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Contribution to the study of the Greek insular flora: The chasmophytic flora of Crete.

Abstract

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In the present study 100, almost vertical, limestone cliffs on the island of Crete have been investigated floristically and a total of 614 taxa has been registered. According to the degree of specialization to the cliff habitats four categories of chasmophytes have been recognized. The biological and the chorological spectra of the Cretan chasmophytic flora have been constructed and compared to the corresponding ones of the Cretan flora. Annual therophytes are almost absent from the category of the obligatory chasmophytes and the percentage of endemism (including Greek and/or Aegean endemics) comes up to 76% suggesting a positive correlation between chasmophytism and endemism. This notion is also supported by the observation that the cliffs on the western side of the island, an area rich in endemics, house also the richest and the most diverse chasmophytic flora

Introduction

The island of Crete, whose flora is one of the best studied in Greece, is very interesting because of its high percentage of endemism. For years now it has been observed that the limestone cliffs house the majority of the Cretan endemics but, up to present, no thorough floristic investigation of these habitats has been done. This was the subject of the Ph. D. thesis supported by one of the authors (Z.K.) at the University of Patras and the main results and conclusions are presented in this communication. It has also been pointed out that in the framework of this study even four species new to science have been found and described.

Material and Methods

This study has mainly been based on plant collections and field observations made during the last ten years. One hundred, almost vertical, limestone cliffs, located in different geographical positions and altitudes, have been investigated floristically (Fig. 1). Species growing at the base and at the lower part of the cliffs have not been taken into account.

