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REVIEW

Essential oils of Anatolian Lamiaceae - An update

Kemal Hüsnü Can Başer[1*] and Neşe Kırımer[2]

[1] Department of Pharmacognosy, Near East University, Faculty of Pharmacy, Lefkoşa (Nicosia), N. Cyprus, Mersin 10, Turkey

[2]Anadolu University Faculty of Pharmacy Department of Pharmacognosy, 26470 Eskişehir, Turkey

*Coresponding author Email: khcbaser@gmail.com

Abstract

In the present review, Lamiaceae genera studied for their essential oils during 2006-2017 were investigated and compiled. *Acinos, Ajuga, Ballota, Calamintha (Clinopodium), Coridothymus, Cyclotrichium, Dorystoechas, Hymenocrater, Hyssopus, Lallemantia, Lavandula, Marrubium, Melissa, Mentha, Micromeria, Nepeta, Ocimum, Origanum, Pentapleura, Perilla, Phlomis, Rosmarinus, Salvia, Satureja, Scutellaria, Sideritis, Stachys, Teucrium, Thymbra, Thymus, Wiedemannia,* and *Ziziphora* species were comparatively listed and grouped referring to their major essential oil components. In addition, commercially important culinary and aromatic plants of Lamiaceae were also highlighted.

Keywords: Lamiaceae, essential oil, aromatic plant

Introduction

Turkey is situated in geographically between 42°N and 36°N altitudes. She is under the influence of three different climates, namely: Mediterranean, Continental, Oceanic. Her transect is between the sea level and 5137 m (Mt. Ararat). Anatolia is a peninsula thrusting from east to west. She has land in Anatolia and Thrace being at the junction of Asia and Europe. Turkey covers *ca.* 0.8 million sq. km. and supports *ca.* 80 million of human population in the rich flora and fauna.

Turkey is at the junction of three phytogeographic regions. Aegean and Mediterranean coastal areas are under the Mediterranean influence. Central and eastern parts enjoy the Irano-Turanian influence and the northern parts are affected by the Euro-Siberian phytogeography.

Flora of Turkey is well documented thanks to the efforts of the late Prof. P.H. Davis of Edinburgh University. He had edited and published the Flora of Turkey and the East Aegean Islands in nine volumes and one supplement between 1965 and 1988. Volume 11 (second supplement) was edited by Profs. Tuna Ekim, Adil Güner, Neriman Özhatay and K. Hüsnü Can Başer and published by Edinburgh University press in 2000 (distributed in April 2001). Publication of the Illustrated Flora of Turkey (in Turkish) [Resimli Türkiye Florası] started in 2014, to be completed in 2023.

Lamiaceae is the third largest family in Turkey with 46 genera, 782 taxa comprising 603 species and 179 subspecies and varieties. 346 taxa (271 species and 75 subspecies and varieties) are endemic. Endemism ratio is ca. 44%. There are 28 hybrids of which 24 are endemic.

The largest five genera are as follows: *Stachys* (118 taxa), *Salvia* (107 taxa), *Sideritis* (54 taxa), *Phlomis* (53 taxa) and *Teucrium* (49 taxa) (Celep & Dirmenci, 2017).

Extensive research has been carried out into studying the chemical composition of essential oils of the Lamiaceae plants of Turkey by our group (Başer, 1993; Başer & Kırımer, 2006).

So far, essential oils of 323 taxa (281 species) belonging to 32 genera in Lamiaceae have been investigated.

In this present work, Lamiaceae genera studied for their essential oils are *Acinos, Ajuga, Ballota, Calamintha (Clinopodium), Coridothymus, Cyclotrichium, Dorystoechas, Hymenocrater, Hyssopus, Lallemantia, Lavandula, Marrubium, Melissa, Mentha, Micromeria, Nepeta, Ocimum, Origanum, Pentapleura, Perilla, Phlomis, Rosmarinus, Salvia, Satureja, Scutellaria, Sideritis, Stachys, Teucrium, Thymbra, Thymus, Wiedemannia,* and *Ziziphora* species, which were comparatively reviewed and listed.

Results and Discussion

The first review on the essentail oil on Lamiaceae species were reported in 2006 (Baser & Kirimer). Recent literature, which cover the years 2006 and 2017 are summarized in this present work as below.

Ajuga laxmannii (Murray) Benth.

Ajuga is represented by 23 taxa including 13 species in Turkey. Endemism ratio is 46% on species basis; 30% on taxon basis. Recently, essential oil composition of *Ajuga laxmannii* was reported.

Table 1. Essential oil composition of *A. laxmannii*

Sample	Main Compounds %	References
A	nonacosane 18, heptacosane 12, hexahydrofarnesyl acetone 11	Köse et al., 2015
B	hexadecanoic acid 21, dodecanoic acid 12, hexahydrofarnesyl acetone 9	
C	phytol 13, hexadecanoic acid 10, hexahydrofarnesyl acetone 9	
D	hexahydrofarnesyl acetone 9, hexadecanoic acid 9	
E	hexadecanoic acid 14, phytol 13	

Main components in the essential oil of the aerial parts of *Ajuga orientalis* L. from Erzurum were reported as phytol (36.7 %), *n*-hexadecanoic acid (14.2 %) and dodecanoic acid (12.2 %) (Kücükbay et al, 2013).

Ballota spp.

Ballota is represented by 18 taxa including 12 species. Endemism ratio on species basis is 67%; on taxon basis 61%.

Table 2. *Ballota nigra* essential oils

Species	Main Compounds %	References
B. nigra subsp. *uncinata*	caryophyllene oxide 21, hexadecanoic acid 20, β-caryophyllene 19	Kaya et al., 2017
B. nigra subsp. *anatolica*	hexadecanoic acid 41, β-bisabolene 13	

The volatiles of *Ballota nigra* subsp. *anatolica* P.H. Davis leaves and flowers from Kütahya were evaluated and 59 components were characterized, where hexenal (17.6%), germacrene D (6.7%) and β-caryophyllene (8.8%) were the main compound (Arikaya, 2017).

Calamintha spp.

Calamintha has recently been merged with *Clinopodium* and the status of the following species mentioned in the table to *Clinopodium nepeta* subsp. *nepeta*, *Clinopodium nepeta* subsp. *glandulosum*, *Clinopodium menthifolium* subsp. *menthifolium*, *Clinopodium menthifolium* subsp. *ascendens*. The genus *Clinopodium* is represented by 21 species and altogether 32 taxa in Turkey. 12 taxa are endemic.

Table 3. *Clinopodium nepeta* essential oils

Species	Main Compounds %	References
C. nepeta	*cis*-piperitone epoxide 49, piperitenone oxide 22, limonene 14	Gormez et al., 2015
	caryophylleneoxide 34, β-caryophyllene 20	Ceker et al., 2013
C. nepeta subsp. *glandulosa*	pulegone 20, menthone 10	Alan et al., 2011
	trans-piperitone oxide 34, limonene 17, piperitenone oxide 11	
	pulegone 54, menthone 16	Demirci B. et al., 2011
	piperitone oxide 34, piperitenone oxide 16, isomenthone 11	Yasar et al., 2011
C. sylvatica subsp. *sylvatica*	*cis*-piperitone oxide 46, terpinen-4-ol 9	Alan et al., 2010
C. *sylvatica* subsp. *ascendens*	*cis*-piperitone oxide 22, limonene 16, piperitenone oxide 11	Alan et al., 2010

Cyclotrichium niveum (Boiss.) Manden & Scheng

This species is characterized by pulegone (60-77%) as main constituent in the oil (Cetinus et al., 2007; Inan et al., 2014; Inan & Tel, 2014).

Dorystaechas hastata Boiss. & Heldr. ex Benth.

Dorystaechas hastata is a monotypic endemic species distributed only in Antalya region of Turkey. 1,8-Cineole 26%, borneol 19%, camphor 17% were found as main constituents in the oil (Oz et al., 2012; Baser & Ozturk, 1992).

Hyssopus officinalis L.

