Nat. Volatiles & Essent. Oils, 2015; 2(1): 37-48

NVEO Natural Volatiles & Essential Oils

RESEARCH ARTICLE

Essential oil content of cultivated *Satureja* spp. in Northern Greece

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Abstract

Eighteen populations of *Satureja montana, S. parnassica* subsp. *hellenica*, *S. pilosa* subsp. *pilosa*, *S. pilosa* subsp. *origanita* and S. *thymbra*, originated from different localities of Greece, were cultivated at the Laboratory for the Conservation and Evaluation of Native and Floricultural Species (North Greece). After one year of cultivation the plants were analyzed on the basis of their essential oils. The essential oils (EOs) of the aerial parts were obtained by hydrodistillation in a modified Clevenger-type apparatus, and their chemical analyses were performed by GC and GC-MS. The essential oil contents showed a positive response to cultivation. Oxygenated monoterpenes constitute the main fraction of 15/18 EOs (51.1%-89.6%). Some constituents were found even in different percentages in almost all samples: carvacrol, thymol, *p*-cymene, γ-terpinene, linalool, borneol, *cis*-sabinene hydrate, spathulenol and caryophyllene oxide. It is noteworthy that most *Satureja* species produce high amounts of carvacrol/thymol/*p*-cymene or linalool or geraniol/geranyl acetate, which are related biosynthetically. The results obtained are an important indication of the potential economic utility of cultivated *Satureja* spp. as a raw material and source of useful industrial oil compounds.

Keywords: *Satureja* L.; Cultivation; Essential oil; Oxygenated monoterpenes; GC-MS

Introduction

The genus *Satureja* L. comprises more than 30 species, distributed in the eastern Mediterranean area. Many members of this genus are well known for their aromatic and medicinal character, used as culinary herbs and in folk medicine to treat various ailments. Especially popular today is the concept of food that combines nutritional and medicinal benefits. *Satureja* spp. have been used in local market spices and as medicinal herbs. Because of the strong phenolic character of their essential oils characterized by high amounts of carvacrol (mainly *S. montana*), they are reminiscent of the taste and fragrance of commercial oregano and thyme oils (Milos et al, 2001). The content in carvacrol is considered very important, since this aromatic monoterpene holds a significant commercial interest, as it is a known antimicrobial, antiseptic and antioxidant agent with low acute toxicity and weak genotoxic potential. It is approved by both the FDA and the European Commission as an additive (De Vincenzi, 2004). Carvacrol is a common component of the oils from oregano, thyme, marjoram and summer savory (Hanlidou et al., 2004; Kokkini & Vokou, 1989).

The overall objective of the present research was to examine whether *Satureja* species growing wild in different localities of Greece could be cultivated in the Balkan Botanic Garden of Kroussia (North Greece) and to determine the effects of cultivation on essential oil yield and composition. The chemical composition of the essential oils of the cultivated plants were compared with the previously stated in the literature. The results could be very important because they could enforce the cultivation of this economically important genus.

Materials and Methods

Plant material

All eighteen members of *Satureja* spp. were collected from natural populations and voucher specimens have been deposited at the Balkan Botanic Garden of Kroussia (Greece)-Laboratory for the Conservation and Evaluation of the Native and Floricultural Species. Details of the collection localities are presented in Table 1. To make our results comparable, only plants in similar stages of development were analysed.

Table 1. List of *Satureja* taxa investigated with provenance and abbreviations.

