The endemic flora in the south of the Iberian Peninsula: taxonomic composition, biological spectrum, pollination, reproductive mode and dispersal

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Summary

The taxonomical composition and four ecological characteristics (life form, seed-dispersal, pollination and reproductive mode) of the 553 endemic species occurring in the south of the Iberian Peninsula have been investigated. A comparative analysis of the results reveals that this endemic flora does not comply with the general patterns previously observed in local floras, Mediterranean regional floras and floras of temperate latitudes. Predominant life forms are chamaephytes (45%) and hemicryptophytes (33%). By contrast, therophytes (11%) and phanerophytes (1%) are relatively infrequent. This spectrum of life forms mirrors the altitudinal distribution of the endemic species, their seed-dispersal strategy and the type of phytocoenoses in which they occur. As far seed-dispersal is concerned, 44% of the endemic species lack any noteworthy adaptive feature. However, the results clearly suggest that this limitation in their disseminative potential has only encouraged endemicity among the therophytes inhabiting lowlands. Among chamaephytes and hemicryptophytes of medium and high altitude, there is a relatively high frequency of exozoochory and anemochory, an adaptation that has contributed to the survival of small plant populations. 91% of the endemic species are pollinated by animals (insects), and only 3 species are dioecious. The dichotomies that the above mentioned characteristics produce (herbaceous vs woody life form, animal-assisted vs abiotic seed-dispersal, animal-assisted vs abiotic pollination and dioecious vs hermaphroditic reproductive mode), have been used to plot statistically significant associations. These are three: Pollination mode is linked with the seed-dispersal strategy, life form with pollination mode, and pollination mode with the reproductive mode. These associations contrast distinctly with results of previous surveys on whole floras, a contrast which makes the singularity of the endemic flora of the Southern Iberian peninsula even more remarkable.

Key words: endemic species, life forms, biological spectrum, seed dispersal, Mediterranean flora, Iberian Peninsula.

Introduction

Although the Mediterranean basin only encompasses 1.6% of the earth’s surface, the flora of the area is particularly rich and diverse. The panoply of over 25,000 species in the region includes 10% of the vascular plants so far recorded (Quézel 1985). This diversity is caused by a high local diversity, i. e., by the simultaneous occurrence of a large number of species in the same areas, but also by a high regional diversity, since ecological conditions and landscapes change dramatically even between neighbouring zones (Blondel & Aronson 1995).

In order to assess correctly the preservation priorities in the Mediterranean basin, a number of biodiversity...
hotspots have been recently defined (Médail & Quézel 1997; Myers et al. 2000). One of these biodiversity hotspots lies in the south of the Iberian Peninsula and the north of Morocco, including the Baetic-Riftan complex. Preliminary estimates concede from 3,800 to 4,000 species or subspecies living in the south of the Iberian Peninsula (Hernández Bermejo & Clemente 1994), 436 of which are presumed endemic taxa (Rivas Martínez et al. 1991).

Since a close examination of the geographical distribution of endemic plants provides objective and most valuable criteria to assess and manage the territories (Gómez Campo & Malato Beliz 1985), the high rate of endemism in the south of the Iberian Peninsula, up to 36% in some areas, has led to the publication in recent years of a number of surveys mostly dealing with this topic (see, e.g. Blanca & Valle 1996 and the references included). Other recent works on endemic plants in the south of the Iberian Peninsula also deal with their biological profile, vulnerability and preservation (Hernández Bermejo & Clemente 1994; Blanca et al. 1999, 2000).

Ecological features such as life form and mode of dispersal, pollination and reproduction seem to play an important role in the diversification of plant groups (Herrera 1989; Midgley & Bond 1991; Eriksson & Bremer 1992; Tiffney & Mazer 1995; Buide et al. 1998). A large number of surveys have concentrated on detailed analyses of some of these features (Howe & Smallwood 1982; Shmida & Ellner 1983; Sorensen 1986; Guittán & Sánchez 1992; Pakeman 2001; Van der Wall 2001). More recently, data bases have led to the identification of the relationships between ecological characteristics and geographical distribution patterns (Gentry 1988; Renner & Ricklefs 1995). Data bases have also been applied to the analysis of these features in local floras (Fitter & Peat 1994) or to particular taxonomical groups (Ricklefs & Renner 1994). However, a complete endemic flora has not been so far studied using this approach.

The study of the ecological features of an endemic flora reveals general patterns, but also peculiarities and differences of the endemic part of a flora when compared with the whole flora of the area. In this respect, the aims of our research have been both (1) to collate information on the frequency of particular ecological characters among the endemic species in the south of the Iberian Peninsula and (2) to identify possible associations between these characters.

**Material and methods**

**Study area**

The area under study encompasses the south of the Iberian Peninsula (Fig. 1), from the Portuguese Algarve to the semi-arid territories of Almería and Murcia, and mostly coincides with the administrative territory of Andalucía. The area has a Mediterranean macroclimate in which four subtypes can be distinguished: pluviseasonal-oceanic, pluviseasonal-continental, xeric-oceanic and desertic-oceanic (Rivas Martínez...
Another remarkable feature of the area under study is its great orographical, geological and edaphic diversity, which has produced enormous diversity in flora, phytocoenoses and biogeographical units. The border lines of the study area have been plotted following the limits of natural areas, since the limits of administrative provinces and regions are too arbitrary to be of any use in the survey. There are three very clear morphostructural units: the Betic ranges, Sierra Morena and the depression of the Guadalquivir (Fig. 1).

The mountainous range of Sierra Morena constitutes the southernmost slope of the Iberian Meseta. Altitude decreases to the west, ranging from 1,300 m in Sierra Madrona to 200 m on the western edge in the Sierra de Aracena. The Portuguese Alentejo acts as an extension to the west. For the most part, the soil consists of silica, slates, granites and quartzites, with occasional outcrops of Palaeozoic limestones.

