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SPORE MORPHOLOGY OF SOME BARTRAMIACEAE SPECIES (BRYOPHYTA) IN TURKEY

TALIP CETER, MERVE CAN GOZCU, GURAY UYAR

ABSTRACT. In this study, spore morphology of *Bartramia pomiformis* Hedw., *B. halleriana* Hedw., *Philonotis calcarea* (Bruch & Schimp.) Schimp. and *Plagiopus oederianus* (Sw.) H.A.Crum & L.E.Anderson were examined by light microscopy (LM) and scanning electron microscopy (SEM). All spores are small, the length of the polar axis (P) is between 12.36 µm and 19.14 µm, equatorial diameter (E) is between 19.59 µm and 26.23 µm. The smallest spores of them are *Philonotis calcarea* and the biggest spores of them are *Plagiopus oederianus*. The shapes of the spores are determined as suboblate for *Bartramia pomiformis*, *B. halleriana*, and oblate for *Philonotis calcarea, Plagiopus oederianus*. Verrucate-granulate, gemmate-microecinate, perforate, gemmate-pilate and verrucate ornamentation types were observed on the distal pole. In addition to spore morphology, capsule structures were also examined and were photographed with SEM. As a result, the spore size, shapes, ornamentation types and the capsule structures show some differences among these species and these differences can be used as distinctive characters in the identifications of them.

1. INTRODUCTION

Bartramiaceae Schwägr. is a large and cosmopolitan family with almost 400 species. The family members, in general, have globose to oblong-cylindric capsules, with the neck absent or inconspicuous, and they have dense, often reddish tomentum on their stems [1]. They generally spread on soil and rocks in moist habitats [2]. The family are represented by 18 taxa of Turkey. The taxa belong to genera *Anacolia* Schimp. (*A. menziesii* (Turner) Paris, *A. webbii* (Month.) Schimp.), *Bartramia* Hedw. (*B. aprica* Mull. Hal, *B. halleriana* Hedw., *B. ithyphylla* Brid., *B. pomiformis* Hedw.), *Philonotis* Brid. (*P. caespitosa* Jur., *P. calcarea* var. *calcarea* (Bruch & Schimp.) Schimp., *P. calcarea* var. *orthophylla* Schiffner, *P. calcarea* var. *seriatifolia* Schiffner, *P. capillaris* Lindb., *P. fontana* (Hedw.) Brid., *P. hastata* (Duby) Wijk & Margad., *P. marchica* (Hedw.) Brid., *P. rigida* Brid., *P. seriata* Mitt., *P. tomentella* Molendo) and *Plagiopus* Brid. (*P. oederianus* (Sw.) H.A.Crum & L.E.Anderson) [3]. The division of Bartramiaceae

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and separation of the genera has been made according to gametophytic and sporophytic characters. Some of the characters used were leaf cells, leaf shape, capsule structure and spore ornamentations [4]. The spore morphology is an important taxonomic character for this family. Some recent papers have shown that the spore external morphology is useful to characterize moss taxa at the generic and specific levels [5-12]. However, the bryophyte spores in Turkey are not fully known.

For this reason, in this study, the detailed spore morphological structures of some Turkish Bartramiaceae species were studied with light microscope (LM) and scanning electron microscope (SEM), in order to contribute to the taxonomy and palynology works. In addition to spore morphology, capsule structures were examined and photographed with SEM.

2. Material And Methods

The spore and capsule materials were obtained from the bryophyte herbarium of Ankara Hacı Bayram Veli University Polatlı Science and Arts Faculty. List of spores examined are given in the Table 1. The external surfaces of the spores were observed using light microscopy (LM) and scanning electron microscopy (SEM). The spores were prepared by the Wodehouse [13] method for LM photographs. Measurements of the diameters in the polar axis (P) and in the equatorial view (E) were taken in 20 randomly selected spores. The Simpson and Roe graphical test was used for graphical calculations [14]. The capsules were observed using stereo microscopy and scanning electron microscopy. The mouth diameter, length and width in 20 randomly selected capsules were measured. Olympus SZX7 model light microscope, BX47 model stereo microscope and SC 100 Model image analysis system were used to photograph and measurements the spores and the capsules.

For scanning electron microscopy, the spores and capsules were directly placed onto stubs which have double-sided carbon band. The stubs were coated with gold-palladium alloy at voltage of 40 mV for 60 seconds in a vacuum evaporator and examined with Quanta Feg 250 scanning electron microscopy in Kastamonu University Central Research Laboratory.

The terminology for spore morphology was proposed by Erdtman [15], Boros and Járai-Komlódi [16], Blackmore and Barnes [17], Punt et al. [18] and Kapp et al. [19].

