Distribution and clinal variation of Salvia fruticosa Mill. (Labiatae) on the island of Crete (Greece)

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Distribution and clinal variation of *Salvia fruticosa* Mill. *(Labiatae)* on the island of Crete (Greece)

Abstract

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The distribution of the aromatic species *Salvia fruticosa* on the island of Crete (S Greece) is presented in a grid map. Discriminant analyses of the variation in morphological features and essential oil content of 34 *S. fruticosa* populations from all over the distributional range on the island reveal that both the morphological and chemical variation form a W-E directed cline.

Introduction

Salvia fruticosa Mill. *(Labiatae)* is a native species of the E Mediterranean basin distributed from Italy, Sicily and Cyrenaica through the S Balkan Peninsula (Albania and Greece) to W Syria (Hedge 1982, Greuter & al. 1986). In Greece it occurs in almost all littoral areas of the mainland as well as on the Ionian and Aegean Islands, forming extended populations in the Mediterranean ecosystems. *S. fruticosa* is known under the vernacular name "faskomilo" and is widely used as a culinary herb and in local medicine (Fragaki 1969).

A number of names given by earlier taxonomists to distinguish different taxa, now treated as synonyms (Greuter & al. 1986), suggest that it is a variable species. During our previous studies on the Cretan *Labiatae* we observed that a number of morphological characters as well as the essential oil content of *Salvia fruticosa* populations vary within the distributional range of the species on the island. The question arose whether this variation possibly corresponds to the climatic conditions on this island. Although Crete entirely belongs to the Mediterranean climatic zone, it is characterized by significant climatic differences, mainly concerning the annual precipitation, the mean annual temperature and the annual duration of sunshine. Furthermore, the topographic diversity of the island affects strongly the local climatic conditions (Pennas 1977, Kotini-Zambaka 1983, Hager 1985, Egli 1993). This study therefore aims to analyse the variation in morphological features and essential oil content of selected Cretan populations of *S. fruticosa* in relation to their provenances within Crete.

Material and methods

The Cretan distribution data of *Salvia fruticosa* (Fig. 1) are based on both our own collections deposited in TAU and on material examined from the herbaria ATH and B (abbreviations

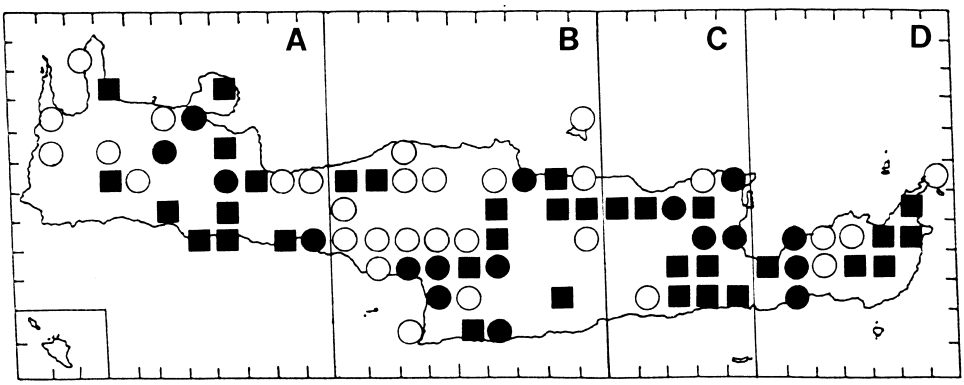

Fig. 1. Distribution of *Salvia fruticosa* on the island of Crete based on specimens seen (solid symbols) and literature sources (open symbols). – ■: localities of the populations analysed in this study; A-D: phytogeographical divisions following Greuter (1971), A: W Crete, B: Central Crete, C: Lasithi area, D: Sitia peninsula; grid based on 8.25 km^2 squares according to Turland & al. (1993).

according to Holmgren & al. 1990). A list of specimens examined is available from the authors upon request. In addition, literature sources were taken into account (Halàcsy 1902, Rechinger 1942a,b, Turland & al. 1993).

