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Bryophyte survey as a basis for the validity of the Mediterranean isoclimatic areas in Portugal

Abstract

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The total number of bryophyte taxa for each UTM square (10 km) in Portugal is given and the general phytogeographical variation of the bryoflora is outlined. Some cumulative maps are discussed and finally a phytogeographycal synthesis is presented. Maps of species distribution have always been a valuable tool for the evaluation of bioclimatic zones and for the Mediterranean area, some bryophytes taxa, as *Riccia* and *Sphagnum*, are good examples. The limit of Mediterranean influence in Portugal given by this bryofloristic analysis is compared with the phytogeographical division proposed by different authors for Portugal. The conclusions lead to the identification of two different situations in Portugal relative to endemic groups, that are related with the possible center of origin.

Introduction

Portugal is part of the Iberian Peninsula, in the mid latitudes of the northern hemisphere and in the vicinity of the Mediterranean Basin. It presents a very pronounced variation of climatic influences and the ecosystems range from small areas with boreal systems to large zones with thermo-xerophytic vegetation. On the other hand the oceanic influence has an important part to play in the maintenance, in restricted areas, of an evergreen broad-leaf trees vegetation related to Tertiary subtropical forests.

The Iberian Peninsula comprises about 20% of the surface area of the Mediterranean region (Quézel 1985) and Portugal covers more than 75% of the area in this region (70000 Km^2 to 91000 Km^2) according to Médail & Quézel (1997).

In Portugal and northern Spain some bioclimatic criteria and woody vegetation types were used to distinguish the Eurosiberian from the Mediterranean region (Tormo Molina 1992, Morla & Pineda 1985, Moreno & al. 1990). However, due to pronounced geomorphological contrasts, the boundaries between both phytogeographic regions are not always easy to define.

Welwitsch (1872) is excited in the pointing out, for the first time, the presence of some bryophytes in Portugal, at low altitudes, that are characteristic in highlands in central

Europe e.g. *Andreaea rothii* and *Scapania undulata*. The phytogeographical importance of the Iberian bryoflora was also expressed in Allorge's works (1931, 1947) as the consequence of its geographical position and long term isolation (Sérgio 1990).

Apart from interesting and well defined distribution patterns in the Iberian cartography (Casas & al. 1985, 1989, 1992, 1996) and in the Red List of Iberian Peninsula (Sérgio & al. 1994) there is no single synthesis of the total data from Portuguese bryophytes. Araujo (in press) has recently used an important biodiversity approach and presented some correlations between the distribution patterns of vascular plants, pteridophytes and bryophytes.

The aim of this work is to determine whether the bryophytic vegetation, based on biodiversity data, can delimit the phytogeographyc regions (Eurosiberian and Mediterranean) in Portugal. On the other hand it is possible to present the main centers of biodiversity and the endemic "hot-spot" areas. So a further objective of this work is to show the relationship between the conventional bioclimatic criteria and both the bryofloristic composition in Portugal and with the endemochorologic centres.

Methodology

Species data included in this study are based on all records of bryophytes referred from Portugal, in different works and dates (about 25000 records). Each locality is integrated in the UTM grid (10 × 10 km). The first stage of analysis was to select the different species recorded in each 10 km square (about 10700 records). Each Portuguese region, "provincia" is considered for each record and the abbreviations used correspond to those of Casas & al. (1985) (Fig. 2).

The cartographic methodology used to support this work is based on Desktop Mapping software application.

The nomenclature mainly follows Corley & al. (1981) and Corley & Crundwell (1991) for the mosses, and Grolle (1983) for the liverworts.

The information on bryophyte chorology and criteria for phytogeographical analysis are based on Düll (1983, 1984, 1985, 1992) as well as those used in the Red List of Iberian Peninsula (Sérgio & al. 1994) with small alterations.

Results and discussion

In Portugal, despite its small area (92000 km^2) and low altitudes (less than 2000 m a.s.l.), the bryophyte flora is very rich with about 38% of the whole European taxa and 65% of the Iberian bryoflora (Sérgio & al. 1994).

The bryophyte flora of Portugal consists of about 670 taxa, including more than 25 new other ones compared to the former list by Sérgio & al. (1994). So there are 7,3 species/1000 km^2, or 137 km^2/species).

