STUDIA GEOBOTANICA
10: 105-117, 1990

TERPENES OF SALVIA SPECIES LEAF OILS: CHEMOSYSTEMATIC IMPLICATIONS.

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Key Words. *Salvia* L. species, Labiatae, leaf oils, chemotaxonomy, pharmaceutical properties.

Abstract. Wild specimens of *Salvia* L. were collected in three different moments of anthesis and their volatile leaf oils were analyzed by GC/GCMS. The quantitative terpene composition is very variable with the anthesis. *S. bertolonii* is the richest species in α-thujone. *S. officinalis* is characterized by high percentages of 1,8 cineole, 4-terpineol, isorboneol and α-bisabolol. In *S. verticillata* high percentages of borneol and β-cariophyllene are present. In the three species α-thujone was always more abundant than β-thujone. The three taxa are characterized by peculiar combinations of terpenoids. The multivariate analysis of the chemical data indicates the degree of affinity between the three taxa and their chemotaxonomical status. Some components of *Salvia* essential oil have pharmaceutical activities.

Introduction

Salvia officinalis L., *S. bertolonii* Vis. and *S. verticillata* L. (Labiatae) are abuntantly spread in the Karst Plateau, (N-E Italy, near Triest).

S. officinalis is widespread in the *Salvieto-Euphorbietum fragiferae* (Lausi & Poldini 1962), s. restr. Poldini 1980 an association in which Labiatae and Euphorbiaceae prevail. It is a pioneer steppe-like association of the calcareous rocks along the litoral, in which the grassland communities are very discontinuous. (Lausi & Poldini 1962).

S. verticillata is present in ruderal vegetation and along the borders of the roads. *S. bertolonii* is a Balkan-endemic entity; it substitutes *S. pratensis* in the North-Eastern Adriatic region; its *Salvia* distribution is little known. (Poldini, 1978).

S. bertolonii is present in the association *Arrhenatheretum* Br.-Bl. ex Scherr. 25 (Karstic race). This association has a zoogenic origin; the consequences of centuries of pasture practised on deforested areas are a thin soil and a highly specialized vegetation: low, discontinuous and creeping. The climatic conditions are slightly more mesophytic than those of *Salvieto-Euphorbietum fragiferae*. These two Karstic *Salvia*-species had not been studied before from the point of view of their chemical composition.

S. officinalis from the isle of Pag (Dalmatia, Yugoslavia) was also examined, since it is the most commercially valued taxon.

The essential oil of this taxon as well as its productivity, the best stage of its sampling, the influence of the edaphic-environmental factors on the qualitative and quantitative composition of its essence were extensively studied (Devon, 1972; Steinegger & Hänsel, 1972; Dalferth, 1963; Banthorpe et al., 1977; Brieskorn & Kapadia, 1980; Holeman et al., 1983; Pitarevic et al., 1984; Kustrak et al., 1984; Bellomaria et al., 1988; Devetak et al., 1967; Tucakov, 1952; Cenci & Calvarano, 1967). As regards *S. officinalis* of the Karst Plateau, only the aminoacids and carbohydrates and some consituents of the essential oil (Poldini et al., 1971) were analyzed.

In the present study we report on the chemical differentiation of the three *Salvia* taxa and on the evidence of chemotaxonomic significance of the terpene composition. Several sources of biochemical data were used for systematic purposes, including the components of the essential oil (Emboden & Lewis, 1967; Kubeczka & Ullmannn, 1983; Alston & Turner, 1963; Hegnauer, 1962; Vernet et al., 1977; Coassini Lokar et al., 1986; Corsi et al., 1984; Servettaz et al., 1984; Cenci & Calvarano, 1967).

In addition, the problem of various biological activities of some terpene derivatives, particularly α- and β-thujone, well known substances at high level of toxicity, was considered in relation to the commercial use of the drugs.

Materials and methods

Plant material and sampling

Several sets of leaf samples (from 15 individuals) were randomly collected in the North-Adriatic Karst territory in the mentioned associations, during the anthesis (pre-, full- and post- anthesis). All specimens are on deposit at TBS (accession number: 7290). Some samples of *S. officinalis* were collected from the *Stipo-Salvietum officinalis* H-ić (1956) 1958 in the isle of Pag (Dalmatia, Yugoslavia), during the pre-anthesis. This taxon was used as standard sample.

Distillation procedures

Fresh, weighed leaf material (125 g) was frozen until steam distilled. The volatile terpenoids were removed by steam distillation for 4 h for quantification analyses and for 24 h for yeld calculations. Volatile oil yields were recorded as ml per 100 g of dry leaf weight. The extracts were kept at − 20° until analyzed to minimize chemical degradation.