The morphological features and essential oil content were analysed in 34 populations (see Fig. 1) and a total of 136 individuals collected by the authors. In order to avoid variability due to different developmental stages, plants used for both the morphometric analysis and essential oil content estimation, were consistently collected during summer and in post-flowering stage.

For the morphometric analysis the specimens were scored with regard to 10 vegetative characters (Tab. 1).

For the estimation of the essential oil content, the samples were subjected, after air-drying, to hydrodistillation in a Clevenger apparatus for 2 h. The essential oil content is expressed in ml 100g^{-1} dry weight.

Discriminant analysis by means of Wilk's lambda stepwise method and the appropriate programs of SPSS (Norussis 1991) was carried out in order to examine if the variation observed is related to the geographical distribution of the species on the island.

Tab. 1. Characters used for the morphometric analysis of *Salvia fruticosa* (at post-flowering stage).

Characters	Scores
Length of non-woody part of branches [cm]	
Number of leaf verticillaster per branch	
Distance of leaf verticillaster [cm]	
Branch length/number of leaf verticillaster	
Leaf length [mm]	
Leaf width [mm]	
Colour of upper (adaxial) leaf face	1: dark green; 2: light green
Leaf blade	1: flat; 2: slightly canaliculate; 3: strongly canaliculate
Leaf margin	1: flat; 2: slightly undulate; 3: strongly undulate
Leaf dissection	1: entire; 2: shallowly three-lobed; 3: deeply three-lobed

Results

Distribution

Salvia fruticosa presents a continuous distribution all over the island (Fig. 1). It has been found at altitudes between sea level and 900 m. Jahn & Schönfelder (1995) also report occurrences up to 1350 m. We have found that *S. fruticosa* dominates particularly in Central Crete as well as in the Lasithi area and the Sitia peninsula, where it is accompanied by *Phlomis lanata* Willd. and forms extended populations. In W Crete it is less common and coexists with, or is replaced by, the Greek endemic *Salvia pomifera* L. subsp. *pomifera* (Karousou 1995).

Salvia fruticosa, similar to *Phlomis lanata* Willd., *Asperula rigida* Sm., and *Micromeria juliana* (L.) Reichenb., is one of the characteristic species of the suballiance Phlomido fruticosae-Euphorbienion acanthothamni, occurring on calcareous substrates in strongly degraded areas (Jahn & Schönfelder 1995).

Variation of morphological characters and essential oil content

Several vegetative characters vary both between and within the different Cretan populations of *Salvia fruticosa*. As a result of the discriminant analysis on the character set of Tab. 1 using as predefined groups the 34 populations, the discriminant scores of the population centroids along functions 1, 2 and 3 (accounted for 38.0 %, 24.3 % and 16.0 % of the total variance respectively) are given in Fig. 2 for the four phytogeographical regions of Crete. As can be seen, the discriminant scores of the population centroids are changing gradually along a W-E direction. The population centroids from W Crete and Sitia peninsula form two opposite "poles", whereas those from Central Crete and the Lasithi area are scattered between them.

In order to elucidate the affinities among the different populations, a second discriminant analysis was run on the same data set of Tab. 1, using as predefined groups the four phytogeographical divisions of the island. The characters finally used in this analysis and their relative usefulness for discrimination among the groups are given in Tab. 2. As a result of the second

Tab. 2. Characters used in the second discriminant analysis and their relative usefulness (F-to-remove values) in discrimination among groups.

Variables	F-to-remove
Leaf length	10.60
Leaf dissection	3.86
Leaf margin	2.62
Colour of the adaxial leaf face	1.97
Leaf blade	1.74
Number of leaf verticillaster	1.65

Tab. 3. Classification results of *Salvia fruticosa* 4-group material, corresponding to the four parts of Crete, according to the second discriminant analysis.