Name	Abbreviation	Locality
S. montana	Stm1	Mont Pelion, alt. 500 m
S. montana	Stm2	Mont Pelion, alt. 500 m
S. montana	Stm3	Mont Pelion, alt. 500 m
S. montana	Stm4	Mont Pelion, alt. 500 m
S. montana	Stm5	Mont Tzena, Pella, alt. 640 m.
S. montana	Stm6	Mont Phalakro, Drama
S. montana	Stm7	Mont Olympos, Leptokarya, alt. 800m.
S. montana	Stm8	Mont Olympos, alt. 800m.
S. parnassica subsp. *hellenica*	Stp9	Island of Samothrace, alt. 150 m.
S. parnassica subsp. *hellenica*	Stp10	Island of Alonissos, Cap Gerakas, alt. 50 m.
S. pilosa subsp. *pilosa*	Stpi11	Mont Phalakro, Drama
S. pilosa subsp. *pilosa*	Stpi12	Mont Phalakro, Drama
S. pilosa subsp. *pilosa*	Stpi13	Mont Phalakro, Drama
S. pilosa subsp. *pilosa*	Stpi14	Mont Orvilos, Serres, alt. 750 m.
S. pilosa subsp. *origanita*	Stpi15	Mont Sapka, Evros, alt. 660 m.
S. pilosa subsp. *origanita*	Stpi16	Ferres, Evros, alt. 50 m.
S. pilosa subsp. *origanita*	Stpi17	Xanthi, Thrace, alt. 250 m.
S. thymbra	Sth18	Mont Athos, Chalkidiki

Propagation and Conservation conditions

The plants have been asexually propagated by softwood tip cuttings of 3-5 cm, under mist. Cuttings were placed in propagation trays in a substrate of peat (Klasmann, KTS 1) and perlite (1:3 v/v) and maintained at bottom heat benches in a polycarbonate greenhouse. Soil temperature was kept at 18-21 °C, while air temperature was 15-25 °C, depending on weather conditions, and relative humidity 90% (Hartman et al., 2002).

Young plants produced, were transplanted in 2 l pots in a mixture of peat (Klasmann, TS3) and perlite (2:1 v/v) and continue growing in the greenhouse. The temperature was different during the day and night and among the seasons (average temperatures day/night: winter 18/10 °C, spring 25/10 °C, summer 32/20 °C). The relevant humidity (RH) was kept at 55%. Drip irrigation system was applied for the plants and was dependant on the weather conditions (approximately 3 times/week, 400 ml/pot). Plants were fertilized with: a) 80% humic acid + 10% K_2O (1 g/l, 200 ml/pot), b) 20-20-20 N-*P*-K (3 g/l, 200 ml/pot).

At spring plants were transferred outside in a shaded (60%) nursery area. The pots were maintained on gravel for better drainage conditions. Irrigation was applied according to the weather conditions. Plant material for distillation was collected at two subsequent years (2005 and 2006) during the flowering stage.

Essential oil extraction

30 g of air-dried aerial parts of each plant material were cut in small pieces, and the essential oils were obtained by hydrodistillation for 2 hours in a modified Clevenger apparatus with a water-cooled oil receiver to reduce artefacts due to over-heating (Hellenic Pharmacopoeia, 2002). The oils were taken in 2 ml of capillary GC grade *n*-pentane and dried over anhydrous sodium sulphate and subsequently stored at -20 ºC to minimize the loss of volatile compounds. Two oil samples for each plant material were prepared and then analysed by GC and GC–MS analyses.

GC analysis

GC analyses were carried out on a Perkin-Elmer-8500 gas chromatograph with FID, fitted with a Supelcowax-10 fused silica capillary column (30 m x 0.32 mm (i.d.), film thickness: 0.25 μm). The column temperature was varied from 75 ºC to 200 ºC at a rate of 2.5 ºC/min. The injector and detector temperatures were programmed at 230 °C and 300 °C, respectively. The injection volume was 2 μl of the pure oil.