Methods of chemical analysis

GC/MS analysis were run with a Dupont 21492 B mass spectrometer coupled with a Varian 2700 gaschromatograph, using a glass column (3m x 2mm) packed with Carbowax 20M on Chromosorb W (80-100 mesh). All MS analysis were made using the carrier with an average linear velocity through the column of 40 ml/min. The column temperature was programmed from 50° C (isot. 3 min) to 225° C at 10° min. The temperature of injector was 210° C and that of GC detector (FID) was 275° C. The EI mass spectra collected with a data system (HP 2109) were obtained at ionization voltage 75 e V, filament emission 250 μA, source temperature 250° C. Quantification was made by peak area integration. The compounds were identified by comparison of their retention time and their mass spectra with those of authentic samples or/and MS of known terpenes and researcher of spectra from literature.

The GC-analysis of oils were carried out by Fractovap 2450 gaschromatograph (Carlo Erba) with a flame ionization detector and dual stainless steel column (2m x 2 mm), 10% Carbowax 20M on Chromosorb W (60-80 mesh); T° programmed from 60°C to 200°C at 4°C/ min; N_2 flow rate 30 ml/min; injector and detector temperature 250° C.

Methods of data analysis

Dissimilarities between the three taxa were computed with CHICORSOM method on the basis of chemical characters. The symmetric dissimilarity matrix was factored by principal components analysis (Eivava, Autovave, Copri 1, Copri 2) following the programs of Priscart and by the Euclidean distances following Dendro and Distance (Nie et al., 1970; Wishart, 1975; Feoli et al.; 1982a; 1982b).

Analysis of the results

The composition of the volatile leaf oils of the taxa (plus sample of Dalmatia) is shown in Table 1. The methods for the identification of components are indicated. The percentage data are average of three separated analysis. Of the 49 terpene derivatives, 32 were identified by GC/GCMS analysis and, when possible, by comparison with authentic samples of substances.

S. officinalis is characterized by high percentages of 1,8 cineole and α-bisabolol. The oxygenated terpenes and the hydrocarbons prevail. *S. verticillata* is characterized by the prevalence of β-cariophyllene and borneol; in *S. bertoloni* α- and β-thujone and β-cariophyllene prevail. In both these taxa the sesquiterpene hydrocarbons are prevalent. The percentages of chemical constituents show a wide range of variation during the anthesis. *S. verticillata* and *S. bertolonii* are more similar to *S. officinalis* (A' sample) as regards percentages of borneol and differ for β-cariophyllene. In the *S. officinalis* of the Karst Plateau (A sample) the percentage variation of some terpene constituents is more evident: during the anthesis only the yield of borneol tends to increase, while all the major constituents decrease. *S. officinalis* from Dalmatia (A' sample) differs from the Karst Plateau popolation for the percentages of 1,8-cineole, β-cariophyllene, borneol and δ-cadinene.

In *S. verticillata* α- and β-thujone, β-cariophyllene and isoborneol decrease with the anthesis; only borneol increases little. *S. bertolonii* is characterized by the absence of several low-boiling terpenese; at the stage of full anthesis it is

Table 1 — Percentage composition of the essential oils extracted from the leaves of *Salvia* species during the anthesis. (a = pre-anthesis, b = full-anthesis, c = post-anthesis; AS = authentic sample; A = *S. officinalis* from Karst Plateau; A' = *S. officinalis* from isle of Pag; B = *S. bertolonii*; C. = *S. verticillata*).

