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***Laboulbeniales* (Ascomycetes) in the Mediterranean area**

Abstract

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Laboulbeniales are obligate parasitic fungi on living arthropods, mostly insects. The present knowledge of these fungi from the Mediterranean countries is far from complete and very uneven. *Laboulbeniales* have been extensively studied in very few countries, such as Spain (221 recorded species), Italy (180), France (149), and Algeria (72); in all the other countries these parasites are very poorly known: Albania (3 recorded species), Cyprus (1), Egypt (7), Greece (13), Israel (11), Lebanon and Malta (no record), Lybia (2), Morocco (25), Portugal (18), Syria (3), Tunisia (8), Turkey (18), and the countries of the former Yugoslavia (27). These figures are to be considered very provisional.

Laboulbeniales are obligate parasitic fungi on living arthropods. Most of the about 1900 species known to date are found on insects, while millipedes (*Diplopoda*) and mites (*Acarina*) are hosts to no more than 60 species. Because of their peculiar morphology, their determinate development, and their non hyphal structure, the position of the *Laboulbeniales* among the *Ascomycetes* has been controversial for a long time. Even their position within the *Ascomycetes* has been questioned. Only recently DNA sequencing demonstrated their close relationship with the mycoparasitic genus *Pyxidiophora*, whose species are found in dung and wood (Blackwell 1994). The very high specificity of *Laboulbeniales* can be used to assess phylogenetic relationships among their hosts, although this opportunity has been seized only occasionally to date (Rossi & Vigna Taglianti 1979, Vigna Taglianti & Rossi in press).

The present knowledge of the *Laboulbeniales* from the countries around the Mediterranean Sea is far from complete and, above all, very uneven (Santamaria & al. 1991, Santamaria & Rossi in press). These fungi have been extensively studied in a few countries only, such as Spain (221 recorded species), Italy (180), France (149), and also Algeria (72). The gap between these and all the other Mediterranean countries is very large: Albania (3 recorded species), Cyprus (1), Egypt (7), Greece (13), Israel (11), Lebanon (no record), Lybia (2), Malta (no record), Morocco (25), Portugal (18), Syria (3), Tunisia (8), Turkey (18), and the countries of the former Yugoslavia (27). It will be observed that figures decrease moving both eastward and southward (Table 1). Obviously,

Table 1. Number of species of the *Laboulbeniales* recorded to date in the countries of the Mediterranean area (from Santamaria & Rossi, in press).

FRANCE	149	ex YUGOSLAVIA	27
ITALY	180	ALBANIA	3
SPAIN	221	GREECE	13
PORTUGAL	18	TURKEY	18
MOROCCO	25	SYRIA	3
ALGERIA	72	CYPRUS	1
TUNISIA	8	LEBANON	-
MALTA	-	ISRAEL	11
LYBIA	2	EGYPT	7

these figures are the result of historical and socio-economical factors, and do not reflect the real situation of the biodiversity in the Mediterranean Area. As in other little known systematic groups, not only among the fungi, the known distribution of the *Laboulbeniales* better reflects the distribution of the *Laboulbeniologists*, past and present. It might be remembered that the first species of the *Laboulbeniales* was described in France by C. P. Robin in 1853, and that the first monograph of the *Laboulbeniales* of an European country was the one by S. Colla (1934) on Italian *Laboulbeniales*.

It should be pointed out that all the figures presented here are very provisional for several reasons. First of all, the problem of those parasites displaying different morphologies, which are found on different portions of the body of the same host has not yet been resolved. In the past all these "morphs" have been described as different species, and a theory of "sex of host specificity and position specificity" has also been put forward (Benjamin & Shanor 1952). As a consequence, 12 "species" have been described on the different parts of the body of the mole cricket *Grillotalpa africana* Palis, some 15 species on the ground-beetles *Pericalus* spp., and up to 16 species on the aquatic beetle *Orectogyrus specularis* Aubé (Benjamin 1971). More recently, the studies of Scheloske (1976a, 1976b) on *Laboulbeniales* parasitic on aquatic beetles demonstrated, for example, that the parasites growing on the forelegs of the males and on the pronotum of the female of the same host-insect, although morphologically very different belong to the same species and can be transmitted during mating only. More recently, Rossi (1998) came to

the same conclusion in the case of two "species" of *Ilytheomyces*, one growing on the right, posterior femur of the males of the South American dipteran *Zeros flavipes* (Wiliston), the other on the posterior portion of the right wing of the females of the same species of host. The solution to these problems, which might cause a complete reappraisal in the systematics of the *Laboulbeniales* and a drastic contraction in the number of known species, may be achieved within a short time with DNA sequencing, which is presently being carried out (Weir & Blackwell 1998). The major problems to these studies are caused by the dimensions of the parasitic fungi, which seldom reach half millimeter in length, and the failure to culture these fungi away from their hosts.

