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INVESTIGATION OF SPORE MORPHOLOGY OF SOME POTTIACEAE (SCHIMP.) TAXA (BRYOPHYTA) IN TURKEY

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Abstract

Turkey is one of the centres of diversity for bryophytes. Since spore morphology is beneficial in taxonomy, this study consists of the spore morphology of nine Pottiaceae taxa. The purpose of the study is to provide the detailed taxonomical, morphological and ecological characterization of the Pottiaceae family in Turkey. The spores of the *Syntrichia calcicola* J.J. Amann, *S. montana* Nees, *Tortula canescens* Mont., *T. inermis* (Brid.) Mont., *T. lanceola* R. H. Zander, *T. modica* R. H. Zander, *T. muralis* Hedw., *T. subulata* Hedw., and *T. truncata* (Hedw.) Mitt. types have been studied under light and through scanning electron microscopes. The aperture region of all the spores is composed of a leptoma. The spore morphology of the examined taxa of the family are of six types depending on the sclerine ornamentation – granulate, granulate-pliate, verrucate, baculate-verrucate, rugulate, and rugulate-verrucate. The shape of the spore is prolate-spheroidal. The spore dimensions of the studied taxa of the Pottiaceae family vary from 5 to 42 µm. The examined species belong to the saxicolous and terrestrial habitat. The taxonomic and ecological content of the Pottiaceae family has been discussed on the basis of spore morphology.

Key words: Bryophyta, Pottiaceae, spore morphology, light microscope (LM), scanning electron microscope (SEM), Turkey.

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 (Yildiz & Aktoklu, 2012; Goffinet & Shaw, 2009). In the studies carried out in Turkey to-date, 163 taxa (species and sub-species) in the Hepaticae class, 3 species in the Anthocerotae class and 721 taxa (species and sub-species) in the Musci classis have been recorded (Kürschner & Erdağ, 2005).

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. Members of Pottiaceae Arn. family are acrocarpous mosses. 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 (Alataş, 2006).

In our study, we have examined the spore morphology of 9 taxa belonging to the Pottiaceae family of the Bryophyta. As a result of this study, the polar and equatorial measurements of the spores have made it possible to determine the species; besides the ornamentation shapes on the surfaces of the spores have made this determination easier. The ornamentation shapes also show the habitats of the bryophytes and the climate conditions.

The distinction between Pottiaceae family and its genera have been made according to their gametophytic and sporophytic characteristics. Spore characteristics are widely used in the taxonomic analyses of bryophytes. These characteristics within the systematic of bryophytes can be a model for spore morphology applications. While spore morphology has limited value in taxonomy, it is useful in the solution of taxonomic problems. At the same time, this is also a potential source of information for the evolutionary processes which result in the determination of the biological and taxonomic boundaries (Carrion *et al.*, 1995). Some sources (Gambardella *et al.*, 1994; Carrion *et al.*, 1995; Estebanez *et al.*, 1997; Luizi-Ponzo & Barth, 1998, 1999; Khoshravesh & Kazempour Osaloo, 2007; Potoglu Erkara & Savaroglu, 2007; Savaroglu *et al.,* 2007; Savaroglu & Potoglu Erkara, 2008; Medina *et al.*, 2009; Aşçı *et al.*, 2010; Caldeira *et al.*, 2013) in recent years have proved that the in tine structure and external spore morphology are useful in the characterization of bryophytes in terms at generic and species level. However, there is still a need for further studies in this field.

The bryophyte spores in Turkey are not fully known. The detailed spore morphological characteristics of certain Pottiaceae species have been examined in this study through a light microscope (LM) and a scanning electron microscope (SEM). The aim of this study is to characterize the spore morphology of nine species in the Pottiaceae family, and thereby shed light on studies in the areas of taxonomy, ecology and paleobotany.

Materials and Methods

Plant materials: All the specimens were collected from their natural habitats in Turkey, as detailed below:

Pottiaceae Schimp.

Syntrichia calcicola J.J. Amann A1 Osmaneli (Bilecik): Vezirhan-Sarmasık highway, marble quarries, forest road, *Pinus nigra, Quercus* sp., *Juniperus oxycedrus*, 378 m, N 40° 14´ 37.8´´, E 029° 35.8´´, 15.05.2008, on rock, Savaroglu 1356.

S. montana Nees A2 Osmaneli (Bilecik): Kozan village, mountainous terrain, forestry area, *Pinus nigra, Quercus* sp., *Juniperus oxycedrus,* 189 m, N 40° 26´ 45.4´´, E 030° 07´ 48.4´´, 10.04.2006, on rock, Savaroglu 875.

Tortula canescens Mont. A2 Osmaneli (Bilecik): Kazancı village, inside valley, canyon, 218m, N 40° 20´08.6´´, E 030° 12´46.1´´, 26.05.2006, on rock, Savaroglu 1077.

T. inermis (Brid.) Mont. A2 Osmaneli (Bilecik): Sogucakpınar-Sögütcük road, canyon, 238m, N 40° 20´04.1´´, E 030° 12´57.9´´, 24.04.2006,on earth which covers the rocks, Savaroglu 978.

T. lanceola R.H. Zander A2 Osmaneli (Bilecik): Sogucakpınar-Sögütcük road, canyon, 238m, N 40° 20´04.1´´, E 030° 12´57.9´´, 24.04.2006, on soil, Savaroglu 981.