N.	**Compounds**	**Identification method**		**A'**	**S.officinalis (A)**			**S.bertolonii (B)**		**S.verticillata (C)**		
					a	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**
1	α-thujene	GC	AS	-	0.35	tr	tr	-	0.27	-	-	0.37	-
2	α-pinene	MS-GC	AS	0.07	1.43	1.78	2.55	-	0.08	0.60	-	0.85	-
3	camphene	GC	AS	0.06	2.16	2.33	5.34	-	-	-	-	0.10	-
4	β-pinene	GC	AS	0.27	1.84	2.67	1.40	0.16	-	1.37	-	1.40	-
5	β-myrcene	MS-GC		0.06	0.34	0.23	0.50	0.08	-	-	-	0.35	-
6	α-phellandrene	MS-GC		6.00	0.05	tr	tr	-	-	-	-	-	-
7	1,8-cineole	MS-GC	AS	4.78	15.93	19.10	15.50	0.44	0.38	-	0.34	1.60	0.80
8	limonene	MS-GC	AS	-	0.81	0.70	0.50	0.12	0.16	-	-	0.85	-
9	α-terpinene	MS		0.69	0.28	tr	tr	0.20	0.21	-	-	1.10	-
10	p-cimene	MS-GC	AS	0.27	0.11	tr	0.30	-	-	-	-	-	-
11	γ-terpinene	MS-GC		-	tr	tr	tr	-	-	-	-	-	-
12	ox.monot.MW 152	MS-GC		-	tr	tr	tr	0.39	0.40	-	0.69	0.67	0.11
13	α-thujone	GC	AS	12.59	16.00	6.25	17.70	13.45	27.49	14.78	15.06	21.86	11.21
14	β-thujone	GC	AS	4.66	1.75	1.90	2.10	7.05	3.58	0.75	4.33	3.64	3.43
15	linalyl acetate	MS-GC	AS	0.41	tr	tr	tr	-	-	-	-	-	0.59
16	camphor	MS-GC	AS	2.24	8.73	2.94	tr	-	0.81	1.25	0.19	0.60	0.66
17	linalool	GC	AS	1.24	0.95	1.00	2.20	0.76	1.13	0.60	1.08	0.73	0.55
18	bornyl acetate	MS		0.78	1.03	0.97	11.00	-	-	-	-	-	-
19	*β-caryophyllene	MS-GC	AS	8.29	11.23	18.27	8.00	27.64	28.46	23.78	35.90	23.80	25.62
20	terpinen-4-ol	MS-GC	AS	0.43	0.07	tr	tr	-	-	0.50	-	-	-
21	isoborneol	MS		6.51	8.57	10.26	4.20	4.76	2.64	1.20	5.04	4.10	3.53
22	borneol	MS-GC	AS	24.12	6.90	11.26	13.20	22.25	18.01	5.24	22.32	25.37	24.79
23	β-bisabolene	MS-GC		1.98	tr	tr	tr	5.51	3.17	0.42	22.32	25.37	24.79
24	carvone	GC	AS	tr	0.05	tr	tr	-	-	-	-	-	-
25	δ-cadinene	MS		4.28	1.77	0.10	0.16	3.52	1.98	1.12	2.72	2.80	2.94
26	myrtenol	MS		0.43	tr	tr	tr	-	-	-	-	-	-
27	calacorene	MS		0.14	tr	tr	tr	0.21	0.32	0.45	-	-	0.29
28	----			0.10	tr	tr	tr	-	-	-	-	-	-
29	----			0.08	tr	tr	tr	0.46	0.37	3.75	0.26	0.22	0.50
30	----			0.10	tr	tr	tr	-	-	-	-	-	0.34
31	nerolidol	MS-GC		0.27	2.50	3.69	0.79	0.85	0.86	15.98	0.65	0.90	3.64
32	----			-	tr	tr	tr	-	-	-	-	-	-
33	terpenyl acetate	MS-GC		0.11	0.09	0.09	tr	-	-	0.50	-	-	-
34	sesquit. alcohol 222	MS		1.20	1.77	2.43	0.69	-	-	0.28	-	0.09	0.14
35	sesquit. MW 220			-	-	-	-	1.01	-	-	0.65	0.10	0.34
36	α-bisabolol	MS-GC		14.64	14.34	10.72	11.00	1.45	0.94	4.37	0.81	1.20	3.25
37	----			0.06	tr	tr	tr	0.41	-	0.94	0.39	0.40	0.56
38	----			0.33	tr	tr	tr	-	-	0.60	-	0.41	0.43
39	----			-	0.06	0.20	0.71	0.08	1.62	-	-	-	-
40	----			0.50	tr	tr	tr	0.14	3.77	1.20	0.52	0.73	0.84
41	----			0.61	tr	tr	tr	1.94	-	5.17	0.97	0.70	3.08
42	----			0.39	0.45	0.79	0.63	0.30	-	3.90	0.10	0.23	1.00
43	----			-	0.16	0.35	0.39	-	-	2.60	-	0.25	1.52
44	----			0.12	0.42	0.87	0.23	0.24	-	-	0.65	0.25	-
45	----			-	tr	tr	tr	0.18	-	4.05	0.60	-	1.20
46	----			-	tr	tr	tr	3.04	1.32	1.62	1.94	1.05	1.90
47	----			-	tr	tr	tr	1.21	-	0.32	0.17	0.15	1.12
48	----			-	tr	tr	tr	2.13	1.98	2.25	1.20	0.93	3.08
49	----			7.48	1.34	1.00	0.50	-	-	-	-	-	-

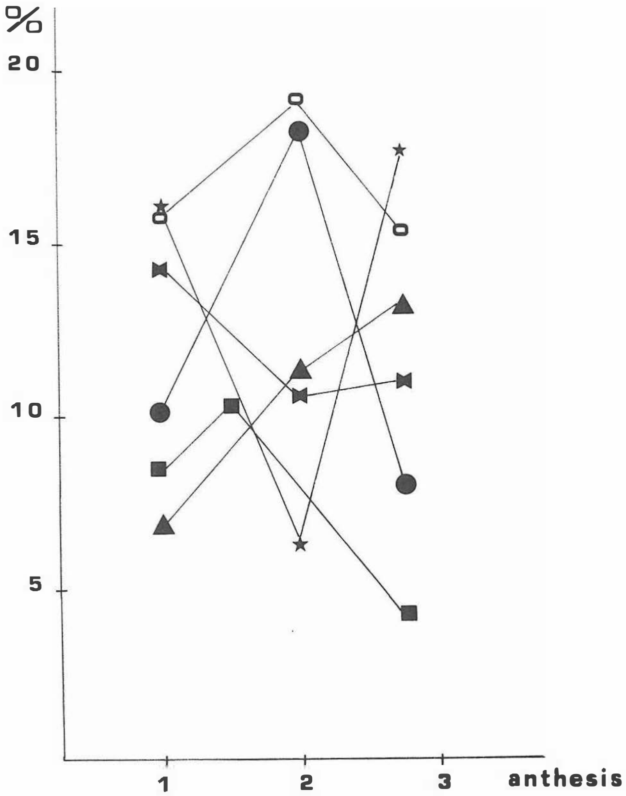


Fig. 1 — Variation of 1,8-cineole (○), α-bisabolol (⧓), isoborneol (■), borneol (▲), α-thujone (*) and β-caryophyllene (●) content in *S. officinalis* during the anthesis.

characterized primarily by high percentages of β-cariophyllehne and α-thujone.