GC-MS analysis

GC-MS analyses were performed on a Hewlett-Packard 5973-6890 system operating in EI mode (70eV) and equipped with a split/splitless injector (220 ºC). A split ratio 1:10 and two different columns were used: a fused silica H*P*-5MS capillary column [30 m x 0.25 mm (i.d.), film thickness: 0.25 μm] and a H*P*-Innowax capillary column [30 m x 0.25 mm (i.d.), film thickness: 0.50 μm]. The temperature program for the HP-5MS column was from 60 ºC (5 min) to 280 ºC at a rate of 4 ºC/min and for the H*P*-Innowax column from 60 ºC to 260 ºC at a rate of 3 ºC/min Helium was used as a carrier gas at a flow rate of 1.0 ml/min. The injection volume was 2 μl. The identification of the components was based on comparison of their mass spectra with those of the Wiley libraries (Massada, 1976) and with those described by the bibliography (Adams, 2007; Davies, 1990). Retention indices (RI) for all compounds were determined according to Van den Dool and Kratz (1963), using *n*-alkanes (C_9-C_{24}) as standards. In many cases, the essential oils were subject to co-chromatography with authentic compounds (Fluka, Sigma).

Optical rotation

The $[\alpha]_D^{20}$ values were determined at 20 ºC at 589 nm in CH_2Cl_2 on Perkin-Elmer 341 Polarimeter.

Results and Discussion

The essential oils obtained were yellow in colour, with characteristic and picking odour. The identified volatile components are listed in Table 2, together with their retention indices and percentages. Oxygenated monoterpenes constitute the dominant group of the 15 samples. The rate ranges from 51.1% (Stpi12) to 89.6% (Stpi17).

S. montana (Stm1-8)

The first three samples are very similar in chemical composition and their predominant compound is carvacrol (61.0%, 56.7%, 51.4%, respectively). In contrast, Stm4 is characterized by the presence of monoterpene hydrocarbons (54.4 %), while in Stm5 and Stpi14 the main sub-group is the oxygenated sesquiterpenes (89.7 %; 80.9 %, respectively), with caryophyllene oxide and spathulenol as main components. It should be noted that Stm5 and Stpi14 are the only oil-poor specimens. Stm7 was distinct in chemical composition from the other samples containing as a major components geranyl acetate (28.6%) and geraniol (21.6%). According to Dardiotis (2005), the essential oils of plants from Mont Tzena are characterized by the predominance of sesquiterpenes, such as caryophyllene oxide, while plants of Mont Olympus are characterized by the predominance of geraniol and geranyl acetate. We observe that there is a fixed frequency in the appearance of some substances even with differentiated rates among the samples. Taken in consideration components with rate ≥ 5%, the major constituents are carvacrol, thymol, *p*-cymene, γ-terpinene, linalool, borneol, *cis*-sabinene hydrate, spathulenol and caryophyllene oxide. In fact, we can notice that appears a tendency of the plants to produce large quantities of carvacrol / thymol / *p*-cymene and linalool or to differentiate completely, producing geraniol and geranyl acetate. It is worth noting that the biosynthetic ways of these components are related, as γ-terpinene is enzymatically converted to *p*-cymene which in turn is converted to thymol. It is argued that by a similar mechanism are produced carvacrol and γ-terpinene, while linalool and geraniol are considered minor products of this pathway. Michaelakis et al. (2007) cite as major components of Greek *S. montana* carvacrol, *p*-cymene, γ-terpinene and trans-β-caryophyllene, while according Dardiotis (2005) linalool dominates (> 23%) in all essential oils of plants from almost all areas of Greece. In large rates and also with great frequency appear geranyl acetate (0%-66.4%), *p*-cymene (0%-64.8%), geraniol (0%-51.6%), caryophyllene oxide (0.3-50.6 %) and spathulenol (1.0-45.3%) (Dardiotis, 2005). The comparison of the composition of *S. montana* essential oils from other than Greece regions showed that the components derived from the mevalonate metabolic pathway (γ-terpinene, *p*-cymene, thymol and carvacrol) are the predominant components (Angelini et al., 2003, Bilia et al., 1992, Fraternale et al., 2007, Panizzi et al., 1993, Piccaglia et al., 1991, 1993, Prieto et al., 2007, Slavkovska et al., 1997, 2001, Bezić et al., 2005, Kustrak et al., 1996, Mastelić & Jerković, 2003, Milos et al., 2001, Radonic & Milos, 2003, Skočibušić & Bezić, 2003, 2004a, 2004b, Bezbradica et al., 2005, Ćavar et al., 2008). There are also cases with other main components, such as linalool (Slavkovska et al., 1997, 2001), α-terpineol / linalool (Lampronti et al., 2006), geraniol (Ćavar et al., 2008), limonene/*p*-cymene (Konakchiev & Tsankova, 2002). This chemical variation is due to the polymorphism of *S. montana*.