T. modica R.H. Zander A2 Osmaneli (Bilecik): Kozan village, mountainous terrain, forestry area, *Pinus nigra, Quercus* sp., *Juniperus oxycedrus,* 189 m, N 40° 26´ 45.4´´, E 030° 07´ 48.4´´, 10.04.2006, on soil, Savaroglu 881.

T. muralis Hedw. A2 Osmaneli (Bilecik): Mekece village road, opposite Kartalkayası, by the side of the ring road, rocks, 100 m, N 40° 24´ 36.5´´, E 030° 01´ 34.5´´, 10.04.2006, on rock, Savaroglu 854.

T. subulata Hedw. A1 Osmaneli (Bilecik): Cerkesli village, upper areas, forestry area, *Pinus sylvestris,* 381 m, N 40° 25´ 53.5´´, E 030° 56´ 44.8´´, 18.05.2006, on soil, Savaroglu 1025.

T. truncata (Hedw.) Mitt. A1 Osmaneli (Bilecik): Vezirhan-Sarmasık highway, forest road, 361 m, N 40° 14´ 43.4´´, E 029° 58´ 44.6´´, 02.04.2006, on soil, Savaroglu 1401.

Morphological studies: The spore material used in this study was obtained from the herbarium of Faculty of Science and Arts of Osmangazi University. The external surface was observed using LM and SEM. The untreated spores were prepared with glycerine jelly on microscope slides (Wodehouse, 1935) using the acetolysis method (Erdtman, 1957; 1966) for LM. Measurements of the shortest and the largest diameters (in polar view), as well as the polar axis and the equatorial diameter (in equatorial view), were carried out through 25 randomly selected spores. The mean, standard deviation, standard error and range were then established. The sclerine thickness and the largest length of the aperture region were based on 25 measurements, with only presenting the mean. 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 were examined with a JEOL 5600LV SEM at an accelerating voltage of 20 kV. The first exsiccate listed under the ‘‘Specimens examined’’ is the reference specimen, while the others are the comparisons. The terminology for spore morphology was proposed by Erdtman (1957); Boros & Járai-Komlódi (1975); Blackmore & Barnes (1991); Punt *et al.* (1994) and Kapp *et al.* (2000).

Results

General remarks: The sporoderm of the Pottiaceae family contains perine, exine, and in tine. Since it may be difficult to identify the difference between exine and perine, sclerine is a more appropriate term to use. Ornamentation is different in each genus and it may be possible to identify species according to these characteristics. The aperture region may be comprised of an open space. One or more of the ornamentation elements may, or may not form hoops.

The spore morphology of the examined taxa of the family are of six types. The ornamentation of the following types are observed: *Tortula inermis* and *T. subulata*- granulate (Type I); *T. modica* and *T. truncata*- granulate-pliate (Type II); *Syntrichia calcicola* and *S. montana*- verrucate (Type III); *T. lanceola*- baculate-verrucate (Type IV); *T. canescens*- rugulate (Type V); and *T. muralis*- rugulate-verrucate (Type VI). All of the spores have a radial symmetry and are isopolar and the shapes of the spores are prolate-spheroidal (Figs. 1-5). The spore dimensions in the Pottiaceae family have been determined as 5-42 µm.

The measurements of the reference specimens is consistent with the measurements of the compared specimens. However, the mean is a little different. This issue reflects the existence of a variation within the species. The polar axis measurements (P) in the equatorial aspect have been assessed in accordance with preparations made ready according to the Erdtman method (Table 1). The morphometric data of the spores is given in Tables 1-3.

Descriptions of the spores: *Syntrichia calcicola*; Verrucate, spores are ellipsoid, occasionally clearly plano-convex, with varied dimensions 15, 0-19, 0 µm (mean value 17, 3 µm) (Fig. 1a-c).

S.montana; Verrucate, spores are sub-spherical to plano-convex or concave-convex, dimensions 11, 0-14, 0 µm (man value 12, 4 µm) (Fig. 1d-f).