Closely related with the anthesis are borneol, β-bisabolene and δ-cadinene, which strongly decrease. The percent variation of some main components during anthesis is visualized in some graphs (fig. 1-3). All the taxa always show a high percentage of α-thujone than β-thujone in all phases of anthesis. Essential oil yields from the genus *Salvia* species showed wide inter-specific variation (Table 2).

Table 3 shows the main groups of terpene derivatives.

The two *Salva officinalis* populations are very similar and differ only for the percentages of monoterpene hydrocarbons and of 1,8-cineole. *S. bertolonii* and *S. verticillata* have essential oils of very similar composition; they differ from *S. officinalis* for their smaller percentage of oxygenated monoterpenes and sesquiterpenes, of camphor and 1,8-cineole. In addition they show a percentage almost 3 times higher of sesquiterpene hydrocarbons. Alpha- and beta-thujone are more abundant in *S. bertolonii* and *S. verticillata.*

Some components of the essential oils seem to significatively characterize the

Table 2 — Mean terpene percentage composition of essences of *Salvia* species.

N.	Compounds	A'	A	B	C
1	α-thujene	-	0.11	0.10	0.12
2	α-pinene	0.07	1.92	0.22	0.28
3	camphene	0.06	3.27	-	0.03
4	β-pinene	0.27	1.97	0.51	0.46
5	myrcene	0.06	0.35	0.02	0.11
6	α-phellandrene	-	0.01	-	-
7	1,8-cineole	4.78	16.48	0.27	0.93
8	limonene	-	0.67	0.09	0.28
9	α-terpinene	-	-	-	-
10	p-cimene	0.27	0.13	-	-
11	γ-terpinene	-	-	-	-
12	ox.monot.MW 152	-	-	0.26	0.49
13	α-thujone	12.59	13.31	18.57	16.04
14	β-thujone	4.66	1.91	3.79	3.80
15	linalyl acetate	0.41	-	-	-
16	camphor	2.64	3.89	0.68	0.48
17	linalool	1.24	1.38	0.82	0.78
18	bornyl acetate	0.78	4.33	-	-
19	β-caryophyllene	8.29	12.50	26.62	28.44
20	terpinen-4-ol	0.43	0.02	0.16	-
21	isoborneol	6.51	6.41	2.86	4.22
22	borneol	24.12	10.45	15.16	24.16
23	β-bisabolene	1.98	0.01	3.03	2.01
24	carvone	-	-	-	-
25	δ-cadinene	4.28	0.67	2.20	2.81
26	myrtenol	0.43	-	-	-
27	calacorene	0.14	-	0.32	0.09
28	----	0.10	-	-	-
29	----	0.08	-	1.52	0.32
30	----	0.10	-	-	0.11
31	nerolidol	0.27	2.32	5.89	1.72
32	----	-	-	-	-
33	terpenyl acetate	0.11	0.06	0.16	-
34	sesquit.alcohol 222	1.20	1.63	0.93	0.07
35	sesquit.MW 220	-	-	0.33	0.36
36	α-bisabolol	14.64	12.02	2.25	1.75
37	----	0.06	-	0.45	0.44
38	----	0.33	-	0.19	0.28
39	----	-	0.32	0.56	0.08
40	----	0.50	-	-	0.69
41	----	0.06	-	-	1.58
42	----	0.39	0.62	1.39	0.44
43	----	-	0.30	0.86	0.58
44	----	0.12	0.50	0.08	0.29
45	----	-	-	-	-
46	----	-	-	-	-
47	----	-	-	-	-
48	----	-	-	-	-
49	----	7.48	0.94	-	-

examined populations. The best combinations of terpenoid characters are reported in some triangular graphs, shown in fig. 4. It is evident that borneol, isoborneol and nerolidol are the terpenes that best discriminate the three taxa. It is to be noted that borneol, isoborneol, nerolidol are all oxygenated terpenes with an alcoholic group. In the space definited by chemical variables, taken three by three, the taxa are