Table 4. *Hyssopus officinalis* essential oils

Main Compounds %	References
isopinocamphone 57, β-pinene 7, terpinene-4-ol 7, pinocarvone 6	Kızıl et al., 2010a
β-phellandrene 78, β-myrcene 20	Salman et al., 2015
pinocarvone 27, β-pinene 19, pinocamphone 14, isopinocamphone 14	Kürkçüoğlu et al., 2016

Lallemantia iberica (M.Bieb.) Fisch. & C.A.Mey

Germacrene-D 36%, β-caryophyllene 18%, bicyclogermacrene 10% were found as main constituents in the oil from herbal parts (Yuce & Bagci, 2012).

Lavandula spp.

Lavandula stoechas, the only native *Lavandula* species, is represented by two subsp. *stoechas* and *cariensis* in Turkey (Davis, 1982). Other *Lavandula* species mentioned are introduced taxa.

Table 5. *Lavandula* spp. essential oils

Species	Main Compounds %	References
L. x intermedia	linalool 43, linalyl acetate 34, isoborneol 9	Salman et al., 2015
L. stoechas subsp. *stoechas (leaves)*	α-fenchone 42, 1,8-cineole 16, camphor 12	Kirmizibekmez et al., 2009
L. stoechas subsp. *stoechas (flowers)*	α-fenchone 39, myrtenyl acetate 10	Kirmizibekmez et al., 2009
L. stoechas subsp. *stoechas*	α-thujone 66, L-camphor 18	Sertkaya et al., 2010

Oils from cultivated samples revealed T-cadinol (17-9%), borneol (14-9%) ve δ-3-carene (9%) as main constituents while those from micropropagated samples linalool (15-22%), lavandulyl acetate (13-15%), T-cadinol (10-11%) ve linalyl acetate (5-15%) were found as main constituents of *L. angustifolia* (Kırımer et al, 2017).

Marrubium spp.

Marrubium is represented by 21 species and altogether 27 taxa in Turkey. The rate of endemism on species basis is 52%, on taxon basis 63% (Celep & Dirmenci, 2017).

Table 6. *Marrubium* spp. essential oils

Species	Main Compounds %	References
M. anisodon	*(Z)*-β-farnesene 20, β-caryophyllene 13	Kırımer et al., 2015
M. bourgaei subsp. *bourgaei*	hexadecanoic acid 33, hexahydrofarnesyl asetone 6	Kürkçüoğlu et al., 2007
M. globosum subsp. *globosum*	spathulenol 16, β-caryophyllene 9	Sarıkurkcu et al., 2008

Melissa officinalis L.

Oil samples from micropropagated plants via tissue culture showed geranial (43-45%), neral (27-30%) as main constituents (Mokhtarzadeh et al, 2017).

Mentha spp.

The genus *Mentha* is represented in Turkey by 6 species and altogether 15 taxa including 5 hybrids (Baser et al, 2012). Recent results on mint oils of Turkey are represented here. Previously communicated results on *Mentha* oils did not include *M. x rotundifolia*. Here, we incorporate those results as well.

Table 7. *Mentha* spp. essential oils

Species	Main Compounds %	References
M. aquatica	2 samples: menthofuran 35-58 3 samples: menthofuran 14-30 1,8-cineole 15-27	Baser et al., 2012
M. x *dumerotum*	menthofuran 28, menthyl acetate 18, β-caryophyllene 12, menthol 9	Baser et al., 2012
	carvone 40, eucalyptol 14, dihydrocarvone 13, limonene 8	Onaran et al., 2014; Yilar et al., 2013
M. longifolia subsp. *longifolia*	menthone 19, pulegone 12, piperitone 11	Okut et al., 2017
	An unknown compound with RI: 2209 at GC (35%), 1,8-cineole 15	Baser et al., 2012
	carvone 52, limonene 14, 1,8-cineole 13	Baser et al., 2012
M. piperita	menthol 38, menthol 36, neomenthol 7	Kızıl et al., 2010b
	isomenthone 50, menthol 22, menthofuran 5	Orhan et al., 2011
M. pulegium	11 samples: isomenthone 29-74 pulegone 10-57 One sample: pulegone 36, menthone 34 One sample: piperitone 95	Baser et al., 2012
M. x rotundifolia	piperitenone oxide 64 α-pinene 4	Baser et al., 2012
M. spicata	carvone 75, limonene 8	Orhan et al., 2011
	carvone 75, limonene 8	Kızıl et al., 2010b
	carvone 60, limonene 10, 1,8-cineole 7	Sertkaya et al., 2010

M. spicata subsp. *spicata*	7 samples: carvone 59-77, limonene 2–23, 1,8-cineole 1-7 One sample: isomenthone 32, *cis*-piperitone oxide 30, menthone 14	Baser et al., 2012
	carvone 48,1,8-cineole 21	Sarer et al., 2011
M. spicata subsp. *tomentosa*	13 samples: piperitenone oxide 1-74, *trans*-piperitone oxide 0-61, *cis*-piperitone oxide 0-11, 1,8-cineole 1-9 One sample: isopulegyl acetate 30, isopulegol 21, pulegone 15	Baser et al., 2012
M. suaveolens	piperitenone oxide 63-77, limonene 2-6	Baser et al., 2012
M. X *villosa-nervata*	*trans*-piperitone oxide 58-76, piperitenone oxide 2-13, 1,8-cineole 1-7	Baser et al., 2012

Micromeria spp.

Micromeria is represented by 9 species and altogether 13 taxa of which 8 are endemic in Turkey (Duman & Dirmenci, 2017). Recent results on *Micromeria* essential oils are as follows.

Table 8. *Micromeria* spp. essential oils

Species	Main Compounds %	References
M. congesta	piperitone oxide 40, pulegone 24	Herken et al., 2012
M. fruticosa	pulegone 57-61, isomenthone 15-19, piperitenone 7-9, β-pinene 1-4, β-caryophyllene 1-2, piperitone tr-2	Arslan, 2012

Nepeta spp.

Nepeta is represented by 39 species and altogether 46 taxa in the flora of Turkey. The rate of endemism on species basis is 44% (Celep & Dirmenci, 2017). The following table shows the results of recent studies on the essential oils of *Nepeta* taxa of Turkey.

Table 9. *Nepeta* spp. essential oils

Species	Main Compounds %	References
N. baytopii	1,8-cineole 23, nepetalactone 13	Kilic et al., 2013
N. cataria	nepetalactone 28, 1,8-cineole 11, germacrene D 9	Kilic et al., 2013
N. conferta	*p*-cymene 26, eucalyptol 10	Yayli et al., 2014
N. congesta var. *congesta*	1,8-cineole 30, germacrene D 20, sabinene 10	Kaya et al., 2007
N. fissa	1,8-cineole 24, nepetalactone 18	Kilic et al., 2013
N. italica	linalool 42, T-cadinol 21	Hasimi et al., 2015
N. meyeri	4aα,7α,7aβ-nepetalactone 83, 4aα,7α,7aα-nepetalactone 9	Mutlu et al., 2010
N. nuda subsp. *albiflora*	4aα,7α,7αβ-nepetalactone 74, 2(1H)-naphthalenone, octahydro-8a-methyl-*trans*- 10	Bozok et al., 2017
N. nuda subsp. *nuda*	camphor 24, 1,8-cineole 21, borneol 19	Kilic et al., 2011
N. nuda	4aα,7β,7aα-nepetalactone 18, germacrene 16, elemol 14, β-caryophyllene 9	Gormez et al., 2013
N. transcaucasica	4aα,7α,7aβ-nepetalactone 40, 4aα,7α,7aα-nepetalactone 28, germacrene D 16	Iscan et al., 2011)

Ocimum basilicum L.

Main constituents in the oils from leaf, flower and branches were found as follows: Leaves: estragole 53%, limonene 14% and *p*-cymene 2%; flowers: estragole 58% and limonene 19%, branches: dill apiole 50%, estragole 16% and apiole 9% (Chalchat & Ozcan, 2008).

In two cultivated samples linalool 40-76%, 1,8-cineole 0-18%, (*E*)-methyl cinnamate 1-13% and δ-cadinene 1-12% were found as main constituents (Orhan et al., 2011; Karaman et al., 2008).

