The composition of the leaf essential oils of *J. sabina* var. *balkanensis*: comparison between oils from central Italy with oils from Bulgaria, Greece and Turkey

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Abstract

The composition of the leaf oil of *J. sabina* var. *balkanensis* from central Italy was compared to volatile leaf oils from Bulgaria, Greece and Turkey, as well as *J. sabina* var. *sabina* from Switzerland, Pyrenees, and Kazakhstan. The leaf oils in central Italy had chemotypes with some plants of *J. sabina* var. *balkanensis* oils with high sabinene (HiSab, 28.4 - 40.2%), low trans-sabinyl acetate chemotype (LoTSac) and other plants with the low sabinene (LoSab, 9.6 - 14.8%), high trans-sabinyl acetate (HiTSac, 36.0 - 47.4%) chemotype. These same chemotype patterns were also found in Bulgaria, Greece, and Turkey. There appear to be no consistent chemical differences between the oils of var. *balkanensis* in Bulgaria, Greece, Turkey and the oil from central Italy. The lack of chemical differentiation between eastern (Bulgaria, Greece, Turkey) and western (Italy) var. *balkanensis* populations may reflect the recent origin of var. *balkanensis* or gene flow. Comparing the compositions of the leaf essential oils of central Italy (var. *balkanensis*) with oils of *J. sabina* var. *sabina*, from Pyrenees, and Switzerland revealed oils of *J. s.* var. *balkanensis* differ only slightly from *J. s.* var. *sabina*, Switzerland and Pyrenees. The presence of chemotypes in var. *balkanensis* populations make it very difficult to determine any differences among var. *balkanensis* populations and between var. *balkanensis* and var. *sabina* oils. Published on-line www.phytologia.org *Phytologia 101(1): 38-45 (March 21, 2019).* ISSN 030319430.
KEY WORDS: *Juniperus sabina* var. *balkanensis*, volatile leaf oils, terpenes, composition. *J. sabina.*

As part of an on-going investigation of *Juniperus sabina* L., we investigated the leaf volatile oil composition of var. *balkanensis* R. P. Adams & A. N. Tashev from central Italy, where it was recently discovered (Adams, et al. 2018a). *Juniperus s.* var. *balkanensis* was initially discovered in Bulgaria (see Adams, Schwarzbach and Tashev, 2016).

Juniperus sabina var. *balkanensis* contains the chloroplast of *J. thurifera* and nuclear nrDNA of *J. sabina* L. (Adams, Schwarzbach and Tashev, 2016). The new variety appears to be morphologically, nearly identical to *J. s.* var. *sabina*. In addition to the type locality in Bulgaria, Adams et al. (2017) later reported var. *balkanensis* in far western Turkey and in northern Greece, and as far west as Macedonia, Croatia and central Italy. (Adams et al. 2018a).

The volatile leaf oils of *J. sabina* have been often analyzed (see a review in Adams, Nguyen and Liu, 2006). In same paper they reported on a detailed analysis of the composition of the leaf oils from seven populations of *J. sabina* and one population of *Juniperus sabina* var. *arenaria* (E. H. Wilson) Farjon (now treated as *J. davurica* var. *arenaria* (E. H. Wilson) R. P. Adams), as well as the oils of *J. chinensis* L. and *J. davurica* Pall. Adams, Nguyen and Liu (2006) found considerable differentiation in populations of *J. sabina* from the Iberian Peninsula and far eastern populations (Kazakhstan, China). The amounts of cedrol, citronellol, safrole, trans-sabinyl acetate, terpinen-4-ol and trans-thujone were found to be polymorphic in several populations.

The leaf oils of the aforementioned species, except var. *balkanensis*, have been reported, and reviewed: *J. chinensis* (Adams, Chu and Zhong, 1994); *J. davurica* (Adams, Shatar and Dembitsky, 1994), *J. sabina* (Adams, Dembitsky and Shatar, 1998, Adams, 2014).