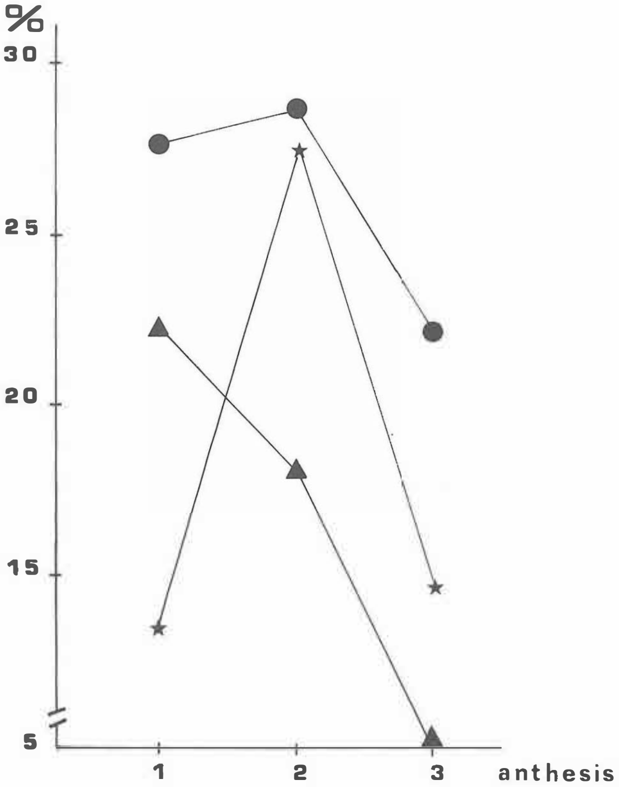


Fig. 2 — Variation of α-thujone (*), β-caryophyllene (●) and borneol (▲) content in *S. bertolonii* during the anthesis.

clearly identifiable and sufficiently isolated. A' population from Dalmatia is an obviously very close position to A population from the Karst Plateau. The terns borneol, α-bisabolol, β-cariophyllene put the A taxon in a more isolated position and accomunate B and C taxa.

Table 4 shows the percentages of the monoterpene derivatives, which allow the identification of each taxon. *S. officinalis* is recognized by percentages of α-bisabolol $\geq$ 15.16% and 1,8 cineole $\geq$0.83%; *S. verticillata* by percentages of borneol $\geq$ 15.16%; *S. bertolonii* by percentages of nerilidol $\geq$ 2.32%. All terpene derivatives (markers) are oxygenated, in particular alcohols.

In order to visualize the chemical relationship among the taxa, dissimilarities were computed (Table 5) and a multivariate analysis was performed. The two clusters of the dendrogram (fig. 5) join together the most similar populations. In the first cluster the two *S. officinalis* populations are joined at high similarity; in the second *S. bertolonii* and *S. verticillata* are joined at a high degree of similarity. The clusters are linked by a very low degree of similarity.

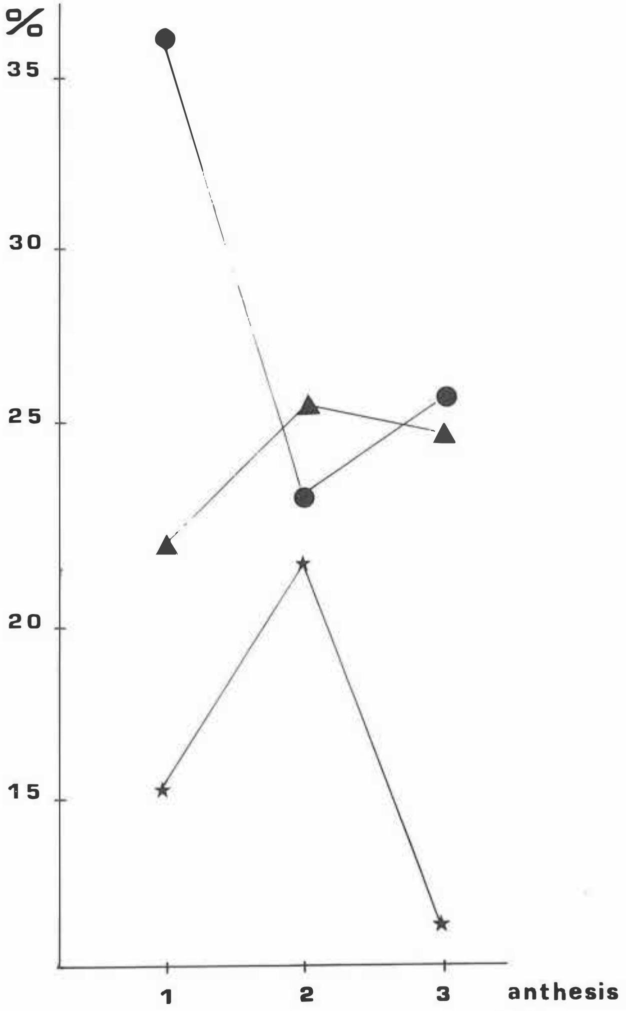


Fig. 3 — Variation of α-thujone (*), β-caryophyllene (●) and borneol (▲) content in *S. verticillata* during the anthesis.