Biodiversity characterisation

As for the distribution patterns of bryophytes in Portugal as well as species richness, the results are related to different factors such as: historical; accidental finds; environmental

variables particularly due to the climatic influences (Sim-Sim & al. 1995, Sim-Sim & Sérgio 1998).

The biodiversity analysis corresponds to the presence and absence of all bryophyte taxa in 10 km squares. This analysis shows that, despite the presence of a large number of made worked squares, particularly significant in eastern regions, certain points can be stressed concerning the results of the different biodiversity patterns:

This evaluation shows (Fig. 1) that there are no records from 383 squares corresponding to about 40% of the total area of Portugal. From the studied squares we can evaluate ± 12 taxa on average. There is a significant number of squares (32 squares) with only one species referred to them, however some squares (13) have a high species richness with more than 180 taxa. Some of these correspond to the mountain areas of Gerês (NG62/NG72), Bussaco (NE56), Estrela (PE16/PE17), Sintra (MC69) and Monchique (NB33). These richer squares correspond, as expected, to areas of natural reserves specially in the northern part of Portugal such as Peneda-Gerês, Estrela, Aires-Candeeiros and in the South to the Serra Monchique mountain. In the Alentejo it is important to refer the richness of S. Mamede Natural Park (PD46), which has been recently investigated (Sérgio & al. 1997), with about 225 species.

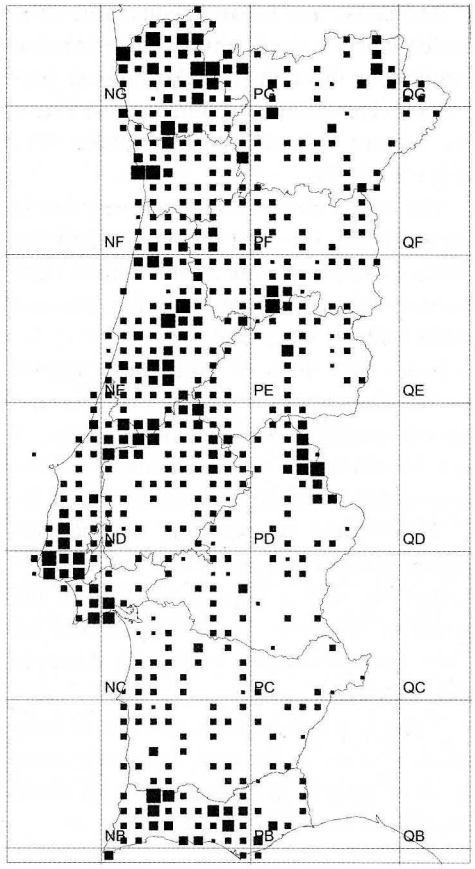

Fig. 1. Total number of bryophyte species recorded in each 10 Km square (range: 0-1; 2-30; 31-80; 81-180 and 181-375 species by square)

The difference in species diversity between areas depends in great part upon heterogeneity in habitat within the region (habitat complexity). However, another result which also emerged from the analysis is the finding of squares with high biodiversity due to historical reasons or with significant differences given by different studies. Examples are the region of Paredes do Coura (NG34) Oporto (NF25/NF35), Coimbra (NE45), and Lisbon, as result of the early works of Machado, Newton, Henriques and Welwitsch, respectively.

Phytogeographic approach

A synthesis of the results obtained for the present biodiversity of all bryophytes (Fig. 2) reveals the following chorological data. The results, corresponding to the simplified classes of phytogeographical elements, are displayed in figure 2, where the different UTM squares, and each regional area are shown.

The alpine and subarctic-subalpine categories have a very small representation throughout the country. The highest proportions are in the northern regions where the highest mountains exist (about 3%) (Figs. 2 and 5).

The boreal elements are relatively few in Portugal but are well represented to the North of the river Tagus, in Minho, Trás-os-Montes, Douro Litoral, Beira Alta and Beira Baixa (Figs. 2 and 6).

More than 40% of Portuguese species are included in the oceanic, sub-oceanic and oceanic-mediterranean elements (Figs. 2 and 3) which are very well and regularly represented throughout the country (Fig. 2).