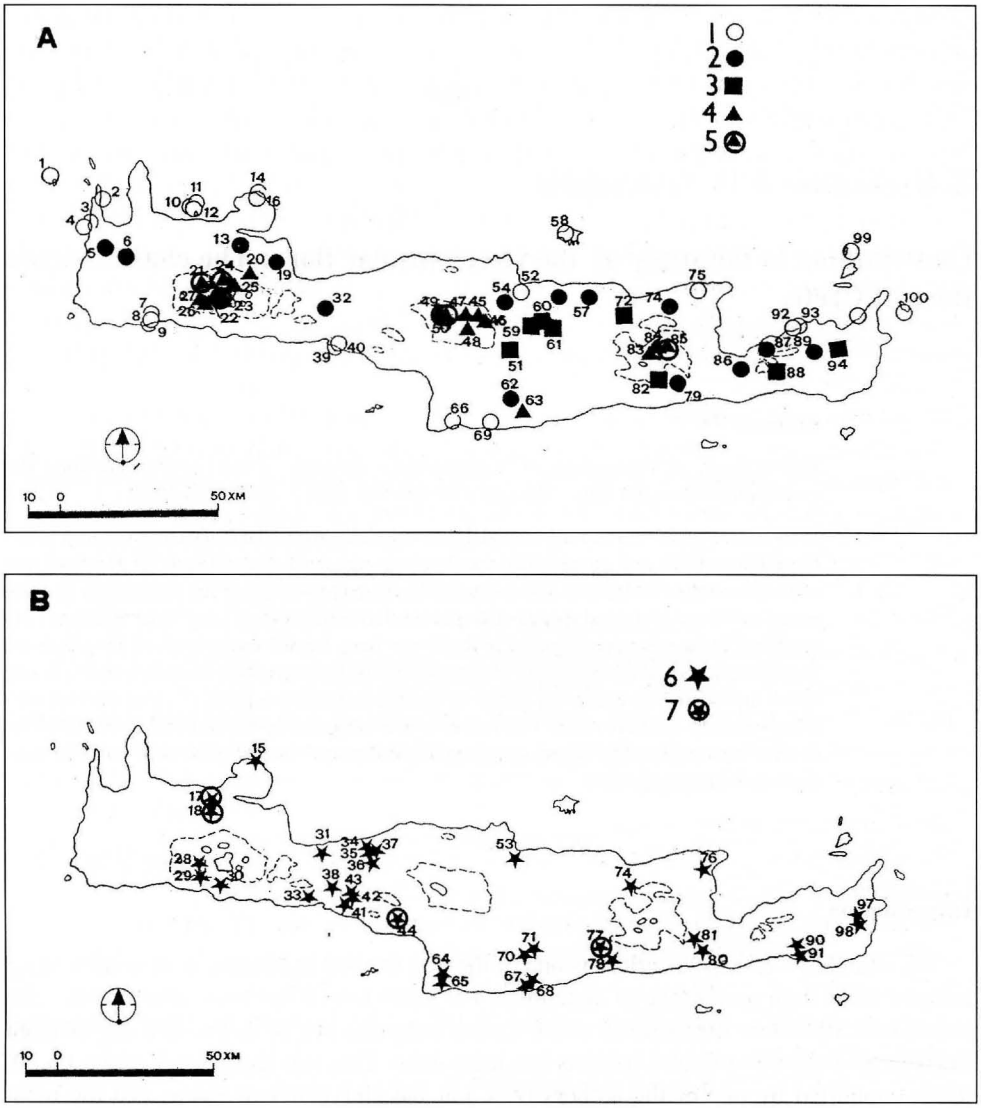

Fig. 1. Habitats type and geographical position in Crete of the cliffs investigated. A: singe cliffs 1: coasal cliffs, 2,3,4 and 5: interior cliffs at the altitutes of <500, 500-1000m, 1000-1500 and >1500m, respectively. B. Gorges' cliffs 6: cliffs of gorges ending to the sea, or more or less to the sea level. 7: Cliffs of interior gorges at the altitute of 500-1000m.

Depending on the altitude of the area studied as well as on the type of the cliffs i.e. gorges (system of two opposite cliffs) or single cliffs, the 100 cliffs investigated were classified into 7 types of habitats. Five of them correspond to single cliffs (Fig. 1A) and the other two to gorge cliffs (Fig. 1B). It should be pointed out that typical gorges do not occur in altitudes higher than 1000 m.

In the present study under the term "chasmophytic flora" the total number of plant taxa that were found on the vertical cliffs of the investigated area is included. Based on the author's field observations and experience, but also on earlier bibliography (e.g Davis 1951), the registered species have been classified in 4 major categories.

1. The obligatory chasmophytes (O. ch): The species occurring almost exclusively, on cliff's crevices.
2. The mainly chasmophytes (M. ch): The species occurring mainly on vertical cliffs and, at an evidently lower frequency, in other kinds of habitats.
3. The partially chasmophytes (P. ch): The species which are very often met on cliffs but frequently occur in other habitats as well. Species like *Allium circinatum* subsp. *circinatum*, *Centaurea raphanina* subsp. *raphanina*, *Origanum onites, Scaligeria napiformis,* belong to this category.
4. The spontaneous chasmophytes (S. ch): The species which mainly occur on - and very often characterize - other types of habitats and only occasionally are registered from cliff crevices. Species like *Anagyris foetida, Asphodeline lutea, Cichorium spinosum, Limonium graecum, Styrax officinalis* e. t. c have been classified into this category.