Analyses of the volatile leaf oils of var. *balkanensis* from Bulgaria, Greece and Turkey (Adams et al. 2018b) revealed considerable polymorphisms in the oils, notably in high amounts of trans-sabinyl acetate (HiTSac) with low amounts of sabinene (LoSab) and vice versa (Table 1). All plants sampled in the Greece population were low trans-sabinyl acetate (LoTSac)/ high sabinene (HiSab) (Table 1). However, both the Bulgaria populations (eastern Rhodopes and Rilla Mtns.) contained plants with HiTSac/LoSab and LoTSac/ HiSab. Interestingly, the *J. sabina* var. *sabina* oils from Switzerland (SWZ), Pyrenees (PYR) and Kazakhstan (KAZ) were all high in sabinene (HiSab), but the oil of SWZ was also a HiTSac population, whereas PYR and KAZ had LoTSac oils (Table 1). Several plants had high concentrations of individual components: α-pinene, cis-thujone, trans-thujone, trans-sabinol, methyl eugenol and elemicin (highlighted in green in Table 1). As reported by Adams, Nguyen and Liu (2006), components typical of *Juniperus* wood oils (α-cedrene, allo-cedrol, cedrol, epi-cedrol, α-acorenol) were found only in the oil from Kazakhstan. The presence of several chemotypes precluded analysis of any trends among the oils of the populations.

The purpose of this paper is too extend analyses on the composition of the volatile leaf oil(s) of *J. sabina* var. *balkanensis* to the western-most known populations in central Italy.

MATERIALS AND METHODS

Specimens used in this study (species, popn. id., location, collection numbers):
J. sabina var. *balkanensis*

Bulgaria and Greece

BeR: Eastern Rhodopes. In protected site “Gumurdjinsky Snejnik”, locality “Madzharsky Kidik”. On limestone rocks above the upper border of a forest of *Fagus sylvatica* ssp. *moesiaca* with *Juniperus communis*. 41° 14' 44.7" N; 25° 15' 31.9" E. elev. 1270 m, 13 Aug. 2012, *Adams 13725-13729 (A. Tashev 2012-1-5*);

BSk: Central Stara Planina (the Balkan). National Park “Central Balkan”. Reserve “Sokolna”. On a steep, rocky limestone slope, with *Sorbus aucuparia, S. aria, S. borbasii, Amelanchier ovalis, Carpinus orientalis, Sesleria latifolia, Pastinaca hirsute, Cephalanthera rubra, Laserpitium siler, Hieracium alpicola* etc. near a forest of *Fagus sylvatica.* 42º42'13.3" N,25º08'10.4" E, 1501 m , 22.08.2015. Bulgaria, *Adams 14721 (A. Tashev 2015 Balkan 1*;

BkR: Rila Mountain, National Park “Rila”. On the eco-path, Beli Iskar”, near river Beli Iskar, in a forest with *Pinus sylvestris, P. peuce, Picea abies, Abies alba, Juniperus communis, J. sibirica, Vaccinium* *myrtillus, Rosa canina, Sorbus aucuparia, Acer hyrcanum, Chamaespartium sagittale, Hypericum perforatum, Thymus* sp. etc. 42º14'26.5" N, 23º32'33.8" E, 1242 m, 24.06.2015. Bulgaria, *Adams 14722-14726 (A. Tashev 2015 Rila 1.1-1.3, 2.1-2.2)*;

BkG: Mt. Tsena, Greece, *Adams 14727-14731* (*A. Tashev 2015 So. 1-5 Tsena*);

Italy

Val di Foro, loc. Colle dell'Angelo, radura boschiva, Coll. Fabrizio Bartolucci, F. Conti, L. Di Martino 61-2082, A1, A2, 42.19372° N,14.12086° E, 1002 m,10 July 2018, Lab Acc. Robert P. Adams 15500, 15501; Colle le Macchie, Coll. Fabrizio Bartolucci, F. Conti, L. Di Martino 64-2245 B1,B2, 42.10842° N, 14.19584° E, 1030 m,10 July 2018, Lab Acc. Robert P. Adams 15502, 15503; M. San Domenico (Pizzoferrato, Chieti) rupi, 1484 m, Coll. Fabrizio Bartolucci, F. Conti, L. Di Martino 64-2241, C1,C2, 41.92854° N, 14.21135° E, 10 July 2018, Lab Acc. Robert P. Adams 15504, 15505.