Discussion

A study of the occurence of various monoterpenes in some other *Salvia* species (*leucophylla, mellifera, spathacea* and *apiana*) from different localities was carried out to determine their usefulness as taxonomic characters and as markers for studies of hybridization and introgression (Emboden & Lewis, 1967). Other attempts were made to relate terpene content to taxonomy in various groups of plants (Swain, 1963a, 1963b; Alston & Turner, 1963; Hegnauer, 1962) especially after the advent of modern and sophisticated methods of analysis. Therefore the

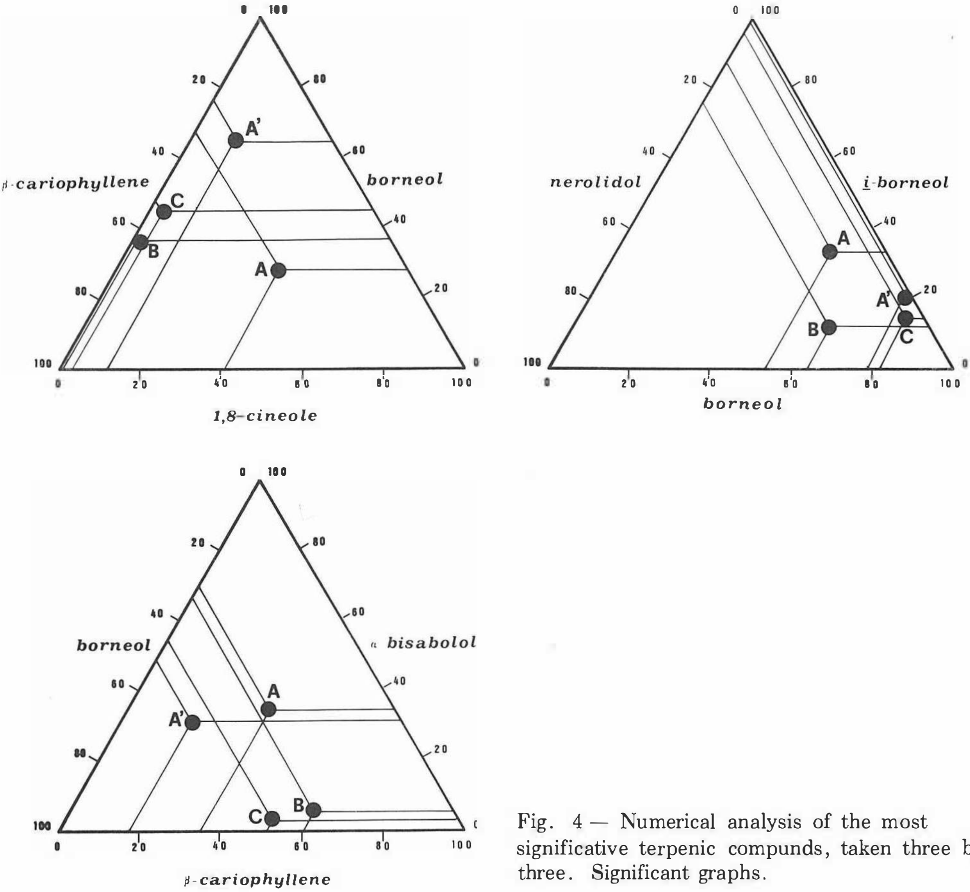


Fig. 4 — Numerical analysis of the most significative terpenic compunds, taken three by three. Significant graphs.

purpose of this study was to provide a new set of characters that might further clarify inter-specific relationships.

The difference in terpene content between species primarly concerns the relative abundance of the various terpenes rather than the presence of absence of a given compound. However each species has a characteristic terpene composition that permits its identification on the basis of chemical data. Statistical comparison of chemical data demonstrates the validity of chemical markers for taxonomic purposes.

In our study quantitative differences in essential oils carried taxonomic value at the level of species. The classification of the three taxa on a chemical basis confirms the morphological classification. Biosyntheses of some terpenes seem to occur in more immature foliage while conversion into derivative terpenes occurs in older foliage. Our results showed some significant differences between young and older leaves: in *S. officinalis* older leaves, borneol and bornyl acetate increase, while camphor decreases and finally disappears. Camphor is presumably a breakdown

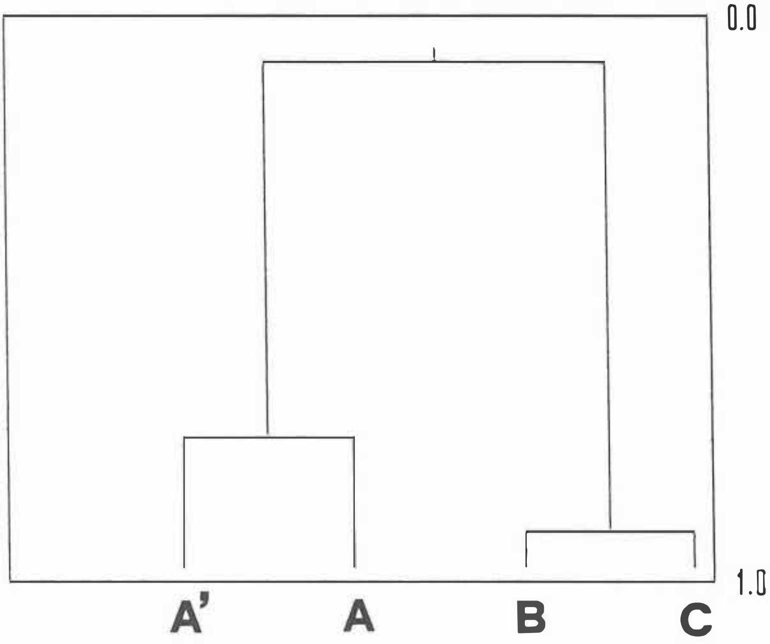
Table 3 — Terpene pattern groups and main components present in the *Salvia* populations.