Species of the first two categories behave as more or less well adapted and specialized to the cliff habitats and are considered as "the true chasmophytes".

Crete has been subdivided into four phytogeographical regions (K_1, K_2, K_3, K_4 from West to East) according to Greuter (1971). Cliffs N° 1-32, 33-71, 72-85 and 86-100 belong to the subdivisions K_1, K_2, K_3, K_4, respectively.

For the chorological analysis Pignatti (1982) and Davis (1965-1985) have been taken into consideration. However, for practical reason in the present paper only 3 main chorological groups are taken into account.

1. The mediterranean elements (M).
2. The widespread elements (W), including taxa with a distribution range extending to the Mediterranean region.
3. The endemic elements; including taxa with a distribution range restricted to:
   a) The area studied (Crete and offshore islets), E1
   b) The southern Aegean area (Crete - Kasos - Karpathos), E2
   c) The Aegean area, including the Eastern coasts of mainland Greece and the Western coasts of Asia Minor, E3 and
   d) The island of Crete and the mainland of Greece. E4

The biological spectrum and the life forms categories are according to Raunkier (1934). For more information regarding the geographical sites of the investigated cliffs and the chorological and biological analysis of the chasmophytic flora, see Kypriotakis (1998).

Results & Discussion

In a total of 100 Cretan cliff habitats investigated, 614 plant taxa have been registered. This number represents about 33% of the whole Cretan flora and is very high taking into consideration that the total area of the cliffs investigated corresponds to a much smaller percentage of the total area of the island. In the framework of this investigation four

Table 1. Obligatory chasmophytes (in parenthesis the biological and chorological type of each taxon).