Turkey

Bk/Turk: Spil Daği Milli Parki (National Park), Turkey, Manisa, 38°, 57' N, 27° 41' E, 1024 m. *Adams 14934*, (*Tuğrul Mataraci 2016-1*)

Other plants referenced in this paper:

J. chinensis, CH, Lanzhou, Gansu, China, Adams 6765-67; *J. davurica*, DV, 15 km se Ulan Bator, Mongolia, Adams 7252, 7253, 7601; *J. sabina*, SN, Sierra Nevada, Spain, Adams 7197, 7199, 7200; PY, Pyrenees Mtns., Spain/ France border, Adams 7573-77; SW, 2 km s of St. Niklaus, Switzerland, Adams 7611, 7612, 7614, 7615; KZ, 30 km n. of Jarkent, Kazakhstan, Adams 7811-13; AM, Altair Mtns., Mongolia, Adams 7585-88; TS, Tian Shan Mtns., Xinjiang, China, Adams 7836-38; MS, sand dunes, 80 km sw Ulan Bator, Mongolia, Adams 7254-56; AR, sand dunes, Lake Qinghai, Qinghai, China, Adams 10347-52.

Voucher specimens for all collections are deposited at Baylor University Herbarium (BAYLU).

Fresh, air dried leaves (50-100 g) were steam distilled for 2 h using a circulatory Clevenger-type apparatus (Adams, 1991). The oil samples were concentrated (ether trap removed) with nitrogen and the samples stored at 20 ºC until analyzed. The extracted leaves were oven dried (100 ºC, 48 h) for determination of oil yields.

Oils from 4-5 trees of each taxon were analyzed and average values reported. The oils were analyzed on a HP 5971 MSD mass spectrometer, scan time 1/ sec., directly coupled to a HP 5890 gas chromatograph, using a J & W DB-5, 0.26 mm x 30 m, 0.25 micron coating thickness, fused silica capillary column (see Adams, 2007 for operating details). Identifications were made by library searches of our volatile oil library (Adams, 2007), using the HP Chemstation library search routines, coupled with retention time data of authentic reference compounds. Quantitation was by FID on an HP 5890 gas chromatograph using a J & W DB-5, 0.26 mm x 30 m, 0.25 micron coating thickness, fused silica capillary column using the HP Chemstation software.

RESULTS

The compositions of the leaf oils are given in Table 2. For central Italy, three plants of *J. sabina* var. *balkanensis* oils were high sabinene (HiSab, 28.4 - 40.2%), low trans-sabinyl acetate (LoTSac) chemotypes and three were LoSab/ HiTSac chemotypes (Table 2). This pattern was also found in Bulgaria (Table 1, east. Rhod. and Rila).

Although there are no chemical polymorphisms shown (Table 1, 2), for the three *J. s.* var. *sabina* populations (SWZ, PRY, KAZ), oils from the Sierra Nevada, Spain area have been reported as the most polymorphic of all the var. *sabina* populations examined (Adams et al. 2006), with large variations for trans-thujone (0.5 - 8.7%), terpinen-4-ol (3.6 - 14.4%), trans-sabinyl acetate (6.4 - 41.3%), and methyl eugenol (0.01 - 12.1%). Additional samples from Spain are needed.

A few compounds, sabina ketone, (2E,4Z)-methyl decadienoate, (E)-caryophyllene, trans-murrola-3,5-diene, trans-cadina-1(6),4-diene and cubebol appear to be larger in the Italy samples than in the var. *sabina* populations (SWZ, PRY, KAZ, Table 2). However, most of these compounds are in low concentrations, so additional analyses may not support these small differences. It might be noted that our previous work (Table 1 above, updated from Adams, 2018b) gave a similar pattern. It is interesting to note that trans-muurola-4(14),5-diene was only a trace in the Bulgaria, Greece, Turkey populations (Table 1), but ranged trace to 1.7% in the central Italy plants (Table 2).