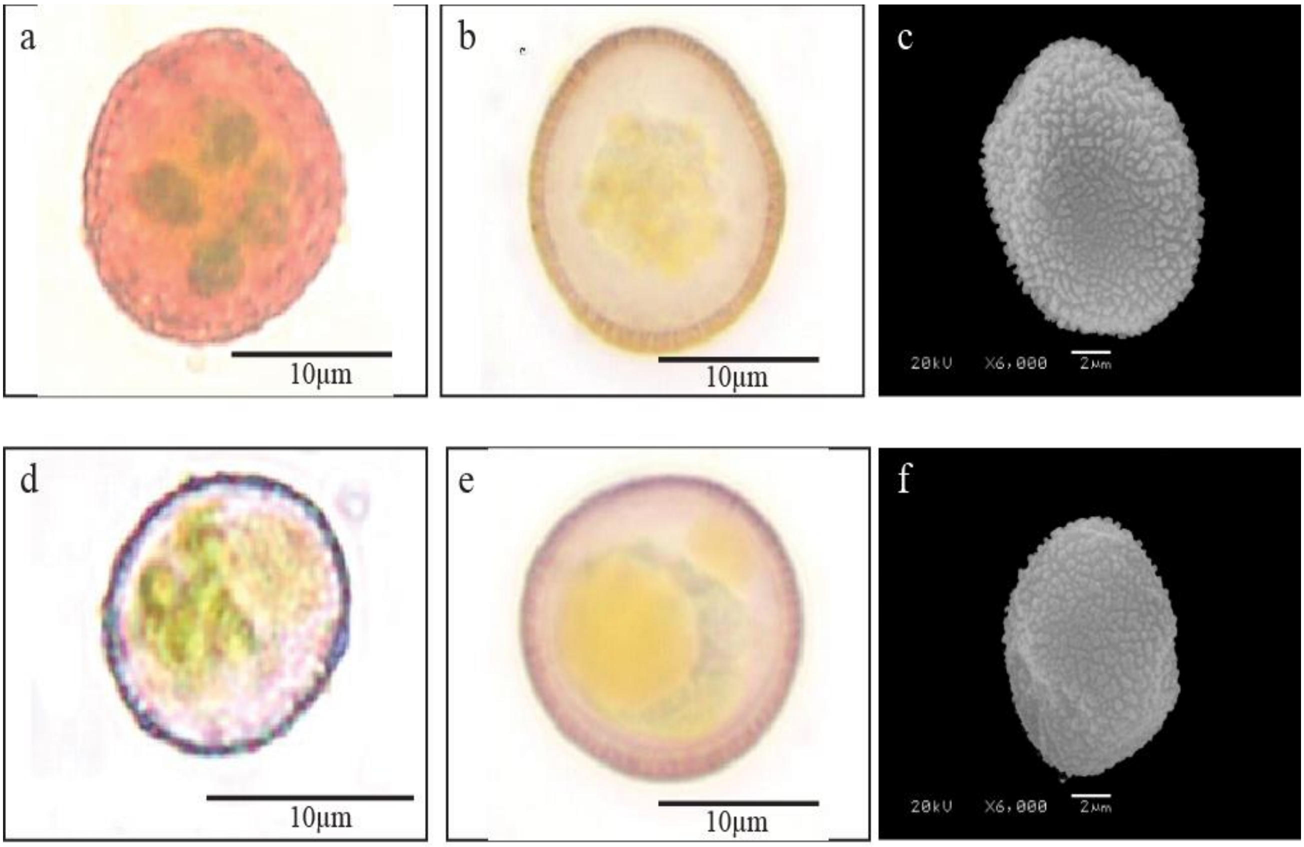

Fig. 1. **a-c:** *Syntrichia calcicola* **a.** Proximal view (IM, N), **b.** Proximal view (IM, A), **c.** Distal surface (SEM). **d-f:** *S. montana* **d.** Proximal view (IM, N), **e.** Proximal view (IM, A), f Proximal view (SEM).

