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RESEARCH REPORT

The Leaf Essential Oils and Taxonomy of *Juniperus centrasiatica* Kom., *J. jarkendensis* Kom., *J. pseudosabina* Fisch., Mey. & Ave-Lall., *J. sabina* L. and *J. turkestanica* Kom. from Central Asia

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Abstract

The leaf essential oils of *Juniperus centrasiatica* Kom., *J. jarkendensis* Kom., *J. pseudosabina* Fisch., Mey. & Ave-Lall., *J. sabina* L., and *J. turkestanica* Kom. have been analyzed by GC/MS. The oils were very similar and were dominated by α-pinene, sabinene and cedrol with moderate amounts of limonene, terpinen-4-ol and elemol. On the basis of the oils and morphological observations, it is concluded that *J. centrasiatica*, and *J. turkestanica* is conspecific with *J. pseudosabina*. Comparisons were made with the leaf oil of a shrub form of *Juniperus indica* Bertol from Nepal. *Juniperus indica* (shrub form) from Nepal was found to be very distinct from *J. centrasiatica*, *J. pseudosabina* and *J. turkestanica*. In addition, *J. jarkendensis* oil was found to be very similar to *J. sabina* oil (Tian Shan Mtns. China).

Key Word Index

Juniperus centrasiatica, *Juniperus jarkendensis*, *Juniperus indica*, *Juniperus pseudosabina*, *Juniperus sabina*, *Juniperus turkestanica*, Cupressaceae, essential oil composition, α-pinene, sabinene, β-thujone, trans-sabinyl acetate, germacrene D-4-ol, cedrol, taxonomy.

Introduction

The taxonomy of *Juniperus* of central Asia has recently been re-examined (1-4). Farjon (1) noted that a total of 18 new species and 7 varieties have been named in the region. All of the revisions have been

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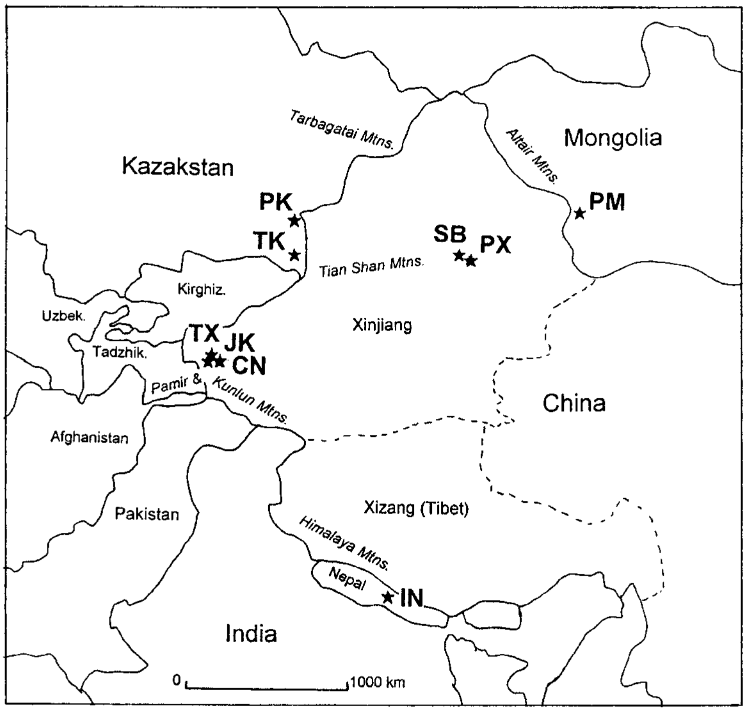

Figure 1. Map depicting locations of populations of *Juniperus* sampled in this study.
PK = *J. pseudosabina*, Kazakstan; PM = *J. pseudosabina*, Mongolia; PX = *J. pseudosabina*, Xinjiang, China;
TK = *J. turkestanica*, Kazakstan; TX = *J. turkestanica*, Xinjiang, China; CN = *J. centrasiatica*, Xinjiang, China;
JK = *J. jarkendensis*, Xinjiang, China; SB = *J. sabina*, Xinjiang, China; IN = *J. indica*, Nepal

based on morphological data from herbarium specimens. In the central Asia area of the present study (Figure 1), the following species are reported: *J. centrasiatica* Kom. (type locality from near Kasgar, Xinjiang, China, close to CN in Figure 1), *J. jarkendensis* Kom. (type locality from site JK in Xinjiang, Figure 1), *J. pseudosabina* Fisch., Mey. & Ave-Lall. (type locality from the Tarbagatai Mtns., north of PK, Figure 1.), *J. sabina* L. (a widely distributed species ranging from Spain into China and Mongolia), *J. sibirica* Burgsd. (often treated as *J. communis* var. *montana* Aiton) which is in section *Juniperus* and is not included in this study, and *J. turkestanica* Kom. (restricted to this central Asia region). All the above junipers, except *J. sibirica* are in section *Sabina*.

