Available online: December 17, 2018

Commun.Fac.Sci.Univ.Ank.Series C
Volume 27, Number 2, Pages 215-223 (2018)
DOI: 10.1501/commuc_0000000217
ISSN 1303-6025 E-ISSN 2651-3749
http://communications.science.ankara.edu.tr/index.php?series=C

SPORE MORPHOLOGY, TAXONOMICAL AND ECOLOGICAL IMPORTANCE OF BRYOPHYTA FROM TURKEY

ISMUHAN POTOGLU ERKARA, FILIZ BIRGI, ONUR KOYUNCU

ABSTRACT. Turkey is one of the main centers of diversity for the bryophytes. Spore morphology has been useful in taxonomy. This study includes spore morphology of Orthotrichaceae, Grimmiaceae, Encalyptaceae, Hypnaceae, Pottiaceae, Brachytheciaceae and Bryaceae taxa. The aims of this study are to provide a detailed taxonomical, morphological, ecological and paleobotanical characterization of Bryophyta in Turkey. The spores of some Bryophyta taxa were examined by light and scanning electron microscopy for the first time. The apertural region forms a leptoma in all spores. The spore morphology of the examined taxa of the families belonged to granulate, granulate-pliate, verrucate, baculate-verrucate, rugulate, rugulate-verrucate, gemmate types (smooth, finely papillose, warty, coarsely papillose). The spore shape of all studied species was spheroid. The spore wall of the Bryophyta included sclerine and intine. The examined species of mosses belonged to three habitat types: corticolous, saxicolous and terrestrial type. We also discussed the taxonomical and ecological implications of the some Bryophyta with respect to its spore morphology.

1. INTRODUCTION

Geographically, Anatolia is located at the intersection of Europe and Asia, and climatically, it is situated in an area where the climates of the Mediterranean, Iran–Turan and Europe–Siberia overlap. This variety increases due to the presence of formations such as mountains, plains, streams and valleys within short distances, and as a result of all of these characteristics, the phytogeographical structure of Anatolia displays multiple varieties. This varied phytogeographical structure contains non-vascular plants as well as vascular plants. The bryophytes among these non-vascular plants hold a significant position within the Anatolian flora.

Bryophytes, the most basic members of the plant kingdom, constitute the second largest group after seeded plants with about 23.000 species, and are spread over a wider area across the world than seeded plants [11; 28]. In the studies carried out in Turkey to-date, 163 taxa (species and sub-species) in the Hepaticae class, 3 species

Received by the editors: December 08, 2018; Accepted: December 11, 2018.
Key word and phrases: Bryophyta, Musci, Spore morphology, Ecology, Taxonomy, Turkey.
Submitted via II. Aerobiology and Palynology Symposium 07-10 October 2018 (APAS 2018)

in the Anthocerotae class and 721 taxa (species and sub-species) in the Musci classis have been recorded [14].

Bryophytes have the ability of surviving in various climates and habitats. They not only can survive in terrestrial environments, but also have developed the necessary adaptation to live in sand dunes, on rocks, in marshes, on the surface of water, on roof tiles of man-made structures, on gravestones, on pavement stones, and in extremely dry and extremely humid atmospheres. The plant stems of bryophytes are generally small. They grow by clinging to the soil, trees and rocks through thread-like, single or multi-cell structures known as rhizoids. While acrocarpous bryophytes form lumps or clusters in areas where they exist, pleurocarpous ones spread out like a carpet. As bryophytes are mostly small in size, they could not be distinguished when they are on their own in an area, and their forming of clusters or lumps makes them noticeable [1].

Bryophyta have been made according to gametophytic and sporophytic characters. Some of these characters include leaf shape, laminal cells, capsule shape and spore ornamentation. The spore morphology of bryophytes is an important character for use in taxonomy. It has been useful in resolving taxonomic problems. It is also a potential source of information about evolutionary processes, information which may prove to be useful for the definition of biological or taxonomic boundaries [7]. Therefore, studies of bryophyte spores have increased in recent years [2; 3; 5; 6; 7; 9; 10; 15; 16; 17; 18; 19; 21; 22; 23; 24; 25; 26]. Nevertheless, much study is needed in this field.