		Predicted group membership (%)			
	n	W Crete	Central Crete	Lasithi area	Sitia peninsula
W Crete	42	83.3	11.9	4.8	0
Central Crete	37	21.6	40.5	21.6	16.2
Lasithi area	28	0	6.9	62.1	31.0
Sitia Peninsula	29	0	3.6	42.9	53.5

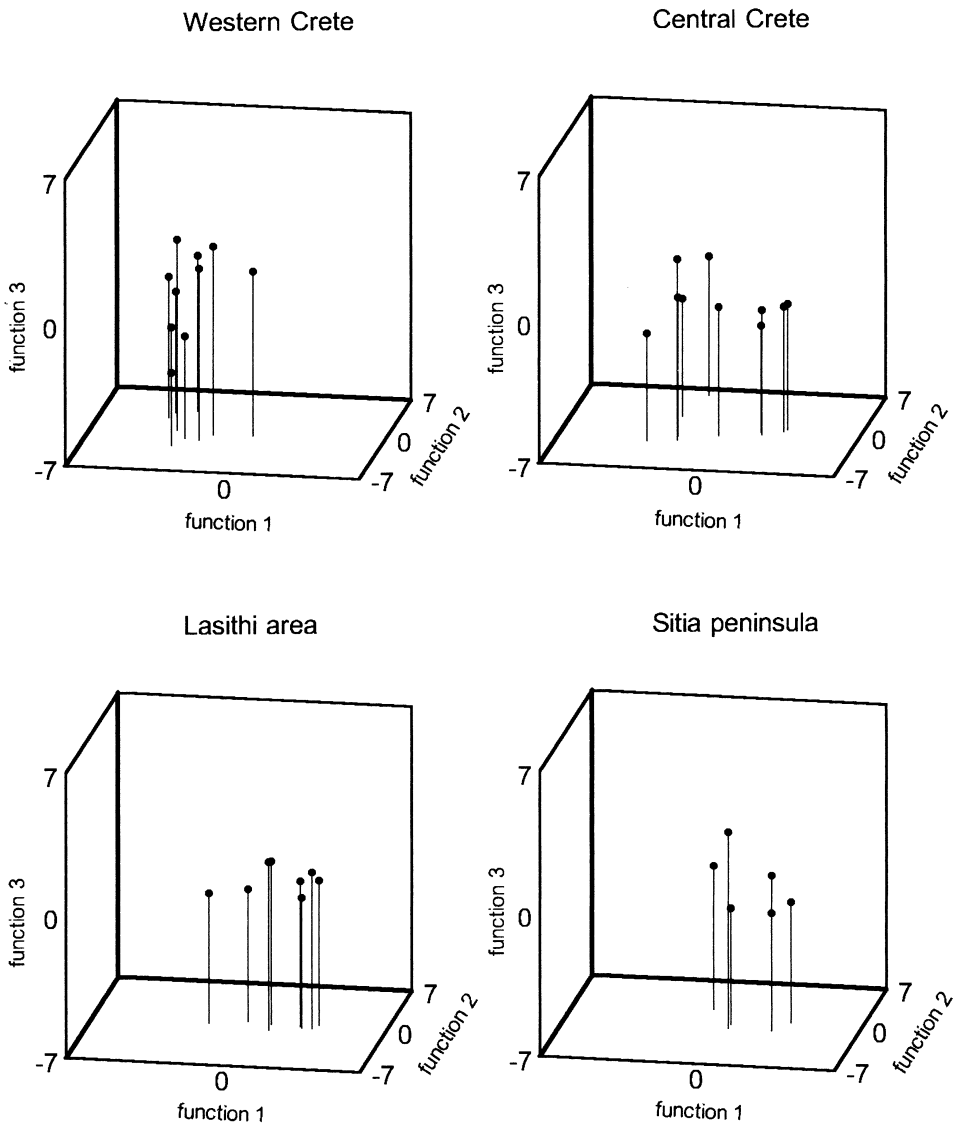

Fig. 2. Discriminant scores of *Salvia fruticosa* population centroids, along their horizontal distribution in Crete, as provided by the first discriminant analysis.

discriminant analysis, the different *S. fruticosa* populations are grouped into four geographically related clusters (Fig. 3A) by the ranges of their discriminant scores along function 1 (accounted for 86.2% of the total variance), which is mainly based on the leaf length, the leaf blade type and the leaf colour.