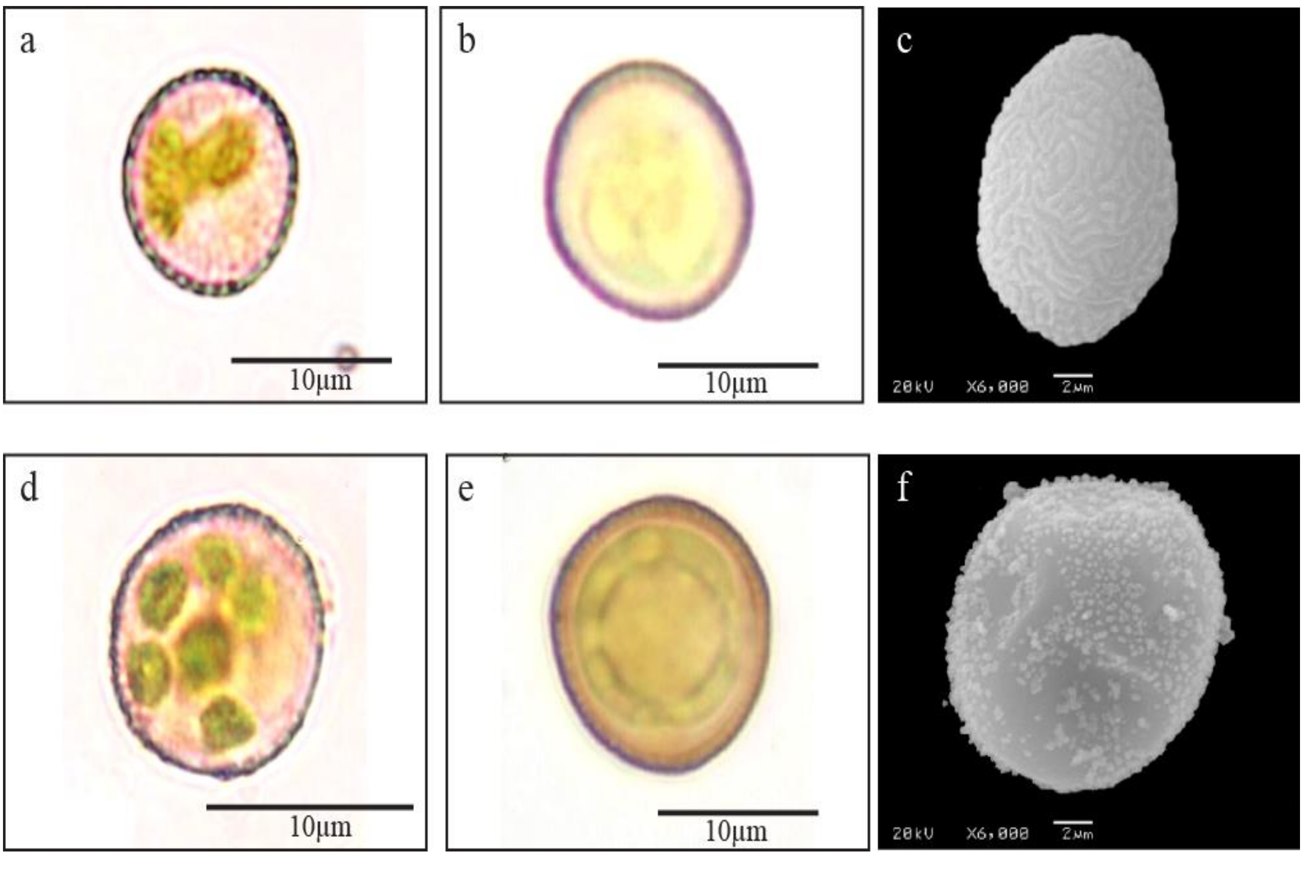

Fig. 2. **a-c:** *Tortula canescens* **a.** Proximal view (IM, N), **b.** Proximal view (IM, A), **c.** Distal surface (SEM). **d-f:** *T. inermis* **d.** Proximal view (IM, N), **e.** Proximal view (IM, A), **f.** Distal view (SEM).

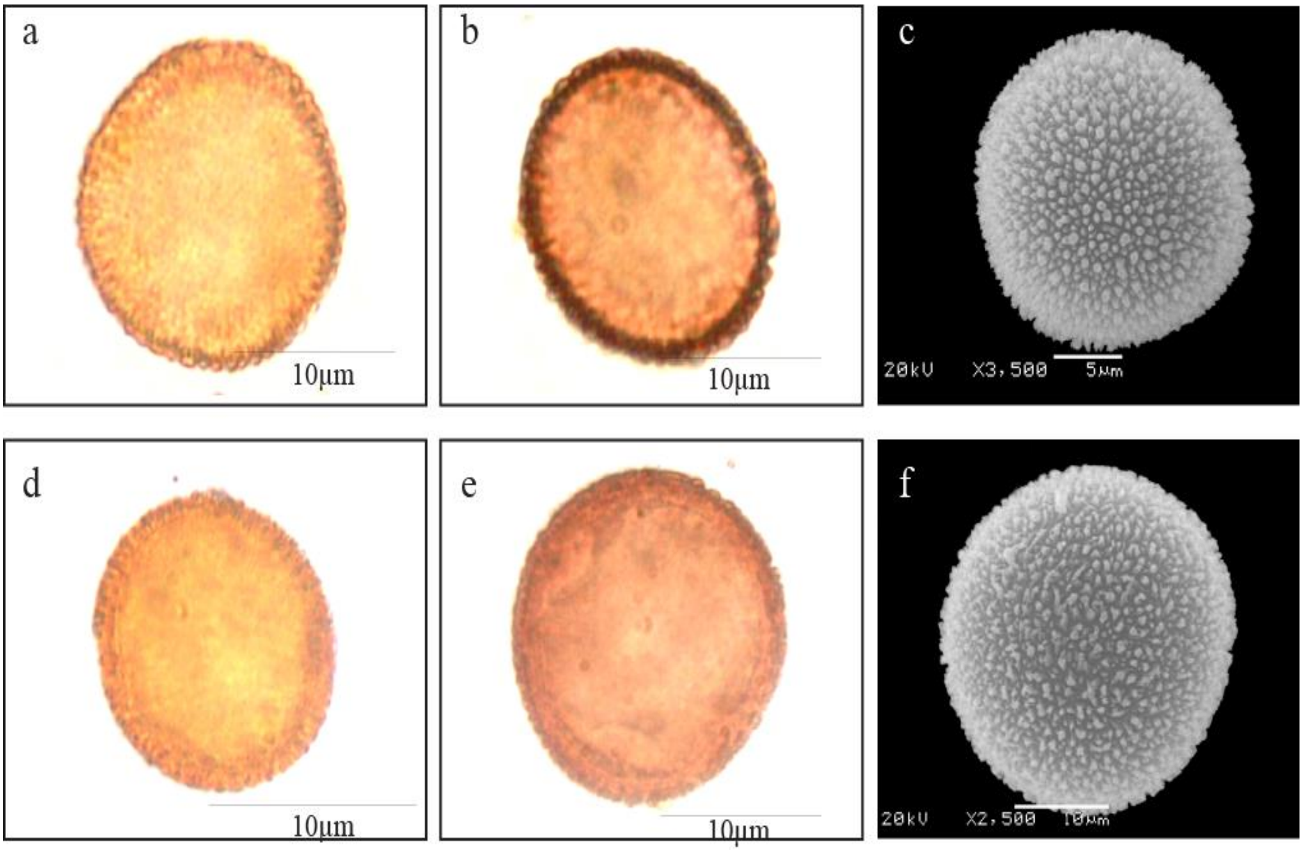

Fig. 3. **a-c:** T*ortula lanceola* **a.** Proximal view (IM, N), **b.** Proximal view (IM, A), **c.** Distal surface (SEM). **d-f:** *T. modica* **d.** Proximal view (IM, N), **e.** Proximal view (IM, A), **f.** Distal view (SEM).