Giachino et al. reported the existence of 7 genotypes in their study with 14 *O. basilicum* samples. Main compounds found in the oild of these genotypes were as follows: linalool, methyl chavicol, citral/methyl chavicol, methyl eugenol, methyl cinnamate/linalool, linalool/methyl eugenol, methyl chavicol/linalool (Giachino et al., 2014). Telci et al. reported the occurrence of linalool, citral and methyl chavicol in three genotypes (Telci et al., 2006).

A study involving hydrodistillation with fresh samples resulted in the characterization of linalool 41%, γ-cadinene 10%, methyl chavicol 10% and germacrene D 9%. Results with steam distillation indicated linalool 36%, *(E)*-methyl cinnamate 17%, eugenol 15% and β-sesquiphellandrene 9% as main constituents (Onar et al., 2010).

***Origanum* spp.**

According to recent results, *Origanum* is represented in Turkey by 27 species and altogether 31 taxa. The rate of endemism on species basis is 67%, on taxon basis 58% (Celep & Dirmenci, 2017).

Table 10. *Origanum* spp. essential oils

Species	**Main Compounds %**	**References**
O. acutidens	*m*-cymene 40*, allo-aromadendrene 25, aromadendrene 12	Yilmaz, H. et al., 2017
	carvacrol 87, linalool acetate 2, *p*-cymene 2, borneol 2	Tozlu, 2011
	carvacrol 87, *p*-cymene 2, borneol 2, linalool acetate 2	Kordali et al., 2008
O. bilgeri	carvacrol 93, *p*-cymene 2, borneol 2, γ-terpinene 2	Koc, S. et al., 20013
	carvacrol 85, *p*-cymene 4, ɣ-terpinene 3, borneol 2	Kose et al., 2013
O. brevidens	carvacrol 72, carvone 9	Yilmaz, H. et al., 2017
O. haussknechtii	aromadendrene 24, carvacrol 16, allo-aromadendrene 15, α-himachalene 12	Yilmaz, H. et al., 2017
O. husnucanbaseri	*cis*-β-terpineol 24, menth-3-en-8-ol 23, menthone 13	Yilmaz, H. et al., 2017
	borneol 13-15, terpinen-4-ol 11-12, α-terpineol 12-11, *trans*-sabinenehydrate 10-12	Uysal et al., 2010
O. hypericifolium	*p*-cymene 43, carvacrol 32, ϒ-terpinene 8	Celik, A. et al., 2010
	cymene 34, carvacrol 22, thymol 20. ɣ-terpinene 14	Ili & Keskin, 2013
O. leptocladum	T-muurolene 20, *p*-cymene 17, borneol 16	Yilmaz, H. et al., 2017
O. saccatum	*p-cymene* 83, *p*-cymene-8-ol 1, carvacrol 1	Ozcan & Chalchat, 2009
O. rotundifolium	isopulegyl acetate 20, aromadendrene 16, limonene oxide 15, viridiflorol 10	Yilmaz, H. et al., 2017

*It is unusual to find *m*-cymene in the absence of *p*-cymene as a major constituent. This must be read as *p*-cymene. Recent literature information on commercial *Origanum* species are shown in the following table. In a study, DNA data have indicated that the status of *O. majorana* recorded in the Flora of Turkey must be changed to *O. dubium*. Therefore, all the previous literature on the oils of *O. majorana* rich in carvacrol from Turkey must be read as *O. dubium* (Lukas et al., 2013).

Table 11. *Origanum* spp. essential oils

Species	Main Compounds %	References
O. dubium	carvacrol 63, ɣ-terpinene 11, *p*-cymene 9	Maral et al., 2017.
O. majorana	carvacrol 53, linalool 45	Erdogan A. & Ozkan, 2017
	carvacrol 80, ɣ-terpinene 7	Orhan et al., 2011
	linalool 88, thymol 12	Karaborklu et al., 2011
O. minutiflorum	carvacrol 79, *p*-cymene 8 *micropropagation*: carvacrol 86, *p*-cymene 4, ɣ-terpinene 4	Ozkum et al., 2010
	carvacrol 98	Oz et al., 2012
	carvacrol 74, *p*-cymene 7	Altundag et al., 2011
O. onites	carvacrol 68, ɣ-terpinene 15	Orhan et al., 2011
	carvacrol 84-89, ɣ-terpinene 3-6	Ozkan, G. et al, 2010a
	carvacrol 70, linalool 12, thymol 9	Ayvaz et al, 2010
	carvacrol 68, *p*-cymene 11, ɣ-terpinene 7	Sertkaya et al, 2010
	carvacrol 83, thymol 13	Gormez, O. et al, 2014
	carvacrol 47, *p*-cymene 16, ɣ-terpinene 9, myrcene 9	Yaylı et al., 2014
	carvacrol 81, linalool 6	Koca & Cevikbas, 2015
	carvacrol 64, linalool 14, *p*-cymene 7	Bostancıoglu et al., 2012
	carvacrol 57, ɣ-terpinene 9, linalool 8, *p*-cymene 8	Atak et al., 2016
	13 samples: carvacrol 65-81, ɣ-terpinene 4-9, *p*-cymene 2-6 One sample: thymol 66, carvacrol 6, ʋ-terpinene 5	Tonk et al., 2010
O. vulgare subsp. *hirtum*	20 samples: carvacrol 8-83, thymol 0.3-60, *p*-cymene 6-31 20 samples, cultivated: carvacrol 5-89, thymol 0.3-68, ϒ-terpinene 3-20, *p*-cymene 4-32	Esen et al., 2007
	carvacrol 61, linalool 9, *p*-cymene 7	Maral et al., 2017

Table 12. Oregano exports of Turkey (TUIK 2016):

Kekik	2011	2016
Ton	13.112	17.085
USD ($)	29.721	63.351
Unit Export Value ($/kg)	2.3	3.7

Table 13. Cultivation areas and production in Turkey (TUIK 2016):

Year	Cultivation Areas (Hectare)	Production (Ton)
2009	8.496	12.329
2012	9.428	11.598
2016	12.112	14.724

Phlomis spp.

Phlomis is represented in Turkey by 33 species and altogether 53 taxa. The rate of endemism on species basis is 48%, on taxon basis 57% (Celep & Dirmenci, 2017). Recent results are summarized in the following table.

Table 14. *Phlomis* spp. essential oils

Species	**Main Compounds %**	**References**
P. amanica	8(14),15-isopimaradien-11α-ol 23, germacrene-D 15, bicyclogermacrene 11	Demirci B. et al., 2009
P. armeniaca	hexadecanoic acid 5, pentacosane 3, hexahydrofarnesyl acetone 2, spathulenol 2, heptacosane 2	Demirci B. et al., 2009
	germacrene D 27-23, (*E*)-2-hexenal 10-12, β-caryophyllene 12-17	Sarikaya & Fakir, 2016
P. bourgaei	β-caryophyllene 15-22, α-cubebene 14-16, germacrene-D 11-15	Sarikaya & Fakir, 2016
	germacrene D 11, β-caryophyllene 11, manoyl oxide 4	Başer et al., 2008
P. chimerae	β-caryophyllene 35, germacrene D 16, caryophyllene oxide 6	Başer et al., 2008
P. grandiflora var. *grandiflora*	β-eudesmol 61-62, β-curcumene 3-6, ar-curcumene 2	Ozcan et al., 2011
	β-eudesmol 42, α-eudesmol 16, ar-curcumene 3	Demirci F. et al., 2008
	α-pinene 19-26, α-cedrene 19-28, α-curcumene 12-14	Sarikaya & Fakir, 2016
P. lunarifolia	hexadecanoic acid 10, β-caryophyllene 9, germacrene-D 8	Demirci B. et al., 2009
P. lycia	germacrene-D 16, β-caryophyllene 18, limonene 14	Sarikaya & Fakir, 2016
P. monocephala	8(14),15-isopimaradien-11α-ol 13, germacrene D 6, manoyl oxide 6	Demirci B. et al., 2009
P. nissoli	limonene 16-24 , β-caryophyllene 10-13, germacrene-D 12-21	Sarikaya & Fakir, 2016
	germacrene D 34, bicyclogermacrene 15, (*Z*)-β-farnesene 11, β-caryophyllene 9	Kirimer et al., 2006
P. pungens var. *pungens*	(*E*)-2-hexenal 13-18, vinyl amyl carbinol 13-19, germacrene-D 8-10	Sarikaya & Fakir, 2016
P. rigida	β-caryophyllene 31-39, β-selinene 13-15, caryophyllene oxide 4-5	Demirci B. et al., 2006
P. russelina	β-caryophyllene 22, germacrene-D 15, caryophyllene oxide 8	Demirci F. et al., 2008
P. samia	germacrene D 34, β-caryophyllene 6	Demirci B. et al., 2006
	germacrene-D 19-23, β-caryophyllene 14-15, α-copaene 10-11	Sarikaya & Fakir, 2016
P. sieheana	germacrene D 16, β-caryophyllene 11, α-pinene 8	Ozdemir FA et al., 2017
	spathulenol 3, hexahydrofarnesyl acetone 2, hexadecanoic acid 2	Demirci B. et al., 2009
P. X vuralii	caryophyllene oxide 17, diterpene 8,12-epoxylabd-14-en-13-ol 6	Başer et al., 2008