The classification results (Tab. 3) suggest that plants from W Crete form the most homogenous group, whereas those from Central Crete are very variable. Furthermore, plants from the Lasithi area and the Sitia peninsula present very close affinities and are morphologically distant from plants of W Crete.

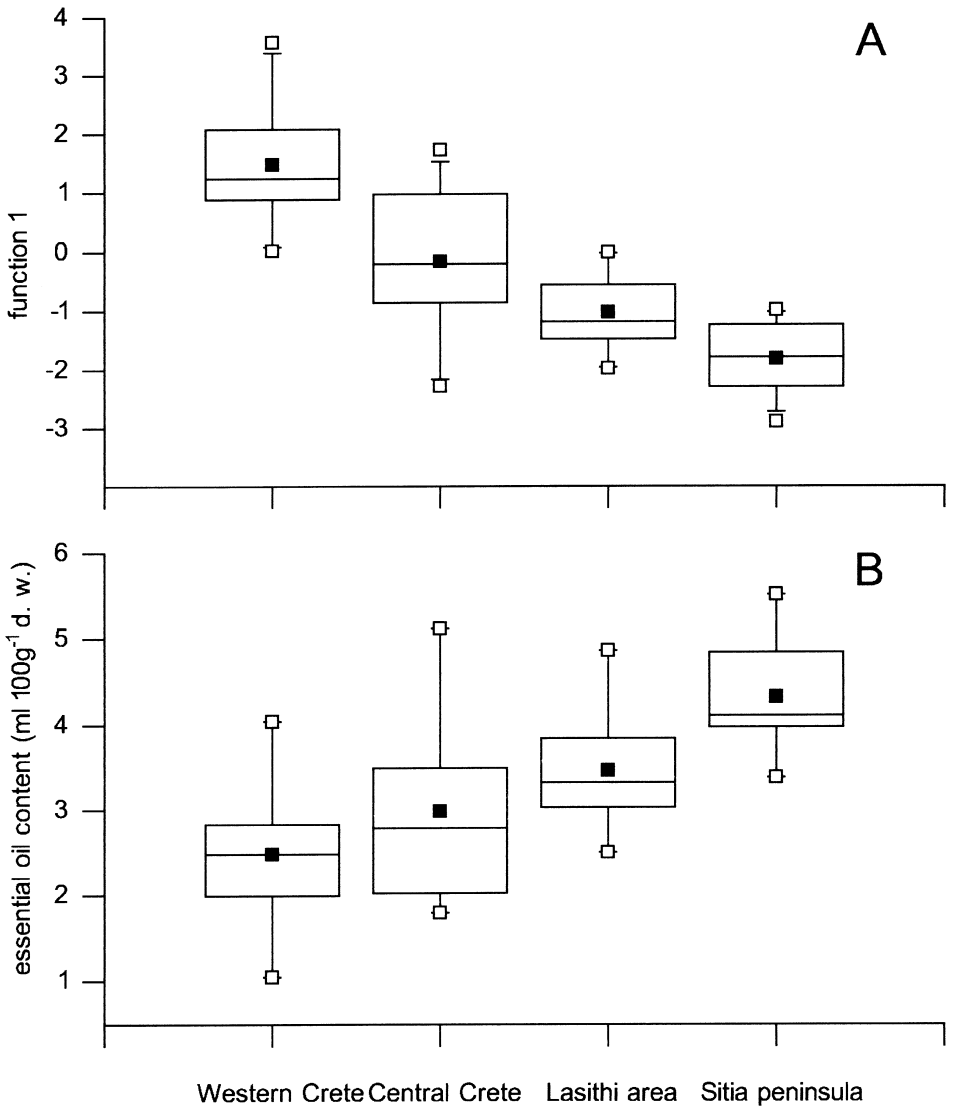

Fig. 3. A: Box plots of the discriminant scores of *Salvia fruticosa* plants provided by the second discriminant analysis. – B: Essential oil content variation of *Salvia fruticosa* plants on the basis of the geographical entities of A (horizontal lines of the boxes show the 25, 50 and 75th percentile, while the outer limits of the whiskers, and/or open squares, show the min. and max. values; solid squares indicate the average value).