There seem no consistent chemical differences between the oils of var. *balkanensis* in Bulgaria, Greece, Turkey and the oil from central Italy. The lack of chemical differentiation between eastern (Bulgaria, Greece, Turkey) and western (Italy) populations may reflect the recent origin of var. *balkanensis,* considerable gene flow among populations, or only small amounts of natural selection.

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Table 1. Comparisons of the per cent total oil for leaf essential oils for *J. sabina* var. *balkanensis* and *J. s.* var. *sabina* populations. *J. s.* var. *sabina* population codes: PYR Pyrenees Mtns.; SWZ, Switzerland; KAZ, Kazakhstan; Components that tend to separate the species are highlighted. Modified from Adams et al. 2018b. See text for discussion.

		J. sabina var. *balkanensis*							*J. s.* var. *sabina*		
		low trans-sabinyl acetate (LoTSac), and high sabinene (HiSab)					high TSac, low sabinene		high TSac	low TSac	
RI	Compound	Tur-key	Greece		Bulg. east. Rhod	Bulg. Rila mts.	Rila Hi TSac	Rhod Hi TSac	SWZ Hi TSac	PYR Lo TSac	KAZ Lo TSac
931	α -thujene	1.2	1.2	1.7	1.3	1.0	0.3	0.5	0.9	1.0	0.6
939	α-pinene	2.4	3.7	2.6	3.0	1.3	2.2	1.3	2.0	1.8	15.8
953	camphene	t	-	t	t	t	t	t	t	t	0.3
976	sabinene	56.1	42.5	59.7	41.2	41.3	3.7	7.5	34.8	54.9	42.6
980	β-pinene	t	0.3	0.2	0.4	t	0.6	0.3	t	t	0.7
991	myrcene	3.4	2.8	3.9	2.9	2.7	1.6	2.0	4.2	3.1	3.8
1005	α-phellandrene	t	t	t	0.1	0.1	t	t	t	0.1	t
1011	δ-3-carene	0.1	1.5	t	0.1	0.1	0.1	1.0	-	0.1	0.2
1018	α-terpinene	1.2	1.4	1.6	1.6	1.6	0.3	0.4	1.0	1.5	0.7
1026	p-cymene	0.3	0.4	0.5	0.6	0.5	0.6	0.4	0.2	0.4	0.1
1031	limonene	1.5	0.8	1.3	0.6	1.0	0.8	0.6	3.0	2.4	2.1
1031	β-phellandrene	1.6	0.8	1.3	0.9	1.0	0.8	0.9	t	t	1.4
1032	1,8-cineole	t	0.1	0.1	0.4	t	t	0.2	-	t	t
1050	(E)-β-ocimene	0.9	0.3	0.2	0.5	t	0.1	0.1	1.1	0.7	0.1
1062	γ-terpinene	2.2	2.3	2.7	2.9	3.2	0.6	0.8	1.1	2.5	0.1
