Composition and Antibacterial Activity of the Essential Oils from *Satureja wiedemanniana* (Lallem.) Velen

Kemal Hüsnü Can Başer[a*], Gülendam Tümen[b], Nurhayat Tabanca[a], and Fatih Demirci[a]

[a] Medicinal and Aromatic Plant and Drug Research Centre (TBAM), Anadolu University, 26470-Eskişehir, Turkey. Fax: +90 222 335 01 27. E-mail: khcbaser@anadolu.edu.tr

[b] Faculty of Science and Letters, Department of Biology, Balikesir University, 10100 Balikesir, Turkey

* Author for correspondence and reprint request

Z. Naturforsch. **56 c,** 731–738 (2001); received April 18/May 5, 2001

Satureja wiedemanniana, Essential Oil, Antibacterial Activity

Satureja wiedemanniana (Lallem.) Velen (Lamiaceae) is an endemic species of Turkey. Aerial parts of the plant collected from eleven different localities in Turkey were subjected to hydrodistillation to yield essential oils which were analysed by a GC/MS system. Carvacrol, thymol, *p*-cymene and γ-terpinene were found as the main constituents. Antibacterial evaluation of the oils was also carried out.

Introduction

The genus *Satureja* (Lamiaceae) is represented by 15 species of which five are endemic, including *S. pilosa* which has recently been discovered as a new record for Turkey (Davis, 1982; Tümen *et al.*, 1998).

Several *Satureja* species are used as herbal tea in various regions of Turkey (Başer, 1995). Savory species when compared to thyme and oregano are similar in aroma and due to these properties, savories are mainly used as culinary herbs. Medicinal properties which have been ascribed to *Satureja* species are tonic, antispasmodic, antiinflammatory, antidiarrhoeal, antiedema, stimulant, diuretic, laxative, anaemia, carminative, antimicrobial, mutagenic, and they are used for rheumatic pains, heart disorders, gastrointestinal disorders and against common cold (Hajhashemi *et al.*, 2000; Stanic *et al.*; 1993; Martinez *et al.*; 1984; Dafni *et al.*; 1984; Heinrich *et al.*; 1992; Sanches De Rojas V., 1994; Jatem-Lasser *et al.*, 1998; Tümen *et al.*, 1997; Bown, 1995; Duke, 1986; Grieve, 1983; Müller-Riebau *et al.*, 1995; Akgül and Kivanç, 1988; Kivanç and Akgül, 1989). Our group has previously found analgesic activity of the essential oil of *S. cuneifolia* which is also used in folk medicine (Aydin *et al.*, 1996).

Satureja species are locally known and consumed as "Zahter" or "Kekik". Kekik is a collective name given to members of various Lamiaceae genera, such as *Origanum, Thymus, Thymbra and Coridothymus* in Turkey. A common feature of these species is that they all possess a thymol or carvacrol type odour (Kirimer *et al.*, 1995).

Previously, the essential oil of *S. wiedemanniana* was reported to contain caryophyllene oxide (8.5%), borneol (8.3%), germacrene D (8.1%), limonene (7.7%), spathulenol (7.7%), β-caryophyllene (6.5%) and β-bisabolene (6.0%) as main constituents (Ezer *et al.*, 1995).

Here, we report on the GC/MS analyses of the essential oils of eleven different located (Western to Eastern Turkey) *S. wiedemanniana* (Lallem.) Velen. This endemic species is locally known as "Dereçayi", "Kaya Kekigi" and "Kekik" in the regions where it grows. The essential oils were also evaluated for their antibacterial properties against common pathogens.

Experimental

Plant material and isolation of the oils

Aerial parts of the plants collected from various localities (A-L) are shown in Table I. Air dried plant materials were hydrodistilled for 3 h using a Clevenger-type apparatus. The percentage yields (%) of the oils calculated on moisture free basis are also indicated in Table I. The voucher speci-

0939–5075/2001/0900–0731 $ 06.00 © 2001 Verlag der Zeitschrift für Naturforschung, Tübingen · www.znaturforsch.com · D

Table I. Site and date of collection and oil yield of *Satureja wiedemanniana.*

Code	Region	ESSE*	Collectionperiod	Yield (%)
A	Çanakkale: Ayvacik- Behramkale	13162	8.1999	3.0
B	Balikesir: Balya, Kadiköy	12471	8.1997	1.5
C	Balikesir: Bigadiç	12467	8.1993	1.1
D	Bursa: Inegöl, Turgutalp, Cerrahlar	12488	10.1997	0.8
E	Bursa: Mezitler	12161	9.1996	1.3
F	Denizli: Babadag	12485	9.1997	2.16
G	Isparta: Sütçüler, Dedegöl	12734	8.1999	1.3
H	Eskişehir: Gökçekaya Dam	12753	9.1998	1.1
I	Ankara: Haymana	12835	9.1999	0.9
K	Çorum: Eskiekin Village	12795	9.1998	0.4
L	Amasya: Bogazköy	10666	8.1994	0.1

* Acronym of the Herbarium of the Faculty of Pharmacy, Anadolu University, Eskişehir, Turkey

mens are kept at the Herbarium of the Faculty of Pharmacy, Anadolu University, Eskişehir, Turkey (ESSE).

