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A phytogeographical comparison of the major Mediterranean islands on the basis of Atlas Florae Europaeae

Abstract

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The phytogeographical affinities of Corsica, Sardinia, Sicily, Crete, the Maltese and the Balearic Islands are analysed on the basis of the chorological information in the Atlas Florae Europaeae 1-13. Data for 1109 indigenous phanerogam species were used for the production of a similarity matrix and taxon richness maps for each island, showing the representation of its flora in Europe. Jaccard's similarity index values of each island and related mainland areas show a strong floristic similarity between the large W Mediterranean islands Corsica, Sardinia and Sicily, and parts of their adjacent mainland, which reflects a common geological history. The maps show that the Balearic Islands have many species in common with Malta, which depends on the prevailing pan-Mediterranean element. Many Sicilian taxa show up in the Balkans, while many species of (the mountains of) Corsica, Sicily and to a lesser extent of Sardinia appear in Central Europe. Such an element is absent in Crete, Malta and the Balearic Islands. Crete deviates widely from the other investigated areas as it has many species in common with the Cyclades and mainland Greece, but less so with the Balkans.

Key words: phanerogams, phytogeography, Balearic Islands, Corsica, Crete, Malta, Sardinia, Sicily.

1. Introduction

The Mediterranean has a rich flora containing c. 24 000 species of which c. 60 % are endemics (Greuter 1991) and it favourably rivals the diversity at tropical latitudes. However, according to Humphries & al. (1999) the taxon richness or the number of species found on a site is quite similar in more northern latitudes, like Central Europe or even southern parts of Sweden. These authors demonstrate that the Mediterranean area differs from more northern latitudes by a high incidence of species with a narrow range of distribution (endemics). This is chiefly regarded as a result of the strong fragmentation of the environment, which appears scattered on numerous islands spread over the Mediterranean. When the islands are compared with adjacent mainland areas of the same size, the islands display a greater abundance of endemic taxa (Greuter 2001).

The flora of the main Mediterranean islands has developed already millions of years ago, when the islands split off from the mainland. For instance, Corsica and Sardinia, located adjacent to the coast of the Provence and Languedoc, belong to the same tectonic micro-plate that formed a part of the Hercynian mountain chain and linked the Pyrenees with the Alps. The Corsica-Sardinia micro-plate drifted to its recent position in the Lower Miocene (Gamisans 1991). However, according to Jeanmonod & al. (2001), Corsica separated from the continent much later, c. 4 million years ago. Climatic and evolutionary changes apparently had less effect on the flora of the islands than of the mainland, where large-scale migrations easily shift the balance between taxa. Many relic components have survived on the islands and Greuter (2001) called the Mediterranean insular flora conservative.

2. Material and methods

Thirteen volumes of Atlas Florae Europaeae (AFE) have been published since the initiation of the program (Jalas & Suominen 1972-94, Jalas & al. 1996, 1999, Kurtto & al. 2004). The published volumes include altogether 3556 maps and cover Flora Europaea 1 (Tutin & al. 1964, 1993) and a part of the family *Rosaceae* of Flora Europaea 2 (Tutin & al. 1968). The number of mapped species is 3276 and that of subspecies 1151. The maps of AFE volumes 1-12 were prepared by hand. In 1992 an AFE database was started (Lahti & Lampinen 1999) and a new grid system adopted with the preparation of Atlas Florae Europaeae 13. At present, the chorological data are inserted electronically into a base map based on the Universal Transverse Mercator (UTM) projection and the Military Grid Reference System (MGRS), with grid cells of 50 km high and 33-66 km wide, distributed in a regular pattern. For more information, see the homepage of Atlas Florae Europaeae (http://www.fmnh.helsinki.fi/english/botany/AFE/index.htm). The maps of the first 12 volumes, based on the old grid system, were later digitized and converted into the new grid system.