As it would be expected, the mediterranean species are relatively well represented but with a large percentage to the South of the river Tagus (Fig. 2 and 4). They are particularly evident in Alentejo and Algarve.

There is a considerable number of temperate species in Portugal that occur more or less regularly in all regions, with about 20-35% in each 10 km square (Fig. 2).

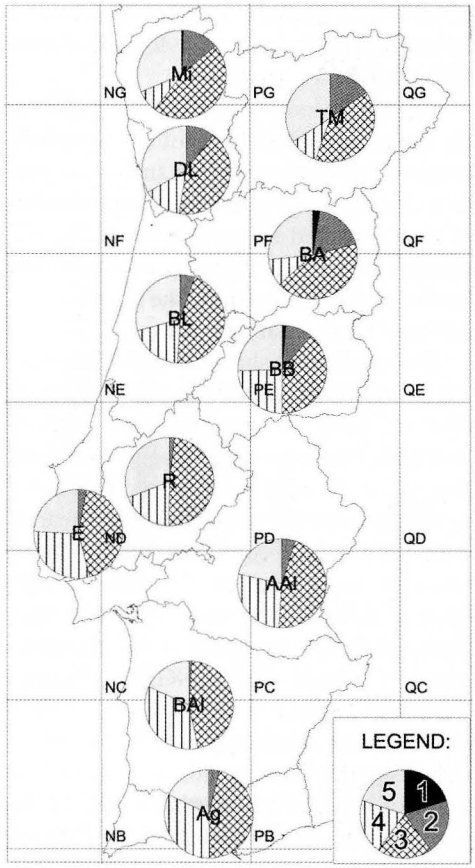

Fig. 2. Different phytogeographical elements of bryophytes species (in %) recorded by each region. Species were assigned to phytogeographical patterns based, with few adaptations, on criteria used for all European regions (Düll 1983, 1984, 1985).

Legend: **1**: arctic-alpine and subarctic-subalpine (subarctic-alpine, dealpine, subarctic); **2**: boreal (subboreal, subcosmopolite-boreal, subcosmopolite-subboreal); **3**: suboceanic (-subalpine, suboceanic-alpine), oceanic (euoceanic, oceanic-subtemperate, oceanic-subalpine) and oceanic-mediterranean (suboceanic-mediterranean, suboceanic-submediterranean); **4**: mediterranean, submediterranean-suboceanic and submediterranean; **5**: temperate (temperate-subalpine). Regional abreviations: Mi: Minho, TM: Trás-os-Montes e Alto Douro, DL: Douro Litoral, BL: Beira Litoral, BA: Beira Alta, BB: Beira Baixa, E: Estremaura, R: Ribatejo, AAl: Alto Alentejo, BAl: Baixo Alentejo and Ag: Algarve.

Taxic diversity

The taxic diversity is a measure of the dispersion of a taxonomic group (Bisby 1995) and can present an interesting perspective for some Portuguese bryophytes. A taxonomic group that presents a particular bioclimatic requirements can give important information about the biogeographical position of the occupied area. We can present two examples.

The mediterranean climate is the most important component of the abiotic factors for some bryophytes such as the *Marchantiales* (Jovet-Ast & al. 1976). Therefore *Riccia* species distribution can define the potential ecosystem as being the Mediterranean type in Portugal (Fig. 7).