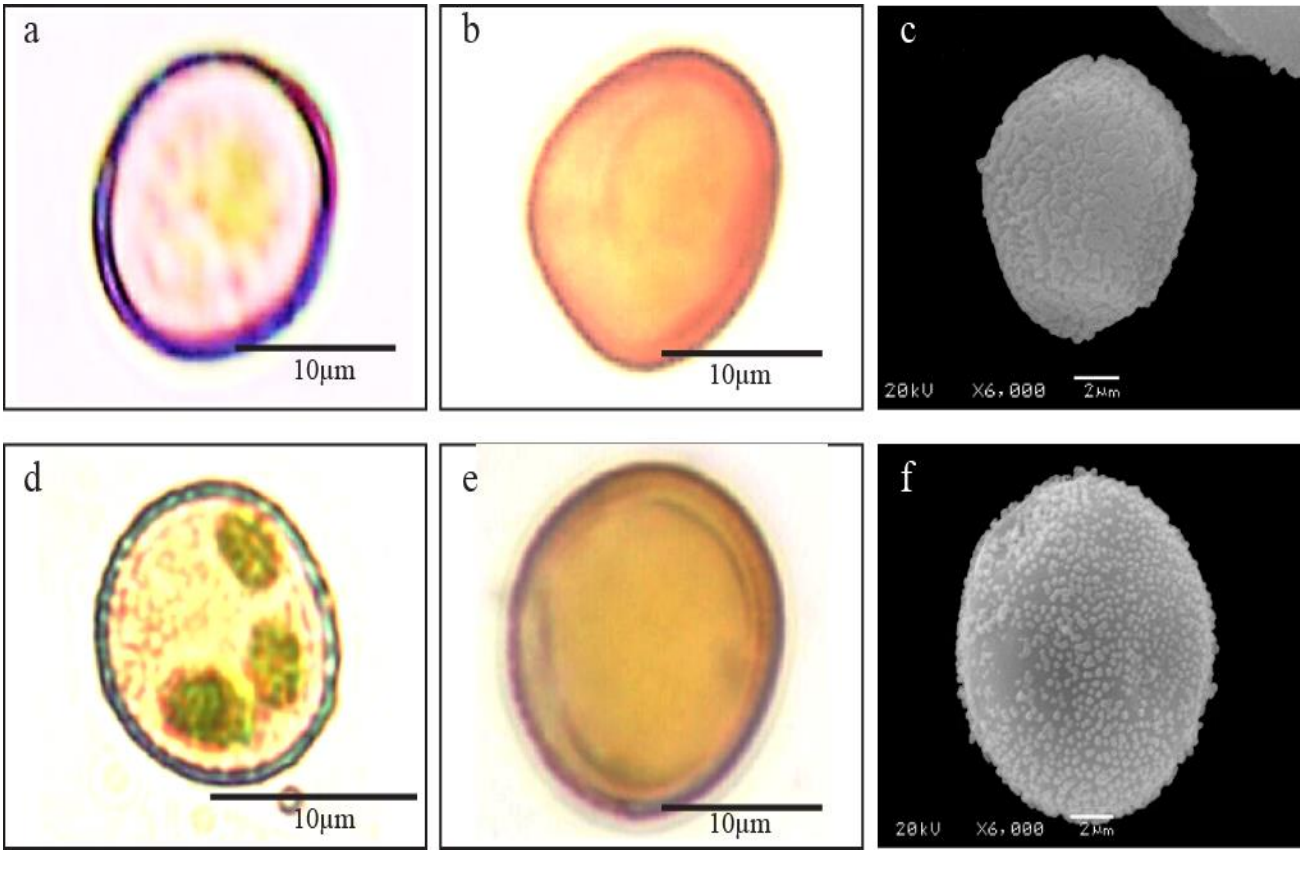

Fig. 4. **a-c:** *Tortula muralis* **a.** Proximal view (IM, N), **b.** Proximal view (IM, A), **c.** Distal surface (SEM). **d-f:** *T. subulata* **d.** Proximal view (IM, N), **e.** Proximal view (IM, A), **f.** Distal view (SEM).

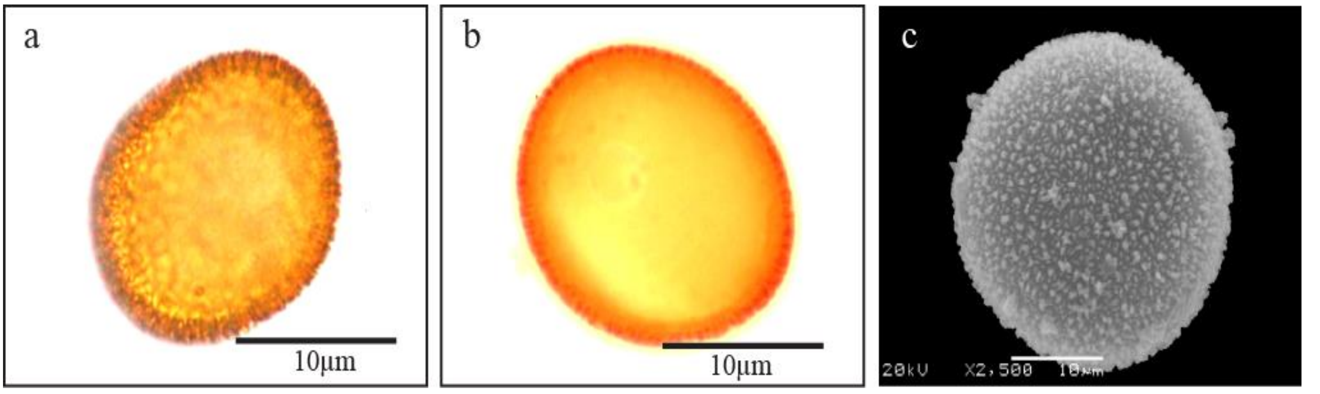

Fig. 5. **a-c:** *Tortula truncata* **a.** Proximal view (IM, N), **b.** Proximal view (IM, A), **c.** Distal surface (SEM).