The converted AFE data of volumes 1-12 and the data of volume 13 are used here for a comparison of the species richness and distribution of the indigenous vascular plant flora on the major Mediterranean islands, i.e. Sardinia, Sicily, Corsica, Crete, the Balearic Islands and the Maltese Islands (Malta) (Table 1), with each other and with selected mainland areas. Cyprus was left out because it is not included in the area of AFE. The mainland areas were selected for their presumed floristic affinities with the islands: S Spain (9 grid cells), NE Spain (7 grid cells), S France (28 grid cells), W Italy (13 grid cells) and SE Greece including the Cyclades (9 grid cells) (Fig. 1). Altogether distribution data of 1109 indigenous species were used. Infraspecific taxa and introduced taxa, as well as taxa with unknown or uncertain status were omitted. Since AFE so far covers about 20 % of the Mediterranean flora, the incompleteness of the data may distort the results, particularly because many important families, such as *Fabaceae*, *Apiaceae* and *Asteraceae,* and the whole class *Liliopsida* (Monocots) are still waiting their treatment in AFE.

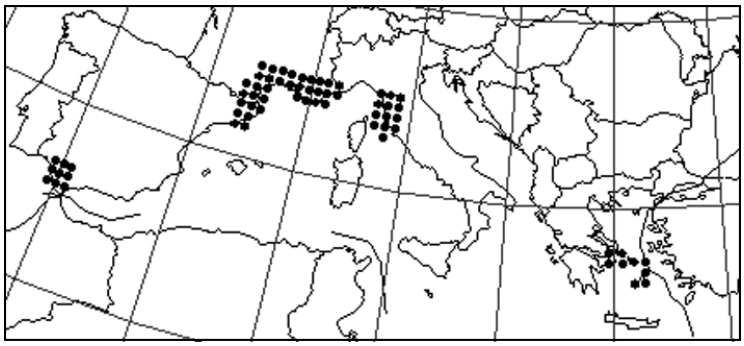

Fig. 1. The areas selected for comparison with the islands.

For the comparison of the species richness Jaccard's similarity index (JS) is used: JS = 100 × C / (A+B-C), where A = species number on the island A; B = species number on the island B; and C = number of common species of the islands A and B (Jaccard 1901). This index is scaled so that the value is 100 when the taxa of two islands are identical, and 0 when their floras are completely different. The index values are shown in Table 2.

Furthermore we produced taxon richness maps for each island flora, showing its overall distribution and frequency in Europe (Fig. 2-7). Frequencies are given as a percentage of the total species number of the island concerned, and are divided into three classes, 0-33 %, 33-67 %, and 67-100 %.

3. Results and discussion

The richest flora is found in Sicily and Corsica, which have about the same number of species in AFE 1-13 (Table 1). The numbers based on Med-Checklist (Greuter 1991) and the estimates given by Brullo & al. (2004) and Jeanmonod & al. (2001) are a bit more in favour of Sicily. Jeanmonod & al. (2001) compared the plant diversity and endemism of the W Mediterranean islands with their size and demonstrated that Corsica has the highest α-diversity and endemism rate per surface unit. Both Corsica and Sicily are close to the mainland and their habitats are very diverse, e.g., because of their mountainous environment. The number for Sardinia, less close to the mainland and with lower mountains, is somewhat lower according to AFE, and much lower according to Webb (1978). However, the number by the latter, calculated from Flora Europaea, is based on a relatively broad species concept. If figures (incl. species and subspecies) given by Greuter (1991) are set against the other islands, the total species number of Sardinia is surely higher, approaching nearly the species number of Corsica, i.e. 2400. Also the numbers for other islands given by Webb (1978) are clearly lower than more recent figures given in Table 1.

Table 1. Size and maximum altitudes of selected Mediterranean islands, with numbers of vascular plant taxa and endemism, from different sources. Numbers in italics = sources treating only part of the flora, in AFE 1-13 slightly over 20 %, in Greuter (1991) c. 44.5 %; * = Greuter (1991) included in his analysis both species and subspecies.

Island	Area km²	Max. altitude m	Native species	Endemic species	Endemism %	Source
Sicily	25 707	3350	*506*	*14*	*2.8*	AFE 1-13
			1357	*77*	*5.7*	Greuter (1991)*
			2707	305	11.3	Brullo & al. (2004)
Sardinia	24 090	1834	*427*	*9*	*2.1*	AFE 1-13
			1122	*61*	*5.4*	Greuter (1991)*
			1900-2000			Webb (1978)
Corsica	8680	2710	*499*	*11*	*2.2*	AFE 1-13
			1161	*34*	*2.9*	Greuter (1991)*
			2465	131	4.5	Jeanmonod & al. (2001)
Crete	8259	2456	355	*34*	*9.6*	AFE 1-13
			1051	*122*	*11.6*	Greuter (1991)*
			1635	165	10.1	Jahn (2003)
Balearic Isl.	5014	1445	*290*	*3*	*1.0*	AFE 1-13
			825	*65*	*7.9*	Greuter (1991)*
			c. 1500	50	3.3	Rivas-Martinez & Costa (1987)
Maltese Isl.	316	253	*186*	*1*	*0.5*	AFE 1-13
			513	*4*	*0.8*	Greuter (1991)*
			c. 800	14	1.8	Lanfranco (2004)