GC/MS analysis

The essential oil analyses were carried out by GC/MS using a Hewlett Packard GCD system. HP-Innowax FSC column (60 m × 0.25 mm i. d., with 0.25 *m*m film thickness) was used with helium as a carrier gas (1 ml/min). GC oven temperature was kept at 60° C for 10 min and programmed to 220° C at a rate of 4° C/min, then kept constant at 220° C for 10 min and finally programmed to 240° C at a rate of 1° C/min. Alkanes were used as reference points in the calculation of relative retention indices (RRI). Split ratio was adjusted at 50:1. The injection temperature was at 250° C. MS were recorded at 70 eV. Mass range was from *m/z* 35 to 425. Library search was carried out using the combination of "Wiley GC/MS Library" and "TBAM Library of Essential Oil Constituents". Relative percentage amounts were calculated from TIC (total ion chromatograms) by the computer. The compounds identified in the essential oils are given in Table II.

Bioassay

Microdilution broth susceptibility assay was used (Konemann, 1997). Stock solutions of essential oils were prepared in DMSO. Serial dilutions of essential oils were prepared in sterile distilled water in 96-well microtiter plate. Freshly grown bacterial suspensions in double strength Mueller-Hinton broth (Merck) were standardised to 10^8 CFU/μl. Sterile distilled water served as growth control. 100 μl of each bacterial suspension was then added to each well. The last row containing only the serial dilutions of antibacterial agent without microorganism was used as negative control. After incubation at 37 °C for 24 h the first well without turbidity was determined as the minimal inhibitory concentration (MIC). Human pathogens *Escherichia coli* (ATTC 25292), *Staphylococcus aureus* (ATTC 6538), *Pseudomonas aeruginosa* (ATTC 27853), *Enterobacter aerogenes* (NRRL 3567), *Proteus vulgaris* (NRRL 123), and *Salmonella typhimurium* (NRRL 4420), were obtained through the culture collection of the Microbiology Department in Anadolu University (Table III)

Results and Discussion

Essential oils from aerial parts of *S. wiedemanniana* collected from eleven different parts of Turkey have been analysed by GC/MS. The results of analyses are shown in Table II and the summary of main components are shown in Fig. 1 comparatively representing all regions (A-L) . The overall yields ranged between 0.1–3.0%. A total of one hundred eighty six compounds representing 82.1–99.7% of the oils were characterised.

As observed, carvacrol (29.1–61.9%) was the main component in the oils of *S. wiedemanniana* growing in the Western part of Turkey. It was noted that carvacrol content gradually decreased towards the East. Other major components were *p*-cymene (3.8–29.7%), thymol (0.2–14.3%) and γ-terpinene (0.02–18.5%).

The oil of the sample from Eskişehir (H) which is located in the Western side of Central Anatolia was characterised with almost equal amounts of carvacrol (20.5%) and thymol (16.3%) as major constituents.

Thymol (39.8%) was the main constituent in the oil of Ankara sample (I) while borneol (15.9%) was detected as main component in the oil of Çorum sample (K). Both provinces are located towards the Eastern side of Central Anatolia.

The oil sample from Amasya (L) which is located in North-East Anatolia was rich in sesquiterpenes, spathulenol (12.9%), borneol (10.8%) and

Table II. The Composition of the Essential Oils of *Satureja wiedemanniana*.