Allium bourgeaui ssp. bourgeaui (Gbulb, E_1)	Galium canum ssp.ovatum (Chsufrut, E3)
Anthylis aegaea (NPh, E3)	Helichrysum orientale (Chsufrut, E3)
Arenaria filicaulis ssp.graeca (Chsufrut, W.)	Helichrysum heldreichii (Chsufrut, E1)
Asperula tournefortii (Chsufrut, E3)	Hellenocarum multiflorum (Hscap, W.)
Asperula taygetea (Chsufrut, E3)	Hypericum jovis (Chfrut, E1)
Asplenium ruta- muraria ssp. ruta muraria (Hros, W.)	Hypericum amblycalyx (Chfrut, E1)
Asplenium trichiomanes - ramosum (Hros, W.)	Hypericum aciferum (Chfrut, E1)
Athamanta macedonica (Hscap, W.)	Inula candida ssp.candida (Chsufrut, E3)
Bellevalia dubia (Gbulb, M.)	Lomelosia minoana ssp.minoana (Chfrut, E1)
Brassica cretica ssp. aegaea (Chsufrut, M.)	Lomelosia minoana ssp. asterusica (Chfrut, E1)
Brassica creticassp. cretica (Chsufrut, M.)	Lomelosia albocincta (Chfrut, E1)
Bupleurum kakiskalae (Hscap, E1)	Lutzia cretica (Chsufrut, E3)
Campanula jacquinii (Chsufrut, E1)	Matthiola sinuata (Hros, M)
Campanula laciniata (Hscap, E3)	Medicago strasseri (NPh, E1)
Campanula saxatilis ssp.saxatilis (Chsufrut, E1)	Onobrychis sphaciotica (Chsufrut, E1)
Campanula trichocalycina (Hscap, M.)	Origanum dictamnus (Chsufrut, E1)
Carlina diae (Chsufrut, E1)	Origanum calcaratum (Chsufrut, E3)
Centaurea argentea (Chsufrut, E3)	Petromarula pinnata (Hros, E1)
Centaurea lancifolia (Hscap, E1)	Petrorhagia dianthoides (Hcaesp, E1)
Centaurea poculatoris (Hscap, E1)	Potentilla speciosa (Chsufrut, M)
Centaurea redempta ssp. redempta (Hscap, E1)	Rosa heckeliana ssp. heckeliana (Chfrut, W.)
Cephalaria squamiflora ssp. squamiflora (Chsufrut, E3)	Rosa dumalis (NPh, W.)
Cheilanthes persica (Hros, W.)	Sanguisorba cretica (Hscap, E1)
Convolvulus argyrothamnos (Chfrut, E1)	Scariola acanthifolia (Hscap, E3)
Crepis auriculifolia (Hscap, E1)	Scrophularia heterophylla (Chsufrut, M.)
Daphne jasminea (Chfrut, E4)	Securigera globosa (Chsufrut, E1)
Dianthus fruticosus ssp. amorginus (Chsufrut, E3)	Serratula cichoracea ssp. cretica (Thscap, E1)
Dianthus fruticosus ssp. creticus (Chsufrut, E1)	Seseli gummiferum ssp. crithmifolium (Hscap, E3)
Dianthus juniperinus ssp. kavusicus (Chsufrut, E1)	Sesleria doerfleri (Hcaesp, E1)
Dianthus juniperinus ssp. aciphyllus (Chsufrut, E1)	Silene fabaria (Chsufrut, E3)
Dianthus juniperinus ssp. idaeus (Chsufrut, E1)	Silene antri-jovis (Chsufrut, E1)
Dianthus juniperinus ssp. juniperinus (Chsufrut, E1)	Silene gigantea (Hscap, M.)
Dianthus juniperinus ssp. bauhinorum (Chsufrut, E1)	Silene fruticosa (Chsufrut, M.)
Dianthus fruticosus ssp. occidentalis (Chsufrut, E3)	Silene vulgaris ssp. suffrutescens (Hscap, E3)
Dianthus fruticosus ssp.sitiacus (Chsufrut, E1)	Sorbus aria ssp. cretica (MPh, W.)
Dianthus juniperinus ssp. pulviniformis (Chsufrut, E1)	Sorbus umbellata ssp. umbellata (MPh, W.)
Dianthus juniperinus ssp. heldreichii (Chsufrut, E1)	Staehelina fruticosa (Chsufrut, E3)
Eryngium ternatum (Hscap, E1)	Staehelina petiolata (Chsufrut, E1)
Euphorbia sultan-hassei (NPh, E1)	Teucrium cuneifolium (Chsufrut, E1)
Ferulago thyrsiflora (Hscap, E1)	Verbascum arcturus (Chsufrut, E1)

Table 2. Mainly chasmophytes (in parenthesis the biological and chorological type of each taxon).