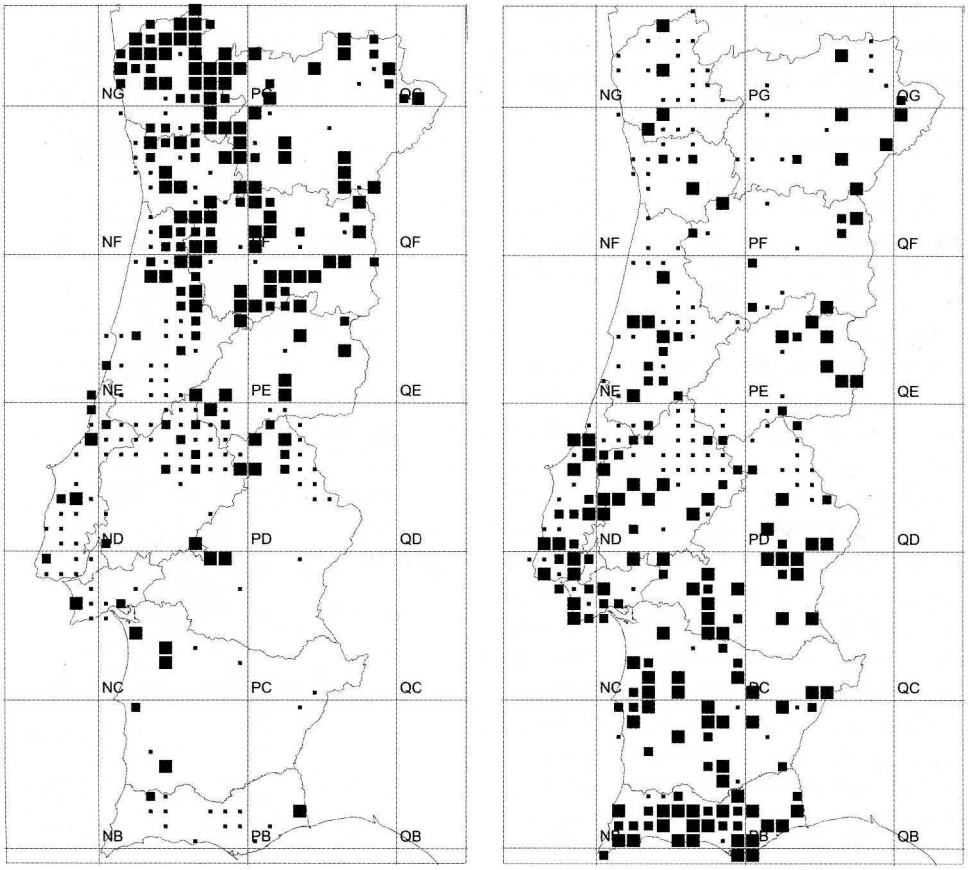

Fig. 3-4. Total number of oceanic with sub-oceanic and submediterranean with mediterranean bryophytes respectively recorded in each 10 Km square (range: 0-20%; 20-30% and 30-100%).

On the other hands the species of the genus *Sphagnum*, a taxonomic group that presents opposite ecological and bioclimatic requirements from that of *Riccia* Daniels & Eddy (1985) have considered that the main distribution center of *Sphagnum* in Europe is represented by boreal and sub-arctic zones. In Portugal (Fig. 8) the correlation between the distribution of all *Sphagnum* species and the predefined Eurosiberian-Mediterranean boundary is clear (Rivas-Martinez & al. 1990). However we propose an increase in the Eurosiberian area in Portugal (Fig. 7 and 8). This suggestion is supported not only by the distribution of *Sphagnum* species but also by the distribution of boreal and alpine bryophytes, the limits of different values of Emberger's index (Alcofurado & al. 1982) and also the dominant of the vegetation type, main tree species, proposed by Moreno & al. (1990) for North Spain.

Endemic species

Endemic bryophytes in Portugal are few and quite difficult to select because this status

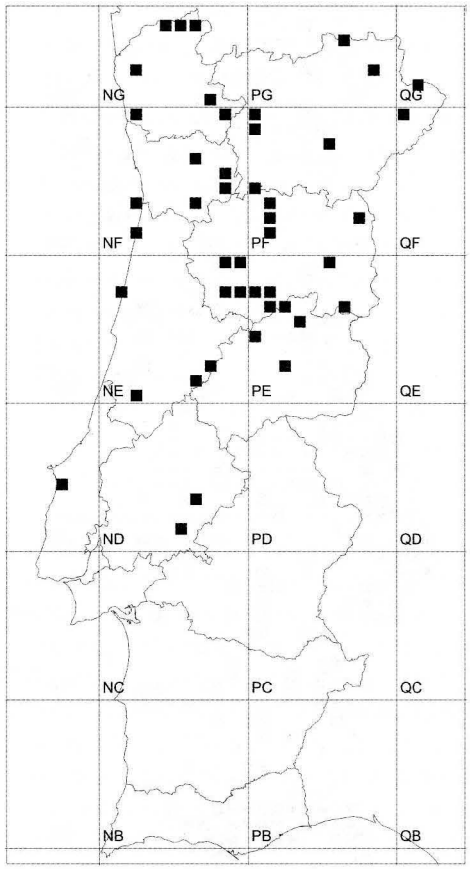

Fig. 5. Squares with values high than 30% of alpine, subarctic-subalpine and boreal bryophytes.