Compound	RRI	A	B	C	D	E	F	G	H	I	K	L
Tricyclene	1014	–	0.03	–	–	–	0.01	–	0.01	0.02	0.03	–
Methyl 2-methylbutyrate	1018	–	–	–	–	–	–	0.04	–	–	–	–
Methyl 3-methylbutyrate	1024	0.01	0.01	–	–	–	–	0.02	–	0.02	–	–
α-Pinene	1032	0.77	0.96	0.66	0.29	0.86	0.33	0.46	0.44	0.48	1.53	0.15
α-Thujene	1035	1.02	0.99	0.15	0.04	0.30	0.33	0.48	0.48	0.30	0.16	0.07
2,5-Diethyltetrahydrofuran	1051	–	0.02	0.02	–	–	0.01	–	0.02	0.01	–	–
Camphene	1076	0.19	0.62	0.25	0.10	0.23	0.28	0.59	0.39	0.57	1.28	–
β-Pinene	1118	0.18	0.23	0.11	0.05	0.09	0.10	0.10	0.16	0.16	0.25	0.03
Sabinene	1132	0.05	0.02	–	0.08	0.20	0.01	0.01	0.01	–	0.37	0.03
δ-3-Carene	1159	0.05	–	0.05	–	–	0.04	0.03	0.05	0.05	0.02	–
Myrcene	1174	2.17	1.90	0.13	0.43	0.72	1.10	1.07	1.47	1.22	0.99	0.20
α-Terpinene	1188	2.57	1.37	0.89	0.27	1.01	1.17	1.00	1.40	0.93	0.23	0.26
Dehydro-1,8-cineole	1195	–	0.02	–	–	–	0.01	–	0.01	–	0.02	–
Limonene	1203	0.49	0.45	0.37	2.82	2.76	0.25	0.27	0.46	0.48	8.83	2.53
1,8-Cineole	1213	0.63	0.70	0.76	1.51	0.58	0.38	0.12	0.59	0.83	3.13	1.39
β-Phellandrene	1218	0.19	0.20	0.17	0.14	0.22	0.13	0.11	0.15	0.15	0.30	0.06
(*E*)-2-Hexenal	1232	0.03	0.06	0.01	–	0.02	0.02	0.04	0.07	0.03	tr	–
(*Z*)-β-Ocimene	1246	3.09	3.01	0.18	1.21	0.61	0.99	1.36	2.75	1.47	0.92	0.23
γ-Terpinene	1255	18.54	8.37	0.02	2.90	4.16	8.36	8.57	10.37	5.47	0.57	0.97
(*E*)-β-Ocimene	1266	1.11	0.44	–	0.43	0.17	0.19	0.52	0.74	0.58	0.82	0.24
p-Cymene	1280	3.84	19.27	29.72	7.73	12.15	11.82	8.54	23.76	17.31	10.64	2.37
Terpinolene	1290	0.08	0.12	0.05	0.09	0.37	0.09	0.11	0.10	0.10	0.13	0.25
3-Octyl acetate	1345	–	–	–	–	–	–	–	–	–	0.01	0.10
6-Methyl-5-hepten-2-one	1348	–	0.03	–	–	–	–	–	0.01	0.01	0.01	–
cis-Alloocimene	1382	0.04	0.05	0.02	0.02	–	0.02	0.02	0.01	0.02	0.02	–
1-Octenyl acetate	1386	–	–	–	–	–	–	–	0.05	–	0.06	0.09
3-Octanol	1393	0.13	0.05	0.15	0.21	0.02	0.14	0.10	0.01	0.21	–	0.48
Nonanal	1400	0.02	0.02	–	–	–	0.02	–	0.29	0.02	0.01	0.07
Rosefuran	1415	–	0.02	–	–	–	–	–	–	–	0.01	–
Perillene	1429	–	–	–	–	–	–	–	–	–	0.01	0.03
α,*p*-Dimethylstyrene	1452	0.01	0.08	0.14	0.04	0.07	0.08	0.02	0.12	0.11	0.06	0.03
1-Octen-3-ol	1452	0.05	0.07	0.08	0.43	0.22	0.13	0.15	0.53	0.28	0.12	0.37
trans-Linalool oxide	1452	–	–	–	–	–	–	–	–	–	–	0.03
cis-1,2-Limonene epoxide	1458	–	–	–	–	–	–	–	–	–	0.18	–
1-Heptanol	1463	–	–	–	–	–	–	–	0.01	–	–	0.02
α-Cubebene	1466	0.01	–	–	–	–	–	–	0.01	0.01	–	0.02
trans-1,2-Limonene epoxide	1468	–	–	–	–	–	–	–	–	–	–	0.07
trans-Sabinenehydrate	1474	0.64	0.54	0.36	4.01	9.05	0.47	0.73	0.63	0.57	5.89	2.61
(*Z*)-β-Ocimene epoxide	1476	–	0.05	–	–	–	0.05	0.02	0.09	0.07	–	–
4,8-Epoxyterpinolene	1477	0.01	–	0.03	0.02	0.03	–	–	–	–	–	–
cis-Linalool oxide	1479	–	–	–	–	–	–	–	–	–	–	0.07
Nerol oxide	1480	–	0.01	–	–	–	–	–	–	–	–	–
(*Z*)-3-Hexenyl 2-methylbutyrate	1482	0.01	–	0.02	–	–	0.02	–	–	0.01	–	–
α-Ylangene	1493	0.01	0.01	0.03	–	–	0.01	–	0.02	0.02	0.01	–
Bicycloelemene	1495	0.01	–	–	0.05	–	–	–	–	–	0.05	–
cis/cis-Photocitral	1495	–	0.06	–	–	–	–	–	–	–	–	–
3-Nonanol	1496	0.01	–	–	–	–	0.02	0.05	0.01	–	–	0.03
α-Copaene	1497	0.04	0.08	0.11	0.07	0.07	0.05	0.06	0.09	0.07	0.23	0.33
(*E*)-β-Ocimene epoxide	1498	–	–	–	–	–	–	–	–	0.03	0.03	–
α-Campholenal	1499	–	–	–	–	–	–	–	–	–	–	0.30
(*E*,*E*)-2,4-Heptadienal	1507	–	–	–	–	–	–	–	0.05	0.02	–	–
trans/trans-Photocitral	1519	–	0.12	–	–	–	–	–	–	–	–	–
Camphor	1532	–	–	–	–	–	–	–	–	–	1.52	–
β-Bourbonene	1535	0.06	0.12	0.08	0.35	0.21	0.07	0.07	0.0	0.12	0.06	3.04
Benzaldehyde	1541	–	–	–	–	–	–	–	0.01	0.01	–	–
4-undecanone	1544	–	–	–	–	–	–	–	–	–	0.02	–
β-Cubebene	1549	–	–	–	–	–	–	–	–	–	0.03	0.10
Linalool	1553	0.31	0.26	0.07	0.61	0.21	0.54	–	0.07	1.28	0.88	1.76
cis-Sabinenehydrate	1556	0.17	0.24	0.23	1.12	1.07	0.30	0.29	0.39	0.34	1.10	1.01
Octanol	1562	0.01	0.03	–	–	–	0.02	–	0.06	0.02	–	0.12

Table II. (cont.)