Tortula canescens; Rugulate, spores are ellipsoid, occasionally clearly plano-convex, with varied dimensions 7, 0-10, 0 µm (mean value 8, 6 µm) (Fig. 2a-c).

T. inermis; Granulate, spores are irregular, sub-spherical, occasionally plano-convex, dimensions 11,0-16,0 µm (mean value 13,1 µm) (Fig. 2d-f).

T. lanceola; Baculate-verrucate, spores are irregular, sub-spherical, occasionally plano-convex, dimensions 19, 0-24, 0 µm (mean value 21, 7 µm) (Fig. 3a-c).

T. modica; Granulate-pliate, spores are ellipsoid, occasionally clearly plano-convex, with varied dimensions 29, 0-42, 0 µm (mean value 33, 8 µm) (Fig. 3d-f).

T. muralis; Rugulate-verrucate, spores are sub-spherical to plano-convex or concave-convex, dimensions 7, 0-11, 0 µm (mean value 8, 3 µm) (Fig. 4a-c).

T. subulata; Granulate, spores are sub-spherical to plano-convex or concave-convex, dimensions 10,0-13,0 µm (mean value 12,0 µm) (Fig. 4d-f).

T. truncata; Granulate-pliate, spores are sub-spherical to plano-convex or concave-convex, dimensions 32, 0-37, 0 µm (mean value 34, 6 µm) (Fig. 5a-c).

The spores of the examined taxa exhibit differences on their distal surfaces due to the fact that they are of six types. The sides of the proximal surface do not seem as developed. The spores with smaller dimensions (5µm-42 µm) are bilateral, sometimes radial symmetrical to asymmetrical, heteropolar, circular to semi-circular amb, and flat-convex to concave-convex in shape. The exine surface is decorated with elements similar to verrucates, granulates, rugulates, pliates, and baculates (Figs. 1-5). The aperture region is comprised of a less durable area in a large part of the taxon, and this section is known as leptoma. This area is assessed as an aperture in these taxa where the elements similar to verrucates, granulates, rugulates, pliates, and baculates are larger and more rarely spread. The SEM is useful for spore type characterization. This does not permit a clear distinction between the examined taxa. As well as the creation of this opening (aperture) or leptoma, the most important feature which facilitates the distinguishing of these spores is their measurements of diameter (Table 2). Some of the morphologic differences observed in verrucate, granulate, rugulate, pliate, and baculate elements can also appear in some taxa. However, as far as we have seen, as there are large differences within the types of these characteristics, they are not a reliable source when a distinction is made between species.

Discussion

The spore morphology of the species is based on peristome morphology. The examined taxa have six types of spores. As defined in the findings, it has been determined that the spores of the nine species exhibit the following ornamentations: *Tortula inermis* and *T. subulata*- granulate (Type I); *T. modica* and *T. truncata*- granulate-pliate (Type II), *Syntrichia calcicola* and *S. montana*- verrucate (Type III); *T. lanceola*- baculate-verrucate (Type IV), *T. canescens*- rugulate (Type V); and *T. muralis*- rugulate-verrucate (Type VI). The spores of the examined species are prolate-spheroidal. Previously, Boros *et al.* (1993) and Kapp *et al.* (2000) have also reported the spore types as granulate, granulate-pliate, verrucate, baculate-verrucate, rugulate, and rugulate-verrucate. The general spore morphology of these taxa are consistent with the studies carried out by Boros *et al.* (1993), using LM, while in this study, based on SEM, the spore morphologies of the widespread species of *Syntrichia* and *Tortula* in our country are reported.

Spore surface ornamentations have a distinctive importance in the identification of the taxa within the family, which have been examined as genus or species at a minimum. For example, the findings we have show that the nine species belong to granulate, granulate-pliate, verrucate, baculate-verrucate, rugulate, and rugulate-verrucate spore types.

The studied bryophytes have a saxicolous or terrestrial habitat in terms of their living areas. These species are found extensively on chalky rocks, acidic areas, old roofs, roof tiles, in man-made areas, on walls and gravestones. The saxicolous species which have been studied are subject to extensive sunlight. These species have adapted against drought. There is also a correlation between the exine surface ornamentation and the habitats of the bryophyte species. The species which generally have six types of spore ornamentation reside on both rocks and the soil. The saxicolous types primarily produce sporophytes during the winter season, at high levels of humidity and during periods when daylight is shorter. The spores belonging to saxicolous species which are subjected to continuous sunlight have an intensive ornamentation on their exine surfaces, while the spores of the species which reside on soil display a looser ornamentation. As also stated in the Bryophytes of the Near and Middle East (Kürschner, 2004; Khoshravesh & Kazempour Osaloo, 2007), other morphological adaptations, such as spore dimension, life forms and life strategies are related to the habitat conditions.