The Betic ranges extend along the southern fringe of the area under study and have a higher altitude which ranges from sea level to the impressive 3,482 m of Mount Mulhacén in Sierra Nevada. In addition, there is a large number of ranges over 2,000 m altitude of a high floristic value, such as the sierras of Baza, Filabres, Máquina, Gádor, Tejeda, Almijara, or the mountainous unit formed by the sierras of Cazorla, Segura and Alcaraz. The usual geological substrates are limestones and dolomites, together with large areas of siliceous materials such as mica-schists and phyllites.

The Guadalquivir depression lies between the two former units, with an altitude ranging from sea level in the marshes of Doñana to 300 m on the eastern edge. Here there are abundant detrital materials and marls.

**Information sources**

In order to obtain a list of the endemic taxa in the south of the Iberian Peninsula, we have used, as the main source, the listing provided by Rivas Martínez et al. (1991). These data have been updated with the information of the volumes so far published of Flora Iberica (Castroviejo et al. 1986–2002), some general works (Blanca et al. 2002) and a number of recent publications, either in monographical editions or in scientific periodicals. In our survey, we have not only considered the endemic species whose recorded populations occur entirely within the limits of the study area, but also some species or subspecies found just outside this area. Those endemic species, either of the Iberian Peninsula or of a large part of it, whose distribution considerably exceeds the study area where dismissed. Neither does the survey consider some categories of endemicty, e.g., those suggested by Favarger & Conandriotoulos (1961), since the available information is still very limited.

The data set includes the following Raunkiaer life forms (Raunkiaer 1934): phanerophytes, nanophanerophytes, chamaephytes, hemicyryptophytes, geophytes, therophytes, helophytes and hydrophytes. The classification of taxa according to life form is the result of both the records provided by the already mentioned sources and our own field research. For statistical purposes, life forms were classified as either woody (phanerophytes, nanophanerophytes and chamaephytes) or herbaceous (other life forms).

Pollination mode was determined as either biotic or abiotic on the basis of published reports (Heywood 1978; Faegri & Van der Pijl 1979; Blanca et al. 1999, 2000) and our own field experience.

Seed-dispersal strategy was either determined with the aid of published data (Van der Pijl 1982; Murray 1986; Blanca et al. 1999, 2000), or inferred from fruit morphology and our own field observations. The final classification distinguishes the following groups: endozoochores, exozoochores, myrmecochores, autochores, hydrochores, anemochores because of small diaspore size, anemochores by means of pappi, winged anemochores and semachores/barochores (i.e., with no evident morphological adaptations for seed dispersal). As far as heterochores are concerned, only their main adaptation for dispersal has been taken into account in the analyses: in dubious cases, species were excluded from the analyses. For statistical purposes, dispersal strategies were classified as biotic (endozoochores, exozoochores and myrmecochores) or abiotic (all other categories).

The reproductive mode was determined with the aid of the already published flora catalogues (Castroviejo et al. 1986–2002; Valdés et al. 1987) and our own field experience. Thus, taxa have been classified either as hermaphroditic or dioecious, deliberately omitting other categories such as gynodioecy because the available information is incomplete.

**Data analysis**

Since a total of 9 species could not be readily classified, we did not take them into consideration. All analyses were carried out by means of simplified binary categories (herbaceous vs woody life form, biotic vs abiotic seed-dispersal, biotic vs abiotic pollination, hermaphroditism vs dioecy). The heterogeneity analysis of $2 \times 2$ contingency tables (by chi-square tests, or Fisher’s exact test when one or more cells contained only a small number of cases) was the fundamental tool for finding out any statistically significant associations. For this analysis we used the STATISTICA 6.0 package (StatSoft 2001). Unless otherwise indicated, statistical significance is assumed by p-values lower than 5%.

**Results and discussion**

**Taxonomic composition**

A total of 553 endemic taxa have been recorded in the south of the Iberian Peninsula. Of these, this survey deals with the 544 listed in the Appendix. 528 of the endemic taxa considered occur in Andalucía (362 are exclusive to Andalucía, whereas 166 are shared with neighbouring areas).

The rate of endemic taxa in the south of the Iberian Peninsula (15.2%) is higher than this rate in other areas of the Mediterranean region, including some insular zones remarkable in terms of endemicty, such as Corsica or Sicily (Tab. 1). Geographical isolation, together...
with a complex geological and climatic history, are the main factors which explain the abundance of endemic species in the south of the Iberian Peninsula (Sainz Ollero & Moreno Saiz 2002). Since the Pliocene, 5 million years ago, the Iberian Peninsula has been surrounded by water except in the north-east. Thus, any connection with the European continent has been through the Pyrenean range which, originating in the Alpine orogeny, has acted as an unsurpassable barrier for many taxa. In particular, the south of the Iberian Peninsula has a high number of endemic species (Sainz Ollero & Moreno Saiz 2002), although the distribution of these species is not uniform, most of them occurring in the Baetic ranges, in coastal cliff or dune ecosystems and in arid and mostly salty areas (Hernández Bermejo & Clemente 1994). In the Baetic ranges, Sierra Nevada is the most remarkable endemicty centre in Europe (Pita & Gómez Campo 1990).

The families with larger numbers of endemic species are Asteraceae (81) and Lamiaceae (74). A second group of families with a large number of endemic species, from 34 to 50 each, is formed by Fabaceae, Brassicaceae, Scrophulariaceae, Plumbaginaceae, Caryophyllaceae and Poaceae (Tab. 2). Although this endemic flora encompasses 49 families, 72% of the endemic species belong to one or the other of these 8 families. A third group is formed by the families Cistaceae, Ranunculaceae, Saxifragaceae, Boraginaceae, Liliaceae and Amaryllidaceae, with a minimum of 10 endemic species each.