Compound	RRI	A	B	C	D	E	F	G	H	I	K	L
1-Methyl-4-acetyl-cyclohex-1-ene	1568	–	–	–	0.02	–	–	–	–	–	0.02	0.03
trans-p-Menth-2-en-1-ol	1571	0.03	0.06	0.02	0.16	0.49	0.04	0.04	0.06	0.06	0.33	0.63
8,9-Limonene epoxide II	1571	–	–	–	0.01	–	–	–	–	–	0.02	–
Pinocarvone	1586	–	0.01	–	0.05	0.02	–	–	0.02	0.01	0.09	–
Bornyl formate	1588	–	–	–	–	–	–	–	–	–	0.25	–
trans-β-Bergamotene	1594	0.02	0.02	0.06	–	–	0.02	–	–	0.01	0.03	–
Bornyl acetate	1597	0.01	0.01	–	0.03	–	–	–	0.02	0.03	0.82	2.11
Thymol methylether	1598	–	–	–	–	–	–	–	0.12	0.97	–	–
β-Elemene	1600	–	–	–	0.21	0.06	–	–	0.01	–	0.23	0.32
Calarene	1610	–	–	–	0.07	–	–	–	–	–	–	–
Terpinen-4-ol	1611	0.73	1.74	1.22	6.71	7.43	0.84	–	–	–	3.36	7.74
β-Caryophyllene	1612	–				–	–	1.29	3.50	1.62	–	0.08
Carvacrol methylether	1614	0.04	1.53	1.43	–	0.70	0.23	0.06	1.10	2.66	2.04	–
trans-Dihydrocarvone	1624	0.10	–	–	1.18	0.58	–	0.22	–	–	1.29	0.80
Aromadendrene	1628	0.10	0.29	0.44	–	–	0.02	–	–	0.23	–	0.11
4-Terpinenyl acetate	1630	–	0.09	0.05	0.04	0.04	0.08	–	0.08	0.17	–	–
cis-β-Menth-2-en-1-ol	1638	0.02	0.05	0.04	–	0.36	0.03	0.02	0.04	0.04	0.29	0.61
trans-p-Mentha-2,8-dien-1-ol	1639	–	–	–	0.24	–	–	–	–	–	–	0.24
Dehydrosabinaketone	1643	–	0.01	–	–	–	–	–	–	–	–	–
cis-Isodihydrocarvone	1645	0.07	–	–	3.04	1.59	–	0.09	0.07	0.02	2.40	1.40
Alloaromadendrene	1661	–	–	0.02	0.13	0.01	–	–	–	0.03	0.07	–
Pulegone	1661	–	–	0.02	–	–	0.09	–	–	–	–	–
cis-Verbenol	1663	–	–	–	0.05	0.05	–	–	–	–	–	0.20
Nonanol	1664	0.02	0.08	–	–	–	–	–	0.04	–	–	0.08
trans-Pinocarveol	1664	–	0.04	0.02	0.22	0.13	0.03	0.02	0.05	0.05	–	0.38
(*Z*)-β-Farnesene	1668	0.09	0.05	–	–	–	0.05	0.03	–	0.02	0.06	–
cis-p-Mentha-2,8-dien-1-ol	1678	–	–	–	0.17	0.09	–	–	0.01	–	0.36	–
δ-Terpineol	1682	0.03	0.03	0.03	–	–	0.03	–	0.03	0.05	–	–
α-Humulene	1687	0.02	0.04	0.01	–	–	–	0.02	0.13	0.04	–	–
Cryptone	1690	–	–	–	–	–	–	–	–	–	0.13	–
trans-Verbenol	1691	–	0.07	0.05	0.93	0.47	0.09	–	0.12	0.11	0.56	–
Neral	1694	–	0.49	0.06	0.06	–	0.06	–	–	–	–	–
(*E*)-β-Farnesene	1695	0.03	–	–	–	–	–	–	–	–	–	0.04
p-Mentha-1,8-dien-4-ol	1700	–	0.02	–	–	0.05	–	0.02	0.04	0.03	0.07	–
γ-Muurolene	1704	0.12	0.23	0.28	0.10	0.23	0.18	0.20	0.31	0.23	–	–
Ledene	1708	–	–	–	–	–	–	–	–	–	0.07	–
α-Terpineol	1709	0.25	0.21	0.30	1.67	1.14	0.24	0.23	0.30	0.33	1.55	2.60
Borneol	1719	1.07	2.20	1.38	6.13	2.82	2.48	5.45	3.00	4.56	15.93	10.83
Verbenone	1725	–	–	–	–	–	–	–	–	–	0.60	–
Germacrene D	1726	0.45	0.17	0.03	2.44	1.42	0.06	0.43	0.16	0.03	–	3.72
Neryl acetate	1733	–	0.06	–	–	–	–	–	–	–	–	–
Valencene	1740	0.05	0.10	–	0.07	0.07	0.09	0.07	0.13	0.12	–	–
α-Muurolene	1740	–	–	–	–	–	–	–	0.26	–	–	–
Geranial	1740	–	0.74	–	–	–	–	–	0.01	–	–	–
β-Bisabolene	1741	3.86	2.42	6.19	1.44	0.35	2.72	1.47	–	1.75	3.20	3.95
α-Selinene	1744	–	–	–	0.04	0.03	–	–	–	–	–	–
Sesquicineole	1747	–	–	0.05	–	–	0.01	–	–		–	–
Carvone	1751	–	0.34	0.28	–	–	0.22	–	–	–	–	–
trans-Piperitone oxide	1755	–	–	–	0.02	–	–	–	–	–	–	–
Bicyclogermacrene	1755	0.39	–	–	2.77	0.57	–	0.20	–	0.05	2.44	6.50
cis-Piperitol	1758	–	–	–	0.03	0.13	–	–	0.01	0.04	0.03	–
Naphthalene	1763	–	–	–	–	–	–	–	–	0.02	0.05	–
Geranyl acetate	1765	–	0.14	–	–	–	–	–	–	–	–	–
Decanol	1766	–	–	0.02	–	–	0.01	–	0.05	0.01	–	–
Citronellol	1772	–	0.02	–	–	–	–	–	–	–	–	–
δ-Cadinene	1773	0.20	0.30	0.24	0.47	0.34	0.25	0.25	0.32	0.19	0.20	0.21
γCadinene	1776	0.09	0.18	0.17	0.22	0.17	0.13	0.13	0.20	0.15	0.08	0.16
β-Ylangene	1777	–	0.03	–	0.05	0.08	0.02	0.03	0.05	0.02	0.11	–
β-Sesquiphellandrene	1783	0.04	0.02	0.04	–	–	–	–	–	–	0.01	–
(*E*)-α-Bisabolene	1784	0.11	0.06	0.03	0.03	–	0.11	0.03	–	0.08	0.04	–

Table II. (cont.)