In this study, the elaborated spore morphological structures of some Bryophyta were studied for the first time by light microscopy (LM) and scanning electron microscopy (SEM). The purpose of this study was to define the spore morphology of Bryophyta to aid studies in taxonomy, ecology, and paleobotany.

2. Materials And Methods

The spore materials were supplied by the Faculty of Science and Arts of the Osmangazi University Herbarium (OUFE). The outward surface was investigated with LM and SEM. The spores were prepared untreated with glycerin-jelly on microscope slides [27], using the acetolysis method [8] for LM. Measurements of the shortest and the largest diameters (in the polar view), as well as the polar axis and the equatorial diameter (in the equatorial view), were taken of 25 randomly selected spores. The mean, the standard deviation, the standard error, and the range

were then established. The sclerine thickness, as well as the largest length of the apertural region, was based on 25 measurements, with only the mean presented. For SEM investigations, the unacetolyzed spores were directly placed onto stubs. The stubs were then coated with carbon and gold in a vacuum evaporator to a total thickness of 7.5– 15.0 nm and then examined with a Jeol 5600 LV scanning electron microscope at an accelerating voltage of 20 kV. The specimen and their photograps listed in figure 1. Terminologies for spore morphology suggested by Erdtman (1957), Blackmore and Barnes (1991), Punt et al. (1994) and Kapp et al. (2000) were used throughout.

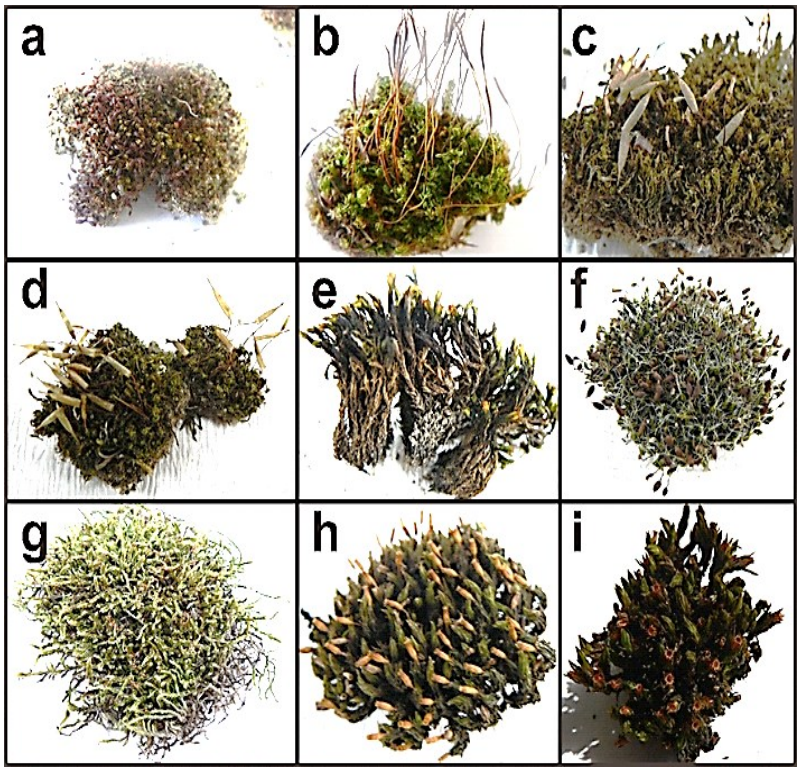

FIGURE 1. General view of studied taxa (a: *Tortula truncata*, Pottiaceae; b: *Tortula subulata*, Pottiaceae; c: *Encalypta streptocarpa*, Encalyptaceae; d: *Encalypta vulgaris*, Encalyptaceae; e: *Schistidium confertum*, Grimmiaceae; f: *Grimmia trichophylla*, Grimmiaceae; g: *Hypnum cupressiforme* var. *lacunosum*, Hypnaceae; h: *Orthotrichum anomalum*, Orthotrichaceae; i: *Orthotrichum cupulatum*, Orthotrichaceae).