The taxonomical composition of the endemic flora in the south of the Iberian Peninsula does not coincide with

**Table 1. Rate and number of endemic taxa of different regions of the Mediterranean basin.**

<table>
<thead>
<tr>
<th>Region</th>
<th>Estimated total number of taxa</th>
<th>Number of endemics</th>
<th>Endemism (%)</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>5600</td>
<td>712</td>
<td>12.7</td>
<td>Heywood &amp; Davis (1995)</td>
</tr>
<tr>
<td>Greece</td>
<td>5000</td>
<td>742</td>
<td>14.8</td>
<td>Heywood &amp; Davis (1995)</td>
</tr>
<tr>
<td>Lebanon</td>
<td>2600</td>
<td>311</td>
<td>12</td>
<td>Davis et al. (1994)</td>
</tr>
<tr>
<td>Israel</td>
<td>2225</td>
<td>165</td>
<td>7.4</td>
<td>Davis et al. (1994)</td>
</tr>
<tr>
<td>Southeast France</td>
<td>3000</td>
<td>215</td>
<td>7.2</td>
<td>Médail &amp; Vézard (1997)</td>
</tr>
<tr>
<td>South Iberian Peninsula</td>
<td>3680</td>
<td>553</td>
<td>15.2</td>
<td>This study</td>
</tr>
<tr>
<td>Corsica</td>
<td>2150</td>
<td>240</td>
<td>11.2</td>
<td>Médail &amp; Vézard (1997)</td>
</tr>
<tr>
<td>Sardinia</td>
<td>2050</td>
<td>200</td>
<td>9.8</td>
<td>Médail &amp; Quézel (1997)</td>
</tr>
<tr>
<td>Sicily</td>
<td>2630</td>
<td>250</td>
<td>9.5</td>
<td>Di Martino &amp; Raimondo (1979)</td>
</tr>
<tr>
<td>Balearic Islands</td>
<td>1500</td>
<td>180</td>
<td>12</td>
<td>Médail &amp; Vézard (1997)</td>
</tr>
<tr>
<td>Cyprus</td>
<td>1620</td>
<td>171</td>
<td>10.6</td>
<td>Alzari (1995)</td>
</tr>
</tbody>
</table>

**Table 2. Number (N) and rate (%) of taxa, species and subspecies, classified by families, in the endemic flora in the south of the Iberian Peninsula (SIP) and in some complete local or regional floras included in this area.**

<table>
<thead>
<tr>
<th>Family</th>
<th>End. SIP (This study)</th>
<th>Natural Park Cardeteta (Méndez &amp; Cano 1998)</th>
<th>Sierra of Baza (Blanca &amp; Morales 1991)</th>
<th>Western Andalucia (Valdés et al. 1997)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Asteraceae</td>
<td>81</td>
<td>14.6</td>
<td>91</td>
<td>10.3</td>
</tr>
<tr>
<td>Lamiaceae</td>
<td>74</td>
<td>13.4</td>
<td>27</td>
<td>3.1</td>
</tr>
<tr>
<td>Fabaceae</td>
<td>50</td>
<td>9.1</td>
<td>91</td>
<td>10.3</td>
</tr>
<tr>
<td>Brassicaceae</td>
<td>46</td>
<td>8.3</td>
<td>35</td>
<td>4.0</td>
</tr>
<tr>
<td>Scrophulariaceae</td>
<td>41</td>
<td>7.4</td>
<td>33</td>
<td>3.7</td>
</tr>
<tr>
<td>Plumbaginaceae</td>
<td>35</td>
<td>6.3</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>Caryophyllaceae</td>
<td>34</td>
<td>6.1</td>
<td>45</td>
<td>5.1</td>
</tr>
<tr>
<td>Poaceae</td>
<td>34</td>
<td>6.1</td>
<td>93</td>
<td>10.6</td>
</tr>
<tr>
<td>Cistaceae</td>
<td>18</td>
<td>3.3</td>
<td>13</td>
<td>1.5</td>
</tr>
<tr>
<td>Ranunculaceae</td>
<td>10</td>
<td>1.8</td>
<td>21</td>
<td>2.4</td>
</tr>
<tr>
<td>Saxifragaceae</td>
<td>10</td>
<td>1.8</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>Boraginaceae</td>
<td>10</td>
<td>1.8</td>
<td>15</td>
<td>1.7</td>
</tr>
<tr>
<td>Liliaceae</td>
<td>10</td>
<td>1.8</td>
<td>23</td>
<td>2.6</td>
</tr>
<tr>
<td>Amaryllidaceae</td>
<td>10</td>
<td>1.8</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>Others</td>
<td>90</td>
<td>16.3</td>
<td>387</td>
<td>43.9</td>
</tr>
<tr>
<td>Total</td>
<td>553</td>
<td></td>
<td>881</td>
<td></td>
</tr>
</tbody>
</table>
the complete local or regional floras in the south of the Peninsula (Table 2). As far as both, endemic flora and complete floras are concerned the highest rate of species or subspecies in this area belongs to the family Asteraceae. Other families, e.g., Fabaceae, Caryophyllaceae, Ranunculaceae and Boraginaceae, exhibit similar rates in both cases. However, some families, such as Poaceae and Apiaceae, are less well represented in the endemic flora than in the whole flora, whereas the opposite pattern can be observed in the families Brassicaceae, Scrophulariaceae, Cistaceae, Saxifragaceae and Amaryllidaceae, and is particularly noticeable in Lamiaceae and Plumbaginaceae (Tab. 2).