Compound	RRI	A	B	C	D	E	F	G	H	I	K	L
ar-Curcumene	1786	–	–	0.04	–	–	–	–	–	–	–	–
p-Methylacetophenone	1797	–	–	0.01	–	–	0.02	–	0.04	0.03	0.08	0.16
Methyl salicylate	1798	0.01	0.02	0.01	–	0.02	0.03	0.03	0.03	–	0.01	–
Cadina-1,4-diene	1799	0.02	–	–	–	–	–	–	–	–	–	–
Cuminaldehyde	1802	–	0.10	0.05	0.24	0.17	0.11	–	0.22	0.13	0.11	0.15
Myrtenol	1804	–	–	–	0.15	0.06	–	–	0.01	0.01	–	0.28
Nerol	1808	–	0.45	–	–	–	–	–	–	–	–	–
3,7-Guaiadiene	1810	0.01	–	0.02	–	–	–	–	0.03	0.03	–	–
trans-*p*-Mentha-1(7),8-dien-2-ol	1811	–	–	–	0.23	0.05	–	–	–	–	0.08	–
2,6-Dimethyl-3(*E*),5(*Z*),7-octatrien-2-ol	1815	–	–	–	–	–	–	–	–	–	0.11	–
p-Mentha-1(7),5-dien-2-ol	1823	–	–	–	–	–	–	–	0.02	0.03	–	–
2,6-Dimethyl-3(*E*),5(*E*),7-octatrien-2-ol	1830	–	–	–	0.02	–	–	–	–	–	0.24	–
trans-Carveol	1845	–	–	–	0.51	0.24	–	–	0.04	0.04	0.04	1.18
cis-Calamenene	1853	–	–	0.12	0.03	0.05	0.02	0.02	0.05	0.08	0.01	–
Carvonoxide	1856	–	–	–	–	–	0.02	–	–	–	0.02	0.03
Geraniol	1857	0.01	1.77	–	–	–	–	–	–	–	–	–
p-Cymen-8-ol	1864	–	0.37	0.34	–	0.72	0.39	0.16	0.79	0.45	0.97	0.47
Thymyl acetate	1867	0.04	–	–	–	0.03	–	–	–	0.22	–	0.21
(*E*)-Geranyl acetone	1868	–	–	0.01	–	–	0.01	–	0.02	–	0.06	–
cis-Carveol	1882	–	–	–	0.17	0.08	–	–	–	–	0.03	0.21
Ascaridole	1889	–	–	–	0.02	–	–	0.04	0.03	0.06	–	–
Carvacryl acetate	1890	0.21	0.03	–	0.02	0.08	0.18	0.05	0.02	–	–	0.02
Epicubebol	1900	0.01	0.03	–	0.15	0.06	0.02	0.03	0.03	–	0.04	0.22
3-Phenylethyl propionate	1904	–	–	–	–	–	–	–	–	0.06	–	–
4-Isopropyl salicylaldehyde	1940	0.01	0.37	0.22	0.18	0.33	0.33	0.18	0.16	0.08	0.11	–
α-Calacorene I	1941	–	0.04	0.04	0.02	0.04	0.02	0.01	0.01	0.04	tr	0.01
Piperitenone	1949	–	–	–	–	–	–	–	–	–	–	0.08
Shyobunol	1953	–	–	–	0.28	–	–	–	–	–	–	–
Cubebol	1957	0.01	0.02	–	0.26	0.07	0.02	0.03	0.02	0.03	–	0.10
Cuminyl acetate	1981	–	–	–	–	–	0.01	–	0.03	–	–	–
2-Phenylethyl 2-methylbutyrate	1988	–	–	–	–	–	–	–	–	0.03	–	–
2-Phenylethyl 3-methylbutyrate	1992	–	–	0.01	–	–	–	–	–	–	–	–
Isocaryophyllene oxide	2001	–	0.02	–	0.28	0.09	–	–	0.08	0.06	0.05	–
Caryophyllene oxide	2008	–	0.95	0.41	4.12	1.66	0.10	0.22	2.05	1.55	0.93	0.66
Perilla alcohol	2029	–	–	–	–	0.04	–	–	–	–	–	0.13
Epiglobulol	2033	–	0.01	–	–	–	–	–	–	–	–	–
Salvial-4(14)-en-1-one	2037	–	–	–	–	0.03	–	–	–	–	0.12	–
Phenyl ether	2041	–	–	–	–	–	–	–	–	–	–	0.17
11-Norbourbonan-1-one	2046	–	–	–	–	–	–	–	–	–	0.04	0.20
Ledol	2057	–	–	–	–	–	–	–	–	–	0.02	–
Germacrene D-4-ol	2069	0.03	–	–	1.42	0.18	–	–	–	–	0.26	0.29
Humulene epoxide II	2071	0.05	0.02	–	–	–	–	–	0.07	0.05	0.03	–
Cubenol	2080	–	–	–	–	–	0.01	–	0.01	0.03	–	–
1-Epicubenol	2088	–	–	–	–	0.04	–	–	0.02	–	–	0.04
Globulol	2098	0.02	0.08	0.07	–	–	–	0.02	0.03	0.08	0.18	–
Viridiflorol	2104	0.03	0.02	0.14	–	–	–	–	–	0.02	0.05	0.09
Cuminalcohol	2113	–	0.14	0.08	0.18	0.29	0.17	0.08	0.28	0.15	–	–
Hexahydrofarnesyl acetone	2131	–	–	–	–	–	–	–	–	–	0.06	–
Spathulenol	2144	0.13	0.60	0.53	1.72	0.38	0.06	0.21	0.17	0.47	7.72	12.93
2-Isopropyl-4-methyl phenol (=Isothymol)	2181	0.04	0.17	0.16	0.13	0.13	0.18	0.15	0.18	0.19	–	–
Eugenol	2186	0.01	–	0.03	–	–	0.03	0.05	0.01	0.01	–	–
T-Cadinol	2187	0.03	0.04	0.03	0.18	0.13	0.03	0.02	0.01	–	–	0.40
Thymol	2198	14.29	4.65	0.42	0.19	8.29	0.62	0.59	16.25	39.82	0.26	1.06
T-Muurolol	2209	–	–	–	0.23	0.08	0.01	0.01	–	–	0.15	–
4-Isopropyl-2-methyl phenol (=Isocarvacrol)	2221	0.03	0.16	0.16	0.20	0.14	0.21	0.16	0.20	0.36	–	–
Carvacrol	2239	40.07	35.17	47.30	29.09	29.69	60.68	61.86	20.48	6.33	4.81	0.78