Terpene groups	**A'**	**A**	**B**	**C**
Monoterpene hydrocarbons	1.42	8.57	1.07	1.63
Oxygenated monoterpenes	66.99	58.60	42.73	51.09
Sesquiterpene hydrocarbons	14.69	13.18	32.17	33.35
Oxygenated sesquiterpenes	15.84	13.65	3.18	1.82
Acyclic sesquiterpenes (nerolidol)	0.27	2.32	5.89	1.72
α + β thujone	17.25	15.22	22.36	19.84
Camphor	2.64	3.89	0.68	0.48
1,8-cineole	4.78	16.84	0.27	0.93

product or the result of an interconversion; the variation of the former is probably related to the distribution of morphologically different trichomes. Three types of trichomes are predominant in this species: capitate, nonglandular and peltate. The oil is produced by the glandular trichomes, which are small and scarce in the young leaves. Their number increases with the onthogenetic cycle. As the anthesis proceeds the contents in monoterpene hydrocarbons tend to increase (Corsi et al., 1982) and correspondently the content in oxygenated terpenes decreases. In *S. officinalis* a certain biogenetic interdependence with inversed correlation among 1,8-cineole, β-cariophyllene, isoborneol and α-thujone and among borneol and α-bisabolol was noted. In *S. verticillata* and *S. bertolonii* there seems to be an inversed correlation between the biosynthesis of borneol and β-cariophyllene.

Table 4 — Terpene components for the characterization of *Salvia* populations.

	A	C	B
1,8-cineole	16.84	0.93	0.27
α-bisabolol	12.02	1.75	2.25
borneol	10.45	24.16	15.16
nerolidol	2.32	1.72	5.87



vertical sequence (dissimilarity) - top/down
59.70327 231.0577 898.043

Fig. 5 — Dendrogram of terpene similarities among *Salvia* species. Similarities based on Jaccard coefficients.

Table 5 — Dissimilarity coefficients based on terpenoids profiles of *Salvia* species.

	A'	**A**	**B**	**C**
A'	0	21.4968	27.2843	25.9968
A		0	26.6700	29.6493
B			0	10.9273
C				0

The biogenetic interdependence between β-thujone and borneol in *S. officinalis* has already been noted (Poldini et al., 1971; Corsi et al., 1982), whereas the correlation between 1,8-cineole and thujones has been never recorded. All the taxa show a high percentage of thujones, well-know substances of high toxicity (epilectic action). Thanks to the significant chetonic fractions, present in all taxa, they would act as remarkable stimulants, vermifuges, antispasmodics. The taxon poorer in chetones and richer in hydrocarbons should be able to perform an anhydrotic action (Duquenois, 1972).

Acknoledgments: This research was supported by funds of Italian Ministry of Public Instruction (MPI 60%).

Special thanks to the dr. P. Ganis of the Department of Biology of Trieste University for assistance in processing data.

Riassunto

Le foglie di alcune specie spontanee di *Salvia* L. sono state raccolte in tre momenti dell'antesi e il loro olio essenziale è stato analizzato mediante GC/GCMS. La composizione terpenica è molto variabile durante l'antesi. *S. bertolonii* è la specie più ricca in α-tujone; *S. officinalis* è caratterizzata da alte percentuali di 1,8-cineolo, 4-terpineolo, isoborneolo e α-bisabololo; in *S. verticillata* sono presenti alte percentuali di borneolo e β-cariofillene. In tutte le tre specie, l'α-tujone è presente in quantità nettamente superiori al β-tujone. I tre taxa sono individuabili sulla base di specifiche combinazioni di derivati terpenici. L'analisi multivariata dei dati chimici ha consentito di individuare il grado di affinità tra i tre taxa e di chiarire il loro status chemotassonomico. Alcuni componenti terpenici dell'olio di *Salvia* hanno interessanti proprietà farmaceutiche.

References

Alston R.E. & Turner B.L., 1963. *Biochemical Systematics*. New Jersey, Prentice Hall, New York.

Banthorpe D.V., Mann Y. & Poots I., 1977. *1,2-Hydrogen-Shifts in the Biosynthesis of the Thujone Skeleton*. Phytochemistry, *16*: 547-550.

Bellomaria B., Perfumi M., Valentini G. & Arnold N., 1988. *Caratteristiche chimiche e farmacobotaniche dell'olio essenziale di tre specie di Salvia del Mediterrannneo orientale*. Atti II Conv. "La ricerca Farmaco-botanica", Siena, 3-5 ottobre.

Brieskorn C.H. & Kapadia Z., 1980. *Bestandteile von Salvia officinalis*. Planta Medica, *38*: 86-90.

Cenci C.A. & Calvarano I., 1967. *Caratteristiche degli oli essenziali di alcune salvie perugine*. Essenze e Deriv. Agrumari, *3:* 141-178.