J. centrasiatica is reported to be distinguished from *J. pseudosabina* and *J. turkestanica* by having yellowish-brown female cones versus brownish black to bluish-black (5). However, examination (RPA) of a syntype of *J. centrasiatica* (W.O. Roborowski, Kasgario, 1889, LE! revealed that it had dark, almost black female cones. *J. centrasiatica* may be merely a small tree form of *J. turkestanica* (a shrub). (note: herbarium abbreviations used [cf. LE] are from Index Herbariorum, Ed. 8, Holmgren et al. 1990, an exclamation mark (!) after the herbarium code indicates that the specimen was examined by the senior author).

Silba (3) reduced *J. jarkendensis* to a variety of *J. sabina* (*J. sabina* var. *jarkendensis* (Kom.) J. Silba). Farjon (1) treated *J. jarkendensis* as a synonym of *J. semiglobosa* Regel. But, Yu and Fu (4) follow Silba in recognizing *J. jarkendensis* as a variety of *J. sabina*. We have included an analysis of *J. sabina* from the Tian Shan Mtns. (SB, Figure 1) to compare with *J. jarkendensis* oil.

In the flora of the USSR, Komarov (6) recognized both *J. pseudosabina* and *J. turkestanica*. However, Silba (7) reduced *J. turkestanica* to a variety of *J. pseudosabina* (*J. pseudosabina* var. *turkestanica*

(Kom.) J. Silba. Yu and Fu (4) have followed Silba's opinion and treated *J. turkestanica* as a variety of *J. psuedosabina*. Examination (RPA) of the lectotype of *J. turkestanica* and representative materials of *J. pseudosabina* at LE, did not reveal any apparent morphological differences between the taxa. So the distinctness of *J. pseudosabina* from *J. turkestanica* is in question.

In addition, there is controversy concerning the distinctness of *J. pseudosabina* and *J. indica* Bertol. In the flora of Bhutan (8), *J. indica* (along with *J. wallachiana* Hook f. & Thomson ex. Brandis) is treated as synonym of *J. pseudosabina*. Jain (9) in his taxonomic revision of the Himalayan junipers recognized *J. pseudosabina* ("native of Altai and Tarbagatay mountains") as the only shrubby juniper with scale like leaves in the Himalayas. In contrast, Hara et al. (10) recognized *J. indica* Bertol. as the scale leafed, shrub in Nepal, this in spite of the fact that *J. indica* was originally described as arborescent (11). Because the oil of *J. indica* (as a shrub) has been recently examined (12), it seems prudent to include that analysis in this research in order to compare it with *J. pseudosabina* oil from the Altair Mtns.

There are no known reports on the oils of *J. centrasiatica* or *J. jarkendensis*. Akimov et al. (13) reported that *J. turkestanica* oil cultivated in Kiev contained large quantities of thujone and sabinyl acetate. Because thujone and sabinyl acetate are key components of *J. sabina* (see Table I), it seems likely that their cultivated plant was actually *J. sabina*.

The most comprehensive report on the leaf oils of *J. turkestanica* and *J. pseudosabina* is by Dembitsky (14). He reports that the leaf oil from the shrub form of *J. turkestanica* is dominated by α-pinene (27-41%) and sabinene (11-36%), with moderate amounts of myrcene (2-5%), terpinen-4-ol (4-7%) and cedrol (0.4-3.5%). His sample of *J. pseudosabina* had 67% α-pinene, 3.5% β-pinene, 0.5% sabinene, and 12% cedrol among other components.

