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New submission to SAUJS
Pollen morphology in the genus *Bolanthus* (Ser.) Reichb. (Caryophyllaceae) in Turkey

Yağmur CÖMERT*, Mevlüde Nur TOPAL¹, Murat KOÇ¹

Abstract

*Bolanthus* including 11 species and all endemic in Turkey. Pollen morphology that belong to the genus *Bolanthus* were investigated using light microscopy (LM) and scanning electron microscopy (SEM). In this study, all of 11 species in *Bolanthus* were studied. Pollen of seven species were determined from Turkey and reported for the first time. Pollen shape has two different ornamentation at genus *Bolanthus* as prolate-spheroidal and oblate-spheroidal. Pollen grains are polipantoporate and isopolar symmetrical. The pollen ornamentation is scabrate-perforate. Pollen diameter, pore diameter, pore numbers, exine thickness, operculum diameter, distance between two pores, spinule numbers, punctum numbers are varying characters between *Bolanthus* species. The taxonomic separations of the species have been demonstrated with SPSS analysis as dendrogram.

**Keywords:** *Bolanthus*, Caryophyllaceae, LM, pollen, SEM

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1. INTRODUCTION

Caryophyllaceae is a large family in terms of the number of species and genus for Turkey [1-2-3]. The Caryophyllaceae family contains about 86 genera and about 2200 species. This family is generally common in temperate regions [4]. The tribe Caryophylleae includes 17 genera, namely Acanthophyllum C. A. Mey., Dianthus L., Gypsophila L., Petrorhagia (Ser. ex DC.) Link, Saponaria L., Vaccaria Medic., Allochrusa Bunge ex Boiss., Ankyropetalum Fenzl, Bolanthus (Ser.) Reichb., Cyathophylla Bocquet et Strid, Diaphanoptera Rech. f., Kohlruschia Kunth, Ochotonophila Gilli, Phrynella Pax et K. Hoffm., Pleioneura Rech. f., Scleranthopsis Rech. f. and Velezia L. and about 600 species [4].

The family Caryophyllaceae of genus Bolanthus is located in the Caryophylleae tribes in the subfamily Caryophyllideae. It is perennial plants in the form of slants or pillows. The leaves are small, stripy and flowers dicazium. The genus Bolanthus comprising 29 species, mostly occurring in the Mediterranean region in the world. The genus is represented by six taxa found in Syria, Palestine, Israel and Lebanon [5-7]. The eight taxa growing in Europe are known from Greece or the East Aegean Islands [8]. The flora of Turkey includes five Bolanthus taxa. As a result of recent studies, six additional taxa were added to Bolanthus, of which one is an overlooked species (B. huber-morathii C. Simon) and five are new species (B. stenopetalus Hartvig & Strid, B. mevlaneae Aytaç, B. turcicus Koç & Hamzaoğlu, B. sandrasicus Hamzaoğlu & Koç, B. aziz-sancarii Koç & Hamzaoğlu) [9-10-11-12]. Together with these additions, the number of taxa belonging to the genus Bolanthus that occur in Turkey increased to 11, all of which are endemic.

There are many studies on pollen morphology of Caryophylleae [15-16-17-18-19-20-21]. Palynological characteristics of Caryophyllaceae such as pore shape, number of pores and ornamentation are proved to have taxonomical importance [22-23-24-25-26-27-28]. Using palynological features, scientists identified new species and also distinguished new species from other similar species [29-30-31-32-33].

The aim of this study is determined the pollen morphology of the genus Bolanthus and contributing to taxonomy. For this purpose, the pollen morphology of 11 endemic species of Bolanthus have studied by using scanning electron microscopy (SEM) and light microscopy (LM). In addition, taxonomic relationships between species have been revealed.

2. MATERIALS AND METHODS

The pollen of 11 taxa of genus Bolanthus were examined with light microscopy (LM) and scanning electron microscopy (SEM) (Figure 1 and 2).

The localities of the specimens are given below Table 1. After the plants were diagnosed and pollen materials the plants were left in the Gazi University Herbarium (GAZI) for storage. Saffron with glycerine-gelatin was used for staining pollen. Pollen grains were prepared for light microscopy (LM) using [34].