1068	cis-sabinene hydrate	2.3	1.6	2.1	3.2	2.3	0.5	1.1	0.7	1.4	0.5
1067	cis-linalool oxide(fur)	0.1	t	t	0.3	t	t	t	t	t	-
1088	terpinolene	1.1	1.2	1.3	1.2	1.2	0.3	0.6	0.8	1.0	0.7
1097	trans-sabinene hydrate	0.9	2.1	1.9	3.1	1.0	t	1.0	0.3	1.1	0.4
1098	linalool	1.0	t	t	3.1	1.0	0.4	1.0	1.5	0.3	0.2
1102	nonanal	-	-	t	-	-	-	-	t	-	t
1102	cis-thujone(α-thujone)	t	t	-	t	t	12.4	1.7	0.1	-	-
1114	trans-thujone(β-thujone)	0.4	t	t	0.2	0.1	6.7	12.7	0.7	0.1	-
1121	cis-p-menth-2-en-1-ol	0.5	0.4	0.4	0.5	0.5	0.2	0.2	0.2	0.6	0.2
1134	iso-3-thujanol	0.2	-	-	-	t	0.2	0.6	-	-	-
1140	trans-sabinol	-	-	-	0.5	0.3	4.3	5.0	0.7	0.3	-
1140	trans-p-menth-2-en-1-ol	-	0.2	0.4	-	-	-	-	-	-	0.2
1153	citronellal	0.1	t	t	-	-	-	-	0.2	0.4	-
1156	sabina ketone	0.1	t	t	0.2	0.1	t	t-	-	-	-
1166	coahuilensol	0.3	-	t	1.1	-	-	-	0.4	-	-
1177	terpinen-4-ol	5.0	3.9	4.4	5.9	4.8	1.6	2.1	1.4	7.2	2.9
1183	p-cymen-8-ol	t	-	t	0.1	t	t	t	-	-	-
1189	α-terpineol	0.2	0.2	0.2	0.5	0.2	t	0.1	0.1	0.3	0.2
1193	cis-piperitol	0.1	t	0.2	0.4	0.3	0.2	0.1	t	0.2	0.1
1205	trans-piperitol	0.2	0.2	0.2	0.3	0.3	t	0.2	-	0.2	0.1
1219	methyl coahuilensol	0.2	-	t	0.6	-	-	-	0.4	-	-
1228	citronellol	0.8	0.3	0.4	2.9	0.2	t	0.3	0.6	4.1	0.4
1257	linalyl acetate	t	0.1	0.1	0.8	0.8	t	0.6	0.2	-	0.3
1261	methyl citronellate	0.3	1.0	1.6	3.3	3.9	1.2	0.6	0.7	0.8	0.1
1285	bornyl acetate	t	t	t	t	t	t	-	t	-	0.4
1285	safrole	-	-	-	-	-	-	-	-	1.8	-
1287	trans-linalyl acetate	0.2	0.6	t	0.2	0.1	t	0.1	-	-	-
1290	trans-sabinyl acetate	1.7	0.5	0.3	0.4	0.4	39.8	39.6	35.0	t	-
1319	(E,E)-2,4-decadienal	t	t	t	0.3	t	0.2	t	-	-	-
1323	methyl geranate	0.4	t	0.3	0.4	0.4	0.9	t	0.3	0.1	0.1
1350	α-terpinyl acetate	0.1	t	t	0.2	0.2	t	0.1	0.1	-	0.2
1376	α-copaene	t	t	t	0.1	t	t	0.1	-	-	-
1401	methyl eugenol	-	13.2	t	0.3	5.8	4.1	0.4	-	1.1	-
1391	2E,4Z-me-decadienoate	t	0.4	0.5	t	0.8	0.3	t	-	-	-
1409	α-cedrene	-	-	-	-	-	-	-	-	-	0.2