The rate of Cistaceae has sometimes been used as an indicator of the Mediterranean character of a given flora, since this family and, particularly, the genus Helianthemum have their main diversification centre in the Mediterranean region. In the endemic flora in the south of the Iberian Peninsula, this rate is 3.3, that is, higher than the rates already recorded for a number of local or regional Mediterranean floras. In the endemic flora in the south of the Iberian Peninsula genera such as Centaurea, Teucrium and Thymus have a considerably high number of species with restricted distribution.

The occurrence of vicariant species in isolated geographical habitats or enclaves indicates evolutive processes in connection with reproductive isolation (Sainz Ollero & Moreno Saiz, 2002). The species of the genus Centaurea included in the section Willkommia are an example of these processes of speciation (Blanca 1981). Similar speciation patterns may have taken place in the family Plumbaginaceae, with a comparatively high endemity rate. Many species of the genus Limonium are vicariant and occur in fragmented habitats (Crespo & Lledó 1998). Processes of fast speciation in the genus Limonium are encouraged by hybridization, polyploidy and apomixis (Palacios et al. 2000).

Characteristics of the flora

Life form. The spectrum of life forms of the endemic flora in the south of the Iberian Peninsula differs from those observed in a number of complete local floras in this territory (Tab. 3). Most of the endemic species in the south of the Iberian Peninsula are chamaephytes and hemicyryptophytes. By contrast, the rate of therophytes is considerably low here.

In general, the rate of hemicyryptophytes (33%) in the endemic flora is relatively high for the south of the Iberian Peninsula. It is, however, similar to the rates recorded for the floras of some mountainous areas (Cueto et al. 1991) and the floras of temperate climates (see, e.g. Preston & Hill 1997). In a number of surveys carried out in the Mediterranean basin, the abundance of hemicyryptophytes has been related to rainfall increase and temperature decrease (Voliotis 1982; Danin & Orshan 1990). This high rate of hemicyryptophytes certainly mirrors the clear orophilous character of the endemic flora studied here.

Therophytes and chamaephytes are the most abundant life forms in the flora of the Mediterranean basin (Quézel 1995). However, the rate of chamaephytes in the endemic flora under study (45%) is considerably higher than the rates recorded for local or regional Mediterranean floras. In some of the Mediterranean communities the rate of chamaephytes can be very high indeed. Many of the endemic plants in the south of the Iberian Peninsula are suffruticose species occurring in considerably diverse bushy habitats. By contrast, nanophanerophytes, although frequent in these habitats, have a considerably low number of endemic species, probably due to their relation with the endozoochorous seed-dispersal strategy, as we shall see later.

Contrary to the abundance of therophytes in the Mediterranean basin, which can reach up to 50% in some local floras (Braun-Blanquet et al. 1964), their rate in the endemic flora under study is a meagre 11%. Some of the surveys carried out in the Mediterranean basin suggest that therophytes have an optimum between 200 and 500 mm of rainfall (Danin & Orshan 1990). Accordingly, therophytes in the area under study are predominant at low mountain level, valleys and plain areas. In these territories plant populations are never truly isolated and highly selective habitats are rare. For

Table 3. Comparative analysis (%) of the biological spectra of the endemic flora in the south of the Iberian Peninsula (SIP) and of some complete local floras of the same territory. Ph = phanerophytes, Na = nanophanerophytes, Ch = chamaephytes, Hm = hemicyryptophytes, Ge = geophytes, Th = therophytes, Hy = hydrophytes, He = helophytes.

<table>
<thead>
<tr>
<th>Flora</th>
<th>Life forms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ph</td>
</tr>
<tr>
<td>Endemic taxa SIP (This study)</td>
<td>1</td>
</tr>
<tr>
<td>Sierras of María and Orce (Cueto et al. 1991)</td>
<td>9</td>
</tr>
<tr>
<td>Natural Park Cardeña (Melendo &amp; Cano 1998)</td>
<td>9</td>
</tr>
<tr>
<td>SW of Almería (Giménez Luque 2000)</td>
<td>11</td>
</tr>
</tbody>
</table>
this reason and because of their easy dissemination, the rate of endemic therophytes is, comparatively speaking, very low.

**Pollination.** 91% of the endemic species are biotically pollinated, mostly by insects. Some of these endemic species are pollinated by only one insect. This is the case of *Viola cazorlensis*, an endemic species of some Baetic ranges which can be pollinated only by the lepidopteran *Macroglossum stellatarum* (Herrera 1990).

Typically, biotic pollination tends to be dominant in low and middle latitudes (Ricklefs & Renner 1994) whereas its frequency decreases as altitude increases (Midgley & Bond 1991). The rate recorded here is higher than the rate observed in whole floras of neighbouring areas of the same latitude (Guitián & Sánchez 1992; Buide et al. 1998). The low occurrence of members of the family Poaceae in the endemic flora under study has probably much to do with this fact.

**Dispersal.** Fig. 2 shows the rates of species in each of the nine seed-dispersal categories. As can be seen, 23% of the species use biotic means of dispersion, exozoochory being the most frequent (16%). In the floras of middle latitudes the rate of exozoochory is very low (Sorensen 1986; Wilson et al. 1990), but in the flora under study the importance of exozoochory can be by no means overlooked. In areas with a Mediterranean climate, exozoochory is probably an important survival resource for small populations (Van der Pijl 1982; Shmida & Ellner 1983), in which most of the endemic species tend to occur. Only 1% of the endemic plants use endozoochorous dispersion, a rate lower than the one recorded in floras of neighbouring areas (Kay 1992; Buide et al. 1998) and extremely lower compared with some Mediterranean communities which are dominated by or are adjacent to woods, where endozoochory can be the dispersal strategy of up to 50% of the woody species (Guitián & Sánchez 1992).