Rosmarinus officinalis **L.**

Table 15. *Rosmarinus officinalis* essential oils

Main Compounds %	**References**
1,8-cineole 21, camphor 20, borneol 9	Atak et al., 2016
1,8-cineole 12-61, camphor 6-17, verbenone tr-45, borneol 2-9, α-pinene 1-14, α-terpineol 1-7	Yesil Celiktas et al., 2007
camphor 17, borneol 11, 1,8-cineole 10, linalool 6, α-pinene 6 (dried)	Bagci et al., 2017
camphor 16, borneol 12, 1,8-cineole 8, linalool 8, bornyl acetate 8, verbenone 6 (fresh, cultivated)	Bagci et al., 2017
camphor 15, 1,8-cineole 14, α-pinene 10, verbenone 9, borneol 6 (fresh)	Bagci et al., 2017
camphor 26, 1,8-cineole 18, α-pinene 13, camphene 8 (dried, cultivated)	Bagci et al., 2017
camphor 35, 1,8-cineole 25, borneol 23, α-pinene 7	Salman et al., 2015
borneol 26, verbenone 24, camphor 20, 1,8-cineole 6	Gudek & Cetin, 2016

Salvia spp.

In the Flora of Turkey, there are 100 species and 107 taxa. Rate of endemism on taxon basis is 54% (Celep & Dirmenci, 2017). The following table summarizes the recent work on the essential oils of *Salvia* taxa of Turkish origin.

Table 16. *Salvia* spp. essential oils

Species	Main Compounds %	References
S. adenophylla	α-pinene 16, β-pinene 14, α-terpineol 5, borneol 5	Kaya et al., 2017b
S. aethiopis	α-copaene 18, α-cubebene 12, (-)-spathulenol 12, germacrene-D 8, α-limonene 7, ledol 7	Goze et al., 2016
S. aramiensis	1,8-cineole 46, β-pinene 10, camphor 9, α-pinene 5	Kelen & Tepe, 2008
S: aucheri var. *aucheri*	1,8-cineole 31, camphor 21, borneol 9, α-pinene 8, camphene 8, β-pinene 6	Kelen & Tepe, 2008
S. ballsiana	caryophyllene oxide 34, β-caryophyllene 8, α-pinene 8	Temel et al., 2016
S. blepharochlaena	1,8-cineol 27, *cis*-β-ocimene 15, β-pinene 8, camphor 6, camphene 6	Goze et al., 2016
S. bracteata	caryophyllene oxide 18, β-caryophyllene 17, β-pinene 11	Doğan et el., 2014
S. ceratophylla	α-pinene27, β-pinene 16, β-caryophyllene 11, bornyl acetate 6	Baser et al., 2015
	α-pinene 25, β-pinene 10, 1,8- cineole 7, α-terpineol 6	Baser et al., 2015
	germacrene D 24, α-copaene 20, 1,8-cineole 8, camphor 6	Kılıç, 2016
	ɣ-muurolene 11, ɣ-cadinene 6, *trans*-pinocarvyl acetate 5, α-copaene 5	Gürsoy et al., 2012
S. cilicica	spathulenol 24, caryophyllene oxide 15, hexadecanoic acid 10	Tan et al., 2016
S. cryptantha	camphor 19, 1,8-cineole 16, borneol 12, viridiflorol 12	Akın et al., 2010
S. cyanescens	spathulenol 23, *p*-cymene 10, 1,8-cineole 9	Temel et al., 2016
S. dicroantha	caryophyllene oxide 22, phytol 6, caryophyllenol II 6	Kunduhoglu et al., 2011
S. divaricata	α-pinene 17, camphor 10, camphene 7, 1,8-cineole 3	Temel et al., 2016
S. euphratica var. *euphratica* (Syn. *S. pseudeuphratica*)	*cis*-sabinol 22, myrcenyl acetate 17, 1,8-cineole 9	Goze et al., 2016
	camphor 54, 1,8-cineole 17, cryptone 5	Temel et al., 2016
S. fruticosa	1,8-cineole 59, α-pinene 6, β-pinene 5, β-myrcene 5, camphor 5	Topcu et al., 2013
	1,8-cineole 36, camphor 19, thujon 8, β-pinene 6, α-pinene 5, camphene 6, caryophyllene 5	Senol et al., 2011
S. heldreichiana	linalool 9, α-pinene 6, 1,8-cineole 6, borneol 6, cryptone 5, linalyl acetate 5	Akin et al., 2010
	α-pinene 14	Basalma et al., 2007
S. hydrangea	camphor 47, camphene 9, 1,8-cineole 7	Temel et al., 2016
	camphor 54, α-humulene 4	Kotan et al., 2008
S. kronenburgii	limonene 12, 2-cyclohexen-1-ol 9, *trans*-verbenol 8, *trans*-(+)-carveol 7	Kocak & Bagci, 2011
S. limbata	spathulenol 30, β-eudesmol 7	Ogutcu et al., 2008
S. macrochlamys	β-caryophyllene 26, caryophyllene oxide 22, β-pinene 5	Temel et al., 2016
	1,8-cineole 27, borneol 13, camphor 11, caryophyllene oxide 8, β-caryophyllene 7	Tabanca et al., 2006
S. multicaulis	caryophyllene oxide 23, spathulenol 13, β-pinene 8	Kilic, 2016
S. nydeggeri	α-pinene 16, β-pinene 9, cubebol 6, caryophyllene oxide 6	Temel et al., 2016
S. officinalis (cultivated)	1,8-cineole 35, camphor 30, α-thujone 20	Salman et al., 2015
	camphor 20, *cis*-thujone 20, 1,8-cineole 18, *trans*-thujone 9	Baydar et al., 2013
	camphor 43, 1,8-cineole 24, *cis*-thujone 16	Baydar et al., 2013