	Table 1 (continued)	*J. sabina* var. *balkanensis*							*J. s.* var. *sabina*		
		low trans-sabinyl acetate (TSAC), and high sabinene					high TSAC, low sabinene		high TSAC	low TSAC	
RI	Compound	Tur-key	Greece		Bulg. east. Rhod	Bulg. Rila mts.	Rila Hi TSac	Rhod Hi TSac	SWZ Hi TSac	PYR Lo TSac	KAZ Lo TSac
1418	(E)-caryophyllene(β-caryophyllene)	t	t	0.1	t	0.2	t	0.1	-	-	-
1468	pinchotene acetate	t	-	-	0.5	-	-	-	0.1	-	t
1477	γ-muurolene	0.1	t	t	0.2	0.1	t	0.3	0.1	t	0.1
1480	germacrene D	0.1	t	t	t	t	t	0.3	-	0.1	-
1491	trans-murrola-4(14),5-diene	t	t	t	t	t	t	t	-	0.6	t
1493	epi-cubebol	0.1	t	t	0.2	0.2	t	0.3	0.1	0.3	-
1495	γ-amorphene	-	-	-	-	-	-	-	-	-	0.1
1499	α-muurolene	0.2	0.1	0.1	0.3	0.3	0.2	0.5	0.1	0.2	0.2
1513	γ-cadinene	0.4	0.5	0.4	0.8	0.6	0.4	1.7	0.3	0.8	0.3
1514	cubebol	t	t	t	t	t	t	t	-	-	-
1524	δ-cadinene	0.8	0.8	0.6	1.1	0.9	0.5	1.9	0.5	1.0	0.8
1538	α-cadinene	0.2		t	0.1	0.3	t	0.2	0.1	0.1	0.1
1549	elemol	0.6	t	t	t	1.9	0.5	0.1	0.8	2.1	0.1
1554	elemicin	0.1	6.0	t	t	2.3	6.4	0.2	-	0.4	-
1574	germacrene D-4-ol	2.6	1.4	1.8	2.2	2.4	0.5	2.5	1.4	0.7	1.1
1587	allo-cedrol	-	-	-	-	-	-	-	-	-	1.1
1596	cedrol	-	-	-	-	-	-	-	-	-	15.9
1606	β-oplopenone	0.7	0.7	0.3	0.6	1.1	0.5	0.4	0.1	0.3	-
1611	epi-cedrol	-	-	-	-	-	-	-	-	-	0.1
1627	1-epi-cubenol	0.1	t	t	t	0.2	0.1	0.2	t	0.4	-
1632	α-acorenol	-	-	-	-	-	-	-	-	-	0.2
1640	epi-α-cadinol	0.4	0.3	0.3	0.5	0.5	0.3	0.8	0.2	0.3	0.3
1640	epi-α-muurolol	0.4	0.4	0.3	0.5	0.6	0.3	0.8	0.2	0.2	0.3
1645	α-muurolol	0.1	0.1	t	0.2	0.2	0.1	0.3	0.1	0.1	0.1
1649	β-eudesmol	t	-	-	-	0.6	0.2	-	-	0.2	-
1652	α-eudesmol	t	-	-	-	0.6	t	-	-	0.3	-
1653	α-cadinol	1.0	0.8	0.7	1.3	1.2	0.9	1.8	0.6	0.5	0.9
1689	shyobunol	0.4	t	0.3	t	0.5	0.1	0.2	0.1	t	0.1
2054	abietatriene	t	t	t	t	t	t	t	t	t	t
2080	abietadiene	0.2	0.2	0.4	0.3	t	t	0.2	t	0.1	t
2288	4-epi-abietal	0.4	0.3	0.5	0.7	0.7	0.3	0.5	t	0.1	t
2302	abieta-7,13-dien-3-one	1.0	0.7	1.3	1.9	2.0	0.5	0.7	0.1	0.1	0.2
2325	trans-ferruginol	t	t	t	t	0.2	t	t	t	t	t
2343	4-epi-abietol	t	t	t	0.3	0.1	t	t	t	t	t