The percentage of endemism in Table 1 counted from Med-Checklist (Greuter 1991) and from territorial sources is higher than the figures taken from AFE due to several reasons. Subspecies are included in Greuter (1991) but excluded from the data of AFE. The knowledge of the Mediterranean flora is poorer especially in the pre-Med-Checklist volumes of AFE. Further, AFE uses broad species concepts because of the close relationship to Flora Europaea.

Only 9 %, i.e. 101 species, of the 1109 island species mapped in AFE are encountered in all islands of the study. The small amount of common species no doubt reflects the fact that Mediterranean insular floras have developed in geographically distant areas and the separation of the island floras from the mainland taxa occurred in different geological epochs.

The number of taxa per grid cell of an island varies considerably due to the variation of habitats, human impact, historical matters and the amount of land surface in a grid cell located at the coast. There are always less taxa in a single grid cell than on the whole island. Moreover, the number of taxa recorded in a grid cell is not necessarily the real number of taxa occurring in the cell but depends much on the botanical activity within the area.

Table 2. Jaccard's similarity index calculated for the selected islands and comparison areas (see Fig. 1).

	Bl	Hs-S	Hs-NE	Co	Sa	Ga	It	Si(S)	Si(M)	Cr	Gr
Balearic Islands = Bl	100										
S Spain = Hs-S	39	100									
NE Spain = Hs-NE	30	33	100								
Corsica = Co	39	36	45	100							
Sardinia = Sa	47	39	35	63	100						
S France = Ga	24	28	64	42	33	100					
W Italy = It	30	29	51	53	43	54	100				
Sicily = Si(S)	40	37	36	48	54	34	45	100			
Malta = Si(M)	47	26	20	29	37	16	23	35	100		
Crete = Cr	32	26	20	27	31	17	23	35	32	100	
SE Greece = Gr	33	30	26	32	36	23	29	40	30	49	100

The Balearic Islands (Table 1, 2, Fig. 2). – The distribution map of the 290 species included in this study shows that the islands have the highest number of species in common with S and NE Spain (16 grid cells, Fig. 1), where 90 % of them occur. Next are the coastal areas of S France and W Italy, Corsica, Sardinia and Sicily. In Italy the areas sharing most species are quite randomly distributed. This supports Rivas-Martínez & Costa (1987), who concluded that the Balearic Islands have a closer floristic affinity with the E Iberian Peninsula than with the Tyrrhenian islands Corsica, Sardinia and Sicily. The similarity index (Table 2), however, indicates a stronger affinity with Sardinia and Malta than with S and NE Spain, Sicily and Corsica. This depends probably on the similarity in topography, with scarce montane habitats.

Malta (Table 1, 2, Fig. 3). – The low number of species in Malta evidently reflects the small size of that island group. Also the level of endemism is very low, probably because the islands were part of a land-bridge between Europe and Africa during the glacial maxims of the Pleistocene, which allowed migration of competitive plants to the warmer south via Sicily and Italy (Haslam & al. 1977). Moreover, the absence of mountain ranges means less possibility for isolation of populations and subsequent speciation. In historical times human impact on the flora of Malta has been very strong, because of its central position at the crossroads of seafaring and immigration. This may have decreased the number of endemics and favoured the early introduction of widespread taxa, which may have entered the dataset with native status. According to Greuter (1991), more than 10 % of the Maltese taxa are non-native, which is more than, e.g., in Sicily (3.8 %) or in the Balearic Islands (6.4 %). Lanfranco (2004) estimates the proportion of introduced species even at c. 20 %.

