FINE STRUCTURES OF SOME BRYOFLORA SPORES FROM SAUDI ARABIA

ABSTRACT:
Spores of some species of different families of Bryophyta from Southwestern Saudi Arabia (Asser region) are studied for the first time by light (LM) and scanning electron microscopy (SEM). These species are: Funaria muhlenbergii Turn. (Funariaceae), Bryum argenteum Hedw., B. capillare Hedw. (Bryaceae), Tortula atrovirens (Sm.) Lendb. (Pottiaceae) and Hypnum vauheri Lesq. (Hypnaceae). The aperture region consists of a leptoma in all spores. The spore wall includes sclerine (the distinction between exine and perine may be difficult to define) and intine. The results show that the surface ornamentation of the spore's sclerine could be divided into four types: type1, baculates in Funaria, type2, scabrate-verrucate irregular distribution in Tortula, type 3, dense piloid in Bryum and type4, scattered piloid in Hypnum. The surface ornamentation is a regular piloid in Bryum argenteum, while its irregular abnormal piloid in B. capillare. These characters are established and reflecting the species taxonomic relationships. The taxonomy of the genus is discussed on the basis of its spore morphology.

INTRODUCTION:
This contribution is part of the study of Bryophyta spores that grow in Southwestern Saudi Arabia. The work is related to studies about biodiversity in Saudi Arabia and aims to provide palynological data, as a complement to the general knowledge of the species. The Arabian Peninsula is one of floristically the poorest known areas of the world. This holds true for flowering plants as well as for mosses and liverworts. Today, however, 224 species of bryoflora are known from this arid area includes Socotra (Kürschner, 1997&2000). Although species diversity is relatively low in comparison with other parts of the world. Since 1980, intensive collection activities have taken place on the Arabia Peninsula, which have led to an enormous increase of records and bryological publications (Kürschner, 1984&1989). Bryophytes are generally small, low-growing, terrestrial plants with no vascular (water-conducting) system as in higher plants.

Bryophytes disperse by small unicellular spores between 7μm, in some species of Grimmia to as much as 250 μm in some species of Archidium (Flower, 1973). Size and weight of the diaspores suggest that both must easily be dispersed and the species must therefore have wide ranges. The spore wall is double, it consists of an outer thicker layer (the exine) and a thin inner membrane (the intine), the exine may be smooth wrinkled or finely to coarsely papillose, sometime spinulose, and in some genera reticulate (Flower, 1973). A large percentage of species is sterile and propagates vegetatively either by special broad bodies or fragments of whole plants. It is shown that there is no difference in the effectiveness between generative and vegetative propagation. Savaroğlu et al. (2007) studied spore morphology of some Bryaceae from Turkey. They also proved that the spore’s morphology in family Bryaceae and its relative show distinguish characters, which are important for taxonomy studies. Savaroğlu and Potoğlu Erkara (2008) studied spore morphology of some Pottiaceae from Turkey. Estebanez et al. (2006) studied the ultrastructure of the spores in four Japanese species of Ptychomitrium. This study includes some mosses families like Funariaceae, Pottiaceae, Bryaceae and Hypnaceae. The
family Funariaceae Schwägr includes 6 genera, 29 species in the flora, worldwide except Antarctica, distributed mainly in Europe, Asia and Africa (Crum and Anderson, 1955). The family of delicate short-lived mosses found growing on soil. They are named after the gourd-like covering (calyptra) to the capsule and it has complex peristome assists in spore release. Spores are spherical or sub-reniform, strongly ornamented to smooth, (Smith, 2004). The family Pottiaceae Schimp is distributed mainly in Europe, Asia, North America and Africa (Allen, 2002). Varieties of Pottiaceae can be seen as spreading tufts, patches or scattered plants amongst other mosses on light soil in open habitats, and on basic rocks and cliffs in mountain habitats (Smith, 2004 and Zander, 1993). Family Pottiaceae and the separation of the genera were made according to gametophyte characters. Some of these characters included leaf shape, lamina cells and the structure of the leaf border, spores and the structure of the leaf border, spores characters included leaf shape, lamina cells, leaf marginal cells, the structure of peristome teeth, and gemmae shape. Some of these characters were the leaf shape, lamina cells, leaf marginal cells, the structure of peristome teeth, and gemmae shape (Smith, 2004). Family Bryaceae and the separation of the genera were made according to gametophyte and sporophytic characters. Some of these characters were leaf shape, lamina cells, leaf marginal cells, the structure of peristome teeth, and gemmae shape (Smith, 2004). The family Hypnaceae is distributed mainly in Europe, Asia; a family of small creeping mosses with a variable appearance. The leaves are curved to one side of the stem and taper gradually to a long fine tip giving a plaited appearance to the shoot. In all the species the spores have similar patterns.