***S. parnassica* (Stp 9 & 10)**

The samples differed considerably in terms of their chemical composition. The dominant component of Stp9 was carvacrol (74.2 %), while of Stp10 was thymol (54.8 %). Furthermore, Stp9 is characterized also by the presence of *p*-cymene (8.4%), while Stp10 of borneol (7.7%). Only one previous report appears in literature concerning the essential oil of native plants of *S. parnassica* ssp. *hellenica* (Dardiotis, 2005) from the same collection areas (Alonissos and Samothrace) as in the present study. Comparing with the essential oils of other *S. parnassica* subspecies, we could notice that carvacrol, thymol, *p*-cymene, γ-terpinene, trans-β-caryophyllene and linalool were detected in almost all samples (Dardiotis, 2005, Chorianopoulos et al., 2004, 2006, Michaelakis et al., 2007, Palic et al., 1988, Satil et al., 2002, Tumen et al., 1992, Tzakou & Skaltsa, 2003).

***S. pilosa* ssp. *pilosa* (Stpi11-14)**

The major components of the first three samples were linalool (42.2%; 33.3%; 28.1%), *p*-cymene (7.7%; 21.3%; 11.8%), thymol (13.4%; 6.4%; 13.8%) and carvacrol (8.3 %; 5.8 %; 6.8 %), while the fourth sample contained mainly caryophyllene oxide (49.5%) and spathulenol (25.5%).

***S. pilosa* ssp. *origanita* (Stpi15-17)**

In Stpi15 and Stpi16, carvacrol (39.8%, 48.8%, respectively) was the main ingredient, while in Stpi17 was thymol (41.3%) followed by carvacrol (22.9%).

Comparing our results with literature data (Dardiotis, 2005), we find a remarkable uniformity. *S. pilosa* ssp. *pilosa* is characterized by the presence of linalool to a large extent, while *S. pilosa* ssp. *origanita* of carvacrol /thymol. Moreover, the consideration of literature revealed that there is a repetition in the detection of certain components (thymol, carvacrol, *p*-cymene, γ-terpinene and borneol) although with quite different rates in different samples (Dardiotis, 2005; Azaz et al., 2002; Konakchiev et al., 2002; Tümen et al., 1998).

***S. thymbra* (Sth 18)**

The key component was carvacrol (50.4%) followed by γ-terpinene (11.5%), *p*-cymene (7.6%), trans-β-caryophyllene (7.8%) and carvacrol methyl ether (6.2%). Based on literature, it appears that the sample presents similarities in the chemical composition with non-cultivated plants (Azaz et al., 2005; Capone et al., 1988; Chorianopoulos et al., 2004, 2006; Fleisher & Fleisher, 2005; Glamočlija et al., 2006; Gören et al., 2004; Karabay-Yavasoglu et al., 2006; Karousou et al., 2005; Karpouhtsis et al., 1998; Loizzo et al., 2008; Michaelakis et al., 2007; Müller-Riebau et al., 1995, 1997; Lagouri et al., 1993; Ravid & Putievsky, 1983, 1985; Schulz et al., 2005; Skoula & Grayer, 2005; Soković et al., 2002). S. thymbra is characterized by two chemotypes, one has carvacrol as main component and the other thymol (Fleisher & Fleisher, 2005; Karousou et al., 2005; Ravid & Putievsky, 1985; Skoula & Grayer, 2005). The present specimen belongs to chemotype carvacrol or at least the growing conditions favoured the biosynthesis of carvacrol (50.4%) against thymol (0.1%).