Table 1. Morphometric data of the Pottiaceae spores (equatorial view).

Taxa	Measurements							
	P				E			
	R (µm)	X ± S_x (µm)	S (µm)	V (%)	R (µm)	X ± S_x (µm)	S (µm)	V (%)
Syntrichia calcicola (N)	15,0-18,0	16,5-0,2	1,0	1,1	13,0-17,0	14,6-0,2	1,2	1,5
Syntrichia calcicola (A)	15,0-19,0	17,3-0,2	1,1	1,2	14,0-18,0	16,0-0,2	1,1	1,3
S. montana (N)	11,0-13,5	12,3-0,2	0,6	0,4	9,0-12,6	10,7-0,2	0,8	0,6
S. montana (A)	11,0-14,0	12,4-0,1	1,0	1,1	9,0-12,0	10,4-0,2	0,8	0,6
Tortula canescens (N)	8,0-10,0	9,2-0,1	0,5	0,2	7,0-9,0	7,8-0,1	0,6	0,4
T. canescens (A)	7,0-10,0	8,6-0,1	0,8	0,6	6,5-9,0	8,0-0,1	0,7	0,5
T. inermis (N)	14,0-21,0	16,1-0,3	1,5	2,2	13,0-18,0	14,6-0,2	1,2	1,3
T. inermis (A)	11,0-16,0	13,1-0,2	1,2	1,5	10,0-14,5	12,1-0,2	1,1	1,2
T. lanceola (N)	22,0-26,0	22,9-0,2	1,1	1,2	17,0-22,0	19,6-0,3	1,6	2,7
T. lanceola (A)	19,0-24,0	21,7-0,3	1,8	3,1	18,0-23,0	20,0-0,3	1,6	2,6
T. modica (N)	25,0-36,0	30,1-0,6	3,2	10,0	21,0-34,0	26,6-0,7	3,4	11,3
T. modica (A)	29,0-42,0	33,8-0,6	3,2	10,4	22,0-36,0	29,3-0,7	3,4	11,7
T. muralis (N)	8,0-9,0	8,7-0,1	0,5	0,5	7,0-8,0	7,7-0,1	0,5	0,2
T. muralis (A)	7,0-11,0	8,3-0,2	0,8	0,7	5,0-10,0	6,6-0,2	1,0	1,0
T. subulata (N)	12,0-17,0	14,0-0,2	1,2	1,3	10,0-13,0	11,9-0,2	0,9	0,8
T. subulata (A)	10,0-13,0	12,0-0,2	0,9	0,9	9,0-12,0	10,3-0,2	0,8	0,6
T. truncata (N)	33,0-39,0	35,4-0,1	1,6	1,6	26,0-33,0	29,9-0,5	2,3	5,5
T. truncata (A)	32,0-37,0	34,6-0,3	1,4	1,9	29,0-35,0	32,0-0,3	1,6	2,6

Abbreviations: P: Polar axis**,** E: Equatorial diameter, R: Range, X: Mean, S_X: Standard error, S: Standard deviation, V: Variation, N: Non-acetolyzed spores, A: Acetolyzed spores

Table 2. Morphometric data of the Pottiaceae spores (polar view).

Taxa	Measurements							
	D_M				D_m			
	R (µm)	X ± S_x (µm)	S (µm)	V (%)	R (µm)	X ± S_x (µm)	S (µm)	V (%)
Syntrichia calcicola (N)	14,0-17,0	15,9-0,1	0,7	0,4	14,0-17,0	15,4-0,2	0,8	0,6
Syntrichia calcicola (A)	14,0-18,0	16,1-0,2	1,0	0,9	13,0-18,0	15,4-0,2	1,1	1,3
S. montana (N)	10,3-12,5	11,5-0,1	0,5	0,3	10,0-12,0	11,3-0,1	0,6	0,3
S. montana (A)	10,0-12,0	11,2-0,1	0,6	0,4	10,0-12,0	11,1-0,1	0,6	0,4
Tortula canescens (N)	7,8-9,0	8,6-0,1	0,4	0,2	7,0-9,0	8,4-0,1	0,7	0,4
T. canescens (A)	7,0-10,0	8,2-0,2	0,8	0,6	7,0-9,0	7,7-0,1	0,7	0,4
T. inermis (N)	13,5-19,3	15,0-0,3	1,3	1,8	13,0-19,0	14,7-0,3	1,4	1,9
T. inermis (A)	10,0-14,5	12,6-0,2	1,2	1,4	10,0-14,0	12,1-0,2	1,0	1,0
T. lanceola (N)	20,0-24,0	22,0-0,2	1,0	1,0	18,0-24,0	20,5-0,3	1,5	2,3
T. lanceola (A)	16,0-24,0	20,1-0,4	2,0	3,9	16,0-24,0	19,1-0,4	2,0	3,8
T. modica (N)	23,0-34,0	27,4-0,7	3,3	10,7	20,0-32,0	25,4-0,7	3,3	11,1
T. modica (A)	22,0-38,0	31,7-0,6	3,1	9,7	22,0-35,0	29,7-0,6	2,9	8,5
T. muralis (N)	7,0-9,0	8,2-0,1	0,5	0,2	7,0-9,0	8,1-0,1	0,5	0,2
T. muralis (A)	7,0-8,0	7,4-0,1	0,5	0,2	7,0-8,0	7,4-0,1	0,5	0,2
T. subulata (N)	12,0-15,0	13,1-0,1	0,7	0,4	11,0-14,0	12,7-0,1	0,7	0,5
T. subulata (A)	10,0-14,0	11,3-0,2	1,1	1,2	9,0-13,5	11,1-0,5	2,3	5,3
T. truncata (N)	28,0-36,0	32,5-0,4	2,0	4,0	27,0-37,0	30,4-0,5	2,5	6,3
T. truncata (A)	30,0-35,0	32,6-0,2	1,0	1,1	28,0-33,0	30,0-0,2	1,1	1,2