The variation of the essential oil content of the populations examined is presented in Fig. 3B on a geographical basis, as derived from the first discriminant analysis. The essential oil content increases gradually from W Crete towards the Sitia peninsula. The lowest value has been found in W Crete (1.0 %, Samaria gorge), the highest value in the Sitia peninsula (5.5 %, near the village of Lithines). However, extremely high values (4.0 %) sporadically are observed all over the island.

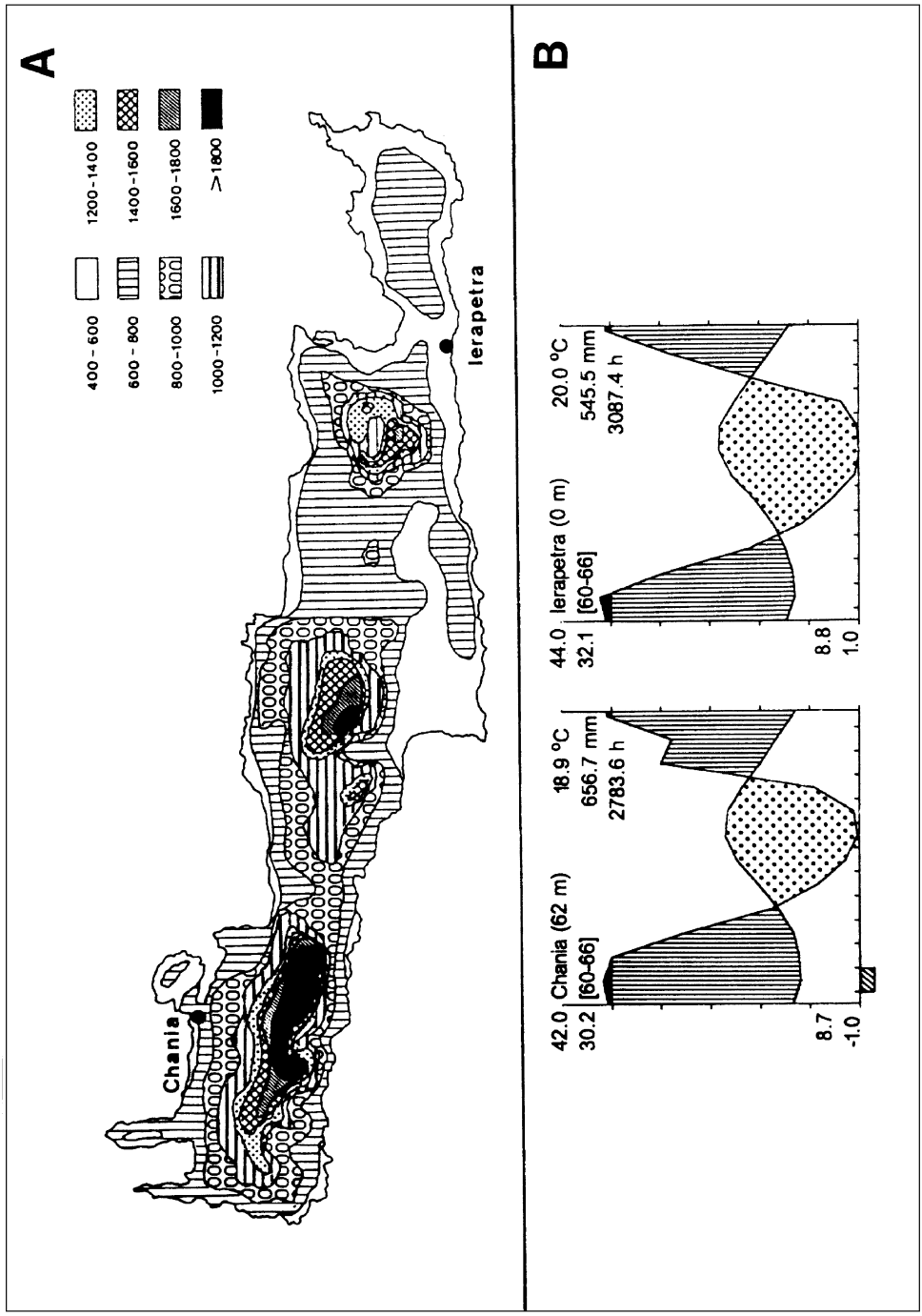

Fig. 4. A: Map of the mean annual rainfall (in mm) on Crete after Hager (1985). – B: Ombrothermal diagramms (after Walter & Lieth 1960) of the meteorological stations of Chania (35° 30′ N, 24° 02′ E) and Ierapetra (35° N, 25° 44′ E). Climatic data of the stations after Pennas (1977).

The above findings suggest that the Cretan *Salvia fruticosa* plants are very variable with respect to their morphological characters. The application of discriminant analysis on the given character complex revealed that the variation observed is linked with the horizontal distribution of the species on the island. The same variation pattern has been found with respect to the essential oil content of the different populations. The most striking differences, both morphological and chemical, have been observed between plants of W Crete and the Sitia peninsula.

Discussion

The discriminant analyses indicate that the morphological variation of *Salvia fruticosa* in Crete results in the formation of a cline (Figs. 2, 3A, Tab. 3). Plants from W Crete are characterized by long branches with few and distant leaf verticillasters, and by large, entire, dark green leaves with flat blade and margins. These characters change gradually towards the eastern part of the island, and in the Sitia peninsula the plants present the shortest branches with numerous, dense leaf verticillasters, and the smallest, light green, strongly canaliculate-undulate, deeply three-lobed leaves. The essential oil content increases progressively towards E Crete (Fig. 3B). The lowest (<3.0 %) and the highest (>4.0 %) values correspond to plants growing on W Crete and the Sitia peninsula, respectively.

The variation of *Salvia fruticosa* linked with its occurrence on Crete follows the local climatic W-E gradient. As can be seen in Fig. 4 the total annual precipitation is decreasing, whereas the mean annual temperature and the total annual duration of sunshine are increasing from the western to the eastern part of the island.