According to our results, the chemical content of *Satureja* spp. reacted positively to cultivation. The present study reveals undoubtedly that under concrete conditions the cultivation of aromatic plants is feasible with a positive effect on their essential oil composition. The herein results could create the background for cultivation of these economically important plant species in many agricultural areas of Greece, even in large scale and consequently the augmentation of their industrial use.

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Table 2. Chemical composition of *Satureja* spp. Essential Oils

Components	**RI[1]**	**RI[2]**	***S. montana***								***S. parnassica***		***S. pilosa***							***S. thymbra***
			Stm1	**Stm2**	**Stm3**	**Stm4**	**Stm5**	**Stm6**	**Stm7**	**Stm8**	**Stp9**	**Stp10**	**Stpi 11**	**Stpi 12**	**Stpi 13**	**Stpi 14**	**Stpi 15**	**Stpi 16**	**Stpi 17**	**Sth 18**
α-thujene	921		-	0.1	-	1.3	-	0.1	-	-	-	-	-	-	0.2	-	1.0	0.8	-	-
α-pinene	933		-	0.1	-	2.1	-	0.3	-	-	-	-	-	4.9	0.4	-	2.8	1.8	-	-
camphene	950		-	0.1	-	1.5	-	0.2	-	-	-	-	-	1.0	0.2	-	2.4	1.6	-	-
sabinene	970	1114	0.2	0.3	-	-	-	0.3	-	-	-	-	-	0.1	-	-	-	-	-	-
β-pinene	973	1110	-	-	0.2	1.1	-	-	-	-	-	-	-	0.3	-	-	-	0.2	-	-
1-octen-3-ol	975	1429	-	0.2	-	-	-	1.2	0.2	1.1	0.3	0.1	0.2	0.8	1.0	-	1.2	0.4	0.5	1.4
myrcene	986	1148	0.1	0.2	-	3.9	-	0.6	-	-	0.1	-	1.6	3.4	2.5	-	1.7	1.2	-	0.3
3-octanol	990	1375	-	-	-	-	-	-	0.1	-	-	-	-	0.3	0.6	-	0.5	0.3	0.2	0.1
α-phellandrene	998	1165	-	-	-	-	-	0.2	-	-	-	-	-	1.0	-	-	0.4	0.3	-	-
δ-2-carene	1002	1150	-	-	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-
α-terpinene	1011	1168	0.1	0.2	0.2	1.0	-	-	-	-	0.3	-	0.2	-	0.5	-	3.1	2.6	tr	0.7
o-cymene	1021	1255	-	-	-	-	-	**8.7**	-	-	-	-	-	-	-	-	-	-	4.5	-
p-cymene	1021	1257	**1.2**	**10.2**	**14.1**	**24.2**	-	-	**0.3**	**0.5**	**8.4**	-	**7.7**	**21.3**	**11.8**	-	**25.9**	**19.6**	-	**7.6**
δ-3-carene	1022	1158	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3
limonene	1025	1202	-	-	-	-	-	-	-	-	-	-	3.7	-	-	-	-	-	-	-
1,8-cineole	1026	1201	0.5	1.4	0.9	-	-	1.2	-	0.5	0.6	0.3	-	-	-	-	-	-	-	-
cis-β-ocimene	1030	1219	-	-	-	-	-	2.6	-	-	-	-	-	4.2	3.4	-	1.0	0.7	-	-
β-phellandrene	1037	1210	-	-	-	1.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
trans-β-ocimene	1044	1247	-	0.3	0.2	4.1	-	3.0	0.1	-	-	-	2.5	3.3	2.8	-	0.1	0.1	0.1	0.1
γ-terpinene	1056	1232	**0.3**	**0.6**	**0.4**	**13.3**	-	**3.2**	**0.1**	-	3.0	-	**3.1**	**2.8**	**2.8**	-	**6.4**	**5.7**	**0.1**	**11.5**
cis-sabinene hydrate	1068	1446	**1.1**	**1.5**	**1.1**	**1.1**	-	**5.6**	-	**1.1**	1.9	0.6	-	0.3	0.2	-	0.5	0.6	1.1	1.1
trans-linalool oxide	1073	1454	-	-	-	-	-	-	-	-	-	0.3	-	0.7	1.3	-	-	-	-	-
cis-linalool oxide	1077	1437	-	-	-	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-	-
terpinolene	1084	1268	-	0.1	-	0.6	-	0.7	-	-	-	-	-	0.2	0.4	-	0.3	0.2	-	0.1
trans-sabinene hydrate	1092	1528	0.5	-	-	-	-	-	-	-	0.9	-	-	-	-	-	0.4	0.5	0.8	0.1
linalool	1099	1526	**8.2**	**6.7**	**5.9**	**6.9**	-	**21.1**	**17.0**	**1.9**	-	3.1	**42.2**	**33.3**	**28.1**	-	-	-	-	2.1
1,3,8-*p*-menthatriene	1118	1382	-	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-