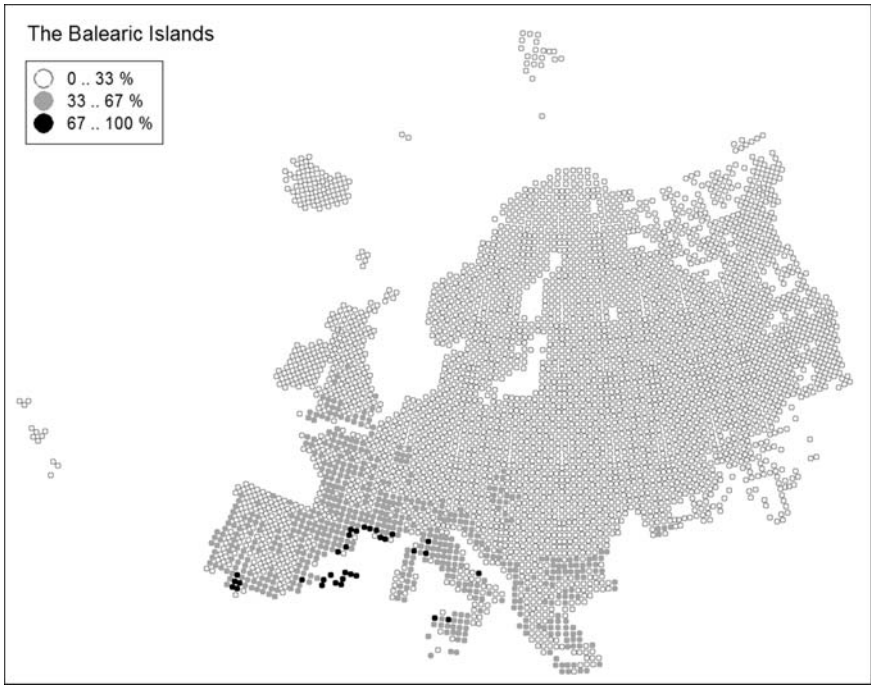

Fig. 2. Representation in Europe of 290 indigenous species of the Balearic Islands based on AFE vol. 1-13.

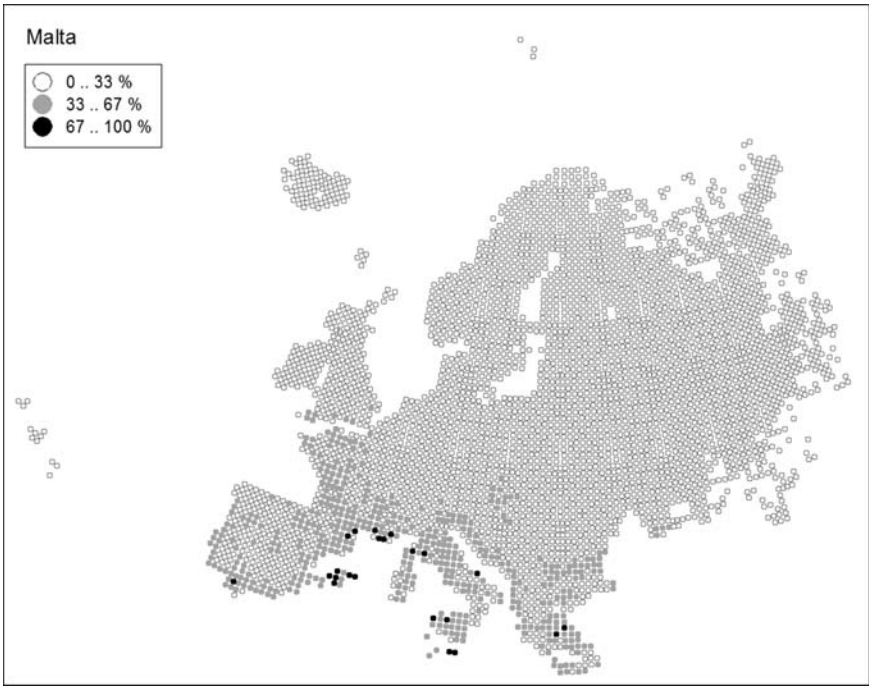

Fig. 3. Representation in Europe of 186 indigenous species of Malta based on AFE vol. 1-13.