Thirty-one per cent of the endemic species present adaptations to anemochorous dispersion. Certain extensions in the diaspores which act much in the same way as do wings are particularly frequent (14%). This rate is remarkably higher than the available rates of floras of temperate regions (Wilson et al. 1990). However, the role of anemochory in the endemic flora cannot be of much importance, since many of these adaptations are not very efficient. Most of the endemic species of the genus *Erysimum* have, for example, seeds with rudimentary wings, as happens also in some species of the genus *Hormatophylla*.

Semachores/barochores are the largest group in proportion (44%). Accordingly, most of the endemic species do not present evident adaptations to promote seed dispersion. Although plants take advantage of other secondary mechanisms for this purpose, their dissemi-

![Fig. 2. Percentages of endemic species in the south Iberian Peninsula flora with biotic seed-dispersal mechanisms (EN = endozoochory, EX = exozoochory, MY = myrmecochory) and abiotic seed-dispersal mechanisms (As = anemochory due to small size, Ap = anemochory due to pappi, Aw = anemochory due to wings, AU = autochory, SB = semachory/barochory).](image-url)

native potential tends to be considerably limited. Nevertheless, the rate of semachores/barochores is lower than the rates found in complete floras of neighbouring zones with a smaller number of endemic species (Buide et al. 1998). These records suggest that, in general, when explaining the richness in endemic species of the south of the Iberian Peninsula, habitat specificity is a much more important factor than the isolation of populations as a result of their limited dispersion. By contrast, this lack of adaptations to promote dispersion does play a significant role among endemic therophytes (Fig. 3).

**Reproductive mode.** The rate of dioecious species varies dramatically from one flora to another (see, e.g. Bawa 1980; Kay & Stevens 1986; Oliveira 1996). It strongly depends on the taxonomical composition of a flora and is relatively independent from local selective pressure (Renner & Ricklefs 1995). In this respect too, the endemic flora in the south of the Iberian Peninsula does not comply with the general patterns observed in the Mediterranean flora as a whole. The rate of dioecious species found in the endemic flora under study only reaches 0.5%. This means that it is clearly lower than, e.g., the 1.7% recorded for the flora of Israel (Rotenberg 1998).

**Associations between characters**

The heterogeneity analysis of contingency tables reveals clear associations between the different variables under consideration (Tab. 4).

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Since endozoochory is dominant among phanerophytes and nanophanerophytes of woods and bushy ecosystems (Gutiérrez & Sánchez 1992; Buíde et al. 1998), there is a relationship between life form (either herbaceous or woody) and seed-dispersal strategy (either biotic or abiotic) in the whole flora of temperate climates. Our research has also revealed this same significant association for the endemic flora of the South of the Iberian peninsula (Tab. 4). Not only do herbaceous species tend to use dispersion mechanisms less specialized than those used by woody species, but also semachory/barochory is more frequent among the former (Fig. 3). Nevertheless, since the predominant life forms in the endemic flora under study are woody chamaephytes and herbaceous hemicryptophytes of semachorous/barochorous dispersion, the association is not as strong as it is in whole floras. In addition, endozoochory does not seem to play a significant role either (Fig. 3) among phanerophytes and nanophanerophytes when they are endemic, since it implies long-distance dispersion.

Significant associations were detected between pollination mode and seed-dispersal strategy, and between pollination mode and life form (Tab. 4). Angiosperm families exhibit the same associations too (Ricklefs & Renner 1994). In other words, an endemic species with a woody life-form has a higher-than-expected probability of being animal-pollinated.
Dioecy has also been related to a number of different characteristics such as woody character, zoochory, flower of small size and fleshy fruits, or wind pollination (Muenchow 1978; Bawa 1980; Fox 1985; Renner & Ricklefs 1995). In contrast to previous surveys (Buide et al. 1998), for this endemic flora our data only reveal a association between dioecy and abiotic pollination by wind. We must not overlook, however, that dioecy is a rare feature among the species considered, since only three of them are dioecious. Such a small number makes any general conclusion on this issue overadventurous.

Conclusions

The remarkable importance of the Asteraceae, Lamia-ceae, Fabaceae, Brassicaceae and Plumbaginaceae families confers a particular taxonomical spectrum on the endemic flora in the south of the Iberian Peninsula, different from that of the whole Mediterranean flora.

This endemic flora does not comply either with the general ecological patterns of the whole Mediterranean flora. In contrast to the usual spectra of life forms in the Mediterranean area, in which annual species are dominant, most of the endemic taxa of the Southern part of the Iberian peninsula are perennial woody species (chamaephytes) or herbaceous (hemicryptophytes). This peculiarity of the endemic flora not only reveals its orophilous character, it also mirrors the tendency of a large number of endemic species to occur in bushy and rocky landscapes.

A large number of endemic species (44%) do not present evident adaptations to promote dispersion. However, this deficiency in the disseminative potential of the plants only plays a significant role among stenochorous therophytes inhabiting depressions, plains and low mountain areas. Among middle and high altitude endemic taxa this parameter is of much less importance than other factors, such as habitat specificity. The data suggest that at middle and high mountain levels adaptations to exozoochorous or even anemochorous dispersion promote the survival of small populations and consequently increase the endemic richness of these territories.

Dioecious species, phanerophytes and nanophanerophytes, because of their relation to endozoochorous dispersion, are rare in the endemic flora under study. As far as between-character associations within this flora are significant, they mostly differ from those observed in whole neighbouring floras. This also underlines the singularity of the endemic flora in the south of the Iberian Peninsula.