The pollens were photographed with a spot in-sight colour digital camera on a LEICA DM1000 microscope with digital imaging system which is Leica Application Suit program equipped with an apochromatic 100x oil immersion objective [34]. Morphological observations were carried out in microscope in the LM of Ankara University.

For scanning electron microscopy, each of the pollen was attached on stubs applying double-sided adhesive tape. Every sample was coated with a 100-Å-thick layer of gold in a Polaron SC7620 rotating and tilting vacuum coating apparatus for 60 s and scanned using a JEOL 5600 LV SEM (Scanning Electron Microscopy) with 20-kV accelerating voltage [35-36]. Morphological observations were carried out in a Jeol 5600 electron microscope in the Electron Microscopy Laboratory of Gazi University.
Pollen ornamentation, operculum ornamentation, pollen diameter, pore diameter, pollen shape, distance between two pore, operculum diameter, pore numbers, spinele numbers, number of spinules on operculum, punctum numbers, punctum diameter, exine and intine thickness measurements were made with 20 to 30 pollen grains. Measurements were made with AlAMet 0.06 program. The average of the measured samples was calculated with Microsoft Office Excel Programme. Pollen morphologies were determined by using glossary of pollen and spore terminology [37]. The taxonomic separation of the species has been demonstrated with SPSS software analysis as dendrogram (Figure 3).

3. RESULTS AND DISCUSSION

Bolanthus including 11 species and all endemic in Turkey. Pollen morphology of four species from this genus was reported from Turkey [38]. Pollen morphology of the other seven species was determined for the first time in this study. Pollen in the Caryophyllaceae family are generally radially symmetrical, apolar or isopolar, spheroidal, polygonal or polygonal spheroidal, oblate-spheroidal, prolate spheroidal, periporate or pantopoporate [13-18-38-39-23-40-41]. The findings of the study shows, Bolanthus taxa pollens are isopolar symmetry, shape of pollen is oblate-spheroidal (9 species) and prolate-spheroidal (2 species). The pollen ornamentation have been observed scabrate-perforate.

Our results are consistent with those reported by Pınar [38] who worked on B. minuartioides, B. spergulifolius, B. thymoides, B. frankenioides var. fasciculatus and B. turcicus. Likewise, in the species, pollen shape is polipantoporate. Pollen and pore diameters are similar average. Pınar’s of the study [38], pollen is spheroidal. In our study, pollen is prolate-spheroidal and oblate-spheroidal. However, in this study, exine thickness was measured about 1.3 µm while Pınar’s of the study as 2 µm in this species [38]. When our study was compared to Pınar’s study, the exine thickness was measured as thinner. In addition, in this study, it was determined that B. minuartioides taxa have a fewer number of pores. Pore numbers of the others taxa are similar average.

The pollen characteristics of Bolanthus taxa in 11 species were listed in detail in Table 2. All characters were evaluated under the separate titles. In addition, the pollen morphologies of Bolanthus taxa were compared with related genera. Moreover, the taxonomic separations of the species were demonstrated as dendrogram (Figure 3).

Cluster analysis divided the taxa into 2 groups: clusters as number of pores which is A and B. Cluster A was divided into 2 subgroups according to the distance between the pores: A1 (B. turcicus, B. stenopetalus, B. cherlierioides, B. aziz-sancarii and A2 (B. minuartioides). Cluster B was divided into 2 subgroups according to the spinule number: B2 (B. frankenioides) and B1, which B1 was further divided C1 and C2 according to punctum number. C1 are B. frankenioides var. fasciculatus, B. thymoides, B. huber-morathii and B. mevlanae C2 is B. spergulifolius (Figure 3). The data obtained and the cluster analysis results are consistent with each other.