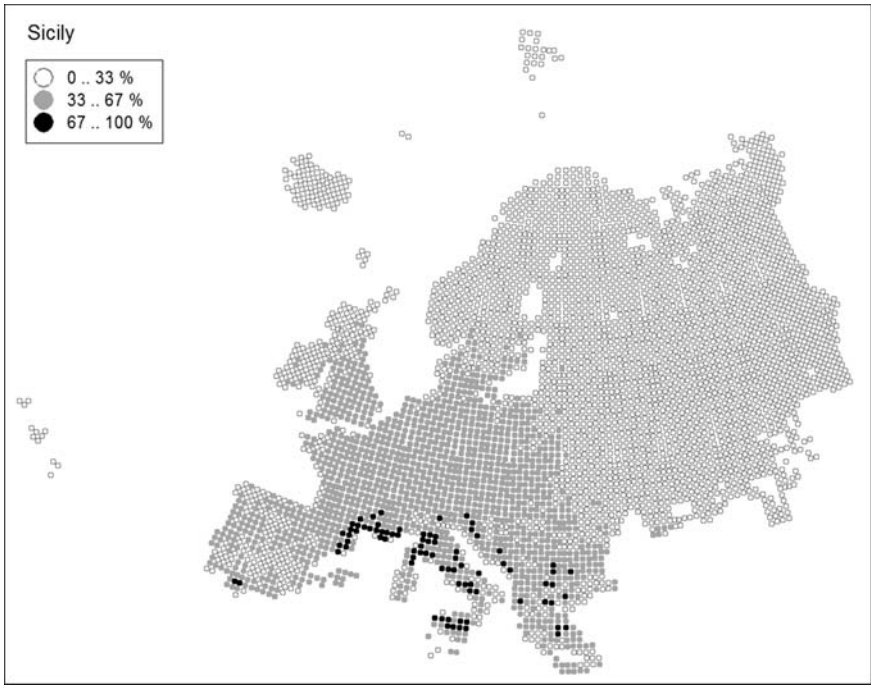

Fig. 4. Representation in Europe of 506 indigenous species of Sicily based on AFE vol. 1-13.

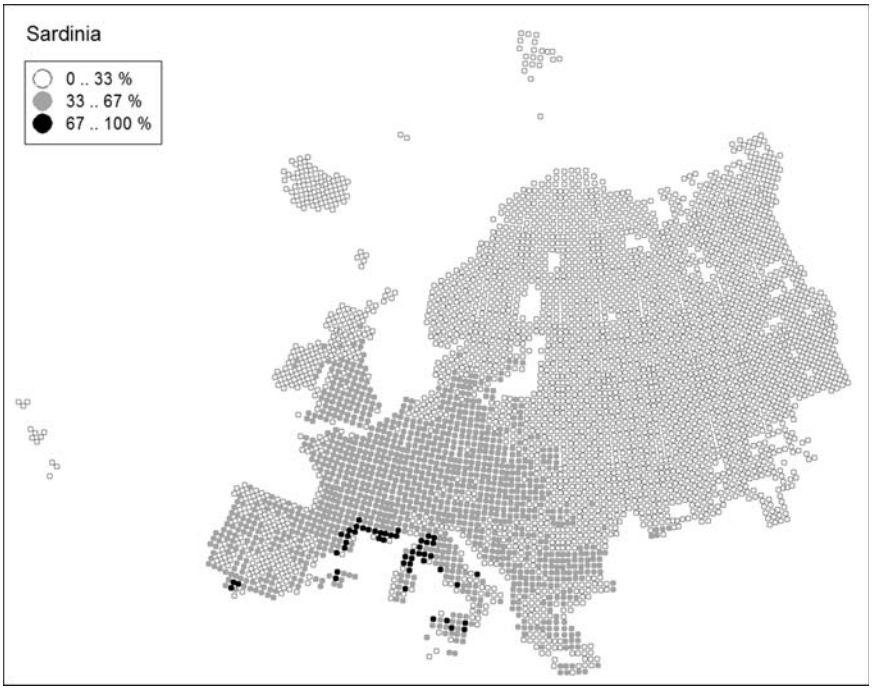

Fig. 5. Representation in Europe of 427 indigenous species of Sardinia based on AFE vol. 1-13.