Appendix

Endemic taxa in the south of the Iberian Peninsula analysed in this survey. Stenochory, biotype, dispersal, pollination and reproductive modes are shown for each of them.

**Stenochory degree:** Ast: endemic in Andalucía sensu strictu, Asl: endemic in Andalucía sensu lato, Aex: endemic in the south of the Peninsula but absent in Andalucía.

**Life forms:** Ph = phanerophyte, Na = nanophanerophyte, Ch = chamaephyte, Hm = hemicryptophyte, Ge = geophyte, Hy = hydrophyte, He = helophyte.

**Seed-dispersal mode:** EN = endozoochory, EX = exozoochory, HI = hidrochory, MY = myrmecochory, As = anemochory due to small size, Ap = anemochory due to pappi, Aw = anemochory due to wings, AU = autochory, SB = semachory/barochory.

**Pollination mode:** B = biotic, A = abiotic.

**Reproductive mode:** H = hermaphrodite, M = monoecious, D = dioecious.

Table 4. Results of heterogeneity analysis of contingency tables cross-classifying the various ecological characters considered in the present study. The binary classifications used were herbaceous (H) or woody (W) for life form, abiotic (A) or biotic (B) for seed-dispersal and for pollination mode, and dioecious (D) or within-plant monoecious (M) for reproductive mode. Heterogeneity analysis was made by the chi-square test or Fisher’s exact test.

<table>
<thead>
<tr>
<th>Life form</th>
<th>Dispersal mode</th>
<th>Pollination mode</th>
<th>Reproduction mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>H</td>
<td>225</td>
<td>53</td>
<td>45</td>
</tr>
<tr>
<td>W</td>
<td>210</td>
<td>77</td>
<td>7</td>
</tr>
<tr>
<td>χ² = 4.8</td>
<td></td>
<td></td>
<td>31.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dispersal mode</th>
<th>Pollination mode</th>
<th>Reproduction mode</th>
<th>Pollination mode</th>
<th>Reproduction mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>31</td>
<td>404</td>
<td>A</td>
<td>433</td>
</tr>
<tr>
<td>B</td>
<td>21</td>
<td>109</td>
<td>B</td>
<td>129</td>
</tr>
<tr>
<td>χ² = 9.8</td>
<td></td>
<td>0.2</td>
<td>χ² = 11.9</td>
<td>P &lt; 0.001</td>
</tr>
</tbody>
</table>

FLORA (2003) 198  267
Biarum carratracense (Haenseler) Font Quer

Biscutella glacialis (Boiss. & Reut.) Jordan

Biscutella lyrata L.

Biscutella sempervirens subsp. vicentina (Samp.) Malag.

Brachypodium boissieri (Boiss.) Nyman

Brachypodium gaditanum

Brachypodium boissieri (Boiss.)

Biscutella lyrata L. Ast/Th/Aw/B/H

Centaurea jaennensis Degen & Debeaux in Degen

Centaurea kunkelii García-Jacas

Centaurea mariana Nyman

Centaurea monticola Boiss. ex DC.

Centaurea pauneroi Talavera & Muñoz

Centaurea pulvinata (Blanca) Blanca

Centaurea sagredoi Blanca

Centranthus nevadensis Boiss. subsp. nevadensis

Cephalaria linearifolia Lange

Chamaeophyllum glabrum (Boiss.) Willk.

Chamaeophyllum macropodum subsp. degenii (Hervier) Figuerola & al.

Chamaeophyllum macropodum (Boiss. & Reut.) Lange in Willk. & Lange subsp. macropodum

Cirsi um gadi tumanum Talavera & Valdés

Cirsi umGregarium Boiss. ex Willk. in Willk. & Lange

Cisti tus libanotis L.

Coincya longirostra (Boiss.) G. Reut. & Burdet

Coincya monensis subsp. nevadensis (Willk.) Leadlay

Crepis granatensis (Willk.) Leadlay

Crepis leucocephala (Dufour) Nyman

Crepis ope rinoidea Boiss. ex Froelich in DC.

Cynara algarbiensis Cosson ex Mariz

Cynara baetica (Sprengel) Pau

Cytisus fontanesii (Boiss.) Calestani

Cytisus galianoi Talavera & P. E. Gibbs

Cytisus grandiflorus subsp. cabezudosi Talavera

Cytisus malacitanus Boiss.

Dactylis juncinella Bory

Dactylorhiza pliocarpa (Link)

Dactylorhiza sulphurea (Link)

Daphne oleoides subsp. hispanica (Pau) Rivas Mart.

Daucus arcanus García-Martín & Silvestre

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Delphinium emarginatum subsp. nevadense (G. Kunze) C. Martín & Silvestre

Dianthus charidemi Pau

Digitalis mariana subsp. heywoodii (P. Silva & M. Silva) Hinz

Digitalis mariana Boiss. subsp. mariana

Digitalis purpurea subsp. bocquetti Valdés

Diplotaxis harra subsp. lagascana (DC.) O. Bolós & Vigo

Draba hispanica subsp. laderoi

Erodium astragaloides

Erodium boissieri

Erodium cazorlanum Heywood

Erodium major (Boiss.) Vierh. subsp. Erucastrum virgatum Boiss.

Erodium rupicola Auriault & Boiss. Ast/Hm/EX/B/H

Echinopspartum boissieri (Spach) Rivas Mart., M. E. García & Penas

Echinopspartum algibicum

Elaoeselinum asclepium subsp. millefolium (Bois.) García-Martín & Silvestre

Erica andevalensis Cabezudo & Rivera

Erigeron frigidus Erodium rupicola

Festuca clementei Boiss.