Table II. (cont.)

Compound	RRI	A	B	C	D	E	F	G	H	I	K	L
trans-α-Bergamotol	2247	–	–	–	0.09	–	–	–	–	0.03	0.60	–
α-Cadinol	2255	0.09	0.10	–	0.62	0.27	–	–	–	0.09	0.29	–
Caryopylla-2(12),6(13)-dien-5β-ol (=Caryophylladienol – I)	2316	–	–	–	0.22	–	–	–	0.03	–	–	–
Caryopylla-2(12),6(13)-dien-5α-ol (=Caryophylladienol – II)	2324	–	–	0.01	0.52	0.12	–	–	0.08	0.05	–	–
Caryopylla-2(12),6-dien-5α-ol (=Caryophyllenol – I)	2389	–	–	–	–	–	–	–	–	–	0.27	–
Caryopylla-2(12),6-dien-5β-ol (=Caryophyllenol – II)	2392	–	–	0.07	0.63	0.17	–	–	0.20	0.15	0.09	–
Hexadecanoic acid	2931	–	–	–	–	–	–	–	–	–	0.25	–
Monoterpene hydrocarbons		33.90	37.65	32.54	13.82	21.09	25.05	22.99	42.42	28.94	18.33	4.87
Oxygenated monoterpenes		59.31	53.73	55.49	62.16	70.13	69.40	70.9	46.10	60.60	58.51	42.16
Sesquiterpene hydrocarbons		5.65	4.08	7.92	8.66	3.66	3.76	4.27	5.35	4.88	6.89	18.60
Oxygenated sesquiterpenes		0.49	1.98	1.35	10.74	3.32	0.33	0.58	2.81	2.70	10.90	15.10
Others		0.30	0.37	0.33	0.66	0.28	0.44	0.43	1.23	0.78	0.74	1.36
Total		99.65	97.81	97.63	96.04	98.48	98.98	99.17	97.91	97.90	95.37	82.09

RRI: Relative retention indices calculated against *n*-alkanes.
tr: Trace (< 0.1%).
%: calculated from TIC data.

terpinen-4-ol (7.2%) as major constituents. This is reminiscent of the previous study in which sesquiterpenes were the predominant components (Ezer *et al.*, 1995).

In a previous study, it was noted that the oils from cultivated forms of *S. hortensis* were rich in carvacrol while those from wild collections contained thymol as major constituent. It was observed that the plants growing in Eastern Turkey were rich in thymol while those growing in the Western part contained carvacrol as the main component in the oils (Başer et al., 2001). Although such an occurrence of chemodiversity is merely an observation, it may have some implication on the evolutionary trends of the *Satureja* species in Turkey. Worthwhile it is to note that *S. hortensis* and *S. cuneifolia* have an international demand and thus they are exported (Tümen *et al.*, 1997).