	camphor 27, 1,8-cineole 18, *cis*-thujone 14, viridiflorol 9	Baydar et al., 2013
	camphor 20, linalool 11, linalyl acetate 11, *cis*-thujone 11, viridiflorol 11, borneol 8	Baydar et al., 2013
S. pachystachys	β-pinene 24, α-pinene 12, spathulenol 10	Temel et al., 2016
S. palestina	caryophyllene oxide 16, *(E)*-caryophyllene 5	Gursoy et al., 2012
S. pilifera	β-pinene 25, myrcene 9, α-humulene 8	Kaya et al., 2017b
	α-pinene 14, 1,8-cineole 9, *trans*-thujone 4	Kelen, 2008
S. pisidica	camphor 24, sabinol 20, α-thujone 14, 1,8-cineole 6	Ozkan et al., 2010b
S. pinnata	bornyl acetate 26-43, camphor 12-18, camphene 10-15 bornyl formate 5-7	Somer et al., 2015
S. potentillifolia	α-pinene 29, β-pinene 15, 1,8-cineole 7	Kıvrak et al., 2009
S. recognita	camphor 42, 1,8-cineole 12, camphene 7	Tabanca et al., 2006
S. rosifolia	α-pinene 16-35, 1,8-cineole 17-25, β-pinene 7-14, *p*-cymene 2-7	Ozek et al., 2010
S. russelli	β-pinene 20, 1,8-cineole 10, α-copaene 9, valeranone 8	Temel et al., 2016
	thymol 32, α-terpinol 13, γ-terpinene 13	Dogan et al., 2014
S. sclarea	germacrene-D 25, β-caryophyllene 16, bicyclogermacrene 10, linalyl acetate 6	Ogutcu et al., 2008
S. sericeo-tomentosa var. *hatayica*	sabinyl acetate 80, α-pinene 3, *trans*-sabinol 3, cumin alcohol 3	Tan et al., 2017
S. tomentosa	β-pinene 37, α-pinene 6	Ulukanlı et al.,2013
	1,8-cineole 32, α-pinene 16, borneol 7, β-caryophyllene 5	Haznedaroglu et al., 2013
	<u>20 samples</u>: pinene 2-39, β-pinene 2-36, camphor 2-41, β-caryophyllene 3-11, borneol 2-12	Karık et al., 2013
S. trichoclada	caryophyllene oxide 25, spathulenol 15, β-pinene 12, 1,8-cineole 7, β-caryophyllene 5	Kılıc, 2016
S. verticillata subsp. *amasiaca*	germacrene D 37, β-caryophyllene 8, hexadecanoic acid 7, β-copaene 6, spathulenol 5	Kunduhoglu et al., 2011
S. *verticillata* subsp. *verticillata*	spathulenol 31, α-pinene 8, limonene 4	Tabanca et al., 2006
S. virgata	1,8-cineole 20, α-copaene 19, germacrene D 18, camphor 5	Kilic, 2016
S. viscosa	α-copaene 13, β-caryophyllene 11, γ-muurolene 10, δ-cadinene 8, germacrene D 5	Kaya et al., 2017b
S. wiedemannii	α-pinene 36, 1,8-cineole 14, β-pinene 13, camphor 7, *p*-cymene 5	Kunduhoglu et al., 2011

Typical groups of compounds found in *Salvia* oils and their classification are as follows (Başer, 1993; Başer & Kırımer, 2006):

Table 17. *Salvia* spp. essential oils

Group	**Taxa (oil yield %) content (%)**
α/β-Pinene	*tomentosa* (0.6-1.3) 2-39/2-37
	rosifolia (0.4) 16-35/7-14
	potentillifolia (0.9) 29/15
	ceratophylla (0.8) 25/10
	wiedemannii (0.4-0.6) 23-36/13-30
	adenophylla (0.3) 16/14
	nydeggeri (0.3) 16/9
	heldreichiana (0.2-0.8) 14/-
	pachystachys (0.1) 12/24
	potentillifolia (0.4) 10/8

	pilifera (0.2-0.8) -/25
	russelli (tr-0.8) -/20
Camphor/1,8-cineole (CaCi)	*euphratica/eupratica* (0.7) 54/17
	hydrangea (0.5-0.8) 47-54/2-7
	officinalis (0.2-0.6) 20-43/18-24
	recognita (0.3-0.6) 37-42/8-12
	tomentosa (0.7-3.5) 2-41/15
	aytachii (0.9) 31/27
	pisidica (0.04-0.4) 24-30/6
	cryptantha (0.4-09) 19-24/16-10
	tchihatcheffii (0.6-1.9) 20-23/16
	aucheri/aucheri (0.7) 21/20
	multicaulis (tr) 19/8
	blepharochlaena (tr) 18/14
	aramiensis (3.0) 17/-
1,8-Cineole/Camphor (CiCa)	*fruticosa* (0.9-2.8) 35-51/7-13
	cryptantha (0.6-0.9) 16-37/6-
	officinalis (-) 35/30
	tomentosa (0.6) 32/-
	divaricata (0.3) 31/10
	macrochlamys (0.2) 27/11
	aucheri/canescens (0.4-0.8) 15-25/14-18
	virgata (-) 20/5
	pililifera (0.2) 9/-
1,8-Cineole/Cryptone	*cadmica* (0.2) 22/12
	smyrnaea (0.4) 18/18
α/β-Thujone	*pomifera* [1.0; 2.7 (Leaf)] 16-20/16-51
	caespitosa (0.6) 24(a+b)
Linalyl acetate/Linalool (LaLi)	*sclarea* (0.3-1.3) 14-49/6-29
	palaestina (0.3) 24/12
	trichoclada (0.3) 24/26
	multicaulis (0.1) 21/12
	heldreichana (0.5) 9/5
	aethiopis (tr) -/20
Other monoterpene esters	*sericeo-tomentosa/hatayica* (-) sabinylacetate 80
	pisidica (0.4-1.1) sabinyl acetate 16-33
	chrysophylla (0.4) α-terpinyl acetate 26
	euphratica/euphratica (0.04) *trans*-pinocarvyl acetate 17
	pinnata (0.06-0.1) bornyl acetate 26-43
	suffruticosa (0.2) bornyl acetate 10
Other oxygenated monoterpenes	*halophila* (0.01) carvacrol 36
	russelli (0.8) thymol 32
	aethiopis (tr) linalool 20
	candidissima/occidentalis (0.2) linalool 9
	cyanescens (0.4) borneol+isoborneol 10
	tomentosa (1.3) borneol 27
	cryptantha (0.6) borneol 25
	heldreichiana (tr) borneol 15
	euprathica/euprathica (-) *cis*-sabinol 22
	albimaculata (0.3) *trans*-verbenol + ɣ-selinene 11
Sesquiterpene hydrocarbons	<u>β-caryophyllene</u>
	virgata (tr-0.02) 28-55

	macrochlamys (0.1) 26
	dichroantha (tr-0.2) 23
	bracteata (0.2) 21
	napifolia (0.4) 20
	microphylla (0.4-0.5) 14-17
	verticillata/amasiaca (0.1) 17
	yosgadensis (0.3) 13
	germacrene D
	chionantha (0.02) 38
	verticillata/amasiaca (-) 37
	argentea (0.2) 27
	sclarea (2.4) 25
	ceratophylla (-) 24
	syriaca (0.1) 24
	candidissima/candidissima (0.2) 21
	verticillata/verticillata (0.06-0.07) 10-16
	forskahlei (0.05) 15
	candidissima/occidentalis (0.1) 13
	hypargeia (0.02) 11
	cilicica (0.04) 10
	others
	aethiopis (0.1-0.2) α-copaene 18-25
	viscosa (0.1) α-copaene 13
	albimaculata (0.3) β-selinene 11 (with *trans*-verbenol)
	ceratophylla (0.8) ϒ-muurolene 11
Oxygenated sesquiterpenes	spathulenol
	verticillata/verticillata (0.05) 31
	limbata (1.5) 30
	cilicica (-) 24
	cyanescens (0.07) 23
	syriaca (0.03-0.08) 11-20
	heldreichiana (0.2) 9
	microstegia (0.1) 5
	caryophyllene oxide
	ballisiana (0.2) 34
	trichoclada (-) 25
	bracteata (0.7) 18
	multicaulis (-) 23
	dicroantha (-) 22
Phenylpropanoids	*viridis* (0.02) methyl chavicol 28

Commercial *Salvia* species belong to the following groups:
CiCa group: *S. fruticosa* (syn. *S. triloba*)
Pinene group: *S. tomentosa*
Thujone group: *S. officinalis*, *S. pomifera* (syn. *S. calycina*)

Sage [*Salvia fruticosa* and *S. officinalis (Cultivated)*] herb exports of Turkey can be seen in the following table (Temel et al., 2018)

Table 18. *Salvia* essential oils commercial figure

Data	2005	2016
Kg	1.689.200	1.918.000
US Dollar	4.694.571	7.285.000
Unit Export Value ($/kg)	2.78	3.80

Satureja spp.

Satureja is represented in the flora of Turkey by 16 species and altogether 17 taxa. Rate of endemism on species basis is 31% and on taxon basis 35% (Celep & Dirmenci, 2017). Carvacrol being a major component in their oils, *Satureja* species are used as a culinary herb like kekik (oregano).