Spore morphology is an important character in taxonomy. Studies of Bryophyta spores have recently increased and started by different authors (Sorsa and Koponen, 1973; Vitt and Hamilton, 1974; Boros and Járai-Komlo’di, 1975; Olesen and Mogensen, 1978; Brown and Lemmon, 1988; Morton, 1993; Estebanez et al., 1997; Luizi-Ponzo and Barth, 1998; 1999, Gui-Sen et al., 1998; Savaroğlu, et al., 2007). However, still a lot of research necessary in this field. In this study, the detailed spore morphological structures of some mosses were studied for the first time in Saudi Arabia. The aim of this work is to characterize the spore morphology of five species of a certain mosses as an aid for studies in taxonomy and palynology.

MATERIAL AND METHODS:
Spores obtained from different localities of Asser region, Southwestern Saudi Arabia (Table 1). Spores of the different specimens were studied by using light microscope (LM) and scanning electron microscope (SEM). For LM the spores were treated with 3% hot sodium carbonate for two min and acetolyzed according to Erdtman (1957). For SEM the materials are treated with 3% hot sodium carbonate, washed, dehydrated, suspended in 96% ethanol and then transferred to acetate plates. After drying, they were coated with gold. All the observations were performed with Olympus BH2 and BHB light microscopes and a JEOL -100 scanning electron microscope at the Faculty of Science of King Khaled University (kku) (Saudi Arabia) and at the Faculty of Science in Zagazig University (Egypt). The descriptions used as described by Punt et al. (1994) terminology.

Table 1. The studied species, collection sites and habitats.

<table>
<thead>
<tr>
<th>No.</th>
<th>Species</th>
<th>Family</th>
<th>Collection Sites</th>
<th>habitats</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Funaria muhlenbergii Turn.</td>
<td>Funariaceae</td>
<td>Asser Abha- kku building</td>
<td>On sandy mud ground (terrestrial)</td>
</tr>
<tr>
<td>2</td>
<td>Tortula atroriens (Sm.) Lendb.</td>
<td>Pottiaceae</td>
<td>Asser- Abha – Alsuoda</td>
<td>On the tree trunks (epiphilitic)</td>
</tr>
<tr>
<td>3</td>
<td>Bryum argenteum Hedw.</td>
<td>Bryaceae</td>
<td>Asser- Belahmer</td>
<td>On the rocks (epiphilitic)</td>
</tr>
<tr>
<td>4</td>
<td>B. capillare Hedw.</td>
<td>Bryaceae</td>
<td>Asser- Abha- Alsuoda</td>
<td>On the rocks (epiphilitic)</td>
</tr>
<tr>
<td>5</td>
<td>Hypnum vaucheri Lesq.</td>
<td>Hypnaceae</td>
<td>Asser-Abha-Alsuoda</td>
<td>On the tree trunks (epiphilitic)</td>
</tr>
</tbody>
</table>

RESULTS:
Description of the spores:
1-Funaria muhlenbergii Turn.: baculates type (Fig. 1a&b). Five specimens studied: Small (inferior than 27 µm) spores (Tables 1–3), bilaterally and sometimes radially symmetric; heteropolar; rounded to subrounded amb; oblate in shape class. The sclerine (exine) surface is ornamented by baculate-like elements (Long densely tapered bacula) (Fig.
2c&d). The baculate elements are bigger and condensed distributed. The apertural region consists of a less resistant leptoma in a circular shape (Fig. 2c&d). Besides the occurrence of an aperture or a leptoma, the most significant features for the distinguishing of these spores are the measurements of their largest diameter and the densely tapered bacula.