RI = Kovat's Retention Index on DB-5(=SE54) column using alkanes. Compositional values less than 0.1% are denoted as traces (t). Unidentified components less than 0.5% are not reported.

Table 2. Comparisons of the per cent total oil for leaf essential oils for *J. sabina* var. *balkanensis* from central Italy. Components that separate the samples are highlighted. *J. s.* var. *sabina* as per Table 1.

		J. sabina var. *balkanensis*, central Italy						*J. sabina* var. *sabina*		
		low trans-sabinyl acetate			high trans-sabinyl acetate			HiTSac	LoTSac	
RI	Compound	15503	15501	15500	15505	15504	15502	SWZ	PYR	KAZ
931	α -thujene	0.9	0.4	0.9	0.4	0.3	0.4	0.9	1.0	0.6
939	α-pinene	1.6	1.4	3.5	2.4	1.8	1.4	2.0	1.8	15.8
953	camphene	t	t	t	t	t	t	t	t	0.3
976	sabinene	35.7	28.4	40.2	13.9	9.6	14.8	34.8	54.9	42.6
980	β-pinene	0.1	0.2	t	0.2	0.2	0.2	t	t	0.7
991	myrcene	1.2	2.2	2.7	2.0	1.8	2.4	4.2	3.1	3.8
1005	α-phellandrene	t	t	t	t	t	t	t	0.1	t
1011	δ-3-carene	t	t	t	t	t	t	-	0.1	0.2
1018	α-terpinene	1.2	0.8	1.0	0.7	0.4	0.5	1.0	1.5	0.7
1026	p-cymene	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.1
1031	limonene	0.9	0.8	0.9	0.6	0.6	0.7	3.0	2.4	2.1
1031	β-phellandrene	0.8	0.7	0.9	0.6	0.5	0.6	t	t	1.4
1032	1,8-cineole	0.1	0.1	t	0.2	t	t	-	t	t
1050	(E)-β-ocimene	t	t	t	0.1	t	0.2	1.1	0.7	0.1
1062	γ-terpinene	2.0	1.6	1.7	1.1	0.7	0.8	1.1	2.5	0.1
1068	cis-sabinene hydrate	1.6	2.0	1.4	0.7	0.7	0.9	0.7	1.4	0.5
1067	cis-linalool oxide (furan)	-	-	-	-	-	-	t	t	-
1088	terpinolene	0.8	0.7	0.8	0.6	0.5	0.6	0.8	1.0	1.0
1097	trans-sabinene hydrate	2.0	1.5	1.0	0.6	0.7	0.6	0.3	1.1	0.4
1098	linalool	t	t	t	0.3	0.2	t	1.5	0.3	0.2
1102	cis-thujone(α-thujone)	t	t	t	3.5	3.3	8.0	0.1	-	-
1106	cis-rose oxide	t	t	-	t	-	t	-	-	-
1114	trans-thujone(β-thujone)	0.2	0.9	1.1	8.4	3.0	2.2	0.7	0.1	-
1121	cis-p-menth-2-en-1-ol	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.6	0.2
1122	trans-rose oxide	t	-	-	-	-	-	-	-	-
1134	iso-3-thujanol	t	t	t	0.1	t	0.2	-	-	-
1140	trans-sabinol	0.1	0.4	0.3	1.0	1.7	1.8	0.7	0.3	-
1140	trans-p-menth-2-en-1-ol	0.1	-	-	-	-	-	-	-	0.2
1153	citronellal	0.9	t	t	-	-	-	0.2	0.4	-
1156	sabina ketone	0.1	0.6	0.3	0.1	t	t	-	-	-
1166	coahuilensol	t	0.3	0.2	t	t	t	0.4	-	-
1177	terpinen-4-ol	4.3	3.9	2.9	2.0	1.7	1.7	1.4	7.2	2.9
1183	p-cymen-8-ol	t	t	t	t	t	t	-	-	-
1189	α-terpineol	0.2	0.2	0.1	t	1.7	0.1	0.1	0.3	0.2
1193	cis-piperitol	t	0.3	0.2	0.1	0.3	0.2	t	0.2	0.1
1205	trans-piperitol	0.1	0.2	t	t	t	t	-	0.2	0.1
1219	methyl coahuilensol	0.3	0.3	0.2	-	t	0.1	0.4	-	-
1228	citronellol	7.5	6.9	3.5	2.6	2.5	t	0.6	4.1	0.4
1253	trans-sabinene hydrate acetate	0.1	-	-	-	-	-	-	-	-
1257	linalyl acetate	t	0.2	t	t	t	t	0.2	-	0.3
1261	methyl citronellate	2.1	8.8	5.9	5.1	6.6	0.3	0.7	0.8	0.1
1285	bornyl acetate	0.6	0.2	0.2	t	t	t	t	-	0.4
1285	safrole	-	-	-	-	-	-	-	1.8	-
1290	trans-sabinyl acetate	0.3	6.8	7.3	36.0	47.4	36.8	35.0	t	-
1319	(2E,4E)-decadienal	0.1	t	t	t	t	0.1	-	-	-
1323	methyl geranate	t	0.3	0.3	0.8	1.0	t	0.3	0.1	0.1
1350	α-terpinyl acetate	t	t	t	t	t	t	0.1	-	0.2
1374	isoledene	0.1	t	t	t	t	t	-	-	-
1376	α-copaene	t	t	t	t	t	0.1	-	-	-
1391	(2E,4Z)-me-decadienoate	0.1	1.0	0.7	0.5	0.6	t	-	-	-