Table 19. *Satureja* essential oils

Species	Main Compounds %	References
S. boissieri	ɣ-terpinene 23, *p*-cymene 23, carvacrol 21, thymol 19	Oke-Altuntas et al., 2016
S. cilicica	*p*-cymene 18, carvacrol 14, ɣ-terpinene 11, thymol 9	Arabaci et al., 2017
	thymol 23, carvacrol 19, *p*-cymene 20, ɣ-terpinene 13	Ozkan G., et al., 2007
S. cuneifolia	carvacrol 67, ɣ-terpinene 15, *p*-cymene 7	Eminagaoglu et al., 2007
	carvacrol 45, *p*-cymene 22, thymol 9	Oke et al., 2009
	carvacrol 59, thymol 16, *p*-cymene 10	Kan et al., 2006
	thymol 42, *o*-cymene 22, ɣ-terpinene 5	Orhan et al., 2011
	carvacrol 33, *p*-cymene 22, ɣ-terpinene 15	Yayli et al., 2014
S. hortensis	thymol 41, ɣ-terpinene 19, carvacrol 14, *p*-cymene 9	Adiguzel et al., 2007
	carvacrol 15, cyclohexanone 15, cymene 13, phenol-2-methyl 12, thymol 11, ɣ-terpinene 9	Bozari et al., 2017
	carvacrol 55, ɣ-terpinene 21, *p*-cymene 12	Tozlu, 2011
	carvacrol 80, ɣ-terpinene 9	Ceker et al., 2014
	carvacrol 79, ɣ-terpinene 9	Gormez et al., 2015
	carvacrol 25, thymol 15, *o*-cymene 11	Sagdic et al., 2013
	carvacrol 41-51, ɣ-terpinene 33-39, α-terpinene 3-6	Katar et al., 2017
S. spicigera	carvacrol 43, ɣ-terpinene 22, *p*-cymene 21	Eminagaoglu et al., 2007
S. thymbra	ɣ-terpinene 41, carvacrol 18, thymol 13, *p*-cymene 13	Karabay-Yavasoglu et al., 2006
	carvacrol 54, ɣ-terpinene 18, thymol 13, *p*-cymene 10	Ayvaz et al., 2010
	carvacrol 35, ɣ-terpinene 23, *p*-cymene 13, thymol 13	Ozturk, M., 2012
	carvacrol 53, thymol 26, ɣ-terpinene 9	Gormez & Diler, 2014

Scutellaria spp.

Scutellaria is represented in the flora of Turkey by 39 taxa including 17 species. Endemism ratio is 44% on taxon basis and 35% on species basis (Celep & Dirmenci, 2017).

Table 20. *Scutellaria* essential oils

Species	Main Compounds %	References
S. diffusa	hexadecanoic acid 30, caryophyllene oxide 9, tetradecanoic acid 6, palmito-ɣ-lactone 5	Cicek et al., 2011
S. heterophylla	germacrene D 21, hexadecanoic acid 16, β-caryophyllene 13, bicyclogermacrene 7	Cicek et al., 2011
S. salviifolia	germacrene D 40, bicyclogermacrene 14, β-caryophyllene 11	Cicek et al., 2011

***Sideritis* spp.**

Two main gene centres for *Sideritis* are Iberic peninsula and Turkey. In the Iberic peninsula, only section *Sideritis* exists with 69 species and altogether 100 taxa. In Turkey, Sections Empedoclia and Hesiodia (annuals) exist with 45 species and altogether 54 taxa comprising 40 endemic taxa. Taxon based endemism ratio is 74% while it is 80% on species basis (Celep & Dirmenci, 2017).

A comprehensive research into taxonomical, anatomical, morphological, caryological, palinological and genetical aspects of all the *Sideritis* species growing in Turkey was recently reported (Duman, 2003).

The essential oil yields ranged between trace (<0.01) and 0.85%. A rough correlation may be established according to the oil yield and main groups of constituents in *Sideritis* oils of Turkey as follows: The higher the oil yield the higher the monoterpene hydrocarbons content. The lower the oil yield the higher the sesquiterpenes content.

Correlation between the oil yield and main groups of constituents are as follows in Table 21.

Table 21. *Sideritis* essential oils

Oil yield	Main Groups of Constituents*
0.85 - 0.2	Monoterpenes
0.2 - 0.02	Monoterpenes+ Sesquiterpenes
0.02 - tr	Sesquiterpenes

*Diterpenes may occur at any yield.

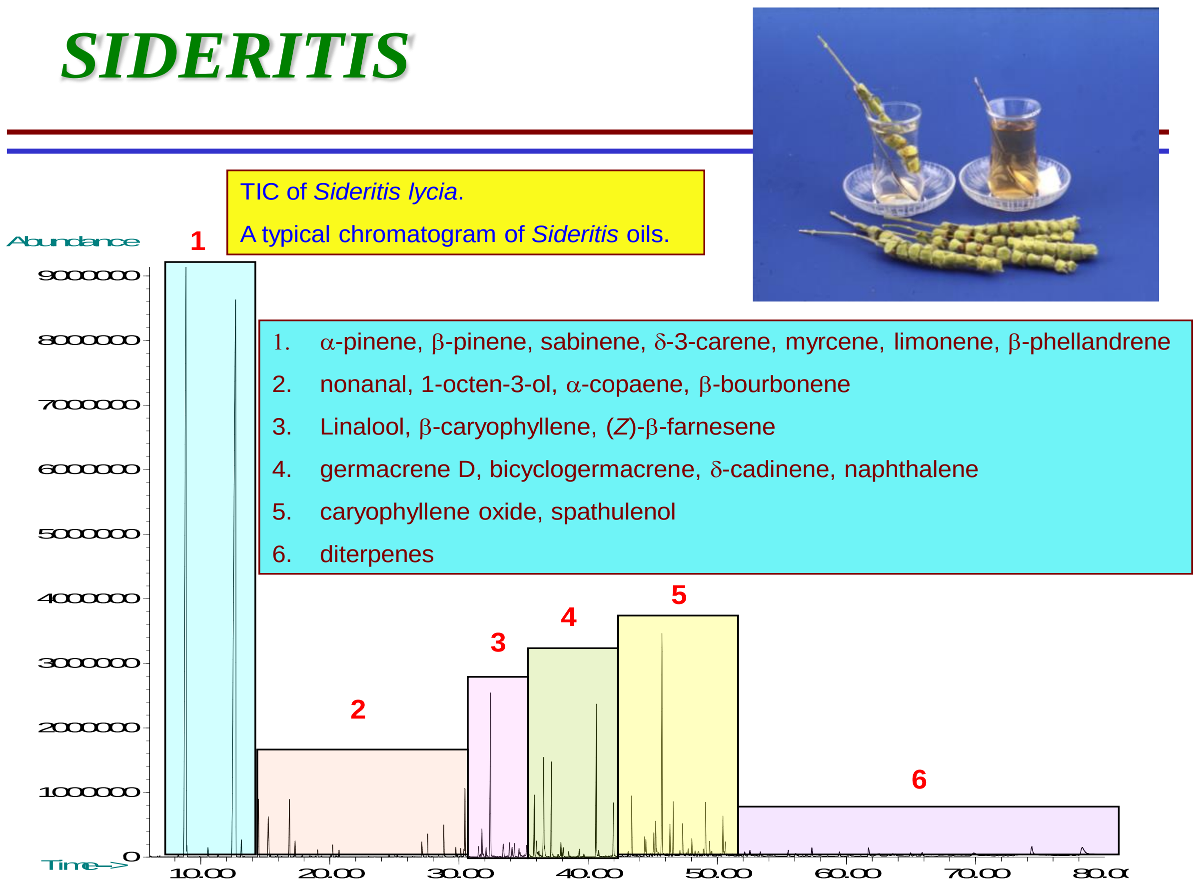

Fig. 1. *Sideritis lycia* Boiss. & Heldr. essential oil GC/MS analysis chromatogram

As far as diterpenes are concerned, plants of section Empedoclia distributed in Turkey and Central and southern Europe contain ent-kaurane type diterpenoids, however, section *Sideritis* distributed in Spain and Canary Islands may comprise ent-kaurane, ent-labdane, ent-trachilobane and ent-beyerene type diterpenoids (Bondi et al., 2000; Topcu et al., 1999).