Our group has previously reported about essential oil compositions of various *Satureja* species. Carvacrol was the main constituent in the essential oils of the following species: *S. cilicica* (Tümen *et*

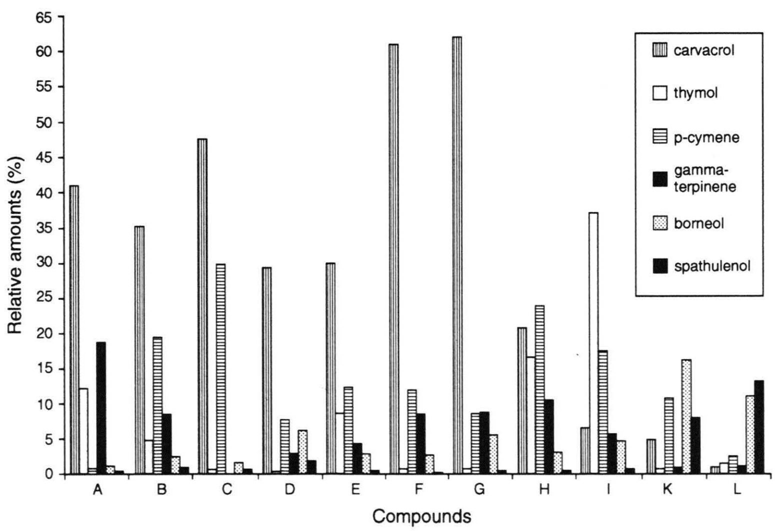

Fig. 1. Distribution of main components in *S. wiedemanniana* essential oils; for explanation of A–L see Table I.

al., 1993), *S. cuneifolia* (Tümen *et al.*, 1998b), *S. hortensis* (Başer *et al.*, 2001), *S. icarica* (Tümen *et al.*, 1998a), *S. montana* (cultivated) (Tümen *et al.*, 1997), S. *parnassica* subsp. *sipylea* (endemic) (Tümen *et al.*, 1992), *S. pilosa* (Tümen *et al.*, 1998a) and *S. thymbra* (Tümen *et al.*, 1997). Thymol and *p*-cymene were identified as main components in the essential oil of *S. spicigera* (Tümen *et al.*, 1996). Linalool was reported as a major component in the essential oil of *S. spinosa* (Tabanca *et al.*, 1999). *S. coerulea*, a rare plant, is listed among the endangered species in the Red Data Book for Turkey and germacrene D was the main component in its oil (Tümen *et al.*, 1998c).

Previous antimicrobial evaluations of different *Satureja* species indicated significant activity (Müller-Riebau *et al.*, 1995; Akgül and Kivanç, 1988; Kivanç and Akgül, 1989). Investigation of the antibacterial activity of the essential oils (A-L) obtained from the plants from various localities suggests that carvacrol and thymol have a strong influence on the inhibition of pathogenic microorganisms. Hence, carvacrol and thymol inhibited the microorganisms *Escherichia coli, Pseudomonas aeruginosa*, and *Enterobacter aerogenes* with better MIC values when compared to the standard antibacterial agent. Interestingly, the essential oil obtained from Ankara region (I) had a MIC value of 31.25 μg/ml against *Escherichia coli*, with good inhibition.

Pseudomonas aeruginosa was strongly inhibited by sample A with the value of 62.5 μg/ml. C, D, E and L essential oil samples showed activity comparable to that of the standard, whereas the other samples inhibited the Gram (−) pathogenic bacteria stronger than Chloramphenicol.

Enterobacter aerogenes was also inhibited by the sample I. Samples B, D, F, and G were less active in comparison to the others with slight activity.

Proteus vulgaris was not inhibited when compared to the standard. A weak activity was observed against *Proteus vulgaris* whereas *Salmonella thyphimurium* was inhibited at the MIC value of 62.5 μg/ml by the samples C, D, F, G, K, and L.

As a consequence, we may state that the samples containing high amounts of the monoterpene phenols thus influence the antibacterial activity (Crippa and Bruno, 1989; Knoblauch *et al.*, 1989; Didry *et al.*, 1993; Sivropoulou *et al.*, 1996). As seen in Table II, hydrocarbons and oxygenated monoterpenes dominate within all samples with high percentages whereas sesquiterpenes are in high amounts in samples D, K, and L.

Acknowledgements

The authors would like to thank Prof. Dr. Hayri Duman (Ankara University) for the identification of plant materials. This study was partially supported by the Research Fund of Anadolu University (AÜAF 980312).

Table III. Antibacterial activity (MIC) of *S. wiedemanniana* essential oils from various localities.

pathogen	A	B	C	D	E	F	G	H	I	K	L	[a]	[b]	[c]
E. coli	125	125	125	125	125	62.5	62.5	2.5	31.25	62.5	125	31.25	62.5	62.5
S. aureus	125	250	125	125	250	125	250	125	125	250	62.5	31.25	62.5	7.81
P. aeruginosa	62.5	125	250	250	250	125	125	125	125	125	250	62.5	62.5	250
E. aerogenes	125	250	125	250	125	250	250	125	62.5	125	125	62.5	62.5	125
P. vulgaris	125	125	250	125	62.5	125	125	62.5	250	62.5	125	62.5	62.5	31.25
S. typhimurium	125	125	62.5	62.5	125	62.5	62.5	125	250	62.5	62.5	62.5	125	62.5

[a]chloramphenicol, [b]carvacrol, [c]thymol

Akgül A. and Kivanç M. (1988), Inhibitory effects of six Turkish thyme-like spices on some common food-borne bacteria. Die Nahrung **32**, 201–203.

Aydin S., Öztürk Y., Beis R. and Başer K. H. C. (1996), Investigation of *Origanum onites, Sideritis congesta* and *Satureja cuneifolia* essential oils for analgesic activity. Phytother. Res. **10**, 342–344.

Başer K. H. C., Özek T., Kirimer N. and Tümen G. (2001), A comparative study of the essential oils of wild and cultivated *Satureja hortensis*. J. Essent. Oil Res. (In press)

Bown D. (1995). Encyclopedia of Herbs and Their Uses, Dorling Kindersley, London, p. 259.