Abbreviations: D_M: Largest diameter, D_m: Smallest diameter, R: Range, X: Mean, S_X: Standard error, S: Standard deviation, V: Variation, N: Non-acetolyzed spores, A: Acetolyzed spores

Table 3. Morphometric data of the sclerine and apertural region of the Pottiaceae spores.

Taxa	Measurements	
	st (µm)	a (µm)
Syntrichia calcicola (N)	1,04	9,96
Syntrichia calcicola (A)	0,86	8,42
S. montana (N)	0,69	7,02
S. montana (A)	0,80	6,36
Tortula canescens (N)	0,79	6,00
T. canescens (A)	0,76	5,06
T. inermis (N)	0,88	10,34
T. inermis (A)	0,87	8,63
T. lanceola (N)	1,08	15,80
T. lanceola (A)	0,94	10,72
T. modica (N)	1,56	19,56
T. modica (A)	1,32	20,70
T. muralis (N)	0,85	4,68
T. muralis (A)	0,81	4,32
T. subulata (N)	1,00	8,52
T. subulata (A)	0,80	6,80
T. truncata (N)	2,60	24,36
T. truncata (A)	1,31	22,68

Abbreviations: st: Sclerine thickness, a: Largest length of the apertural region, N: Non-acetolyzed spores, A: Acetolyzed spores

Besides, there is very little correlation between the size and shape of the spores of the examined species and their living areas. All the species have small spores and widespread sporophytes in order to increase their chances of a successful invasion to new locations and successful spore distribution. These characteristic features are related to the general drought resistance strategy. This strategy is characterised with a longer lifespan, being monoecious, regular sporophyte production and the production of small spores in large quantities. This is typical for functional type saxicolous bryophytes, and is used to balance the high rate of mortality in gametophytes, which is frequently caused by drought in summer or the effects of erosion (Kürschner, 2004). There is a presumed relationship between the taxonomic groups of the bryophytes in the area, their ecological conditions and the spore morphology of the species. These types of studies will hold a light to researchers in terms of future ecologic destruction and their ability to place the species under protection, for rare species of bryophytes and species which are at risk.

The basic spores of bryophytes of the Pottiaceae family may not reveal many of the morphologic features used in distinguishing taxa. The ornamentation shape of the spores has taxonomic importance. This is the evidence of the distribution of different types of spores among the species (Estebanez *et al.*, 1997; Luizi-Ponzo & Barth, 1998, 1999; Khoshravesh & Kazempour Osaloo, 2007; Potoglu Erkara & Savaroglu, 2007; Savaroglu & Potoglu Erkara, 2008; Özçelik, 2014). Granulate, granulate-pliate, verrucate, baculate-verrucate, rugulate, and rugulate-verrucate types of spores have been found in the nine species which were studied. The spores of the *Syntrichia* and *Tortula* species of the Pottiaceae family have been identified by Erdtman (1957), Boros & Járai-Komlódi (1975), Punt *et al.* (1994) and Kapp *et al.* (2000). The conclusions stated in this study are consistent with the conclusions reported by the authors above.

There are, at times, some differences between the means during the analyses of different samples for each taxon. However, the range in the measurements of the compared samples displays consistency with the reference samples. These results are also consistent with those of Olesen & Mogensen (1978). This proves us that there is a need for a comparison with more than one sample in order to be able to determine the spore dimension of a taxon.

This study has revealed that the spores of nine Pottiaceae species have prolate-spheroidal shapes. Furthermore, when their sclerine structures were studied, it has been determined that they are of verrucate type. The fact that these features and the exine structure is among the essential criteria to determine the phylogenetic relationships between Pottiaceae species has been reported in the literature. It has been determined through the differences in the measurements in the analyses of all of the species that they possess genetic differences. This appears to support the claim that the spore structures have valid morphological characters in taxonomy (Estebanez *et al.*, 1997).

The spore morphology among the Pottiaceae family and its relatives display important distinguishing characteristics for taxonomic studies (Sorsa & Koponen, 1973; Vitt & Hamilton, 1974; Boros & Járai-Komlódi, 1975; Olesen & Mogensen, 1978; Brown & Lemmon, 1988; Blackmore & Barnes, 1991; Estebanez *et al.*, 1997; Luizi-Ponzo & Barth, 1998, 1999; Khoshravesh & Kazempour Osaloo, 2007; Potoglu Erkara & Savaroglu, 2007; Savaroglu *et al.*, 2007; Savaroglu & Potoglu Erkara, 2008; Medina*et al.*, 2009; Aşçı *et al.*, 2010; Caldeira *et al.*, 2013).

As well as the systematic characteristics of these taxa in Pottiaceae, 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.

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