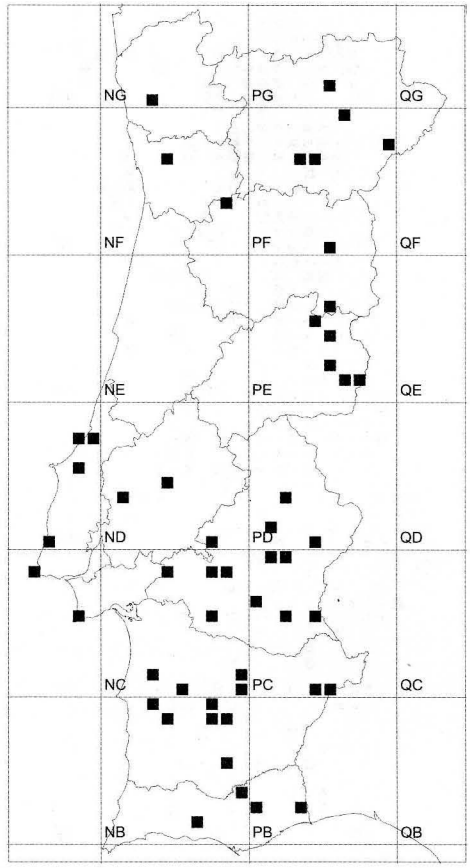

Fig. 6. Squares with values high than 60% of sub-mediterranean, mediterranean-oceanic and mediterranean bryophytes.

is related to the degree of knowledge of other geographical areas, particularly in Europe and Macaronesian islands. For this reason and having in mind that some examples of endemic bryophytes restricted to Portugal or Spain have recently been found in other regions, as *Marsupella profunda* and *Hypnum uncinulatum* in Macaronesia and Ireland (Düll 1985), *Acaulon fontiquerianum* in France (Sérgio & al. 1993), *Bryoerythrophyllum machadoanum* (= *B. campylocarpum,* Düll 1992) in Africa. It will therefore be preferable to present some results based on three kinds of endemics: 1 - Iberian endemics (8 taxa); 2 - Iberian Macaronesian endemics (6 taxa); 3 - Mediterranean endemics (25 taxa).

1. - Only 8 mosses of the Portuguese bryoflora are included as Iberian endemics. Among them, *Triquetrella arapilensis*, *Schizymenium pontevedrensis*, *Anomobryum lusitanicum*, *Racomitrium hespericum*, *R. lusitanicum* and *Orthotrichum ibericum* are included in the recent Iberian Red List (Sérgio & al. 1994). Besides *Didymodon bistratosus* and