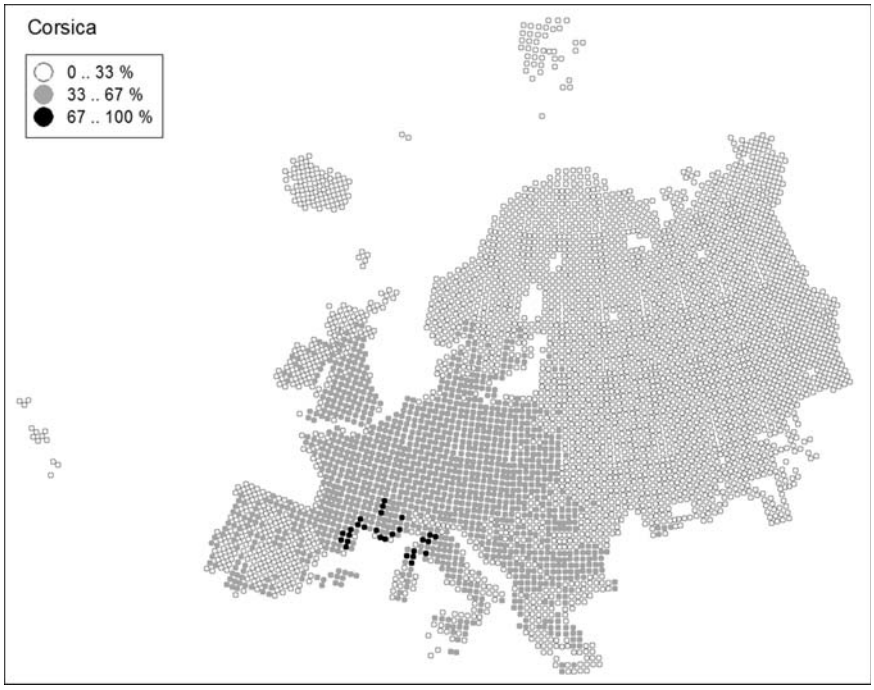

Fig. 6. Representation in Europe of 499 indigenous species of Corsica based on AFE vol. 1-13.

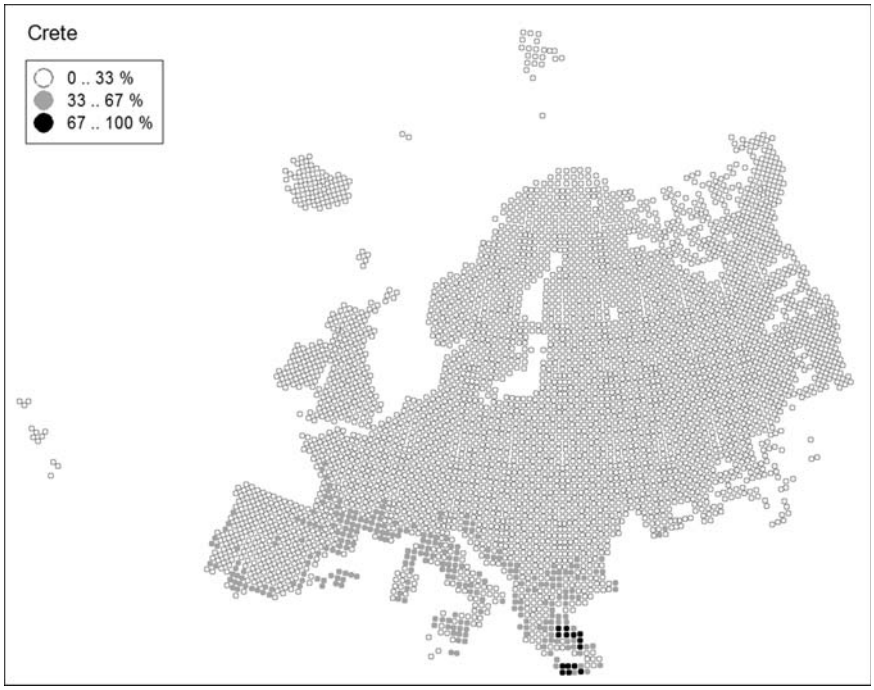

Fig. 7. Representation in Europe of 355 indigenous species of Crete based on AFE vol. 1-13.