There are numerous reports on the oil of *J. sabina* from Europe but there are only a couple of reports on *J. sabina* from central Asia. He et al. (15) reported that the oil from the fruit (female cones) of *J. sabina* (= *Sabina vulgaris* Ant.) from Xinjiang, was dominated by sabinene (64%) with 1-3% α-thujene, α-pinene, myrcene, linalool, terpinen-4-ol, sabinyl acetate, β-caryophyllene, and cedrol. Akimov et al. (13) reported the leaf oil from *J. sabina* from Tashkent contained 18.7% limonene, 15.6% sabinene, 9.6% α-pinene, 8.2% sabinyl acetate and 3.3% thujone. Shatar (16) reported *J. sabina* leaves from Mongolia contained 10-17% sabinene, 2-11% terpinen-4-ol, 11-30% sabinyl acetate, 6-17% sabinol, and 3-10% δ-cadinene with 0-1% cedrol.

As a part of a continuing effort (RPA) to collect all *Juniperus* species from natural sites, this study attempts to resolve taxonomic relationships between *J. centrasiatica*, *J. turkestanica*, *J. pseudosabina*, and *J. indica*. In addition, we would like to examine the relationship between *J. jarkendensis* and *J. sabina*.

Experimental

A map showing the collecting sites is given in Figure 1. Specimens of *Juniperus* species were collected during a field expedition as follows: *J. centrasiatica*, CN: Adams 7826-7828, Oeetak, 125 km S. of Kasgar, 2980 m, Xinjiang, China; *J. jarkendensis*, JK: Adams 7820-7825, same location as CN above; *J. turkestanica*, TK: Adams 7817-7819, 35 km E. of Turgen, 2400 m, Kazakstan; TX: Adams 7829-7831, same location as CN above; *J. pseudosabina*, PK: Adams 7808-7810, 30 km N of Jarkent (Paniflor), 2000 m, Kazakstan; PM: Adams 7592-7595, Altair Mtns., 2550m, Mongolia; PX: Adams 7833-7835, above Heaven Lake, 2120 m, Tian Shan Mtns., 40 km S. of Fukan City, Xinjiang, China; *J. sabina*, SA; Adams 7836-7838, same location as PX above. Voucher specimens are deposited at SRCG herbarium, Baylor University.

Fresh leaves (200 g. fresh wt.) were steam distilled for 2 h using a circulatory Cleavenger-type apparatus (17). The oil samples were concentrated (ether trap removed) with nitrogen and the samples stored at –20°C until analyzed. The extracted leaves were oven dried (48 h, 100°C) for determination of oil yields.

The oils were analyzed on a Finnigan Ion Trap (ITD) mass spectrometer, model 800, directly coupled

Table I. Comparative percentage composition of the leaf oils of *Juniperus centrasiatica*, *J. pseudosabina*, *J. turkestanica*, *J. sabina*, *J. indica* from Nepal and *J. jarkendensis*