3.1. Evaluation of the findings of Bolanthus taxa

3.1.1. Pollen shape

The findings of the study shows, pollen shape have 2 different at genus Bolanthus. prolate-spheroidal (B. spergulifolius, B. huber-morathii) and oblate-spheroidal (B. thymoides, B. aziz-sancarii, B. frankenioides, B. frankenioides var. fasciculatus, B. cherlierioides, B. stenopetalus, B. minuartioides, B. turcicus, B. mevlanae). All the species are isopolar symmetrical. Another study, pollen grains of Bolanthus taxa in 4 species (B. minuartioides, B. spergulifolius, B. thymoides and B. frankenioides var. fasciculatus) were determined as spheroidal [38]. In addition to the pollen grains of Acanthophyllum, Dianthus, Gysophila, Bolanthus have spheroidal [44]. In the literature, B. filicaulis species pollen is radially symmetrical and spheroidal [16]. Bolanthus is isopolar symmetrical.
3.1.2. Pollen ornamentation

The findings demonstrated that, pollen grains ornamentation have scabrate-perforate (Figure 2, Table 2). However, another study, pollen grains of four Turkish endemic Bolanthus taxa belong to B. minuartioides, B. spargulifolius, B. thyoides and B. frankeniioides var. fasciculatus were detected tectate-perforate [38].

The pollen ornamentation was observed scabrate, scabrate-perforate ve scabrate-perforate-foveolate for Dianthus taxa [45]. Silenoideae, a subgroup of the Caryophyllaceae family, is usually characterized by polypantoporate [15]. Likewise Bolanthus taxa pollen aperture type are polypantoporate.

3.1.3. Pollen diameter

The largest pollen diameter has been observed in Bolanthus turcicus as 30.33±1.14 μm (mean±standard deviation), the smallest in Bolanthus frankenioides var. fasciculatus as 22.30±0.30 μm (mean±standard deviation) (Table 2). The pollen grains of Acanthophyllum, Dianthus, Gypsophila, Bolanthus are spheroidal. The pollen grains of Acanthophyllum with a diameter of 28.65–30.87 μm, Dianthus 30.05–40.22 μm and Gypsophila 16.95–27.77 μm [44]. The pollen grains of Bolanthus has been measured as 22.23–30.33 μm. In terms of pollen diameter, Bolanthus is generally smaller than Acanthophyllum and Dianthus, larger than Gypsophila.

3.1.4. Pore diameter

The largest pore diameter has been observed in B. thyoides as 4.25±0.63 μm (mean ± standard deviation), the smallest in B. mevlandae as 2.31±0.40 μm (mean ± standard deviation) (Table 2). The pore diameter was measured as 2.2–9.3 μm for Dianthus taxa [45]. The biggest species Silene bupleuroides subsp. bupleuroides with 6.96±1.65 μm whereas the smallest species Silene cartilaginea with 3.54±0.66 μm of the pore diameter [42]. Pore diameter of Bolanthus taxa is smaller than Silene and Dianthus.

3.1.5. Distance between two pores (μm^2)

The findings shows that the largest species B. minuartioides with 6.75±2.01 μm (mean±standard deviation) while the smallest species B. turcicus with 3.90±1.07 μm (mean±standard deviation) of the distance between two pores. In the literature, Gypsophila and Dianthus have been measured as 4.69–9.86, 9.42–13.07 μm respectively [44]. Comparing the distance between pores, Bolanthus is different from Dianthus, similar to Gypsophila. Therefore, the distance between pores of Dianthus are more than Bolanthus.

3.1.6. Pore numbers

The results demonstrated that the highest species B. spargulifolius with 22±3 while the lowest species B. minuartioides with 10±3 (Table 2) of the pore numbers. In another study, pore numbers have been detected as 21–22 in B. minuartioides and B. spargulifolius 19–22 [38]. Therefore, in this study, it was determined that B. minuartioides taxa have a fewer number of pores. In the literature, pore numbers are determined as 10–16 in Acanthophyllum, Dianthus, Gypsophila [44]. Likewise, Bolanthus pollen is 10–22 pores.

3.1.7. Operculum diameter

The largest operculum diameter has been observed in Bolanthus thymoides as 3.33±0.53 μm, the smallest in Bolanthus turcicus as 1.19±0.22 μm (Table 2). The operculum diameter was measured as 1.2–5.2 μm for Dianthus taxa [45]. Saponaria karapinarensis (Caryophyllaceae) have operculum diameter 2 μm [43] Similarly, Bolanthus taxa have been measured as approximately 2 μm.