Achillea cretica (Chsufrut, M.)	Galium fruticosum (Chsufrut, E1)
Allium callimischon ssp.haemostictum (Gbulb, M.)	Galium graecum ssp. pseudocanum (Chsufrut, E1)
Allium platakisii (Gbulb, E1)	Galium graecum ssp.graecum (Chsufrut, E3)
Amelanchier ovalis ssp.cretica (NPh, W.)	Galium murale (Thscap, W.)
Anthyllis vulneraria ssp. rubriflora (Hscap, M.)	Hieracium schmidtii (Hros, W.)
Arabis alpina (Hscap, W.)	Hypericum aegypticum (Chfrut, M.)
Arenaria fragilima (Chsufrut, E4)	Inula pseudolimonella (Chsufrut, E1)
Arenaria muralis (Thscap, E3)	Limonium cornarianum (Chsufrut, E1)
Arenaria cretica (Chsufrut, W.)	Linum arboreum (Chsufrut, E3)
Arthrocnemum macrostachyum (Chsucc, M.)	Melica ramosa (Hcaesp, M.)
Asperula pubescens (Chsufrut, E1)	Melica rectiflora (Hcaesp, E3)
Asplenium aegaeum (Hros, W.)	Muscari dionysicum (Gbulb, E3)
Asplenium lepidum ssp. haussknechtii (Hros, W.)	Muscari commutatum (Gbulb, M.)
Asplenium lepidum ssp.lepidum (Hros, W.)	Odontites linkii ssp.cretica (Chsufrut, E3)
Asplenium creticum (Hros, E1)	Ornithogalum creticum (Gbulb, E3)
Aurinia saxatilis ssp. megalocarpa (Chsufrut, M.)	Parietaria lusitanicassp. lusitanica (Thrept, M.)
Brachypodium distachyon (Thcaesp, M.)	Parietaria cretica (Hscap, M.)
Bromus tomentellus (Hcaesp, W.)	Phagnalon graecum (Chsufrut, M.)
Campanula aizoides (Hscap, E4)	Piptatherum coerulescens (Hcaesp, W.)
Campanula pelviformis (Hscap, E1)	Poa timoleontis (Hcaesp, W.)
Campanula tubulosa (Hscap, E1)	Polypodium cambricum ssp. australe (Grhiz, W.)
Campanula hierapetrae (Hscap, E1)	Prasium majus (Chsufrut, W.)
Capparis spinosa ssp.rupestris (NPh, M.)	Ptilostemon chamaepeuce (NPh, M.)
Celtis tournefortii (NPh, W.)	Ptilostemon gnaphalodes ssp. pseudofruticosus (NPh,
Ceterach officinarum ssp. officinarum (Hros, W.)	E4)
Cheilanthes maderensis (Hros, W.)	Ranunculus creticus (Hscap, E3)
Cosentinia vellea (Hros, W.)	Rhamnus lycioides ssp. oleoides (NPh, W.)
Crepis fraasii (Grhiz, M.)	Rosularia serrata (Chsucc, E3)
Cymbalaria microcalyx ssp. dodekanesi (Hscap, E3)	Salsola carpatha (NPh, E3)
Cymbalaria microcalyx ssp. microcalyx Hscap, E4)	Satureja juliana (Chsufrut, M.)
Cymbalaria muralis ssp.muralis (Hscap, M.)	Scariola viminea (Hscap, M.)
Dianthus xylorrhizus (NPh, E1)	Scilla talosii (Gbulb, E1)
Ebenus cretica (NPh, E1)	Scutellaria sieberi (Chsufrut, E1)
Ephedra campylopoda (NPh, M.)	Sedum hispanicum (Thscap, W.)
Erigeron glabratus (Hscap, W.)	Sedum creticum (Chsucc, E2)
Eryngium amorginum (Hscap, E3)	Sedum sediforme(Chsucc, M.)
Erysimum candicum ssp. candicum (Chsufrut, E3)	Selaginella denticulata (Chrept, W.)
Euphorbia dendroides (NPh, M.)	Smyrnium creticum (Hscap, E3)
Fibigia lunarioides (Chsufrut, E3)	Teucrium flavum ssp. gymnocalyx (Chsufrut, E4)
Ficus carica (MPh, M.)	Thymbra calostachya (Chfrut, E1)
Gagea graeca (Gbulb, M.)	Umbilicus horizontalis (Gbulb, W.)
Galium citraceum (Hscap, E4)	Umbilicus luteus (Gbulb, W.)
Galium extensum (Hscap, E1)	Valeriana asarifolia (Hscap, E2)