RI	Compound	CN	TK	TX	PK	PX	PM	SB	IN	JK
926	tricyclene	0.1	0.1	t	0.1	0.1	0.1	t	t	t
931	α-thujene	1.2	0.6	1.6	0.2	0.1	t	2.0	1.4	2.0
939	α-pinene	26.2	41.3	23.8	52.1	63.3	36.4	2.6	2.8	4.4
953	α-fenchene	t	t	t	t	-	t	t	t	t
953	camphene	0.3	0.4	0.3	0.5	0.4	0.6	t	t	0.1
976	sabinene	26.1	15.1	37.6	5.8	6.5	0.3	39.0	26.1	43.0
980	β-pinene	3.1	3.8	2.2	4.5	4.1	6.6	0.2	-	0.2
981	1-octen-3-ol	-	-	-	-	-	-	-	0.2	-
991	myrcene	4.3	4.0	4.3	3.8	3.5	5.2	4.2	3.3	3.6
1005	α-phellandrene	t	0.1	t	t	t	t	t	0.1	0.1
1011	δ-3-carene	0.1	0.2	t	0.3	0.1	0.5	0.1	t	t
1018	α-terpinene	1.1	0.7	1.0	0.2	0.2	t	1.0	1.7	1.3
1026	p-cymene	0.1	t	t	t	-	t	0.2	0.2	0.2
1031	limonene	0.7	1.1	0.9	0.9	0.7	2.1	1.8	0.4	1.4
1031	β-phellandrene	1.3	1.0	0.9	1.8	1.5	2.1	0.4	1.6	0.4
1033	1,8-cineole	0.3	t	t	t	t	-	-	1.3	-
1050	(E)-β-ocimene	-	-	-	-	-	-	0.2	-	0.2
1062	γ-terpinene	1.6	1.0	1.5	0.3	0.2	-	1.6	2.7	2.1
1068	cis-sabinene hydrate	0.9	0.3	0.8	0.1	0.1	-	0.8	1.6	1.2
1088	terpinolene	0.9	0.5	0.9	0.3	0.3	0.5	1.0	0.9	1.0
1091	2-nonanone	1.5	1.8	1.2	3.4	0.9	1.0	t	-	-
1097	trans-sabinene hydrate	0.9	0.2	0.6	t	t	-	0.5	1.0	0.8
1098	linalool	2.1	1.4	1.5	2.1	0.9	2.4	1.3	-	0.9
1102	cis-thujone (=α-thujone)	-	-	-	-	-	-	-	2.3	0.3
1114	trans-thujone (=β-thujone)	-	-	-	-	-	-	0.4	16.0	3.5
1116	3-methyl-3-butenyl 3-methylbutyrate	0.7	0.8	0.2	0.6	0.3	0.7	-	-	-
1121	cis-p-menth-2-en-1-ol	0.3	0.1	0.2	t	t	t	0.3	0.6	0.4
1125	α-campholenal	0.1	t	t	t	t	t	-	-	-
1133	iso-3-thujanol	-	-	-	-	-	-		-	0.1
1140	trans-p-menth-2-en-1-ol	0.3	0.1	0.1	0.1	t	t	0.4	0.7	0.2
1140	trans-sabinol	-	-	-	-	-	-	-	1.4	0.3
1149	neo-3-thujanol	-	-	-	-	-	-	-	0.1	-
1148	camphene hydrate	0.2	0.2	t	0.2	0.1	0.5	-	-	-
1153	citronellal	-	-	-	-	-	-		-	0.1
1156	sabina ketone	-	-	-	-	-	-	t	t	t
1165	borneol	0.2	0.1	t	0.1	-	0.2	-	-	-
1171	umbellulone	-	-	-	-	-	-	-	0.2	-
1177	terpinen-4-ol	4.5	2.8	4.3	0.8	0.4	0.1	4.0	9.2	6.0
1189	α-terpineol	0.3	0.2	0.1	0.1	0.1	1.0	0.2	0.2	0.2
1190	(Z)-4-decenal	-	-	-	-	-	0.2	t	-	-
1193	myrtenal	t	t	t	t	t	-	-	-	-
1193	cis-piperitol	t	t	-	-	-	-	t	-	t
1205	trans-piperitol	0.1	t	t	-	-	-	-	-	-
1228	citronellol	0.5	0.1	0.1	0.2	0.1	-	0.1	t	0.3
1237	(Z)-3-hexenyl 3-methylbutyrate	t	0.1	0.1	0.1	0.1	0.1	-	-	-
1240	neral	-	-	-	-	-	-		-	t
1244	methyl carvacrol	-	-	-	-	-	-	-	t	-
1252	piperitone	t	t	t	t	t	t	-	-	-
1253	linalyl acetate	-	-	-	-	-	-	0.7	-	-