TABLE 1. The details of specimens and localities.

Species	Localities
Bartramia pomiformis	Sakarya (Akyazı); on soil, *Fagus orientalis* Lipsky, *Carpinus betulus* L. and *Castenea sativa* Mill forest, 232 m. alt., 40°39'20"N, 30°39'20"E, 12.05.2018.
Bartramia halleriana	Bursa (İznik); on rock, *Fagus orientalis* Lipsky and *Carpinus betulus* L. forest, 775 m. alt., 40°32'29"N, 29°51'59"E, 11.05.2018.
Philonotis calcarea	Sakarya (Akyazı); on rock, *Pinus sylvestris* L., *Fagus orientalis* Lipsky and *Carpinus betulus* L. forest, 1283 m. alt., 40°30'49"N, 30°39'47"E, 12.05.2018.
Plagiopus oederianus	Bursa (İznik); on rock, *Fagus orientalis* Lipsky and *Carpinus betulus* L. forest, 775 m. alt., 40°32'29"N, 29°51'59"E, 11.05.2018.

TABLE 2. The spore morphological parameters (values in µm).

Species	P			E			P/E (mean)	Shape	Ornamentations
	min	max	mean	min	max	mean			
B.pomiformis	15.0	18.48	16.63	19.10	25.6	21.67	0.76	Sub-oblate	Verrucate-granulate
B.halleriana	16.21	19.09	17.29	18.18	23.18	20.64	0.84	Sub-oblate	Gemmate-microechinate
P.calcarea	9.39	15.75	12.36	16.21	22.42	19.59	0.63	Oblate	Gemmate-pilate
P.oederianus	15.6	22.72	19.14	20.6	29.84	26.23	0.72	Oblate	Verrucate

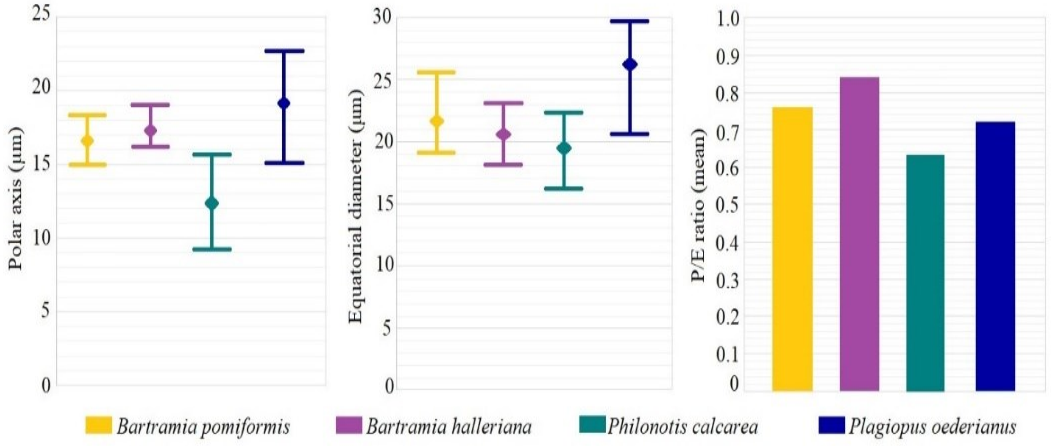

FIGURE 1. Graphical comparison of the length of polar axis (P), equatorial diameter (E) and P/E rotations (minimum, maximum and mean values).

3. Results

***Bartramia pomiformis*:** Spores are small, suboblate, heteropolar and katalept. The length of the polar axis is average 16.63 µm, equatorial diameter is average 21.67 µm in diameter and the ratio of polar axis to equatorial diameter is ~0.76 (Table 2, Figure 1). The sclerine surface is ornamented with big verrucae. The top of the verrucae shows granulate ornamentations in the distal face. The elements are irregular in shape and size, between 1.0-3.5 µm long. The wall structure is thinner on the proximal face. The aperture consists of monolete leptoma. Leptoma shape is ellipsoidal. The surface of leptoma is ornamented by sparse verrucate and granulate elements (Figure 2, 3). Capsules are inclined, globose to ovoid, asymmetrical, furrowed, average 1.8 mm long and 0.9 mm wide, ~2 times as long as wide. Peristome is double, teeth are lanceolate, average 300 µm, reddish-brown, striate, finely papillose. Endostome segments are present, finely seriate-papillose. Cilia available but less developed (Figure 4, 5).