endo-fenchol	1122		-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-
α-campholene aldehyde	1125	1485	-	-	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-
allo-ocimene	1128		-	-	-	-	-	-	-	-	-	-	0.2	-	0.3	-	-	-	-	-
cis-limonene oxide	1129	1438	-	-	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-
1-terpineol	1129	1606	-	0.1	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	0.2	-
trans-pinocarveol	1134	1643	-	-	-	-	-	-	-	-	-	-	-	-	0.2	-	-	-	0.2	-
neo-allo-ocimene	1134		-	-	-	-	-	-	-	-	-	-	0.3	0.2	-	-	-	-	-	-
cis-sabinol	1141		-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
menth-2-en-1-ol	1142		-	-	-	-	-	-	-	-	-	-	-	-	0.2	-	-	-	-	-
camphor	1143	1496	-	0.4	-	-	-	1.5	-	-	-	0.2	-	-	-	-	-	-	0.6	-
trans-verbenol	1145	1676	0.1	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-
pinocarvone	1160	1541	-	-	-	-	-	-	-	-	-	-	tr	-	-	-	-	-	-	-
borneol	1164	1677	**7.4**	**6.2**	**5.4**	**0.7**	-	**3.4**	-	**4.2**	**4.8**	**7.7**	**2.9**	**2.5**	**2.4**	-	**4.9**	**3.9**	**5.7**	4.4
terpinen-4-ol	1173	1581	1.5	1.3	1.3	-	-	2.1	0.2	1.1	1.5	1.1	0.4	0.4	0.5	-	1.4	1.0	1.0	-
p-cymen-8-ol	1181	1829	0.1	0.2	-	-	-	-	-	-	-	-	0.1	-	0.2	-	-	-	0.3	-
α-terpineol	1184	1677	0.6	-	0.2	-	-	2.0	-	-	-	0.5	0.2	0.2	0.3	-	0.1	-	0.3	-
cis-dihydrocarvone	1190	1588	0.4	0.6	0.2	-	-	0.4	-	-	-	-	0.5	0.3	0.4	-	-	-	-	-
trans-dihydrocarvone	1197	1606	0.1	-	-	-	-	0.3	-	-	-	-	1.3	0.8	0.6	-	-	-	-	-
trans-carveol	1214	1815	-	-	-	-	-	0.3	-	-	-	-	0.1	-	-	-	-	-	-	-
iso-dihydrocarveol	1215		-	-	-	-	-	-	0.5	-	-	-	-	-	-	-	-	-	-	-
cuminal	1236	1782	-	-	-	-	-	-	-	-	-	-	0.1	-	0.3	-	-	-	-	-
neral	1237	1660	-	-	-	-	-	-	**5.7**	-	-	-	-	-	-	-	-	-	-	-
carvone	1238	1713	-	-	-	-	-	0.2	-	-	-	-	0.3	0.4	-	-	-	-	-	-
carvacrol methyl ether	1240	1580	1.0	1.4	1.1	3.5	-	1.2	-	-	0.4	2.9	-	-	-	-	-	-	2.1	**6.2**
thymoquinone	1248		2.4	1.9	2.5	-	-	-	-	0.4	0.3	0.6	**0.3**	-	**0.1**	-	**4.5**	**4.8**	**13.1**	-
geraniol	1251	1830	-	-	-	-	-	-	**21.6**	-	-	-	-	-	-	-	-	-	-	-
carvenone	1251		-	-	-	-	-	-	-	-	-	-	-	-	0.8	-	-	-	-	-
isobornyl acetate	1286		0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
thymol	1288	2164	-	**0.6**	-	-	**1.2**	**13.5**	**2.0**	**51.1**	**0.5**	**54.8**	**13.4**	**6.4**	**13.8**	-	**0.2**	-	**41.3**	0.1
carvacrol	1302	2193	**61.0**	**56.7**	**51.4**	**9.5**	-	**11.0**	**0.9**	**33.4**	**74.2**	**16.0**	**8.3**	**5.8**	**6.8**	-	**39.8**	**48.8**	**22.9**	**50.4**
thymol acetate	1349		-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-
neryl acetate	1356		-	-	-	-	-	-	0.7	-	-	-	-	-	-	-	-	-	-	-