Table I. Continued

RI	Compound	CN	TK	TX	PK	PX	PM	SB	IN	JK
1257	trans-myrtanol	-	-	-	-	-	0.2	-	-	-
1261	methyl citronellate	0.1	0.1	t	-	-	-	t	0.1	1.5
1285	bornyl acetate	0.6	0.5	0.3	0.8	0.4	1.4	t	0.2	0.1
1291	trans-sabinyl acetate	t	-	-	0.2	-	t	17.5	15.7	6.2
1291	2-undecanone	0.3	0.1	0.2	t	0.2	-	-	-	-
1314	(2E,4E)-decadienal	-	-	-	-	-	-	-	-	1.5
1322	aromatic terpene, ether	0.8	0.5	0.7	0.9	0.4	0.4	-	-	-
1350	α-terpinyl acetate	-	-	-	-	-	-	0.3	-	-
1351	α-cubebene	-	-	-	-	-	-	-	t	-
1376	α-copaene	-	-	-	-	-	t	-	t	-
1390	β-cubebene	-	-	-	-	-	t	-	t	-
1409	α-cedrene	0.1	0.2	0.1	0.1	0.1	-	0.2	-	t
1410	1,7-di-epi-β-cedrene (=β-funebrene)	-	-	-		-	-	-	-	0.1
1418	β-cedrene	0.1	t	0.1	t	0.1	-	0.1	-	t
1418	β-caryophyllene	-	-	-	-	-	0.2	-	t	t
1429	cis-thujopsene	0.2	0.3	0.2	0.3	0.2	-	0.2	-	t
1446	cis-muurola-3,5-diene	-	-	-	-	-	t	-	0.3	-
1450	trans-muurola-3,5-diene	-	-	-	-	-	t	-	-	-
1454	α-humulene	-	-	-	-	-	-	-	t	-
1460	cis-muurola-4(14), 5-diene	-	-	-	-	-	0.3	t	-	-
1473	β-cadinene*	-	-	-	-	-	-	-	0.2	-
1477	γ-muurolene	t	t	0.1	0.1	0.1	0.3	t	t	-
1480	germacrene D	-	-	-	-	-	0.3	t	-	-
1489	2-phenylethyl 3-methyl butyrate	t	t	t	t	0.1	t	-	-	-
1491	trans-muurolα-4(14),5-diene	-	-	-	-	-	-	-	0.9	-
1493	cis-cadina-1,4-diene	-	-	-	t	t	0.4	-	-	-
1499	α-muurolene	0.1	0.1	0.1	0.4	0.2	0.7	t	0.1	-
1508	(E,E)-α-farnesene	-	-	-	-	-	-		-	0.1
1513	γ-cadinene	0.2	0.3	0.2	0.4	0.3	2.0	0.1	0.7	-
1524	δ-cadinene	0.4	0.7	0.6	1.4	0.6	3.5	0.4	0.8	0.1
1538	α-cadinene	t	t	t	t	t	0.3	t	-	-
1549	elemol	3.2	3.1	1.0	t	0.8	1.8	t	0.6	0.1
1556	germacrene B	-	-	-	-	-	0.6	t	-	t
1564	(E)-nerolidol	t	t	t	t	t	0.2	-	-	-
1574	germacrene D-4-ol	0.8	0.8	0.8	2.0	0.9	14.3	0.5	0.4	t
1596	cedrol	8.5	10.6	7.9	10.7	8.6	-	15.8	-	14.5
1606	β-oplopenone	t	t	t	t	t	0.2	0.1	-	t
1627	1-epi-cubenol	-	-	-	-	-	t	-	0.3	-
1630	α-acorenol	0.2	t	0.2	0.3	0.2	-	t	-	t
1630	γ-eudesmol	0.2	0.2	t	-	-	t	-	t	-
1640	epi-α-cadinol (=T-cadinol)	0.2	0.1	t	0.4	0.2	1.3	t	0.2	t
1641	epi-α-muurolol (=T-muurolol)	0.2	0.4	0.3	0.6	0.3	1.3	t	-	
1642	cubenol	-	-	-	-	-	-	-	0.2	-
1645	α-muurolol (=torreyol)	t	t	0.1	0.4	t	0.4	t	t	-
1649	β-eudesmol	0.2	0.1	-	-	t	-	t	0.1	-
1652	α-eudesmol	0.1	0.3	0.2	-	t	-	-	0.2	-
1653	α-cadinol	0.7	0.7	0.3	1.3	0.6	3.8	0.3	0.2	t
1666	bulnesol	0.5	0.4	0.2	-	0.2	0.7	t	0.1	-
1688	sesquiterpene alcohol	-	-	-	-	-	1.1	-	-	-

Table I. Continued

RI	Compound	CN	TK	TX	PK	PX	PM	SB	IN	JK
1930	ent-rosadiene	-	-	-	-	-	-	-	t	-
1941	pimaradiene	-	-	-	-	-	-	-	t	-
1960	sandaracopimara-8(14),15-diene	-	-	-	-	-	0.1	-	-	
1961	epi-13-manool	0.2	t	t	t	t	-	-	0.3	-
2010	epi-13-manoyl oxide	t	t	t	-	-	t	-	-	-
2054	abietatriene	0.2	0.1	t	t	t	0.1	-	t	-
2054	manool	-	-	-	-	-	0.1	-	0.7	-
2080	abietadiene	1.4	1.6	1.2	0.2	0.5	2.9	-	0.3	t
2126	nezukol	0.1	0.1	-	-	-	0.3	-	t	
2288	epi-4-abietal	-	-	-	-	-	-	t	t	t
2303	trans-totarol	-	-	-	-	-	-	-	t	-
2302	abieta-7,13-dien-3-one	-	-	-	-	-	-	t	-	-