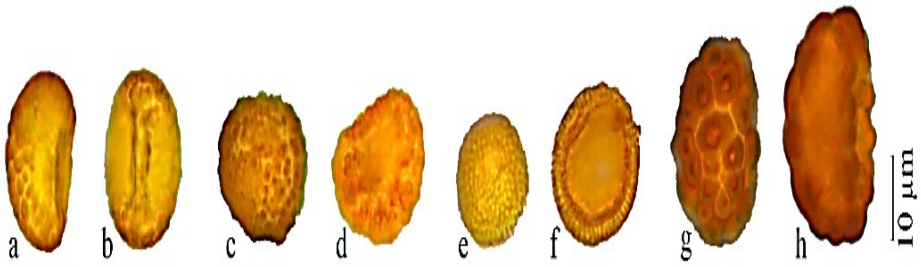

FIGURE 2. LM spore microphotograph. a, b: *Bartramia pomiformis*; c, d: *B. halleriana;* e, f: *Philonotis calcarea;* g, h: *Plagiopus oederianus* (a, h: equatorial view; b, d, f: proximal view; c, e, g: distal view).

***Bartramia halleriana*:** Spores are small, suboblate, heteropolar and katalept. The length of the polar axis is average 17.29 µm, equatorial diameter is average 20.64 µm in diameter and the ratio of polar axis to equatorial diameter is ~0.84 (Table 2, Figure 1). The sclerine surface is ornamented by gemmate with microechinate elements. It was seen perforate ornamentation among the gemmae. The length of the elements is between 0.5-2.2 µm. The aperture consists of irregular concave leptoma (Figure 2, 3). Capsules are subglobose to ovoid, furrowed, average 2.0 mm

wide and 0.9 mm long, ~2 times as long as wide. Operculum is conic and convex. Peristome is double, teeth are lanceolate, average 455 µm, brownish-red, strongly striate, papillose. Endostome segments are present, seriate-papillose. Cilia available but less developed (Figure 4, 5).

Philonotis calcarea: Spores are small, oblate, heteropolar and katalept. The length of the polar axis is average 12.36 µm, equatorial diameter is average 19.59 µm in diameter and the ratio of polar axis to equatorial diameter is ~0.63 (Table 2, Figure 1). The sclerine surface is ornamented by gemmate-pilate elements. The ornamentations are dense in the distal pole, diluted in the proximal pole. The length of the elements is between 0.6-1.0 µm. The aperture consists of concave leptoma (Figure 2, 3). Capsules are inclined, globose, asymmetrical, furrowed, average 3.0 mm long and 1.3 mm wide, ~2.2 times as long as wide. Peristome is present, teeth are lanceolate, average 345 µm, yellowish-red, striate, papillose (Figure 4, 5).

***Plagiopus oederianus*:** Spores are small, oblate, heteropolar and katalept. The length of the polar axis is average 19.14 µm, equatorial diameter is average 26.23 µm in diameter and the ratio of polar axis to equatorial diameter is ~0.72 (Table 2, Figure 1). The sclerine surface is ornamented by big densely verrucate elements. The length of the elements is between 2.5-5.5 µm. The aperture consists of slightly concave leptoma. The ornamentations were diluted and shrunken on the leptoma (Figure 2, 3). Capsules are suberect, subglobose, asymmetrical, furrowed, average 1.7 mm long and 1.1 mm wide, ~1.5 times as long as wide. Peristome is double, teeth are lanceolate, average 172 µm, reddish-brown, striate, finely papillose (Figure 4, 5).

4. Discussion

The spore morphology of Turkish *Bartramia pomiformis*, *B. halleriana*, *Philonotis calcarea* and *Plagiopus oederianus* studied by LM and SEM. Among them, the spores of *Bartramia pomiformis* have previously been photographed with SEM and LM; *Bartramia halleriana*, *Philonotis calcarea* and *Plagiopus oederianus* with only LM by Boros et al. [20]. In the present study, SEM photographs of these taxa were given in detail and the ornamentation structures were compared with the referred study.

