (Moghaddam et al., 2015), and *Thymus capitatus* L. (Casiglia et al., 2015).

The timing of the harvest or collection of herbal crops is one of the most important factors affecting the quality of the essential oils obtained from them. The therapeutic properties of herbal drugs are related to the bioactive substances they contain. For this reason, the drug producer must, first of all, know the bioactive substance exchange of the medicinal and aromatic plant very well and gather the drug which is the richest of the active substances (Baydar, 2013). Essential oils are the most important of other volatile secondary metabolites derived from medicinal and aromatic plants. Therefore, obtaining high essential oil yields with the most desirable chemical compounds is very important for industrial purposes. The selection of appropriate phenological stage can help researchers to fulfil this requirement (Afshari & Rahimmalek, 2018).

In this study, herbage essential oils are composed of sesquiterpene hydrocarbons and oxygenated sesquiterpenes, while capsule essential oils are composed of sesquiterpene hydrocarbons, oxygenated sesquiterpenes, alcohols, and diterpenes. Also, germacrene-D (antimicrobial and insecticidal), bicyclgermacrene (antimicrobial), δ -cadinene (antimicrobial), spathulenol (antimicrobial), and α -guaiene (anti-inflammatory) caryophyllene oxide (anticancer) determined in the essential oils are compounds that exhibit significant biological activities (Jovanovic et al., 2005; Schmidt et al., 2007; Mishra et al., 2011; Montanari et al., 2011; Pérez-López et al., 2011; Eldeen et al., 2016; Fidy et al., 2016).

CONCLUSION

Significant effects of different development periods on herbage essential oil rate and composition were determined. On the other hand, it has been determined that the chemical profiles of essential oils obtained from herbage and capsule are different. The chemical composition of essential oil in medicinal and aromatic plants is an important factor that determines quality. The amount and composition of essential oil contained in plants is an indicator of the economic value of that

product. Considering the change of bioactive substances in plants, it should be well known in which development period the plant will be collected/harvested. In this study, herbage essential oil was higher in before flowering and beginning flowering stages than other growth stages. Therefore, these two growth periods can be recommended as the most suitable harvest time for herbage essential oil. Also, this study is the first to examine the change in the essential oil profile of *H. heterophyllum*. Therefore, the findings obtained will form an important basis for future studies.

Conflicts of Interest

The authors have no conflicts of interest to declare.

Researchers' Contribution Rate Statement Summary

Yazarlar makaleye eşit oranda katkı sağlamış olduklarını beyan eder.

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