RI = Retention Index on DB-5(=SE54) column; *Tentatively identified. Compositional values less than 0.1% are denoted as traces (t); Unidentified components less than 0.5% are not reported.
Legend: CN = *Juniperus centrasiatica* from Xinjiang; TK = *J. turkestanica* from Kazakstan; TX = *J. turkestanica* from Xinjiang; PK = *J. pseudosabina* from Kazakstan; PX = *J. pseudosabina* from Xinjiang; PM = *J. pseudosabina* from Mongolia; SB = *J. sabina* from Xinjiang; IN = *J. indica* c.f. ref. 11; JK = *J. jarkendensis* from Xinjiang

to a Varian 6500 gas chromatograph, using a J & W DB-5, 0.26 mm x 30 m, 0.25 μm coating thickness, fused silica capillary column (see reference 18 for operating details). Identifications were made by library searches of our volatile oil library, LIBR(TP) (18), using the Finnigan library search routines based on fit and purity, coupled with retention time data of reference compounds.

The terpene data for each of the nine Operational Taxonomic Units (OTUs) in Table I was coded and similarity measures were computed using absolute character value differences (Manhattan metric), divided by the maximum value observed in these nine OTUs (= Gower metric, see 19, 20). Principal coordinate analysis (PCO3D) of the similarity matrix follows Gower (21). Program PCO3D is available from RPA for IBM computers.

Results and Discussion

Oil yields (calculated as oil wt./wt. of oven dried, extracted leaves) and colors were as follows: *J. centrasiatica* CN, 0.6 - 0.7%, clear; *J. jarkendensis* JK, 0.8-1.2%, clear; *J. turkestanica*, TK, 0.7-1.0%, clear; TX: 1.0-1.4%, clear: *J. pseudosabina* PK, 0.6- 0.7% clear; PX, 0.7-0.8%, pale yellow; PM, 0.7-1.0%, clear; *J. sabina*, SB, 1.5-1.9%, clear.

The most obvious result was that the oils of *J. centrasiatica*, *J. turkestanica* and *J. pseudosabina* except the *J. pseudosabina* (PM) sample from Mongolia were very similar. All are dominated by α-pinene and sabinene. Cedrol is a moderate component (7.9-10.7%). Clearly, the *J. pseudosabina* from Mongolia is quite different as it has a very small (0.3%) sabinene content, and cedrol is absent (note that all the data in Table I are averages from at least three plants), whereas germacrene D-4-ol is 14.3%. *J. sabina* is high in sabinene (39%) and trans-sabinyl acetate (17.5%) as previously reported from this region (16). *J. indica*, (shrub form) included in this report (12), is somewhat like *J. sabina* in having high sabinene and trans-sabinyl acetate, but *J. indica* has a large amount of trans-thujone (16.0%) and several other differences. *J. jarkendensis* is similar to *J. sabina* in having high amounts of sabinene, trans-sabinyl acetate and cedrol.

To determine the overall similarities among the oils of these taxa, a principal coordinate analysis and ordination was performed. Eight eigenroots were extracted in PCO and accounted for 34.76%, 22.18, 13.61, 9.95, 5.87, 5.64, 4.54, and 3.43% of the variance among OTUs. The eigenroots appear to asymptote at the 5th root (5.87%) and no clear pattern was seen in the OTUs mapped onto coordinates 5 to 8. The first principal coordinate (34.76%) separates *J. centrasiatica*, *J. turkestanica* and *J. pseudosabina* from

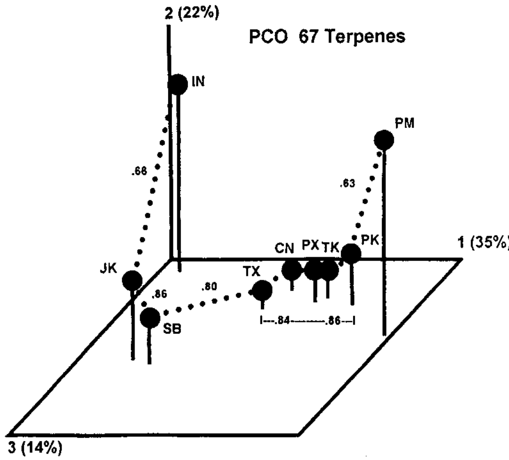

Figure 2. Principal coordinate analysis (PCO) of 9 OTUs based on 67 terpenes. The dotted line is the minimum spanning network. The number next to a dotted line is the similarity between the two connected OTUs. The *J. centrasiatica*, *J. pseudosabina*, *J. turkestanica* OTUs are very similar and all their similarities are in the indicated range of 0.86 to 0.92. See text for discussion