3.1.8. Exine thickness

The findings indicated that, the largest species B. stenopetalus with 1.47±0.14 μm (mean±standard deviation) while the smallest species B. turcicus with 0.94±0.11 μm (mean±standard deviation) (Table 2) of the exine thickness. In the literature, Bolanthus filicaulis was measured 2 μm [16]. In our study, exine thickness have determined as more thinner compered to other studies. Petrotrhagia, which is close to the Bolanthus.
genus, have been measured from 1.73 μm to 3.78 μm [25]. In another study, exine thickness was determined as above 2 for all studied taxa [38]. In our study, exine thickness have been detected as about 1.3.

3.1.9. Intine thickness

The largest intine thickness has been observed in *B. thymooides* as 0.66±0.10 μm (mean±standard deviation), the smallest in *B. frankenioides* as 0.47±0.07 μm (mean±standard deviation) (Table 2). In another study, the intine thickness was measured as 0.4-1.1 μm for *Dianthus* taxa [45].

3.1.10. Spinule and punctum numbers

The most spinule numbers have been observed in *B. frankenioides* as 24-26, the least species *B. minuartioides* as 8-10.

The most punctum numbers have been determined in *B. spergulifolius* as 15-17, the least in *B. frankenioides* as 3-5 (Table 2). All species have differed when compared within themselves. In the literature, the spinule and punctum numbers have been measured as 9-28 and 1-23 μm for *Dianthus* taxa [45].

3.2. Description:

3.2.1. *B. spergulifolius* pollen features: Pollen shape is prolate-spheroidal (P/E=1.06). In general aspect pollen is isopolar. Polar axis is 26.44±0.77 μm, equatorial axis is 24.93±1.98 μm. Pollen type is polipantoporate. Pollen ornamentation is scabrate-perforate. Pore numbers are 19-25. Pore diameter is 2.59±0.27 μm. The distance between two pores are 3.94±1.81 μm. Operculum diameter is 1.31±0.15 μm. Number of spinules on operculum are 5-7. Number of spinule is 13-16. Number of punctum is 15-17. Exine thickness is 1.39±0.09 μm. Intine thickness is 0.60±0.08 μm (Table 2, Figure 1, 1 a-b-c, Figure 2, 1 a-b).

3.2.2. *B. huber-morathii* pollen features: Pollen shape is prolate-spheroidal (P/E=1.04). In general aspect pollen is isopolar. Polar axis is 25.32±0.51 μm, equatorial axis is 24.25±0.71 μm. Pollen type is polipantoporate. Pollen ornamentation is scabrate-perforate. Pore numbers are 13-19. Pore diameter is 3.22±2.65 μm. The distance between two pores are 4.83±1.42 μm. Operculum diameter is 1.72±0.31 μm. Number of spinules on operculum are 6-8. Number of spinule is 13-16. Number of punctum is 11-13. Exine thickness is 1.33±0.07 μm. Intine thickness is 0.56±0.10 μm (Table 2, Figure 1, 2 a-b-c, Figure 2, 2 a-b).

3.2.3. *B. frankenioides* pollen features: Pollen shape is oblate-spheroidal (P/E=0.95). In general aspect pollen is isopolar. Polar axis is 22.91±0.28 μm, equatorial axis is 23.99±0.23 μm. Pollen type is polipantoporate. Pollen ornamentation is scabrate-perforate. Pore numbers are 17-23. Pore diameter is 2.81±0.25 μm. The distance between two pores are 4.02±1.43 μm. Operculum diameter is 1.67±0.20 μm. Number of spinules on operculum are 4-6. Number of spinule is 24-26. Number of punctum is 3-5. Exine thickness is 1.30± 0.10 μm. Intine thickness is 0.47±0.07 μm (Table 2, Figure 1, 3 a-b-c, Figure 2, 3 a-b).