Crippa A. and Bruno E. (1989), Antifungal activity *in vitro* of phenols and other natural substances. Nat. Ecol. **7**, 29–32.

Dafni A., Yaniv Z. and Palevitch D. (1984), Ethnobotanical survey of medicinal plants in Northern Israel. J. Ethnopharmacol. **10**, 295–310.

Davis P. H. (1982), Flora of Turkey and the East Aegean Islands. Vol. **7**, University Press, Edinburgh, p. 319.

Didry N., Dubreuii L. and Pinkas, M. (1993), Antimicrobial activity of thymol, carvacrol and cinnamaldehyde alone or in combination. Pharmazie **48**, 301–304.

Duke A. J. (1986), Handbook of Medicinal Herbs, CRC Press, Boca Raton, Florida, p. 432.

Ezer N., Vilar R., Canigueral S. and Adzet T. (1995), The essential oil of *Satureja wiedemanniana* (Lallem.) Velen. J. Essent. Oil Res. **7**, 91–93.

Grieve M. (1983), A Modern Herbal, Dover Publication, New York, p. 790.

Hajhashemi V., Sadraei H., Ghannadi A. R. and Mohseni M. (2000), Antispasmodic and antidiarrhoeal effect of *Satureja hortensis* L. essential oil. J. Ethnopharmacol. **71**, 187–192.

Heinrich M., Kuhnt M., Wrigt C. W., Rimpler H., Phillipson J. D. Schandelmaier A. and Warhurst D. C. (1992), Parasitological and microbiological evaluation of mixed Indian medicinal plants. J. Ethnopharmacol. **36**, 81–85.

Jatem-Lasser A., Ricardi M. S. and Adamo G. (1998), Herbal traditional medicine of Venezuelan Andes: an ethnopharmacological study. Phytother. Res. **12**, 53–59.

Kirimer N., Başer K. H. C. and Tümen G. (1995), Carvacrol-rich plants in Turkey. Chem. Nat. Comp. **31**, 37–44.

Kivanç M. and Akgül A. (1989), Inhibitory effects of spice essential oil on yeast. Turkish J. Agrl. and Forest **13**, 68–71.

Knobloch K., Pauli A., Iberl B., Weigand H. and Weis, N. (1989), Antibacterial and antifungal properties of essential oil components. J. Essent. Oil Res. **1**, 119–128.

Koneman E. W., Allen S. D., Janda W. M., Schreckenberger P. C. and Winn W. C. (1997), Color Atlas and Textbook of Diagnostic Microbiology. Lippincott-Raven Publ., Philadelphia, pp.785–856.

Martinez M. A. (1984), Medicinal plants used in a Totonac community of Sierra Norte De Puebla: Tuzamapan De Galeana, Puebla, Mexico. J. Ethnopharmacol. **10**, 203–210.

Müller-Riebau F., Beger B. and Yegen O. (1995), Chemical composition and fungitoxic properties to phytopathogenic fungi of essential oils selected aromatic plants growing wild in Turkey. J. Agric. Food. Chem. **43**, 2262–2266.

Sanches De Rojas V. R, Ortega T. and Villar A. (1994), Pharmacological activity of extracts of two *Satureja obovata* varieties on isolated smooth muscle preparations. Phytother. Res. **8**, 212–217.

Sivropoulou A., Papanikolaou E., Nikolaou C., Kokkini S., Lanaras T. and Arsenakis M. (1996), Antimicrobial and cytotoxic activities of *Origanum* essential oils. J. Agr. Food Chem. **44**, 1202–1205.

Stanic G. and Samarzija I. (1993), Diuretic activity of *Satureja montana* subsp. *montana* extracts and oil in rats. Phytother. Res. **7**, 363–366.

Tabanca N., Kürkçüoglu M., Başer K. H. C. and Duman H. (1999), Composition of the essential oil of *Satureja spinosa* L.: Abstracts of the symposium 2000 Years of Natural Products Research, 26–30 July 1999, Amsterdam, The Netherlands.

Tümen G., Sezik E. and Başer K. H. C. (1992), The essential oil of *Satureja parnassica* Heldr.& Sart. ex Boiss. subsp. *sipyleus* . Flav. Fragr. J. **7**, 43–46.

Tümen G., Başer K. H. C. and Kirimer N. (1993), The essential oil of *Satureja cilicica* P. H. Davis. J. Essent. Oil Res. **5**, 547–548.

Tümen G. and Başer K. H. C. (1996), The essential oil of *Satureja spicigera* (C. Koch) Boiss. from Turkey. J. Essent. Oil Res. **8**, 57–58.

Tümen G., Kirimer N. and Başer K. H. C. (1997), The essential oils of *Satureja* L. occurring in Turkey, in: Proceeding of the 27th International Symposium on Essential Oils. (Franz C. H., Mathe A. and Buchbauer G., eds.) Allured Publishing Corporation, Vienna, Austria, pp. 250–254.

Tümen G., Kirimer N., Ermin N. and Başer K. H. C. (1998a), The essential oils of two new *Satureja* species for Turkey, *S. pilosa* and *S. icarica*. J. Essent. Oil Res. **10**, 524–526 .

Tümen G., Kirimer N., Ermin N. and Başer K. H. C. (1998b), The essential oil of *Satureja cuneifolia*. Planta Med. **64**, 81–83.

Tümen G., Başer K. H. C., Demirci B. and Ermin N. (1998c), The essential oils of *Satureja coerulea* Janka and *Thymus aznavourii* Velen. Flav. Fragr. J. **13**, 65–67.