J. indica, *J. jakendensis* and *J. sabina* (Figure 2). The second principal coordinate (22.18%) separates *J. indica* and the Mongolian population of *J. pseudosabina* from all the other OTUs (Figure 2). The third principal coordinate (13.61%) separates *J. jarkendensis* and *J. sabina* from the other OTUs. The fourth axis (not shown) separated *J. centrasiatica* from *J. pseudosabina* PK and PX. The fifth axis (not shown) separated *J. jarkendensis* from *J. sabina*.

To more accurately depict the similarities, the nine OTUs are connected by a minimum spanning network which shows the nearest (most similar) neighbor in the ordination. Notice that CN, TX, PX, TK and PK form a tight cluster and all are connected by similarities of 0.84 to 0.86. JK and SB also form a tight cluster (0.86 similarity). *Juniperus indica* (IN) is very well resolved in this analysis (0.66 to *J. jarkendensis*, JK). The most surprising aspect is the distance of the Mongolian *J. pseudosabina* (PM) from the central *J. pseudosabina* complex. This might represent some founder's effect or genetic drift. The population of *J. pseudosabina* in the Altair Mtns. appeared to be very small (ca. 15-30 individuals). The distance to the next nearest population is unknown. No other *J. pseudosabina* plants were seen on this expedition. It should also be noted that central Asia is a high desert plateau with very high mountains that support small isolated populations of *Juniperus*. For example, the Mongolian population of *J. pseudosabina* (PM) is separated from the PX population in the Tian Shan Mtns. by extensive desert. The populations of Juniperus a very much like island populations and are prone to genetic drift and founder's effects.

Alternatively, the divergence of the *J. pseudosabina* from Mongolia, may be due to polymorphisms in key terpene pathway enzymes. In *Juniperus* the composition of wood oil is almost completely different from the leaf oil (17). Several major leaf oil components of these taxa studied varied greatly among individuals. For example, for four individuals of *J. pseudosabina* from Mongolia (PM): δ-3-carene (0.11, 0.11., 0.98, 0.78%), linalool: (2.06, 0.71, 0.85, 4.83%). elemol (0.34, 0.34, 0.24, 6.32), and germacrene D-4-ol (8.89, 8.97, 10.98, 5.26%) and three individuals of *J. pseudosabina* from Kazakstan (PK): sabinene (17.1, 0.31, 0.37%), δ-cadinene (0.63, 2.59, 2.26%), germacrene D-4-ol (0.70, 3.71, 2.66%), and cedrol (17.37, 0.10, 20.1%). These kinds of chemical polymorphisms were found in all of the taxa examined. The prospect of a single or few genes having major effects on a suite of chemical characters is a constant danger that chemosystematists must face.

Based on these data, several conclusions seem justified. There appears to be no justification for maintaining *J. centrasiatica*, *J. turkestanica* and *J. pseudosabina* as distinct species. By nomenclatural priority, *J. pseudosabina* should be used as the name for both *J. centrasiatica* and *J. turkestanica* plants. *J. centrasiatica* appears to be a tree form of *J. pseudosabina*. These data also support the recognition of *J. indica* as a separate species which appears to be distinct from *J. pseudosabina*. Thus, the common shrubby, scale-leafed juniper of the Himalayas appears to be *J. indica* and not *J. pseudosabina*. Based on terpenes, *J. jarkendensis* and *J. sabina* appear to be closely related. Additional research is now being conducted using DNA fingerprinting to aid in the elucidation of these relationships.

Mass spectra for unidentified constituents: [ITMS, 240°C, m/z (rel. int.): RI 1322, M^+164 (30), aromatic terpene ether, 149(100), 134(4), 121(3), 105(7), 91(53), 78(20), 65(13), 51(19), 43(36); RI 1688, M^+204(12), sesquiterpene; 189(4), 161(49), 147(4), 133(16), 119(46), 105(46), 91(41), 81(38), 67(24), 55(34), 41(100).

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