On the other hand, Weir & Hammond (1997) suggested that there are at least 20,000 species of *Laboulbeniales* still awaiting description. The latter figure might seem too large, but it must be borne in mind that the number of these fungi is clearly underestimated, especially in the tropics. For example, less than 100 species were recorded from Brazil, while more than 300 are known from the nearby Argentina; moreover, less than 30 species are reported from the Democratic Republic of Congo (formerly Zaire), while more than 200 are recorded from Cameroon. *Laboulbeniales* are very poorly known in other very large countries such as China, India and Australia, with about 70, 40, and 20 recorded species respectively. These three latter countries, and the two mentioned above, are among the group of the 12 so-called "megadiversity countries", in which about 2/3 of the world species are said to occur.

Bearing in mind the limits of the data available so far, we might try to outline the characteristics of the Mediterranean *Laboulbeniales*.

A comparison between Mediterranean and non Mediterranean countries is only possible to date for the European continent, lacunae in the knowledge of the *Laboulbeniales* in all the other continents being too large. The total number of species reported for the whole Europe is 413; the species reported in the European countries encircling the Mediterranean Sea are 327 (80%), of which almost half have not been recorded in the rest of Europe. These figures are certainly not definitive, but do reflect a real situation. As a matter of fact, it is well known that the number of insects and other arthropods, which are the hosts of the *Laboulbeniales*, decreases in Europe as you go northwards. Two beetle (*Coleoptera*) families are the hosts of more than half of all the Mediterranean *Laboulbeniales*. These are the ground-beetles (*Carabidae*) and the rove-beetles (*Staphylinidae*). This is true, with slight differences in percentage, throughout the whole world. The Mediterranean area (together with the rest of Europe) differs from most of the other areas in the world in that the shore-flies (*Diptera*, *Ephydriidae*) rank in third place in this classification. However, this might reflect the intensive research carried out in Europe on the parasites of *Diptera* during recent years, paralleled by inadequate research on the same insects in the rest of the world. It might be noted that many of the species of these three host families (i.e., *Carabidae*, *Staphylinidae*, and *Ephydriidae*) are associated with moist habitats.

The differences between the Mediterranean and other European *Laboulbeniales* seem to be related to external parameters such as temperature and moisture levels. Aquatic and semiaquatic insects bear more *Laboulbeniales* in Central and Northern Europe both in number of species and in percentage of infection (Scheloske 1969). On the contrary, parasites which are quite common on shore-flies in the Mediterranean area were never found in Central and Northern Europe (Santamaria & Rossi 1998). As the sticky spores of the

Laboulbeniales are short lived, and therefore can be transmitted only among insects with overlapping generations, the reason for these differences seems to be that aquatic and semiaquatic insects undergo severe stress during hot summers in the South, where only very few, healthy individuals are able to survive; on the other hand, many insects may not be able to overwinter at the adult stage in the North. However, Mediterranean and non Mediterranean countries share almost 200 species of *Laboulbeniales*, which is about 45% of all the species recorded in Europe.

An interesting question is the existence or not of *Laboulbeniales* endemic to the Mediterranean area. The answer is yes. These are to be found among the parasites of those insects which are isolated both taxonomically and geographically. A good example might be *Rhachomyces gratiellae* W. Rossi (Fig. 1): its host, *Sbordoniella indagi* Vigna, belongs to a monospecific genus of ground-beetles (*Carabidae*) inhabiting a single Turkish cave (Rossi 1978). Another *Rhachomyces* species might illustrate a Mediterranean endemism with a wider range: *R. stipitatus* Thaxter (Fig. 2 & 3), linked to a group of endogean species of *Duvalius* (*Carabidae*), is found only in a few countries around the Mediterranean Sea (Rossi & Vigna Taglianti 1979). Besides these true endemisms, a few

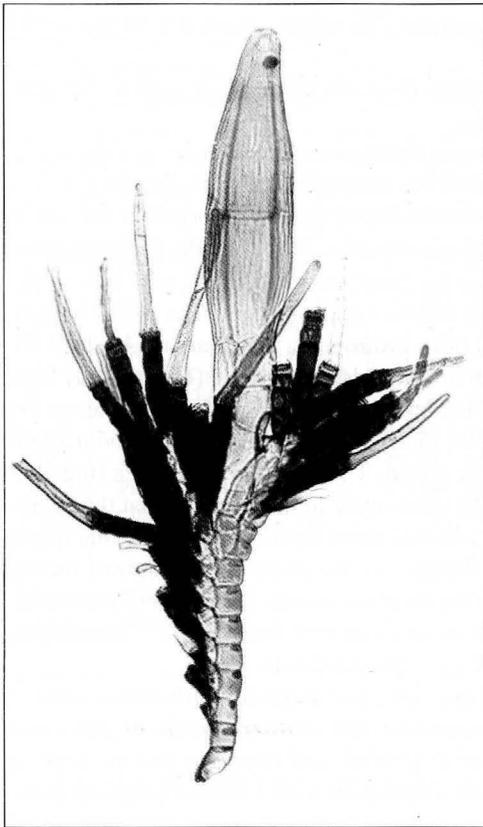


Fig. 1. *Rhachomyces gratiellae* W. Rossi.