3.2.4. *B. frankenioides var. fasciculatus* pollen features: Pollen shape is oblate-spheroidal (P/E=0.97). In general aspect pollen is isopolar. Polar axis is 23.71±0.56 μm, equatorial axis is 24.23±0.80 μm. Pollen type is polipantoporate. Pollen ornamentation is scabrate- perforate. Pore numbers are 15-21. Pore diameter is 3.51±0.40 μm. The distance between two pores are 4.17±1.78 μm. Operculum diameter is 2.65±0.32 μm. Number of spinules on operculum are 4-6. Number of spinule is 16-18. Number of punctum is 7-9. Exine thickness is 1.35±0.09 μm. Intine thickness is 0.66±0.08 μm (Table 2, Figure 1, 4 a-b-c, Figure 2, 4 a-b).

3.2.5. *B. minuartioides* pollen features: Pollen shape is oblate-spheroidal (P/E=0.97). In general aspect pollen is isopolar. Polar axis is 25.86±0.64 μm, equatorial axis is 26.43±0.68 μm. Pollen type is polipantoporate. Pollen

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ornamentation is scabrate-perforate. Pollen numbers are 7-13. Pollen diameter is 3.75±0.87 μm. The distance between two pores are 6.75±2.01 μm. Operculum diameter is 1.89±0.35 μm. Number of spinules on operculum are 5-7. Number of spinule is 8-10. Number of punctum is 10-12. Exine thickness is 1.31±0.07 μm. Intine thickness is 0.55±0.07 μm (Table 2, Figure 1, 5 a-b-c, Figure 2, 5 a-b).

3.2.6. B. cherlierioides pollen features: Pollen shape is oblate-spheroidal (P/E=0.91). In general aspect pollen is isopolar. Polar axis is 21.74±0.29 μm, equatorial axis is 23.86±0.29 μm. Pollen type is polipantoporate. Pollen ornamentation is scabrate-perforate. Pollen numbers are 11-17. Pollen diameter is 3.02±1.64 μm. The distance between two pores are 4.21±1.41 μm. Operculum diameter is 1.39±0.30 μm. Number of spinules on operculum are 4-6. Number of spinule is 15-18. Number of punctum is 4-6. Exine thickness is 0.96±0.12 μm. Intine thickness is 0.57±0.07 μm (Table 2, Figure 1, 6 a-b-c, Figure 2, 6 a-b).

3.2.7. B. turcicus pollen features: Pollen shape is oblate-spheroidal (P/E=0.95). In general aspect pollen is isopolar. Polar axis is 27.11±0.62 μm, equatorial axis is 28.47±0.34 μm. Pollen type is polipantoporate. Pollen ornamentation is scabrate-perforate. Pollen diameter is 4.25±0.63 μm. The distance between two pores are 4.83±1.12 μm. Operculum diameter is 3.33±0.53 μm. Number of spinules on operculum are 7-9. Number of spinule is 16-18. Number of punctum is 9-11. Exine thickness is 0.94±0.06 μm. Intine thickness is 0.66±0.10 μm (Table 2, Figure 1, 9 a-b-c, Figure 2, 9 a-b).

3.2.10. B. aziz-sancarii pollen features: Pollen shape is oblate-spheroidal (P/E=0.92). In general aspect pollen is isopolar. Polar axis is 23.36±0.45 μm, equatorial axis is 25.14±0.35 μm. Pollen type is polipantoporate. Pollen ornamentation is scabrate-perforate. Pollen numbers are 13-19. Pollen diameter is 3.91±0.35 μm. The distance between two pores are 5.19±1.56 μm. Operculum diameter is 2.48±0.52 μm. Number of spinules on operculum are 7-9. Number of spinule is 10-12. Number of punctum is 4-6. Exine thickness is 1.13±0.12 μm. Intine thickness is 0.65±0.06 μm (Table 2, Figure 1, 10 a-b-c, Figure 2, 10 a-b).

3.2.8. B. mevlanae pollen features: Pollen shape is oblate-spheroidal (P/E=0.97). In general aspect pollen is isopolar. Polar axis is 23.26±0.24 μm, equatorial axis is 23.79±0.72 μm. Pollen type is polipantoporate. Pollen ornamentation is scabrate-perforate. Pollen numbers are 15-21. Pollen diameter is 2.31±0.40 μm. The distance between two pores are 3.98±1.42 μm. Operculum diameter is 1.60±0.39 μm. Number of spinules on operculum are 4-6. Number of spinule is 13-15. Number of punctum is 9-11. Exine thickness is 1.25±0.09 μm. Intine thickness is 0.59±0.10 μm (Table 2, Figure 1, 8 a-b-c, Figure 2, 8 a-b).