Fig. 3 shows that the flora of Malta is well represented in coastal areas throughout Mediterranean Europe. Almost all Maltese species considered here (95 %) are found in Sicily, and 80-90 % in Sardinia, Corsica and the Balearic Islands, and still 70 % on Crete. Further, its flora is well represented on the Spanish coast (90 %) and only slightly less in the coastal areas of S France and W Italy, and almost 80 % can be found even in SE Greece. The pan-Mediterranean character of the Maltese flora is probably increased by the strong anthropogenic influence. The similarity index (Table 2) gives a somewhat different impression. It indicates that the strongest floristic linkage of Malta is with the Balearic Islands.

A comparision of the maps for the Maltese and Balearic floras shows surprisingly similar concentrations on the mainland, e.g., in S and NE Spain, S France and W Italy, NW Sicily, E Greece and remarkably in the Pannonian area of Hungary, corroborating the share of c. 13 % of Mediterranean taxa in the flora of Hungary given by Soó (1964: 63).

Sicily (Table 1, 2, Fig. 4). – Sicily shares 65 % of its flora with Sardinia and Corsica. This is reflected in the similarity index (Table 2). Its flora has many species in common with the Apennine Peninsula, which is supported by the figures for W Italy in the similarity index. Fig. 4 shows a strong affinity with S France, NE Spain and S Spain. Sicilian taxa are also markedly frequent on the Balkan Peninsula, quite unlike the other islands.

The flora of Sicily, like that of Corsica and to a lesser degree Sardinia, appears to be very well represented in Central Europe. More than one third of the species of these islands are found in Central and even in southern North Europe. This Central European presence is missing in the maps of the Balearic Islands, Malta and Crete, which show exclusively Mediterranean and Mediterranean-Atlantic connections. Presumably it concerns high mountain species that are less well represented in Sardinia and absent on the Baleares and Malta.

Sardinia (Table 1, 2, Fig. 5). – The Sardinian flora is better represented in Corsica, where 84 % of its flora occur, than in Sicily (77 %); strong similarities with the Balearic Islands, as well as with coastal Spain and France are also clear (Fig. 5). This pattern is expected because the islands have a similar geological history and they, particularly Sardinia, were located closer to the Balearic Islands and the Pyrenees in the Miocene. The similarity index (Table 2) confirms the strong link between the above-mentioned islands, but the connection with the mainland locations is weaker. The floras of Sardinia and Sicily have similar representations on the mainland, i.e. in S and NE Spain and S France and slightly less in W Italy. However, floristic links to the E Mediterranean and the Balkans play a minor role in Sardinia (Fig. 5). The Sardinian flora appears less well represented in Central Europe than that of Sicily or Corsica, probably due to the lack of mountains over 1850 m with a real alpine vegetation belt.

Corsica (Table 1, 2, Fig. 6). – Corsica shows the strongest floristic affinity with Sardinia, where 72 % of its species under consideration here occur. This is reflected in the similarity index (Table 1), but when taxon richness of Corsican species is displayed in single grid cells, the affinity with Sardinia is not evident on the map (Fig. 6). Nevertheless, Gamisans (1991) found the same close affinity between Corsica and Sardinia when he compared endemics shared between W Mediterranean islands. A particularly conspicuous affinity exists also to the adjacent mainland of France (incl. Massif Central), NE Spain and W Italy, where 79-86 % of the Corsican taxa occur (Fig. 6). This is probably due to the small distance between the mainland and Corsica, and the geologically late separation of the island. However, Väre & al. (2003) found that many alpine taxa are shared between the Maritime Alps, the Pyrenees and the Corsican mountains. Corsica has 339 alpine taxa, and most of them belong to the Holarctic element (Gamisans 1991). The similarity index does not support such a strong link to mainland areas compared, perhaps with the exception of W Italy.

Crete (Table 1, 2, Fig. 7). – Crete, being an E Mediterranean island, has a fairly different composition of the flora with a higher number of endemic taxa (Table 1). Within Europe, the greatest

floristic similarity is shown with mainland Greece and the Aegean Islands, but even this affinity is not very strong, c. 74 % in our analysis (see Fig. 7). In the W Mediterranean, Sicily, the Balearic Islands and coastal Spain possess more Cretan taxa than other areas. The similarity index (Table 1) shows that the strongest but rather weak affinities are with Sicily, Malta, the Baleares and Sardinia.

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