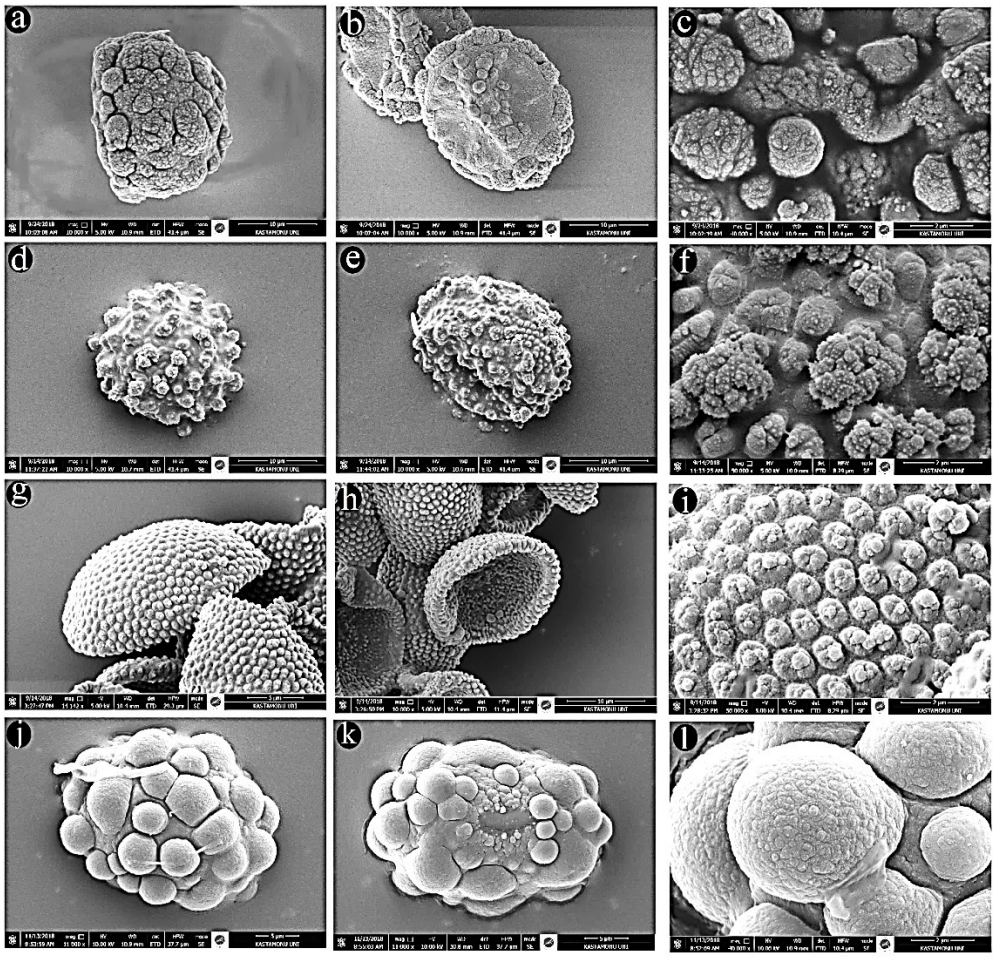

FIGURE 3. SEM spore photograph. a-c: *Bartramia pomiformis*; d-f: *B. halleriana*; g-i: *Philonotis calcarea;* j-l: *Plagiopus oederianus* (a, d, g, j: distal view; b, e, h, k: proximal view; c, f, i, l: spore ornamentation).

All spores are small, the length of the polar axis is between 12.36 µm and 19.14 µm, equatorial diameter is between 19.59 µm and 26.23 µm. The smallest spores of them are *Philonotis calcarea* and the biggest spores of them are *Plagiopus oederianus*. All spores are katalept and heteropolar. Apertures are concave leptoma on proximal pole. The shapes of the spores are determined as suboblate for *Bartramia pomiformis, B. halleriana*, and oblate for *Philonotis calcarea, Plagiopus*

oederianus. Spore wall is thick on distal pole, tapers to proximal pole and forms leptoma. Ornamentations are differing on leptoma, near leptoma and on distal pole. Verrucate-granulate, gemmate-microecinate, perforate, gemmate-pilate and verrucate ornamentation types were observed on the distal pole. The results for *Bartramia pomiformis* and *Plagiopus oederianus* presented here are in accordance with Boros et al. [20]. However, gemmate-microechinate ornamentation types were observed in *Batramia halleriana*, and gemmate-pilate ornamentation types in *Philonotis calcarea* in this study, while verrucate ornamentation types were reported in *Batramia halleriana*, and clavate or baculate ornamentation types in *Philonotis calcarea* in the study of Boros et al. [20].