3.2.9. B. thymoides pollen features: Pollen shape is oblate-spheroidal (P/E=0.99). In general aspect pollen is isopolar. Polar axis is 23.32±0.49 μm, equatorial axis is 23.53±0.43 μm. Pollen type is polipantoporate. Pollen ornamentation is scabrate-perforate. Pollen numbers are 13-19. Pore diameter is 2.78±0.31 μm. The distance between two pores are 3.90±1.07 μm. Operculum diameter is 1.19±0.22 μm. Number of spinules on operculum are 5-7. Number of spinule is 12-15. Number of punctum is 4-6. Exine thickness is 0.94±0.11 μm. Intine thickness is 0.50±0.11 μm (Table 2, Figure 1, 7 a-b-c, Figure 2, 7 a-b).

3.2.11. B. stenopetalus pollen features: Pollen shape is oblate-spheroidal (P/E=0.92). In general aspect pollen is isopolar. Polar axis is 20.84±0.38 μm, equatorial axis is 22.56±0.65 μm. Pollen type is polipantoporate. Pollen ornamentation is scabrate-perforate. Pollen numbers are 11-17. Pore diameter is 3.06±0.31 μm. The distance between two pores are 6.03±1.79 μm. Operculum diameter is 2.39±0.32 μm. Number of spinules on operculum are 5-7. Number of spinule is 13-15. Number of punctum is 4-6. Exine thickness is 1.47±0.14 μm. Intine thickness is 0.54±0.28 μm (Table 2, Figure 1, 11 a-b-c, Figure 2, 11 a-b).
Table 1
List of the studied *Bolanthus* taxa and localities

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Collector Name and Number</th>
<th>Localities</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>B. spergulifolius</em></td>
<td>Koç 2043</td>
<td>B2 Kütahya: Gediz, Murat Mountain, Kaplıcalar road, serpentine soils, grassy levels, 1495 m, 25.06.2016</td>
</tr>
<tr>
<td><em>B. frankenioides</em></td>
<td>Koç 2167</td>
<td>C3 Burdur: Altınıyayla southwestern, Akpınar yaylası around limestone slopes, 1865 m, 04.08.2016</td>
</tr>
<tr>
<td><em>B. frankenioides var. fasciculatus</em></td>
<td>Koç 2188</td>
<td>C2 Muğla: Köyçeğiz, Yayla village, Gökçeova lake around, Sandras Mountain, serpentine rocky, 2030 m, 05.08.2017</td>
</tr>
<tr>
<td><em>B. minuartioides</em></td>
<td>Koç 2006</td>
<td>B2 Kütahya: Aslantepe, between Çavdar and Hisar, calcareous rocks, 1090 m, 24.06.2015</td>
</tr>
<tr>
<td><em>B. cherlerioides</em></td>
<td>Koç 3054</td>
<td>B4 Between Akşehir and Şarkikaraağaç, Yellibel gateway around, slopes around, 38°14’06’” K- 031°19’36” D, 1550 m, 14.07.2017</td>
</tr>
<tr>
<td><em>B. turcicus</em></td>
<td>Koç 2226</td>
<td>B4 Aksaray: Karkin Beldesi, Karbeyaz Hotel around, Hasan Mountain to the south, 2760 m, 07.08.2016</td>
</tr>
<tr>
<td><em>B. mevlanaea</em></td>
<td>Koç 3365</td>
<td>C3 Antalya: Between Akseki and Bozkır, 60. km, Gölcük kuruçay tableland, 1200 m, 23.07.2017</td>
</tr>
<tr>
<td><em>B. thymoides</em></td>
<td>Koç 1848</td>
<td>C3 Burdur: Between Yeşilova and Salda Village, Eşeler Mountain, watchtower around, serpentine, stony places, 37°27’50’” K – 29°39’30” D, 2000 m, 18.08.2016</td>
</tr>
<tr>
<td><em>B. aziz-sancarii</em></td>
<td>Koç 1209</td>
<td>B3 Afyonkarahisar: between Bayat and Iscehisar, 1500 m, 02.07.2010</td>
</tr>
<tr>
<td><em>B. stenopetalus</em></td>
<td>Koç 2196</td>
<td>C2 Muğla: Köyçeğiz, Yayla village, Gökçeova lake around, Sandras Mountain, 2030 m, 05.08.2017</td>
</tr>
</tbody>
</table>
Table 2
Pollen morphological characters of the *Bolanthus* taxa analyzed