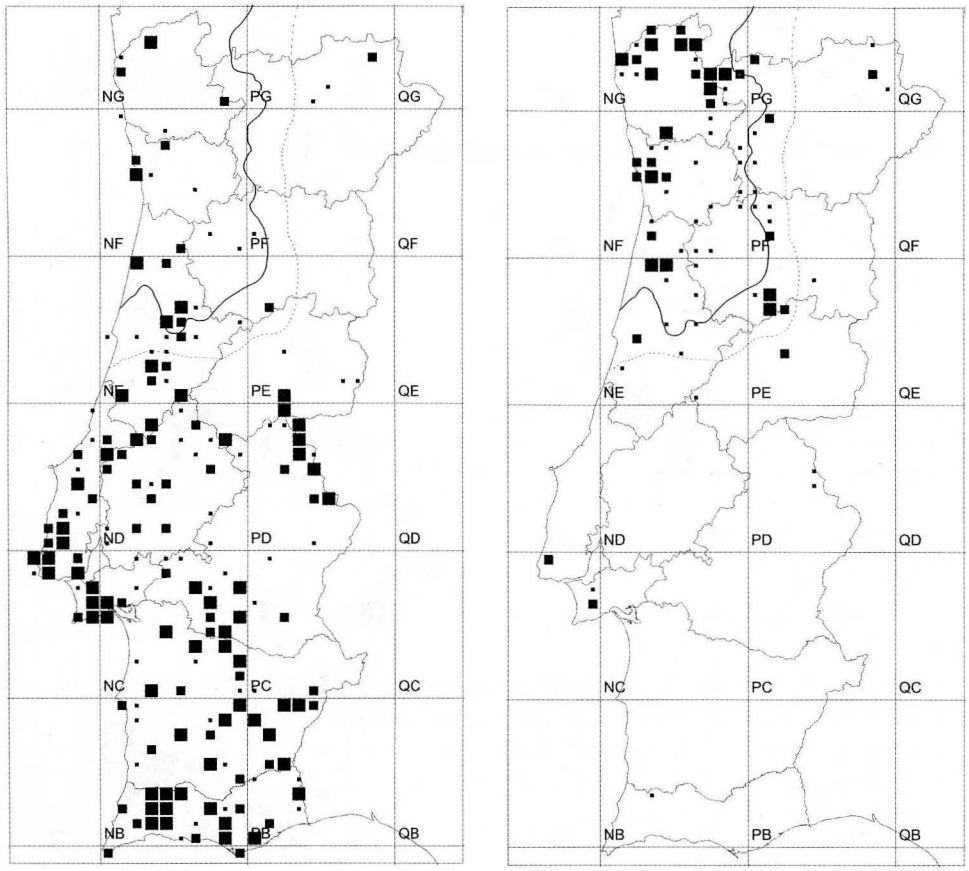

Fig. 7-8. Distribution map of *Riccia* and *Sphagnum* species respectively, in Portugal (range: 0-1; 2-4 and 5-15 species by square).

Bryum minii, considered an Iberian species, (Sérgio & al. 1997, 1998) have recently been described and revalidated respectively while, *Desmatodon merionalis* is a critical taxon.

2. - The Portuguese territory also contains 6 other important taxa with Iberian Macaronesian disjunctive distribution, which are important in clarifying the origin of the Macaronesian flora (Sérgio 1984). They are *Porella canariensis*, *Bryum platyloma*, *Isothecium algarvicum* and *Brachythecium dieckii* recently referred to Portugal (Sérgio & al. in press) as well as *Frullania azorica* (Sim- Sim & al. 1995) and *Rhamphidium purpuratum* occurring in Macaronesia, Portugal and Corsica.

3. - About 3,5% of Portuguese bryophytes are endemic to the circum-Mediterranean area including some Macaronesian islands (± 25 taxa). Among these bryophytes the richest variety are to the *Riccia* species such as *R. atromarginata*, *R. bicarinata*, *R. perennis* etc., also many *Pottiaceae* and *Funariaceae* such as *Funariella curviseta* (Sérgio 1988) and *Grimmiaceae* such as *Grimmia pitardii* and *G. pilosissima* (Sérgio & al. 1997).

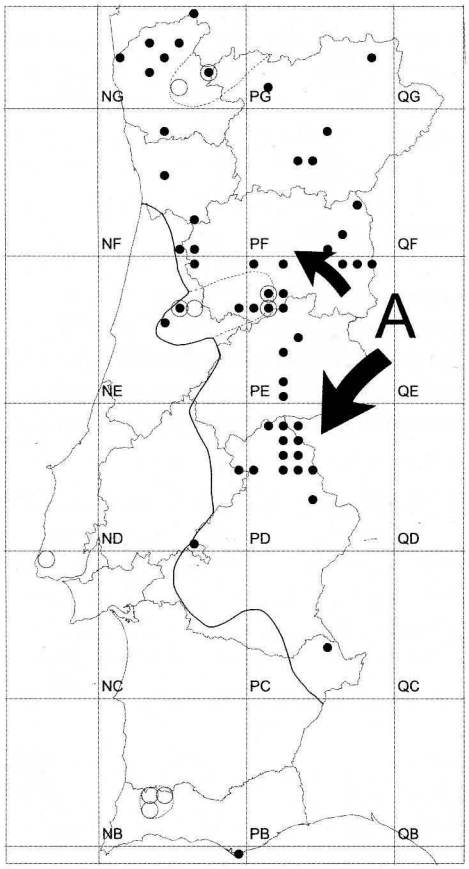

Fig. 9. Distribution map of Iberian (dots) and the Iberian Macaronesian (circles) endemics bryophytes. **A**-From a center Occidental Hercinic. Line corresponds to the principal sector for vascular plants Sainz-Ollero & Hernandez-Bermejo (1985) to Iberian Peninsula.