eugenol	1360		-	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
α-copaene	1371	1471	-	-	-	-	-	-	-	-	-	0.1	0.1	-	0.2	-	-	-	0.1	-
carvacrol acetate	1380		-	-	-	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
β-bourbonene	1381	1497	-	-	-	-	-	0.2	-	-	-	0.1	0.2	0.2	0.4	-	-	-	-	-
β-elemene	1388	1567	-	-	-	-	-	-	-	-	-	-	0.1	-	0.2	-	-	-	-	-
geranyl acetate	1390	1739	-	-	-	-	-	-	**28.6**	-	-	-	-	-	-	-	-	-	-	-
trans-β-caryophyllene	1415	1573	3.6	2.3	3.0	2.2	0.4	0.9	3.0	1.2	0.6	2.1	0.9	1.2	2.5	-	0.7	1.2	1.1	**7.8**
aromaden-drene	1439	1711	1.1	0.7	1.1	0.9	-	-	-	-	-	0.2	-	-	-	-	-	0.1	0.1	0.7
α-humulene	1451	1645	0.2	0.1	0.2	-	-	-	0.2	-	-	0.1	0.1	-	0.1	-	-	-	0.1	0.4
trans-β-farnesene	1455		-	-	-	-	-	-	-	-	-	-	tr	-	-	-	-	-	-	-
allo-aromadendrene	1458	1619	-	0.1	0.1	-	-	-	-	-	-	tr	-	-	tr	-	-	-	-	-
dehydro-aromadendrene	1463		-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
γ-gurjunene	1477	1554	0.1	-	0.7	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
α-amorphene	1480	1664	-	-	-	-	-	-	-	0.2	-	0.2	0.1	-	-	-	-	-	0.1	-
germacrene D	1482	1684	-	-	-	-	-	0.6	0.2	0.2	-	0.1	0.9	0.9	2.5	2.1	-	-	-	-
trans-β-ionone	1486	1942	-	-	-	-	-	-	tr	-	-	-	-	-	-	-	-	-	-	-
β-selinene	1489	1709	-	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-
valencene	1493		-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	0.1	-
bicyclogermacrene	1496	1708	0.7	-	-	-	0.8	0.4	0.5	-	-	-	0.2	0.2	0.7	2.0	-	-	-	-
α-muurolene	1499	1722	-	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-
β-bisabolene	1504	1701	2.3	1.4	2.3	3.9	-	0.5	1.3	0.9	0.5	0.8	0.3	0.2	0.8	-	0.2	0.5	0.3	-
cis-α-bisabolene	1505		-	-	-	-	-	-	tr	-	-	-	-	-	-	-	-	-	-	-
γ-cadinene	1511	1751	-	-	-	-	-	-	-	-	-	0.2	0.1	-	0.2	2.3	-	-	-	-
β-sesquiphellandrene	1518	1762	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
δ-cadinene	1519	1732	-	-	-	-	-	0.1	-	0.4	-	0.3	0.1	-	0.3	-	-	-	0.2	-
trans-γ-bisabolene	1535		-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-hexenyl benzoate	1559		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
spathulenol	1572	2107	-	**0.5**	**2.1**	**5.0**	**17.6**	-	-	-	-	1.0	**2.5**	**0.2**	**3.8**	**25.5**	-	-	-	-
caryophyllene oxide	1581	1972	**3.5**	**2.4**	**3.0**	-	**68.8**	**5.8**	**10.8**	**1.7**	1.3	4.6	**1.4**	**1.7**	**1.3**	**49.5**	-	**0.8**	**2.8**	3.7
viridiflorol	1590	2068	-	-	-	1.1	-	-	-	-	-	0.6	-	-	-	-	-	-	-	-
salvial-4-(14)-en-1-one	1593	1198	-	-	-	-	-	-	-	-	-	-	0.1	-	0.1	-	-	-	-	-