2- Tortula atrovirens (Sm.) Lendb.: verrucate type (Fig. 1e&f). Five taxa studied: Small (inferior than 14 µm) spores (Tables 1–3), bilaterally and sometimes radially symmetric to asymmetric; heteropolar; rounded to subrounded amb; suboblate in shape class. The sclerine surface is ornamented by verruca-like elements (Irregular verrucate). The verrucate elements are bigger and sparsely distributed (Fig. 2a&b). The apertural region consists of a leptoma, bridge-like elliptic shape (Fig. 2a). Besides the occurrence of an aperture or a leptoma, the most significant features for the distinguishing of these spores are the measurements of their largest diameter and the densely tapered bacula. The spore size (16.5-19 µm).

4- B. capillare Hedw.
Scattered piloid type (Figs 1&3), two specimens are studied: B. capillare are small (inferior than 24 µm) sized spores (Tables 1-3), bilaterally and sometimes radially symmetric to asymmetric; heteropolar; rounded to subrounded amb; suboblate in shape class (Fig. 1g). The surface is ornamented by granule-like elements (worm-like piloid), the granule-like elements are bigger and sparsely distributed (Fig. 3c&d). The apertural region consists of a leptoma in longitudinal shape. The spore size is (17x18 µm).

5- Hypnum vaucheri Lesq.: Granuloid sparsely type (Figs 1-3), two specimens are studied: Hypnum vaucheri are medium (inferior than 23 µm) sized spores (Tables 1-3), bilaterally and sometimes radially symmetric to asymmetric; heteropolar; rounded to subrounded amb; spheroidal in shape class (Fig. 1-3). The surface is ornamented by granule-like elements (shortly sparsely piloid). The granule-like elements are bigger and sparsely distributed (Fig. 3a&b). The apertural region consists of a leptoma in triangular shape (Fig. 1h&i). The spore size is (20 x 20.5 µm). Triangular leptoma is characteristic features of the species.
Fig. 1. Spores investigated by LM all x1000: a) Funaria muhlenbergii spores: proximal surface show verrucate sculptures, b) proximal surface show exine thickness. Bryum argenteum spores: c) proximal view show exine thickness, d) proximal view verrucate sculptures. Tortula atrovires spores: e) proximal view show asymmetric shape, f) proximal view of pollenia. Bryum capillare spores: g) proximal surface, 400. Hypnum vaucheri spores: h) proximal surface show leptoma, i) proximal view show asymmetric shape.

Fig. 2. Spores investigated by (SEM): Tortula atrovires spores, a) proximal view show elliptic leptoma, b) proximal surface show verrucate sculptures. Funaria muhlenbergii spores: c) proximal view show symmetrical shape, d) proximal surface show baculate sculptures.
DISCUSSION:

The spores of five species of mosses are studied from Saudi Arabia using LM and SEM for the first time. Four types of spores are determined. The spores are different in shape from oblate to spheroidal. In contrast to tetrads from that they are generally tetragonal or rhomboidal. Free spores or monads are most frequently radio symmetric and spheroids in shape (Boros and Járai-Komlo’di, 1975). The size of spores is small in Tortula but in Funaria are the biggest with thick sclerine. The spores size are different and variable because of the immature of sporophyte which agree with data suggested that the spores in the two side of the capsule not in the same size but unisomorphic, (During and Van Tooren, 1987). The sclerine surface ornamentation of Funaria muhlenbergii is baculates but was recorded before in some species (Funaria hygrometrica) as gemmates sculptures (Khashravesh and Kazempour, 2007). The results show that the Bryum species in piloid sculptures and this agree with studies of Savaroğlu et al. (2007). Also in Hypnum species are comparable in ornamentation to
that of *Bryum* species and these characters are related in the phylogeny point of view. In contrast, in case of Pottiaceae, our work shows that the sclerine is verrucate surface but in some studies before show different manner in ornamentation for the genus *Tortula*. Observations of spore morphology of some Pottiaceae occur in the verrucate and granuloid elements of some taxa. We would not recommend these variations as suitable for the establishing of a distinction between species due to the great intraspecific variation between these characters. The sclerine is seemed to have the same structures of the perine. While the verruca of some species, can be found scattered sparsely over the surface of the perine (sclerine), the verruca of *Tortula* is denser and cover the whole surface is much larger than the other species. In *Tortula* also the tetrads form is somewhat more characteristic but it’s rare in mosses and clear in liverworts. According to leptoma (apertures) are different from species to other in shape. In contrast, the ecological habitats play a role in these variations that the Funariaceae are favorable in terrestrial habitats but in Pottiaceae are preferable the epiphilic like Hypnaceae but in case of Bryaceae the saxicolous or epilithic habitats are favorable. These opinions agreed with Khashravesh and Kazempour (2007).