		J. sabina var. *balkanensis*, central Italy						*J. sabina* var. *sabina*		
		low trans-sabinyl acetate			high trans-sabinyl acetate			HiTSac	LoTSac	
RI	Compound	15503	15501	15500	15505	15504	15502	SWZ	PYR	KAZ
1401	methyl eugenol	5.3	t	t	t	0.1	11.2	-	1.1	-
1409	α-cedrene							-	-	0.2
1418	(E)-caryophyllene(β-caryophyllene)	0.1	0.3	0.2	t	0.1	0.1	-	-	-
1451	trans-murrola-3,5-diene	0.6	0.4	0.3	t	t	0.2	-	-	-
1468	pinchotene acetate	0.2	-	-	t	-	0.2	0.1	-	t
1475	trans-cadina-1(6),4-diene	0.6	0.3	0.3	0.2	t	t	-	-	-
1477	γ-muurolene	t	t	t	t	t	t	t	t	0.1
1480	germacrene D	-	-	-	t	0.4	-	-	0.1	-
1491	trans-murrola-4(14),5-diene	1.7	1.2	0.9	t	0.1	0.6	-	0.6	t
1493	epi-cubebol	0.9	0.5	0.5	t	t	0.3	0.1	0.3	-
1499	α-muurolene	0.2	0.3	0.2	t	0.2	0.2	-	0.2	0.2
1513	γ-cadinene	2.0	1.5	1.3	0.2	0.3	0.6	0.3	0.8	0.3
1514	cubebol	1.6	1.5	1.2	0.2	0.2	0.5	-	-	-
1524	δ-cadinene	1.2	1.2	1.0	0.7	0.7	0.7	0.5	1.0	0.8
1528	zonarene	0.3	0.2	0.2	t	t	0.1	-	-	-
1538	α-cadinene	t	t	t	t	t	t	0.1	0.1	0.1
1549	elemol	t	t	t	t	t	t	0.8	2.1	0.1
1554	elemicin	5.4	-	-	0.2	0.2	1.0	-	0.4	-
1574	germacrene D-4-ol	0.9	4.1	3.2	1.5	1.8	1.2	1.4	0.7	1.1
1587	trans-murrol-5-en-4- α-ol	1.1	t	t	t	-	0.3	-	-	-
1587	allo-cedrol	-	-	-	-	-	-	-	-	1.1
1596	cedrol	-	-	-	-	-	-	-	-	15.9
1606	β-oplopenone	0.7	0.8	0.7	0.3	0.4	0.4	0.1	0.3	-
1611	epi-cedrol	-	-	-	-	-	-	-	-	0.1
1627	1-epi-cubenol	1.6	0.8	0.8	0.1	0.1	0.5	t	0.4	-
1632	α-acorenol	-	-	-	-	-	-	-	-	0.2
1640	epi-α-cadinol	0.3	0.6	0.5	0.3	0.4	0.2	0.2	0.3	0.3
1640	epi-α-muurolol	0.3	0.5	0.5	0.4	0.4	0.2	0.2	0.2	0.2
1645	α-muurolol	t	0.1	0.1	t	t	t	0.1	0.1	0.1
1649	β-eudesmol	-	-	-	-	-	-	-	0.2	-
1652	α-eudesmol	-	-	-	-	-	-	-	0.3	-
1653	α-cadinol	0.5	1.2	1.0	1.1	1.3	0.5	0.6	0.5	0.9
1689	shyobunol	t	t	t	0.6	0.8	0.3	0.1	t	0.1
2054	abietatriene	0.1	0.3	t	t	t	t	t	t	t
2080	abietadiene	0.1	0.2	t	t	t	t	t	0.1	t
2288	4-epi-abietal	0.3	1.2	0.8	0.5	0.4	0.2	t	0.1	t
2302	abieta-7,13-dien-3-one	0.4	2.4	1.6	0.5	0.5	0.6	0.1	0.1	0.2
2325	trans-ferruginol	t	t	t	t	t	t	t	t	t
2343	4-epi-abietol	t	0.1	t	t	t	t	t	t	t

RI = Kovat's Retention Index on DB-5(=SE54) column using alkanes. Compositional values less than 0.1% are denoted as traces (t). Unidentified components less than 0.5% are not reported.