3. Results And Discussion

The sporoderm of the Bryophyta contains the perine, the exine, and the intine. The distinction between the exine and the perine may be difficult to describe, and thus, sclerine is a more suitable term for use. The ornamentation is different in each genus, and it is sometimes possible to recognize species based on these properties. The apertural region is composed of an aperture, which may or may not be enclosed by one or more rings of ornamentation elements. The spore morphology of the examined taxa of the families belonged to granulate, granulate-pliate, verrucate, baculate-verrucate, rugulate, rugulate-verrucate, gemmate types (smooth, finely papillose, warty, coarsely papillose). The ranges of measurements established in the reference specimens are in line with those of the comparison specimens, but the mean may be somewhat different. This reflects the occurrence of intraspecific variation.

SEM studies are useful for spore type characterization but do not permit a clear differentiation of the investigated taxa. In addition to the occurrence of an aperture or a leptoma, the most important properties that facilitate the discriminating of these spores.

The spore morphology of the species was based on the peristome morphology. The examined spores were spheroidal. The general spore morphology of most of these taxa is the same as that which Boros et al. (1993) illustrated using light microscopy. The SEM-based analysis of the spore morphology of examined Bryophyta species is reported here for the first. The spore surface ornamentations are of diagnostic value in the identifications of the examined taxa, at least to the genus level and somewhat to the species level within the families.

The species of mosses examined are of three types with respect to their habitat: saxicolous species that inhabit rock surfaces, terrestrial species that inhabit moist soil and corticolous species that inhabit epiphytic surfaces. There is some correlation between the exine surface ornamentations and the vegetation substratum.

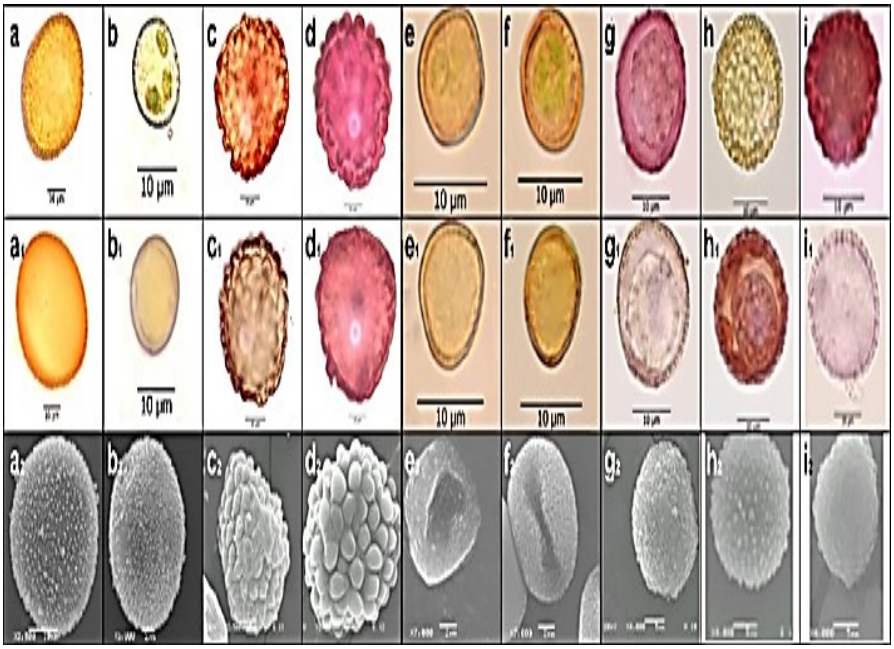

FIGURE 2. a-a_2: *Tortula truncata,* Pottiaceae; b-b_2: *Tortula subulata,* Pottiaceae; c-c_2: *Encalypta streptocarpa,* Encalyptaceae; d-d_2: *Encalypta vulgaris,* Encalyptaceae; e-e_2: *Schistidium confertum*, Grimmiaceae; f-f_2: *Grimmia trichophylla*, Grimmiaceae; g-g_2: *Hypnum cupressiforme* var. *lacunosum*, Hypnaceae; h-h_2: *Orthotrichum anomalum*, Orthotrichaceae; i-i_2: *Orthotrichum cupulatum*, Orthotrichaceae (a-i: Proximal view (IM, N); a_1-i_1: Proximal view (IM, A); a_2-i_2: Distal surface (SEM)).