In conclusion, we can say that, SEM observations are useful for the studies spore characters and permit a clear distinction of the taxa examined. The relatively simple spores of the mosses of these families offer many morphological characters useful for distinguishing taxa. The ornamentation pattern of the spores is important in taxonomic, as evident from the distribution of the different spore types among the families (Luizi-Ponzo and Barth, 1998&1999; Savaroğlu et al., 2007; Savaroğlu and Potoğlu Erkarai, 2008). Spores of the bacute type are found in one species of *Funaria*. Strongly ornamented spores are often large and associated with clistocarpous species (Khashravesh and Kazempour, 2007). The bacute type is very protected for the mail gametophytes during dispersal from sporophyte to almost localities suitable for germination and it’s clear in *Funaria* which have a complete life cycle more than other species, that is in different habitats. While spores of the piloid type are found in the three species of *Bryum* and *Hypnum* but in *Tortula* has verrucate type. The results presented here are in accordance with Boros and Járai-Komlo’di (1975). However, discrepancies of *Hypnum* species which have not previously been referred in the literature, but are found in the present study, are related to the surface ornamentation in *Bryum argenteum* species. Sometimes, there is some variability in the mean found in the different specimens analyzed for each taxon, but the range of measurements of the comparison specimens are always in accordance to the specimen reference. These results confirmed by Olesen and Mogensen (1978) and Savaroğlu et al. (2007). These features are controlled the spore-shape. Most of mosses spores emerged from the spore mother cells as monads. Finally, we agree with Sorsa and Koponen (1973), Vitt and Hamilton (1974), Boros and Járai-Komlo’di (1975), Olesen and Mogensen (1978), Brown and Lemmon (1988), Morton (1993), Estebanez et al. (1997), and Luizi-Ponzo and Barth (1998&1999), Savaroğlu et al. (2007), Savaroğlu and Potoğlu Erkarai, (2008) that the spore morphology in the mosses and its relatives show distinguish characters which are important for taxonomic studies.

**General remarks:**

The sporoderm of the mosses consists of a sclerine and intine. Because the distinction between exine and perine may be difficult to define, sclerine is a more appropriate term. Ornamentation is not clear in different species inside the genus, thus making it occasionally impossible to distinguish species based on these features alone. The apertural region consists of an aperture, surrounded by one or more rings of ornamentation elements. All taxa of the mosses family are not uniform in their spore morphology.

**REFERENCES:**


هياكل الورقة لبعض جنسين الفلورة الجزائرية من المملكة العربية السعودية

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تتم دراسة بعض أنواع المجهر من عائلة مختلفة من جنوب غرب المملكة العربية السعودية (Bryophyta من مجموعات الغرب بواسطة المجهر الضوئي والمجهر الإلكتروني). هذه الأنواع هي: Funaria mühlenbergii (Funariaceae), Bryum argenteum Hedw. B. capillare Hedw. (Bryaceae), Tortula atrivirens (Sm.) Lendb. (Pottiaceae) و Hypnum vaucheri Lesq. (Hypnaceae).

والنوع المحموم: Funaria mühlenbergii

النوع الأول: Funaria argenteum

النوع الثاني: Funaria capillare

النوع الثالث: Funaria atrivirens

النوع الرابع: Hypnum vaucheri

الأنواع: Funaria mühlenbergii

النوع الأول: baculates

النوع الثاني: scabrate

النوع الثالث: verrucate

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