Szwarcbaum (1982) indicated that *Salvia fruticosa* plants cultivated in Israel are presenting a different morphology under conditions of thermal and water stress. As transpiration cannot overcome the heat load, plants decrease their surface area through production of smaller and canaliculate leaves. Furthermore, field measurements have shown that the leaf temperature in canaliculate leaves is approximately 6 ºC lower than in flat leaves. Canaliculate leaves expose to the sunshine their abaxial face whose reflection of the solar radiation, due to a dense trichome layer, is higher than that of the less hairy adaxial face. On the other hand, the increase of leaf dissection observed towards E Crete could also be attributed to the most severe xerothermic conditions on this part of the island. Lewis (1972) showed that the leaves of *Geranium sanguineum* become more dissected as we move from wetter woodland sites to the more xeric steppe. An increase in leaf dissection results in a lowering of the boundary layer resistance, an increase of the diffusion of water vapour and, consequently, in an increase of the heat flow from the leaf surface (Fitter & Hay 1987, see also references therein).

The differences in essential oil content of *Salvia fruticosa* plants from the western and the eastern part of Crete may also be a response to the different climatic conditions. It has been shown that in several Greek *Labiatae* taxa an increase in their essential oil content is associated with the more warm and arid areas of the country (Kokkini & al. 1991, 1994, Vasiliadou & al. 1994, Burse & al. 1995).

A number of taxa described from the E Mediterranean are nowadays considered as synonyms of *Salvia fruticosa* (Greuter & al. 1986). Their original descriptions suggest that they are characterized either by three lobed leaves (*S. triloba* L. fil.), or very small leaves (*S. libanotica* Boiss & Gaill.; *S. cypria* Kotschy; *S. lobryana* Aznav.). This indicates that the clinal variation in the vegetative characters of *S. fruticosa* observed on Crete similarly occurs outside Crete. An extensive study of the morphological variation of *S. fruticosa* considering its total distribution range could thus provide a meaningful pattern, which may prove taxonomically applicable.

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