The species with gemmate spore ornamentations belong to either saxicolous or terrestrial habitats. The saxicolous members produce their sporophytes under conditions of high humidity and short-period sunlight, primarily during the winter season. It is noteworthy that the saxicolous species possess spores that are densely ornamented by exine elements, whereas the moisture-dependent species have spores that are loosely covered by subpatterned exine surfaces. The moss species that were examined are of one type with respect to their habitat: corticolous species that inhabit epiphytic surfaces. There is some correlation between the exine surface ornamentation and the vegetation substratum. The verrucate species exine surfaces prefer corticolous habitats (Figure 2).

Other morphological adaptations, including spore size, life forms and life strategies, that are related to habitat conditions have already been illustrated in the Near and Middle East Bryophytes.

Furthermore, there is little correlation between the size and shape of the spores of the examined species and the species' habitat. All the species possess small spores and common sporophytes that increase their chance of successful dispersal and occupying of new localities. These characteristics are related to a common strategy of drought resistance. This strategy is characterized by a longer life span, monoecy, regular sporophyte production, and the production of large quantities of small spores. This functional type is typical for saxicolous bryophytes and is used to compensate for the high mortality rate of the gametophytes, which is often caused by summer drought or erosion effects [13]. There is a predicted correlation between the spore morphology of the region with the relevant taxonomical groups and the ecological conditions. These types of investigations help us to predict the rarity, future ecological disturbance, and conservation of Bryophytes.

The ornamentation pattern of the spores is of taxonomic importance, as is evident from the distribution of the different spore types among the species [15; 16].
There is sometimes some variability in the mean found in the different specimens analyzed for each taxon, but the range of the measurements for the comparison specimens were always in accordance with the specimen reference. In conclusion, We agree with Vitt and Hamilton (1974), Blackmore and Barnes (1991), Luizi-Ponzo and Barth (1998, 1999), Potoglu Erkara and Savaroglu (2007), Savaroglu et al. (2007), Savaroglu and Potoglu Erkara (2008), Caldeira et al. (2013), Savaroglu (2015), Savaroglu et al. (2016, 2017), Potoglu Erkara (2017) and Potoglu Erkara et al. (2017) that spore morphology in the Bryophyta and its relatives show distinctive properties that are important for taxonomic studies. As well as the systematic characteristics of these taxa in Bryophyta, we believe that their spore morphologies may possess a distinctive criteria. This study will also shed light to the phylogenetic relationship between the studied taxa.

The conclusion is that the morphologic structure of the spores possesses distinctive characteristics for the determination of taxa. Important findings have been achieved in the spore morphology studies which have been conducted, and we are of the opinion that comparisons between the species collected from the region, the other taxa within the family, and interpretations in this respect will make an important contribution to taxonomy.

REFERENCES

[1] M. Alatas, The Moss (Musci) Flora of Yenice forest and Keltepe. *Zonguldak Karaelmas University, Institute of Science and Technology, Master Dissertation*, (2006) 220.

[2] B. Ascı, T. Ceter, N.M. Pınar, H. Colgecen and B. Cetin, Spore morphology of some Turkish *Tortula* and *Syntrichia* species (Pottiaceae Schimp., Bryophyta). *The Herb Journal of Systematic. Botany*, 17(2), (2010) 165-180.

[3] S. Blackmoreand, S.H. Barnes, Pollen and Spores. Patterns of Diversification. *The Systematics Association*, 44, (1991) 391.

[4] A. Boros, M. Járai-Komlódi, Z. Toth and S. Nilson, *An atlas of recent European Bryophyte Spores*, (1993), Budapest, Akademiai Kiado.

[5] R.C. Brown and B.E. Lemmon, Sporogenesis in Bryophytes. *Advanced Bryology*, 3, (1988) 159-223.

[6] I.C. Caldeira, A.P. Luizi-Ponzo and V.G. Esteves, Palynology of selected species of *Fissidens* (Hedw.). *Plant Systematic Evolution*, 299, (2013) 187-195.

[7] J.S. Carrion, M.J. Cano and J. Guerra, Spore morphology in the moss genus *Pterygoneurum* Jur. (Pottiaceae). *Nova Hedwigia*, 61(3-4), (1995) 481-496.

[8] G. Erdtman, *Pollen and spore morphology/plant taxonomy; Gymnospermae, Pteridophyta, Bryophyta* (illustrations), Stockholm, Almquist and Wiksell, (1958) 151.