Table 22. Recent *Sidetis* essential oil studies

Species	Main Compounds %	References
S. brevibracteata	β-caryophyllene 43, germacrene-D 11, α-cadinene 10, carvacrol 5, β-pinene 5	Sagir et al., 2017
S. caesarea	β-caryophyllene 6-13, caryophyllene oxide 7-20, spathulenol 3-6, hexadecanoic acid 9-21	Gunbatan et al., 2017
S. cilicica	β-Pinene 39, α-pinene 28, β-phellandrene 20	Iscan et al., 2005
S. *erytrantha* subsp. *erytrantha*	α-pinene 18, β-caryophyllene 12, sabinene 10, β-caryophyllene 8, α-bisabolol 8	Altundag et al., 2011
S. montana subsp. *montana*	β-caryophyllene 30, α-pinene 13, β-pinene 11	Kilic, 2014
S. vulcanica	α-pinene 16, β-caryophyllene 13, 1,8-cineole 10	Kilic, 2014
S. trojana	valeranone 11, α-bisabolol 11, β-caryophyllene 9	Kirmizibekmez et al., 2017

Classification of *Sideritis* species of Turkey in order of main components of their essential oils is as follows (Başer, 1993; Başer & Kırımer, 2006):

Table 23. *Sideritis* classifications according their essential oil compositions

Monoterpene hydrocarbons	*amasiaca, argyrea, armeniaca, athoa, bilgerana, brevidens, cilicica, congesta, dichotoma, erythrantha* var. *erythrantha, erythrantha* var. *cedretorum, galatica, germanicapolitana* ssp. *germanicapolitana, germanicapolitana* ssp. *viridis, gulendamii, hispida, huber-morathii, libanotica* ssp. *libanotica, libanotica* ssp. *kurdica, lycia, montana* ssp. *remota, niveotomentosa, phrygia, pisidica* var. *termessii, rubriflora, scardica* ssp. *scardica, serratifolia. sipylea, stricta, syriaca* ssp. *nusairiensis, trojana, vulcanica, vuralii*
Oxygenated monoterpenes	*arguta, libanotica* ssp. *microchlamys, romana* ssp. *romana*
Sesquiterpene hydrocarbons	*akmanii, albiflora, brevibracteata, caesarea, cilicica, condensata, curvidens, hololeuca, leptoclada, libanotica* ssp. *linearis, libanotica* ssp. *violascens, montana* ssp. *montana, ozturkii, pisidica* var. *pisidica, romana* ssp. *romana, tmolea, vulcanica*
Oxygenated sesquiterpenes	*phlomoides, taurica, trojana*
Diterpenes	*dichotoma, perfoliata, lanata*
Others	*lanata*

***Stachys* spp.**

The genus *Stachys* is represented in the flora of Turkey by 90 species and altogether 118 taxa. Endemism ratio on species basis is 48%, on taxon basis is 45% (Celep & Dirmenci, 2017). It is generally considered as an oil-poor genus.

Table 24. *Stachys* essential oils

Species	Main Compounds %	References
S. aetherocalyx	germacrene D 25, β-myrcene 16, linalool 12, linalyl acetate 11	Kilic et al., 2017
S. aleurites	β-caryophyllene 34, bicyclogermacrene 15, germacrene D 10, α-pinene 8	Flamini et al., 2005
S. amanica	<u>Sample I:</u> α-pinene 30, α-bisabolol 9, (*E*)-β-caryophyllene 6 <u>Sample II:</u> α-pinene 33 , β-pinene 28, (*E*)-β-caryophyllene 5	Ilcim et al., 2014

S. angustifolia	germacrene D 22, α-terpineol 20, β-myrcene 12	Kilic et al., 2017
S. annua subsp. *annua* var. *annua*	(*Z*)-β-ocimene 25, β-pinene 23, α-pinene 11, benzaldehyde 11, β-bourbonene 7	Renda et al., 2017
	germacrene D 22, α-terpineol 22, 1,8-cineol 22, linalyl acetate 14, linalool 7, β-ocimene 2, dodecanoic acid 2	Kilic et al., 2017
S. antalyensis	bicyclogermacrene 29, β-caryophyllene 15, spathulenol 11, β-pinene 9, viridiferol 7	Fakir et al., 2010
S. balansae subsp. *balansae*	germacrene D 38, β-caryophyllene 18, spathulenol 8	Goren et al., 2011
S. balansae subsp. *carduchorum*	β-caryophyllene 30, germacrene 14, α-cadinene 6	Goren et al., 2011
S. bayburtensis	germacrene D 33, caryophyllene oxide 6	Goren et al., 2011
S. citrina subsp. *citrina*	α-pinene 30, β-phellandrene 14	Iscan, 2012
S. cretica subsp. *mersinaea*	β-caryophyllene 13, germacrene D 12, caryophyllene oxide 12	Kilic et al., 2017
S. cretica subsp. *bulgarica*	germacrene D 28, β-caryophyllene 12, spathulenol 7, caryophyllene oxide 6, α-cadinene 6	Goren et al., 2011
S. cretica subsp. *anatolica*	germacrene D 29, sabinene 9, β-pinene 8	Goren et al., 2011
S. cretica subsp. *cassia*	germacrene D 28, ɣ-elemene 15, β-caryophyllene 9, farnesyl acetate 7	Goren et al., 2011
S. cretica subsp. *garana*	α-cadinol 16, verbenol 11, dodecanoic acid 9, α-humulene 7, spathulenol 7, T-muurolol 7, β-caryophyllene 6, α-cadinene 6	Goren et al., 2011
S. cretica subsp. *kutahyensis*	germacrene D 28, T-muurolol 10, cubenol 9, bicyclogermacrene 7, caryophyllene oxide 7 spathulenol 7, α-cadinol 6	Goren et al., 2011
S. cretica subsp. *lesbiaca*	germacrene D 14, β-caryophyllene 13, α-cadinol 7, α-bisabolol 7, spathulenol 6, verbenol 6, T-muurolol 6	Goren et al., 2011
S. cretica subsp. *smyrnaea*	germacrene D 39, β-caryophyllene 15, caryophyllene oxide 9, β-bourbonene 6, α-cadinol 6	Goren et al., 2011
	trans-β-caryophyllene 51, germacrene-D 33	Ozturk M. et al., 2009
S. gaziantepensis	α-pinene 53 , β-pinene 8	Kaya et al., 2017a
S. germanica subsp. *heldreichii*	germacrene D 27, β-caryophyllene 16, caryophyllene oxide 13	Goren et al., 2011
S. germanica subsp. *bithynica*	germacrene D 23, β-caryophyllene 15, α-copaene 8, caryophyllene oxide 7, *trans*-β-farnesene 7, spathulenol 6	Goren et al., 2011
S. huber-morathii	germacrene D 18, β-caryophyllene 15, *trans*-β-farnesene 10, globulol 7, caryophyllene oxide 6	Goren et al., 2011
S. huetii	germacrene D 30, β-caryophyllene 12, β-bourbonene 9, *trans*-β-farnesene 6	Goren et al., 2011
S. iberica subsp. *stenostachya*	linanyl acetate 24, α-terpineol 20, germacrene D 16, geranyl acetate 6	Kilic et al., 2017
S. iberica subsp. *iberica*	hexadecanoic acid 42, germacrene D 10, phytol 8	Göger et al., 2016
S. lavandulifolia var. *lavandulifolia*	α-bisabolol 56, bicyclogermacrene 5	Barreto et al., 2016
	β-phellandrene 27, α-pinene 19, germacrene D 13	Iscan et al., 2012
	germacrene D 20, β-myrcene 15, α-pinene 13, α-copaene 7	Kilic et al., 2017
S. longispicata	germacrene D 27, β-caryophyllene 10, spathulenol 6	Goren et al., 2011
S. macrantha	carvacrol 29, *p*-cymene 19, α-pinene 11, thymoquinone 9, (*E*)-caryophyllene 9	Renda et al., 2017
S. mardinensis	menthyl acetate 15, isomenthone 15, pulegone 10, menthol 8, spathulenol 7, caryophyllene oxide 7	Kaya et al., 2017a
	β-caryophyllene 25, β-bourbonene 11, spathulenol 13	Kilic et al., 2017
S. obliqua	germacrene D 45, β-caryophyllene 17, limonene 8	Goren et al., 2011