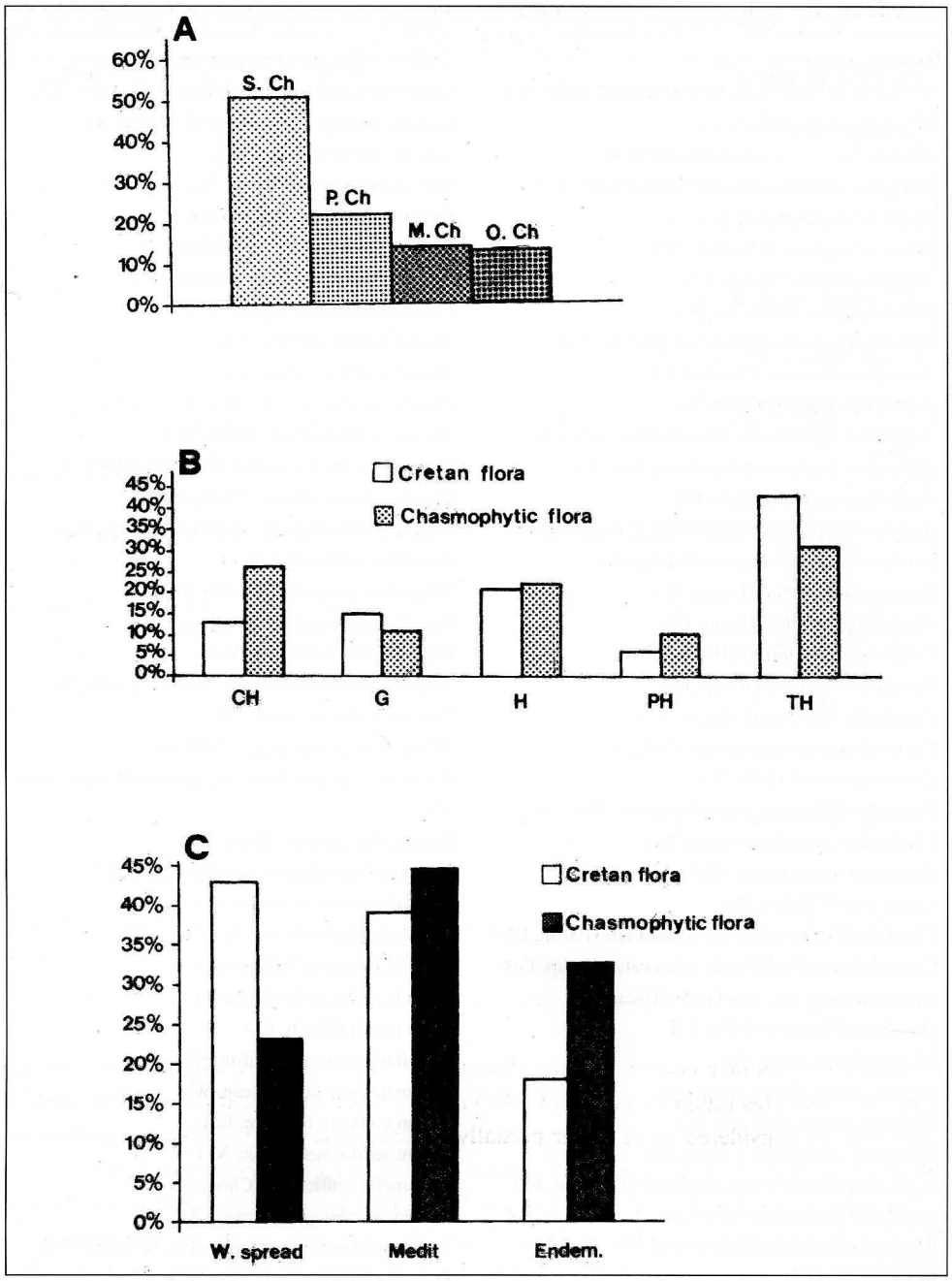

Fig. 2. Floristic Analysis of the chasmophytic flora of the island of Crete. A: Representation of the different categories of chasmophytes in the chasmophytic flora (for abbreviations see in Materials & Methods). B and C: Life form spectrum and chorological spectrum of the chasmophytic flora of the island of Crete respectively, in comparison to the corresponding ones of the total flora of the island.

Table 3. Correlation between distribution range and categories of chasmophytes in the island of Crete.

	Categories of chasmophytes				
Distribution range	**O. ch**	**M. ch**	**P. ch**	**S. ch**	**Total**
Widespread (W)	5	15	29	93	142 (23.1%)
Mediterranean (M)	14	30	62	167	273 (44.5%)
Greek mainland endemics (E_4)	3	5	4	7	19 (3.1%)
Aegean endemics (E_3)	16	15	12	16	59 (9.6%)
South Aegean endemics (E_2)	-	3	6	5	14 (2.3%)
Cretan endemics (E_1)	42	17	22	26	107 (17.4%)
Total	80 (13%)	85 (13.8%)	135 (22%)	314 (51.2%)	614 (100%)

Table 4. Correlation between life forms and the categories of chasmophytes in the island of Crete.

	Life forms					
Categories of chasmophytes	**CH**	**G**	**H**	**PH**	**TH**	**Total**
O. Ch	48	2	24	6	0	80
M. Ch	25	12	31	12	5	85
P. Ch	44	18	37	9	27	135
S. Ch	45	37	45	32	155	314
Total	162 (26,3%)	69 (11,2%)	137 (22,3%)	59 (9,6%)	187 (30,5%)	614 (100%)

species have been described as new to science viz. *Allium platakisii* Tzanoudakis & Kypriotakis (1993), *Limonium cornarianum* Kypriotakis & Altelari (1998), *Scilla talosii* Tzanoudakis & Kypriotakis (1998), and *Bellevalia sitiaca* Kypriotakis & Tzanoudakis (1999).

Out of the 614 taxa constituting the chasmophytic flora of Crete, 80 (13%) are obligatory chasmophytes (table 1) and 85 (13.8%) mainly chasmophytes (table 2). The remaining ones are considered to be either partially chasmophytes (135, 22%) or spontaneous chasmophytes (314, 51%). Complete species lists are given by Kypriotakis (1998).

In spite of the fact that the chasmophytic flora of Crete constitutes almost one third of the Cretan flora, from a qualitative point of view, it is not representative of the whole flora of the island. Comparing, for example, the biological and the chorological spectrum of the Cretan chasmophytic flora to the corresponding ones of the whole flora of the island significant differences are observed (Fig. 2). The main differences concern a significant reduction of the percentages of the therophytes and of the widespread taxa, in the chas-

mophytic flora, which are compensated by a corresponding increase in the percentages of the perennials (mainly of the chamaephytes) and of the endemic taxa.

The differences mentioned above seem to be due to the fact that among the obligatory and mainly chasmophytes, therophytes are almost absent and when summing up these two categories the percentage of the endemic taxa exceeds 60% (tables 1 - 4). From the same tables it is evident that more than 50% of the obligatory chasmophytes are Cretan endemics