caryophylla-4(14).8(15)-dien-5.β-ol	1640	2279	-	-	-	0.2	3.3	-	1.0	-	-	0.1	0.1	-	-	2.5	-	-	-	0.3
T-muurolol	1642	2238	-	-	-	-	-	-	-	-	-	-	-	-	-	3.4	-	-	-	-
cadalene	1668		-	-	-	-	-	-	-	-	-	-	-	-	-	4.4	-	-	-	-
α-bisabolol	1685	2220	-	-	-	0.2	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-
TOTAL			**98.4**	**99.3**	**97.6**	**91.9**	**92.1**	**99.1**	**96.1**	**99.9**	**99.6**	**99.5**	**97.1**	**99.6**	**96.2**	**91.7**	**99.5**	**97.7**	**99.9**	**99.5**
$[\alpha]_D^{20}$ (CH_2Cl_2, *c*)			**-0.91**	**-1.35**	**-1.29**	**-2.15**	**-0.50**	**-1.22**	**-3.04**	**-0.41**	**-0.71**	**-2.37**	**-0.30**	**-0.45**	**-1.75**	**-4.40**	**-2.43**	**-1.87**	**-0.35**	**-2.19**

[a] HP-5 column; b : INNOWAX column; - : <0.01%; tr : < 0.05%

Table 3. Grouped components of *Satureja* spp. Essential Oils

	S. montana								***S. parnassica***		***S. pilosa***							***S. thymbra***
	Stm1	**Stm2**	**Stm3**	**Stm4**	**Stm5**	**Stm6**	**Stm7**	**Stm8**	**Stp9**	**Stp10**	**Stpi 11**	**Stpi 12**	**Stpi 13**	**Stpi 14**	**Stpi 15**	**Stpi 16**	**Stpi 17**	**Sth 18**
Monoterpene hydrocarbons	2.4	13.5	15.8	54.4	-	21.7	0.5	1.0	12.4	0.3	19.3	42.7	25.3	-	45.1	34.8	4.7	20.6
Oxygenated monoterpenes	84.5	78.0	69.1	22.1	1.2	63.3	77.9	93.2	84.5	88.1	70.4	51.1	56.2	-	51.8	59.6	89.6	64.4
Sesquiterpene hydrocarbons	8.0	4.7	7.4	7.7	1.2	2.7	5.2	2.9	1.1	4.7	3.1	2.7	7.9	10.8	0.9	1.8	2.1	8.9
Oxygenated sequiterpenes	3.5	2.9	5.1	6.5	89.7	5.8	12.2	1.7	1.3	6.3	4.1	1.9	5.2	80.9	-	0.8	2.8	4.0
Alcohols	-	0.2	0.2	-	-	1.2	0.3	1.1	0.3	0.1	0.2	1.1	1.6	-	1.7	0.7	0.7	1.5
Fatty acids & esters	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
Aromatic compounds	-	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-