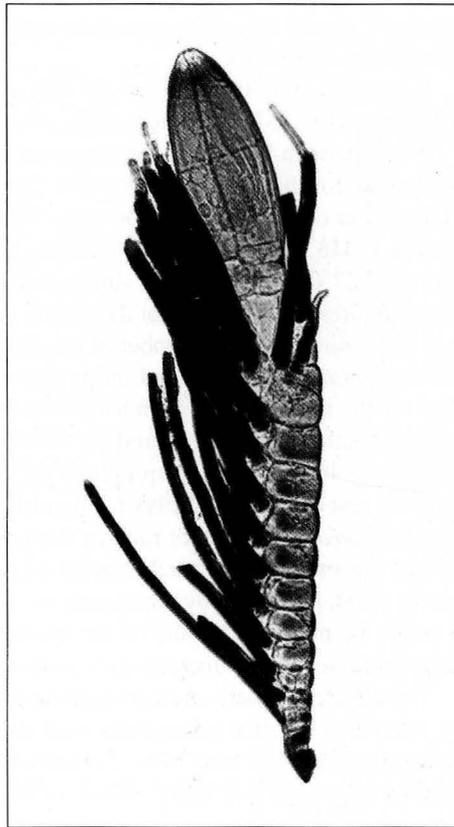


Fig. 2. *Rhachomyces stipitatus* Thaxter.

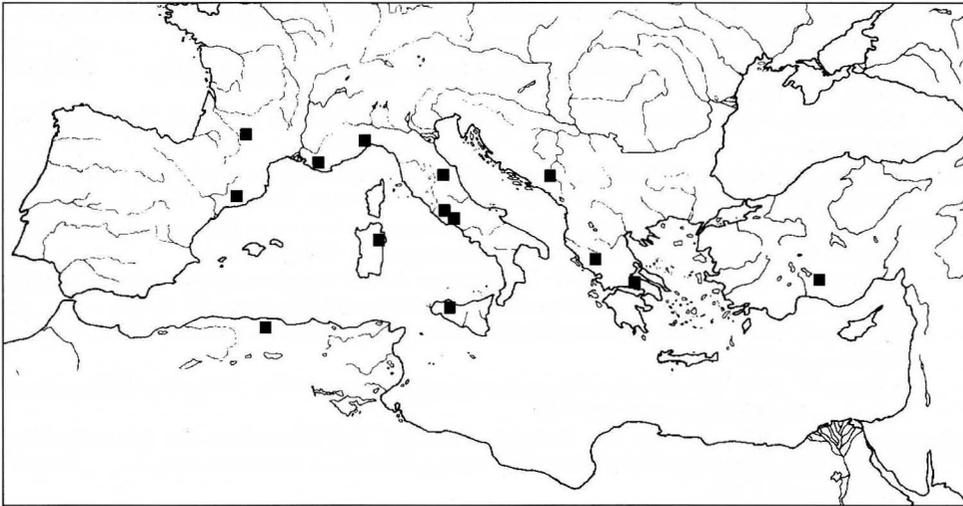


Fig. 3. Distribution of *Rhachomyces stipitatus* Thaxter.

species have been described from one of the Mediterranean countries, but later were found far away. Among the many possible examples, we wish to mention *Dimeromyces balazucii* W. Rossi & Ces. Rossi, which was described from Italy, but was later reported not only from other European countries (i.e., Spain, France, England, Poland, Caucasus), but also from Japan. This enables us to remember the French entomologist Jean Balazuc, who died just a few years ago, and who published several papers on the *Laboulbeniales* between 1970 and 1992.

On the other hand, there are quite a few species which are certainly present in the Mediterranean area, but have not been found there so far. Among these might be mentioned *Hydrophilomyces hamatus* T. Majewski, which is known to date from Poland and West Africa only (Rossi 1990). It is easy to forecast that this fungus, with many others, will be found in most of the countries in between when adequate research is carried out.

In conclusion, we wish to emphasize the fact that what we know about the *Laboulbeniales* from the Mediterranean area is probably less than what remains to be discovered. Recent monographs (Tavares 1985, Santamaria 1989, Majewski 1994), and the reprint edition of old monographs (*Bibliotheca Mycologica*, volume 30, J. Cramer, Lehre 1971) will make the work easier for future studies.

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