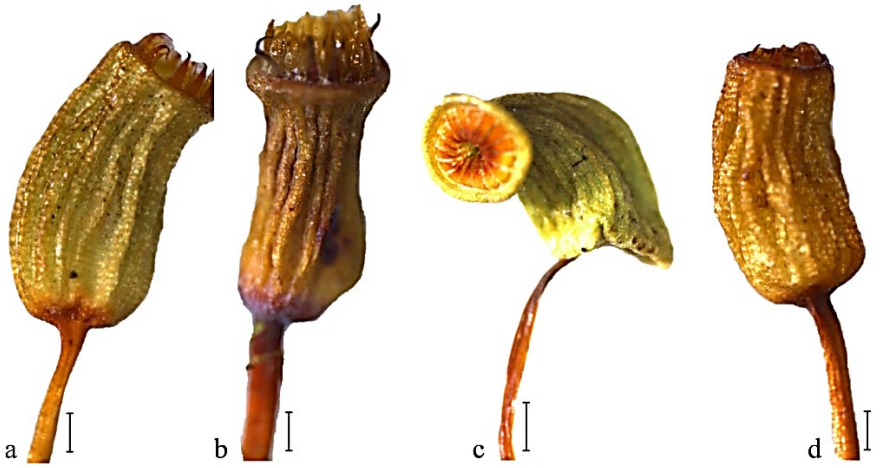

FIGURE 4. Stereo microscope capsule photograph. a: *Bartramia pomiformis*; b: *B. halleriana*; c: *Philonotis calcarea;* d: *Plagiopus oederianus* (Scale bar: a, b, d: 0.25 mm; c: 0.50 mm).

The shapes and sizes of the capsules have some differences. The widths of the capsules are between 0.9 mm and 1.3 mm, length of capsules are between 1.7 mm and 3.0 mm. The smallest capsules are in *Plagiopus oederianus*. All capsules are asymmetrical and furrowed. All species have a developed peristome.

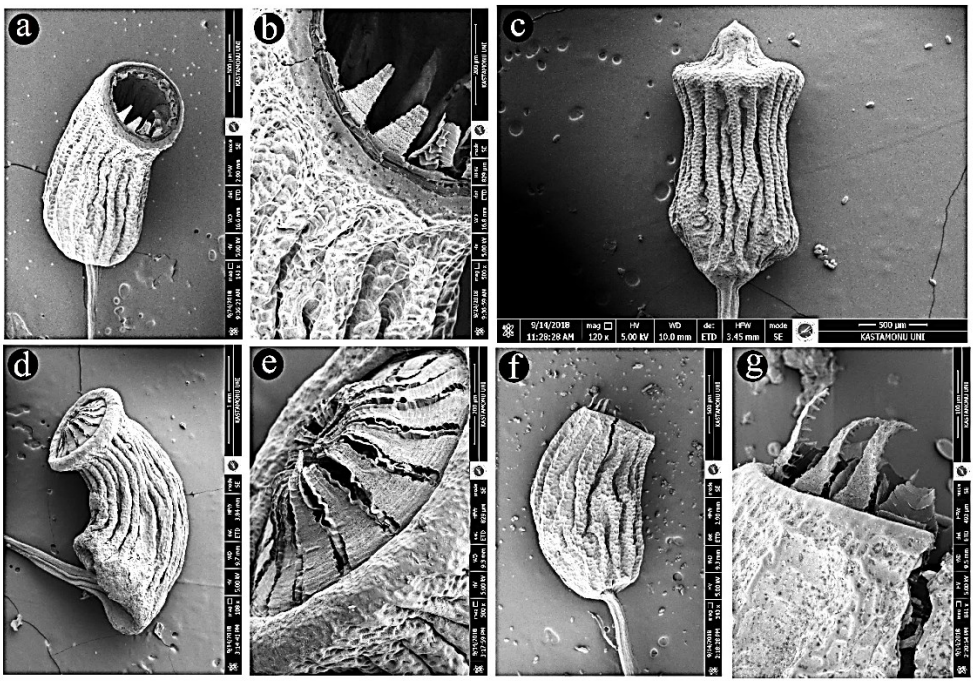

FIGURE 5. SEM capsule photograph a, b: *Bartramia pomiformis*; c: *B. halleriana*; d, e: *Philonotis calcarea;* f, g: *Plagiopus oederianus*.

Consequently, the spore morphology and capsule structures in examined *Bartramia pomiformis*, *B. halleriana*, *Philonotis calcarea* and *Plagiopus oederianus* show distinguish characters which are important for taxonomic studies.

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Current Address: TALIP CETER: Kastamonu University, Faculty of Science and Arts, Department of Biology, Kastamonu, Turkey.
E-mail: talipceter@hotmail.com
ORCID: https://orcid.org/0000-0003-3626-1758

Current Address: MERVE CAN GOZCU: Hacı Bayram Veli University, Polatlı Faculty of Science and Arts, Department of Biology, Ankara, Turkey.
E-mail: mcgozcu@gmail.com
ORCID: https://orcid.org/0000-0001-7935-6314

Current Address: GURAY UYAR: Hacı Bayram Veli University, Polatlı Faculty of Science and Arts, Department of Biology, Ankara, Turkey.
E-mail: gurayuyar@hotmail.com
RCID: https://orcid.org/0000-0003-4038-6107