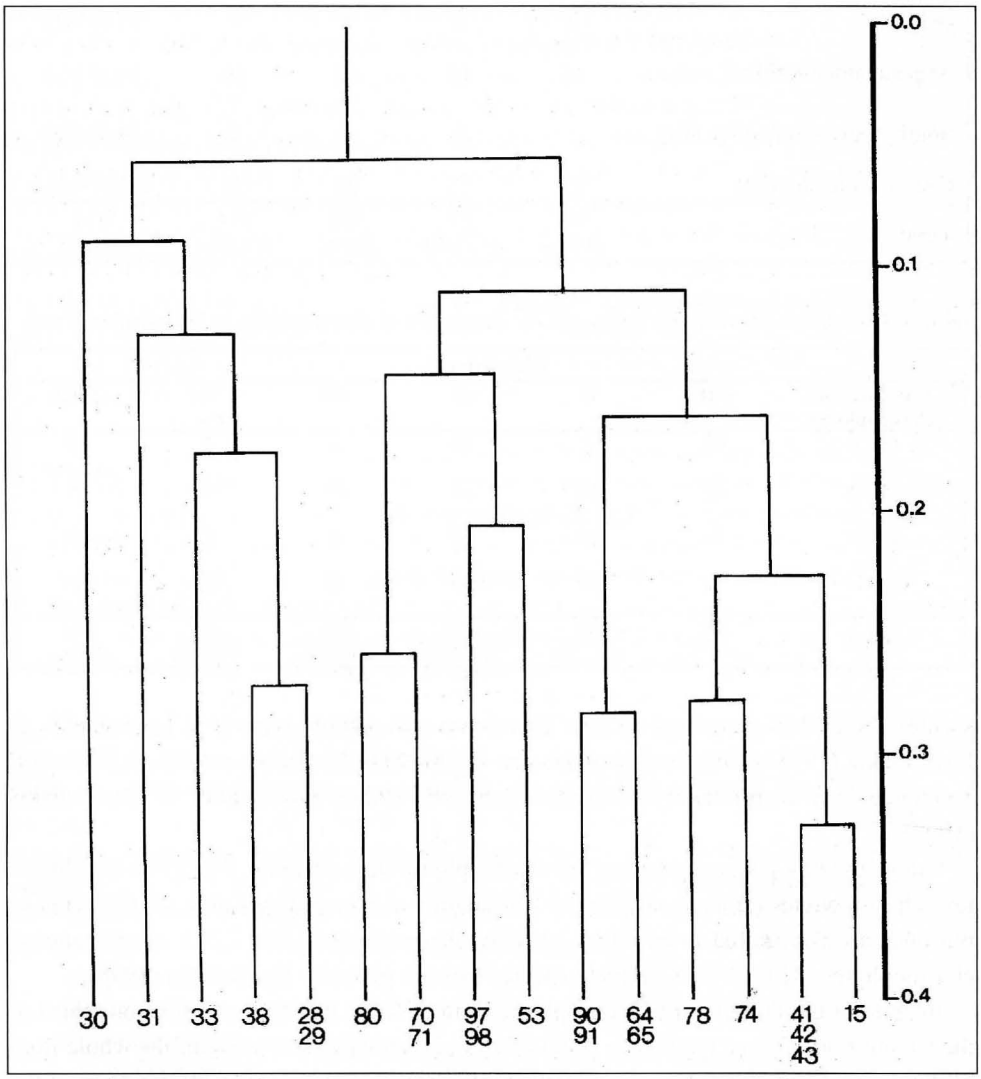

Fig. 3. Dendrogram presenting the floristic similarities (Jaccard's coefficient) between the low altitude (<500m) gorges' crevices of the island of Crete (see Fig. 1B for gorges' sites).
Note that even geographically neighbouring cliffs show remarkable differences in their floristic composition.

and that more than 70% of the taxa of the same category show a distribution range restricted to the Aegean area.

The analysis of the floristic composition of the cliff habitats investigated and the comparison, by estimation of the Jaccard's similarity coefficient, revealed significant differences even among neighbouring and ecologically similar habitats (Fig. 3).

When only obligatory chasmophytes are taken into consideration then it's evident that the taxa under consideration are not evenly distributed in the four phytogeographical subdivisions of the island. Out of the 80 obligatory chasmophytes only 14 occur in all the four subdivisions of the island and the majority of them, 45 (56%), occur only in one of the four phytogeographical regions.

As it has already been pointed out in earlier studies (Snogerup 1971) the western part of Crete (K_1) was found to house the higher number of obligatory chasmophytes and the central - east part (K_3) the lower. According to our results 70% of the obligatory chasmophytes are registered from the subdivision K_1 and 45%, 32% and 39% from K_2, K_3 and K_4, respectively. Similar is the picture regarding the distribution of the 45 obligatory chasmophytes registered as found on one subdivision only since more than 50% of them occur exclusively in the K_1 region and ca 10% only on K_3.

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