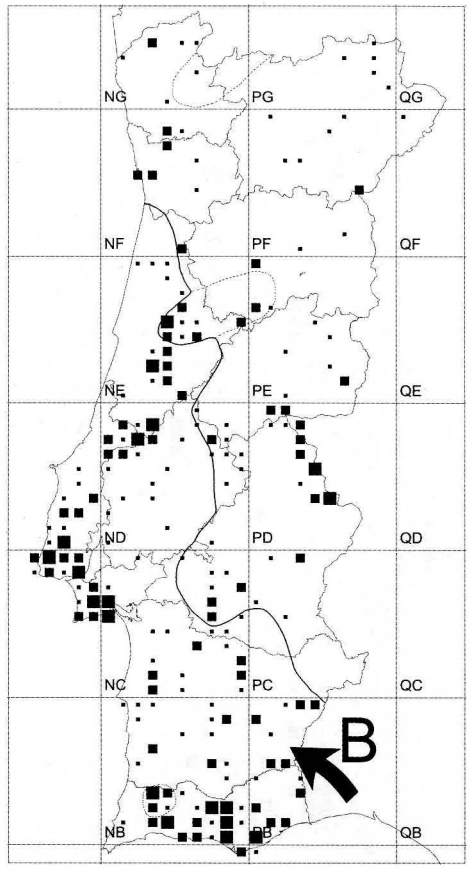

Fig. 10. Distribution map of Mediterranean endemic bryophytes (range: 0-1; 2-5 and 6-10 species by square). **B**- From a distribution center related with the connection Ibero-Maroccan during Mesozoic. Line corresponds to the principal sector for vascular plants Sainz-Ollero & Hernandez-Bermejo (1985) to Iberian Peninsula.

The phytogeographic affinities between the Iberian Peninsula and other regions (Sérgio 1990) have been shown, based on wide disjunctive distribution of some bryophytes. Several of them are typical of the Mediterranean bioclimatic biome, as *Antitrichia californica*, which belongs to the group of "Species disjunctive in Mediterranean Eurasia-Africa and the Pacific coast of North America" (Schofield 1994) that are well represented in the Portuguese bryoflora.

In conclusion referring to endemic "hot-spot" areas, we can propose two different situations in Portugal related with the possible center origin (Fig. 9 and 10).

A - The Iberian and the Iberian Macaronesian endemics (Fig. 9) could have originated

from an Occidental Hercinic center related to an atlantic climate and acid substrates. The oceanic influence has an important part to play in the maintenance of restricted areas of Portugal and Macaronesien Islands, with Tertiary subtropical forests and thermophytic bryophytes such as: *Schizymenium pontevedrensis*, *Anomobryum lusitanicum*, *Porella canariensis*, *Bryum platyloma*, *Isothecium algarvicum*, *Brachythecium dieckii*, *Frullania azorica*, *Rhynchostegiella durieui* and *Rhamphidium purpuratum*. Other endemics are adapted to more xeric conditions such as *Triquetrella arapilencis* and *Didymodon bistratosus*.

B - The circum-Mediterranean endemic bryophytes (Fig. 10) could have originated from a southern center with a Mediterranean type climate and basic substrates. Later they could have carried out a step by step migration from Northern Hemisphere to atlantic-mediterranic regions. This distribution pattern is related to the Ibero-Maroccan connection during Mesozoic (Late Jurassic) and is similar to some *Riccia* species (see distribution maps in Jovet-Ast & al. 1976) and Pteridophytes (see distribution maps in Pichi Sermolli 1979, 1991). This species group includes, among so many *Marchantiales* such as *Oxymitra incrassata*, some mosses such as *Acaulon fontiquerianum*, *Funariella curviseta*, *Grimmia pitardii* and *Scorpiurium sendtneri*.

These interpretations of the distribution of endemic Portuguese bryophytes could be compared with the ideas given by Sainz-Ollero & Hernandez-Bermejo (1985) for Iberian vascular plants (Figs. 9 and 10). The principal sectors proposed for Portugal by these authors correspond, or are similar, to the above distribution of the endemic bryophyte "hot-spots".

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