Festuca costae-alentii

Festuca clementei

Festuca clementei subsp. moleroi (Cebolla & Rivas Ponce)

Festuca clementei Boiss. subsp. moleroi

Festuca cordubensis Devesa

Festuca frigida (Hackel) K. Richter

Festuca longiauriculata de la Fuente, Ortúñez & Ferrero

Festuca pseudoesokia Boiss.

Frangula alnus subsp. baetica (Reverchon ex Willk.) Rivas

Galium eurythrorrhizum Boiss. & Reut.

Galium prininosum Boiss.

Galium pulvinatum Boiss.

Genista pneumonanthe subsp. depressa (Boiss.) Rivas Mart., Asensi, J. Molero & F. Valle

Genista wettsteiniana subsp. sufuba Boiss. & Reut.

Geranium cazorlense Heywood

Geranium fitzii Polatschek

Geranium fitzii Erodium boissieri

Geranium myriophyllum Lange

Geranium nevadense Reut.

Geranium popovii Rothm.

Geranium rononíe Potatschek

Euphorbia paniculata subsp. monchiquensis (Franco & P. Silva) Vicens, Molero & C. Blanché

Escomodendron bourgaeanum Cosson

Festuca baetica subsp. moleroi (Cebolla & Rivas Ponce)

Festuca clementei Boiss. subsp. moleroi

Festuca clementei Boiss.

Festuca cordubensis Devesa

Festuca frigida (Hackel) K. Richter

Festuca longiauriculata de la Fuente, Ortúñez & Ferrero

Festuca pseudoesokia Boiss.
Helianthemum viscidulum subsp. raynaudii (A. Ortega, Romero García & C. Morales) G. López

Helianthemum viscidulum Boiss. subsp. viscidulum

Heliotrichon filifolium subsp. arundanum Romero Zarco

Heliotrichon filifolium subsp. cazorlense (Romero Zarco) Rivas Mart., Asensi, J. Molero & F. Valle

Heliotrichon filifolium subsp. velatum (Boiss.) Romero Zarco

Herniaria algarvica Chaudhri

Herniaria baeticum Boiss. & Reut. in Boiss.

Herniaria boissieri Gay subsp. boissieri

Hieracium baeticum Arvet-Touvet & Reverchon

Hieracium xedendense Pau

Hippocrepis castroviejoi & E. Domínguez

Hippocrepis eriocarpa (Boiss.) Boiss.

Hippocrepis nevadensis (Hrabetová) Talavera & E. Domínguez

Hippocrepis prostrata Boiss.

Hippocrepis rupestris Laza

Hippocrepis scabra DC.

Hippocrepis tavera-mendozae (P. Küpfer) Ast/Hm/SB/B/H

Hormathophylla cadevalliana (Pau) T. R. Dudley

Hormathophylla longicaulis (Boiss.) Cullen & T. R. Dudley

Hormathophylla purpurea (Lag. & Rodr.) P. Küpfer in Castrov. & al.

Hormathophylla reverchonii (Degen & Hervier) Cullen & T. R. Dudley

Hymenostemma pseudanthemis (G. Kunze) Willk.

Hypochoeris ratae Talavera

Iberis carnosa subsp. embergeri (Serve) Moreno

Iberis carnosa subsp. granatensis (Boiss. & Reut.) Moreno

Iberis fontqueri Pau

Iberis grossii Pau

Iberis nazarita Moreno

Jasione crispa subsp. amethystina (Lag. & Rodr.) Tutin

Jasione crispa subsp. mariana (Willk.) Rivas Mart.

Jasione crispa subsp. segurensis Mota, Díaz de la Guardia, Gómez-Mercado & F. Valle

Jasione crispa subsp. tomentosa (A. DC.) Rivas Mart.

Jasione montana subsp. penicillata (Boiss.) Rivas Mart.

Juncus acutiflorus subsp. rugosus (Steudel) Cout.

Juncus emmanuels A. Fernández & García

Jurinea fontqueri Cuatrec.

Klasea flavescens (L.) J.

Holub subsp. flavescens

Klasea monardii (Dufour) J. Holub

Koeleria crassipes subsp. nevadensis (Hackel) Romero Zarco

Lactuca perennis subsp. granatensis Charpin & Fdez. Casas

Laserpitium longiradiatum Boiss.

Lavandula lanata Boiss.

Lavatera oblongifolia Boiss.

Leontodon hory Boiss.

Leontodon carpatus subsp. nevadensis (Lange) Finch & P. D. Sell

Leontodon microcephalus (Boiss. ex DC.) Boiss.

Lepidium petrophilum Cosson

Lepidium stylum Lag. & Rodr.

Lepidium villarissii subsp. anticarium (Valdés Berm. & G. López)

Linaria aeruginea subsp. nevadensis (Boiss.) Rivas Mart., Asensi, Molero & Mesa & F. Valle

Linaria amoi Campo ex Amo

Linaria antica Boiss. & Reut.

Linaria benitoi Fdez. Casas

Linaria boryi Boiss. ex Boiss.