Coassini Lokar L., Maurich V., Mellerio G., Moneghini M. & Poldini L., 1987. *Variation in terpene composition of Artemisia alba (Compositae) in relation with environmental conditions*. Biochem. Syst. & Ecol., *15* (3): 327-333.

Corsi Garbari G., Coassini Lokar L. & Pagni A., 1984. *Biological and phytochemical aspects of Valeriana officinalis*. Biochem. Syst. & Ecol., *12:* 57-62.

Corsi G., Morelli I., Pagni A.M., Bini Maleci L., 1982. *Nuove acquisizioni su salvie coltivate in Toscana*. Atti Soc. Tosc. Sci. Nat. Pisa, Mem. Serie B., 89: 29-45.

Dalferth S., 1963. *Die Mono- und Sesquiterpenoide einiger ätherisher Salbeiöle*. Dissertation zur Erlangung des Doktorgrades der Hohen Naturwissenschaft. Fakultät der Julius-Maximilians-Universität zu Wurzburg.

Devetak Z. & Cenci C.A., 1967. *L'essenza di Salvia officinalis del Montegro, Yugoslavia*. E.P.P.O.S., *49*: 86-88.

Devon T.K. & Scott A.I., 1972. *Handbook of Naturally Occuring Compunds*. Vol II. Academic Press, New York.

Duquenois P., 1972. *Salvia officinalis L. Antique panacèe et condiment de chois*. Quar. Y. Crude Drug. Res., *12:* 1841-1849.

Emboden W.A. & Lewis H.Jr., 1967. *Terpenes as taxonomic characters in Salvia section Audibertia*. Brittonia, *19:* 152-160.

Feoli E., Lagonegro M. & Oroloci L., 1982b. *Information analysis in vegetation research*. Univ. Trieste and Univ. of Western Ontario, London (Canada).

Feoli E., Lagonegro M. & Zampar A., 1982a. *Classificazione e ordinamento della vegetazione. Metodi e programmi di Calcolo*. Consiglio Naz. delle Ricerche, AQ/5/35.

Guenther E., 1949. In: *The essential Oils*, Vol III, Van Nostrand, New York.

Hegnauer R., 1962. *Chemotaxonomie der Pflanzen*. Birkhauser, Basel.

Holemann M., Berrada M., Bellakldar J., Jlidrissi A & Pinel R., 1983. *Etude Chimique Comparative de Huiles Essentielles de Salvia officinalis, S. aucheri, S. verbenaca, S. phlomoides et S. argentea*. Fitoterapia, *LV* (3): 143-148.

Kubeczka K.H. & Ullmann I., 1983. *Chemotypen by Melopospermum peloponnesiacum* (L.) Koch. Z. Naturforsch., *38*c: 189-193.

Kuštrak D., Kuftinec J. & Blažević N., 1984. *Yields and composition of Sage oils from different regions of the yugoslavian Adriatic coast*. J.of Nat. Products, *47:* 520-524.

Lausi D.R., Poldini L., 1962. *Il paesaggio vegetale della costiera triestina*. Boll. Soc. Adr. Scienze, LII - nuova serie.

Nie H., 1970. *Statistical Package for the Social Sciences (SPSS)*. Mac Graw Hill. New York.

Pitarevic I., Kuftinec J., Blazevic N. & Kustrak D., 1984. *Seasonal Variation of Essential Oil Yield and Composition of Dalmatian Sage, Salvia officinalis*. J. of Natural Products, *47*: 409-412.

Poldini L., 1978. *La vegetazione petrofila dei territori carsici nord-adriatici*. Mitteil. Ostalp.-dinar. Ges. Vegetationsk., *14:* 297.

Poldini L., Sancin P. & Sciortino T., 1971. *Contenuto in olii essenziali della Salvia officinalis nel Carso triestino*. Univ. Studi Trieste, Fac. Scienze, Ist. Botanica, n. 74: 5-31.

Servettaz O., Mellerio G. & Venturella G., 1984. *Ricerche chemotassonomiche su Seseli bocconi Guss*. Atti 2° Conv. Naz. Soc. Ital. Fitochimica, Roma, 6-8 giugno.

Steinneger E. & Hansel R., 1972. In: *"Lehrbuch der Pharmakognosie"*, Berlin: Springer-Verlag.

Swain T. (Ed.) (1963a). *Chemical Plant Taxonomy*, Academic Press, New York.

Swain T. (Ed.) (1963b). *Comparative Phytochemistry*, Academic Press, New York.

Tucakov M.Y., 1952. *Variation de la teneur en essence dans les differents organes du Salvia officinalis L. cultivè. Ann. Pharm. Franc., 428-433.*

Vernet P., Guillerm J.L. & Gouyon P.H., 1977. *Le polimorphisme chimique de Thymus vulgaris L.. Repartition des formes chimiques in relations avec certains facteurs ècologiques. Oecol. Plant., 12: 159-180.*

Wishart D., 1975. *Clustan 1c User Manual* Computer Centre University College, London.

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