S. petrokosmos	Sample I: α-pinene 26 , α-bisabolol 7 Sample II: α-pinene 28 , γ-curcumene 9	Ilcim et al., 2014
S. pinetorum	germacrene D 29, β-caryophyllene 11, caryophyllene oxide 8, spathulenol 7, globulol 6	Goren et al., 2011
S. pumila	*trans*-nerolidol 32-39, α-pinene 17-18, β-pinene 9-10	Kaya, D. A., 2015
S. ramossima var. *ramossima*	α-terpineol 21, linalool 17, α-pinene 11	Kilic et al., 2017
S. sericantha	germacrene D 32, β-caryophyllene 23, α-cadinene 7	Goren et al., 2011
	hexadecanoic acid 24, dodecanoic acid 11, caryophyllene oxide 11	Kaya et al., 2017
S. spectabilis	germacrene D 33, β-caryophyllene 10, α-cadinene 9	Goren et al., 2011
	β-myrcene 16, caryophyllene oxide 15, β-caryophyllene 14, germacrene D 13	Kilic et al., 2017
S. sylvatica	limonene 37, α-ledrene 11, γ-muurolene 1, (*2E*)-hexenal 7	Renda et al., 2017
	germacrene D 24, β-caryophyllene 21, α-pinene 20	Kilic et al., 2017
S. thirkei	germacrene D 38, caryophyllene oxide 8, β-pinene 7, *trans*-β-farnesene 7	Goren et al., 2011
S. tmolea	germacrene D 22, β-caryophyllene 20, valeronone 9, spathulenol 6	Goren et al., 2011
S. viticina	β-caryophyllene 62, farnesyl acetate 9	Goren et al., 2011

***Teucrium* spp.**

The genus *Teucrium* is represented in the flora of Turkey by 36 species and altogether 49 taxa. Rate of endemism on species basis is 42, on taxon basis is 35 (Celep & Dirmenci, 2017). The following table shows the recent results.

Table 25. *Teucrium* essential oils

Species	Main Compounds %	References
T. alyssifolium	*trans*-β-caryophyllene 17, *ar*-curcumene 11, bisabolene 11, α-humulene 8	Semiz et al., 2016
T. chamaedrys subsp. *chamaedrys*	germacrene D 16, α-pinene 16, β-caryophyllene 12, β-pinene 9	Kucuk et al. 2006
T. chamaedrys subsp. *lydium*	β-caryophyllene 20, α-pinene 13, germacrene D 9, β-pinene 7, caryophyllene oxide 6	Kucuk et al., 2006
T. chamaedrys subsp. *trapezunticum*	β-caryophyllene 18, nonacosane 12, germacrene D 11, α-pinene 7, caryophyllene oxide 7	Kaya et al., 2009
T. chamaedrys subsp. *syspirense*	caryophyllene oxide 22, α-pinene 11	Kaya et al., 2009
T. lamiifolium subsp. *lamiifolium*	β-caryophyllene 24-45, *trans*-β-bergamotene 22-26, germacrene D 6-22, (*Z*)-β-farnesene 3-14, caryophyllene oxide 3-8	Dogu et al., 2013
T. lamiifolium subsp. *stachyophylum*	*trans*-β-bergamotene 38-41, β-caryophyllene 8-9, α-humulene 6, germacrene D 6-7	Dogu et al., 2013
T. multicaule	germacrene D 13, caryophyllene oxide 11, spathulenol 7	Polat et al., 2010
T. orientale var. *glabrescens*	nonanal 25, thuja-2,4(10)-diene 23, tetracosane 15, pentacosane 7, eicosane 7	Yildirmis et al., 2017
	β-cubebene 27, hexadecanoic acid 13, β-caryophyllene 7	Ozek et al., 2012
T. orientale var. *orientale*	germacrene D 25, β-caryophyllene 23, hexadecanoic acid 8, bicyclogermacrene 7, caryophyllene oxide 6	Ozek et al., 2012
T. orientale var. *puberulens*	germacrene D 33, hexadecanoic acid 13, β-caryophyllene 9, bicyclogermacrene 9	Ozek et al., 2012
T. orientale var. *puberulens*	β-caryophyllene 22, 2-methyl cumarone 20, germacrene D 11	Kucuk et al., 2006

***Thymbra* spp.**

In the flora of Turkey, *Thymbra* is represented by 2 species and altogether 4 taxa. Recent papers on the essential oil of two *Thymbra* taxa are as follows:

Table 26. *Thymbra* essential oils

Species	Main Compounds %	References
T. spicata subsp. *spicata*	carvacrol 71, *p*-cymene 14, ɣ-terpinene 7	Sertkaya et al., 2010
T. spicata	α-terpinene 27, carvacrol 27, *p*-cymene 14, thymol 1	Maral et al.
	carvacrol 83, cymene 8, ɣ-terpinene 6	Gormez & Diler, 2014
	carvacrol 79, ɣ-terpinene 10, *p*-cymene 6	Bayan et al., 2017

***Thymus* spp.**

Thymus is represented in Turkey by 42 species (47 taxa). Rate of endemism on species basis is 48% (Celep & Dirmenci, 2017) Several recent papers have appeared in recent years on the composition of *Thymus* species. Important note: Some papers on *T. vulgaris* and *T. serpyllum* have not been included in this review since the species mentioned there do not exist in the Flora of Turkey, and their botanical identity is in question.

Table 27. *Thymus* essential oils

Species	Main Compounds %	References
T. fallax	thymol 41, o-cymene 27, ɣ-terpinen 16	Yilar et al., 2013; Onaran et al., 2014
*T. pseudopulegioides (*Syn. *T. nummularius)*	thymol 58, ɣ-terpinene 10, *p*-cymene 9	Bektas et al., 2016
T. revolutus	cymene 33, ɣ-terpinene 17, carvacrol 12, thymol 10, borneol 8, α-pinene 6	Erdogan & Ozkan, 2013
T. sipyleus	α-pinene 21, farnesol 16, 1,8-cineole 9, limonene 8, linalool 6	Maral et al., 2017
T. spathulifolius	carvacrol 49, thymol 18, *p*-cymene 12, ɣ-terpinene 7	Celen et al.,2012
T. vulgaris	carvacrol 36, *o*-cymene 8, linalool 6, carvacrol methyl ether 5	Sagdic et al., 2013

Pure Chemotype Patterns in the *Thymu*s Taxa in Turkey:

1. Carvacrol *and/or* thymol, *p*-cymene, γ-terpinene (*oregano or thyme smell*)
2. Geraniol, geranyl acetate (*rose smell*)
3. Geranial, neral (*lemon smell*)
4. Linalool, linalyl acetate (*lavender smell*)
5. α-terpineol, α-terpinyl acetate (*lavender smell*)
6. 1,8-cineole, α-terpineol, α-terpinyl acetate, borneol, camphor, α/β-pinenes, limonene may come together (*e.g., Thymus cariensis, T. cilicicus*)
7. β-caryophyllene, germacrene D, caryophyllene oxide
8. Other sesquiterpenes

***Ziziphora* spp.**

Ziziphora is represented in Turkey by 5 species and altogether 10 taxa (Firat, 2017). Recent data on the essential oils of three species are listed below.

Table 28. *Ziziphora* essential oils

Species	Main Compounds %	References
Z. clinopodioides	pulegone 20, piperitone 14, limonene 11	Kilic & Bagci, 2013
Z. persica	pulegone 80, limonene 7, piperitone 4, β-pinene 2	Ozturk & Ercisli, 2006
	pulegone 33, β-pinene 6, piperitone 5	Kilic & Bagci, 2013
Z. tenuior	pulegone 30, 1,8-cineole 10	Kilic & Bagci, 2013
	pulegone 74, piperitenone 4	Celik et al., 2016

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