[9] B. Estebanez, C. Alfayate and E. Ron, Observations on spore ultrastructure in six species of *Grimmia* (Bryopsida). *Grana,* 36, (1997) 347-357.

[10] R. Gambardella, F. Alfano, M. Gargiulo and C. Squillacioti, Studies on the sporogenous Lineage in the moss *Timmiella barbuloides* IX. development of the tapetum. *Annals of Botany*, 73 (1994) 369-375.

[11] B. Goffinet and A.J. Shaw, *Bryophyte Biology*, Cambridge University Press, Cambridge, UK, (2009) 565.

[12] R.O. Kapp, O.K. Davis and J.E. King, *Pollen and spores, the American association of stratigraphic palynologists foundation*, 2nd Ed. USA, Texas A&M University, (2000) 279.

[13] H. Kurschner, Life strategies and adaptations in Bryophytes from the Near and Middle East. *Turkish Journal of Botany*, 28, (2004) 73-84.

[14] H. Kurschner and A. Erdag, Bryophytes of Turkey: an annotated reference list of the species with synonyms from the recent literature and an annotated list of Turkish bryological literature. *Turkish Journal of Botany*, 29, (2005) 95-154.
[15] A.P. Luizi-Ponzo and O.M. Barth, Spore morphology of some Bruchiaceae species (Bryophyta) from Brazil. *Grana*, 37, (1998) 222-227.
[16] A.P. Luizi-Ponzoand O.M. Barth, Spore morphology of some Dicranaceae species (Bryophyta) from Brazil. *Grana*, 38, (1999) 42-49.
[17] I. Potoglu Erkara and F. Savaroglu, Spore morphology of some Brachytheciaceae Schimp. species (Bryophyta) from Turkey. *Nordic Journal of Botany*, 25, (2007)194-198.
[18] I. Potoglu Erkara, Spore Morphology, Taxonomical and ecological importance of some Encalyptaceae Schimp. species (Bryophyta) from Turkey. *Bangladesh Journal of Botany* 46(1), (2017) 139-145.
[19] I. Potoglu Erkara, F. Savaroglu, R. Tan and S. Pehlivan. Investigation of spore morphology of some Pottiaceae (Schimp.) taxa (Bryophyta) in Turkey. *Pakistan Journal of Botany*, 49(1), (2017) 265-272.
[20] W. Punt, S. Blackmore, S. Nilsson and A. Le Thomas, *Glossary of pollen and spore terminology*. Contributions series No: 1, Netherlands, LPP foundation, (1994).
[21] F. Savaroglu, I. Potoglu Erkara, C. Baycu and M. Alkan, Spore morphology of some Bryaceae Schwagr. species (Bryophyta) from Turkey. *International Journal of Engineering Science*, 1(2), (2007) 49-54.
[22] F. Savaroglu and I. Potoglu Erkara, Observations of spore morphology of some Pottiaceae Schimp. species (Bryophyta) in Turkey. *Plant Systematic and Evolution*, 271, (2008) 93-99.
[23] F. Savaroglu, Spore Morphology of some Orthotrichaceae Arn. species (Bryophyta) from Turkey. *Bangladesh Journal of Botany*, 44(4), (2015) 499-506.
[24] F. Savaroglu, I. Potoglu Erkara and F. Ozcelik, Spore morphology of some Grimmiaceae Arn. species belonging to Moss Flora of Turkey. *Pakistan Journal of Botany*, 48(3), (2016)1045-1050.

Current Address: ISMUHAN POTOGLU ERKARA: Osmangazi University, Faculty of Science and Literature, Department of Biology, 26480 Eskişehir, Turkey.

E-mail : ismuhan@ogu.edu.tr
ORCID: https://orcid.org/0000-0001-5780-4999

Current address: FILIZ BIRGI: Osmangazi University, Faculty of Science and Literature, Department of Biology, 26480 Eskişehir, Turkey.
E-mail : *fbirgi@ogu.edu.tr*
ORCID: https://orcid.org/0000-

Current address: ONUR KOYUNCU: Osmangazi University, Faculty of Science and Literature, Department of Biology, 26480 Eskişehir, Turkey.
E-mail : okoyuncu@ogu.edu.tr
ORCID: https://orcid.org/0000-0002-0364-6638