Linaria burtleri Lange

Linaria inconspicua Coincy

Linaria lamarkii Rouy

Linaria lilacina Lange

Linaria nigricans Lange

Linaria nigricans Lange

Linaria nigricans Lange

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Linaria nigricans Lange

Linaria nigricans Lange

Linaria nigricans Lange

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Linaria nigricans Lange
Silene gadiatana Talav. & Bocquet
Silene germana Gay
Silene inaperta subsp. serpentinicola
Talavera
Silene littorea subsp. ascendentens
(Lag.) Rivas Goday
Silene marianae Pau
Silene stockei Chater
Silene tomentosa Otth
Solenanthus reverchonii Degen
Staelhelia baetica DC.
Tanacetum aucheri Schultz Bip. ex Willk
Tanacetum microphyllum DC.
Taraxacum gaudiumanum Talavera
Taraxacum nevadense H. Lindb. fil.
Teline trinsectata (Webb) Talavera & P. E. Gibbs
Teucrium algarbiense (Cout.) Cout.
Teucrium almeriense Hubbard & Sandwith
Teucrium balhaecrius Sennen
Teucrium carolipaui subsp. fontqueri (Sennen) Rivas Mart.
Teucrium cavanillesianum (Font Quer & Jerón.) Navarro & Rosúa
Teucrium charidemi Sandwith
Teucrium chrysostrichum Lange
Teucrium compactum Clemente ex Lag.
Teucrium erosiphum Willik.
Teucrium fragile Boiss.
Teucrium franchetianum Rouy & Coiney
Teucrium freynii E. Rev. ex Willk.
Teucrium haenseleri Boiss.
Teucrium hieronymyi Sennen
Teucrium intricatum Lange
Teucrium lanigerum Lag.
Teucrium leoniot Sennen
Teucrium lepiscephalum Pau
Teucrium leeuwii Sennen
Teucrium libanitis Schreb.
Teucrium oxylepis subsp. marnianum
Ruiz de la Torre & Ruíz del Castillo
Teucrium oxylepis Font Quer subsp. oxylepis
Teucrium reverchonii Willk.
Teucrium rivaisi Riguad
Teucrium rivas-martinezi Alcaraz, Garre, Mart. Farras & Peinado
Teucrium rivasianum Ruiz de la Torre & Ruiz del Castillo
Teucrium similatum T. Navarro & Rosúa
Teucrium tordatunum (Devesa & Valdés Berm.) Peris, Figueroa & Stübing
Teucrium tardarum Losa & Rivas Goday
Teucrium tervincetum Rouy
Teucrium webbianum Boiss.

Thalictrum foetidum subsp. nevadense
(Font Quer ex P. Montserrat)
Molero Mesa & Pérez Raya
Ast/Hm/Aw/A/H
Thalictrum speciosissimum subsp. allini (Pau) P. Montserrat
Ast/Hm/Aw/A/H
Thlaspi nevadense Boiss. & Reut.
Ast/Ch/SB/B/H
Thymelaea granatensis (Pau) Pau ex Lacaita
Ast/Ch/SB/B/H
Thymus albicans Hoffmanns & Link
Ast/Ch/As/B/H
Thymus baeticus Boiss. ex Lacaita
Ast/Ch/As/B/H
Thymus funkii Coss.
Aex/Ch/As/B/H
Thymus granatensis Boiss. subsp. granatensis
Ast/Ch/As/B/H
Thymus longiflorus Boiss. subsp. longiflorus
Ast/Ch/As/B/H
Thymus lotocephalus G. López & R. Morales
Aex/Ch/As/B/H
Thymus mastichina subsp. donyanae R. Morales
Ast/Ch/As/B/H
Thymus morodei Pau ex Martinez
Ast/Ch/As/B/H
Thymus orospedanuas Huguet del Villar
Ast/Ch/As/B/H
Thymus serpylloides Bory
Ast/Ch/As/B/H
Trisetaria dufourii (Boiss.) Paunero
Ast/Th/EX/A/H
Trisetum antoni-josephini Font Quer & Muñoz Medina
Ast/Hm/EX/A/H
Trisetum glaciale (Bory) Boiss.
Ast/Hm/EX/A/H
Trisetum velutinum Boiss.
Ast/Hm/EX/A/H
Ulex argenteus Welw. ex Webb subsp. argenteus
Aex/Na/MY/B/H
Ulex argenteus subsp. subsericeus (Cout.) Rothm.
Ast/Na/MY/B/H
Ulex australis Clemente subsp. australis
Ast/Na/MY/B/H
Ulex baeticus Boiss. subsp. baeticus
Ast/Na/MY/B/H
Ulex borgiae Rivas Mart.
Ast/Na/MY/B/H
Ulex canescens Lange
Ast/Na/MY/B/H
Ulex erinaceus Welw. ex Webb
Aex/Ch/MY/B/H
Ulex eriocladus C. Vicioso
Ast/Na/MY/B/H
Ulex parviflorus subsp. rivagodayanus Cubas
Ast/Na/MY/B/H
Vaccinium uliginosum subsp. nanum (Boiss.) Rivas Mart., Asensi, Molero Mesa & F. Valle
Ast/Ch/EN/B/H
Valerianella divaricata Lange
Ast/Th/SB/B/H
Vella spinosa Boiss.
Ast/Ch/EN/B/H
Verbascum charidemi Murb.
Aex/Hm/SB/B/H
Verbascum giganticum subsp. martinezii Valdés
Ast/Hm/SB/B/H
Verbascum nevadense Boiss.
Ast/Th/SB/B/H
Veronica tenuifolia subsp. fontqueri (Pau) Mart. Ortega & E. Rico
Ast/Ch/SB/B/H
Veronica turbinella Rivas Mart., Asensi, Molero Mesa & F. Valle
Ast/Hm/SB/B/H
Vicia glauca subsp. giennensis (Cuatrec.) Blanca & F. Valle
Ast/Hm/AU/B/H
Viola cazorlensis Gand.
Ast/Hm/AU/B/H
Viola crassiuscula Bory
Ast/Hm/AU/B/H
Vulpia fontquerana Melderis & Stace
Ast/Th/EX/A/H
Vulpia hispanica subsp. montana (Boiss. & Reut.) Devesa
Ast/Th/EX/A/H
Xolantha brevipes (Boiss. & Reut.) Pau
Ast/Th/EX/A/H
Galgello, Muñoz Garm. & C. Navarro
Ast/Th/SB/B/H
References


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