<table>
<thead>
<tr>
<th></th>
<th><em>B. spergulifolius</em></th>
<th><em>B. hubermorathii</em></th>
<th><em>B. frankenioides</em></th>
<th><em>B. frankenioides var. fasciculatus</em></th>
<th><em>B. minuartioides</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollen diameter (M±SD)</td>
<td>26.50±0.31</td>
<td>23.56±0.32</td>
<td>23.68±0.48</td>
<td>22.23±0.30</td>
<td>26.42±0.23</td>
</tr>
<tr>
<td>Polar axes (M±SD)</td>
<td>26.44±0.77</td>
<td>25.32±0.51</td>
<td>22.91±0.28</td>
<td>23.71±0.56</td>
<td>25.86±0.64</td>
</tr>
<tr>
<td>Equatorial axes (M±SD)</td>
<td>24.93±0.70</td>
<td>24.25±0.71</td>
<td>23.99±0.23</td>
<td>24.23±0.80</td>
<td>26.43±0.68</td>
</tr>
<tr>
<td>Pollen shape</td>
<td>Prolate-spheroidal</td>
<td>Prolate-spheroidal</td>
<td>Oblate-spheroidal</td>
<td>Oblate-spheroidal</td>
<td>Oblate-spheroidal</td>
</tr>
<tr>
<td>Pollen ornamentation</td>
<td>Scabrate-Perforate</td>
<td>Scabrate-Perforate</td>
<td>Scabrate-Perforate</td>
<td>Scabrate-Perforate</td>
<td>Scabrate-Perforate</td>
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<tr>
<td>Exine thickness (M±SD)</td>
<td>1.39±0.09</td>
<td>1.33±0.07</td>
<td>1.30±0.10</td>
<td>1.35±0.09</td>
<td>1.31±0.07</td>
</tr>
<tr>
<td>Intine thickness (M±SD)</td>
<td>0.60±0.08</td>
<td>0.56±0.10</td>
<td>0.47±0.07</td>
<td>0.66±0.08</td>
<td>0.55±0.07</td>
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<tr>
<td>Pore diameter (M±SD)</td>
<td>2.59±0.27</td>
<td>3.22±2.65</td>
<td>2.81±0.25</td>
<td>3.51±0.40</td>
<td>3.75±0.87</td>
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<td>16±3</td>
<td>20±3</td>
<td>18±3</td>
<td>10±3</td>
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<tr>
<td>Distance between two pores (M±SD)</td>
<td>3.94±1.81</td>
<td>4.83±1.42</td>
<td>4.02±1.43</td>
<td>4.17±1.78</td>
<td>6.75±2.01</td>
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<td>Operculum diameter (M±SD)</td>
<td>1.31±0.15</td>
<td>1.72±0.31</td>
<td>1.67±0.20</td>
<td>2.65±0.32</td>
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<td>Number of spinule (10µm²)</td>
<td>13-16</td>
<td>13-16</td>
<td>24-26</td>
<td>16-18</td>
<td>8-10</td>
</tr>
<tr>
<td>Number of spinules on operculum</td>
<td>5-7</td>
<td>6-8</td>
<td>4-6</td>
<td>4-6</td>
<td>5-7</td>
</tr>
<tr>
<td>Number of punctum (10µm²)</td>
<td>15-17</td>
<td>11-13</td>
<td>3-5</td>
<td>7-9</td>
<td>10-12</td>
</tr>
<tr>
<td></td>
<td>B.cherlieroides</td>
<td>B.turcicus</td>
<td>B.mevlanae</td>
<td>B.thymoides</td>
<td>B.aziz-sancarii</td>
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<tr>
<td>Pollen diameter</td>
<td>23.06±0.43</td>
<td>30.33±1.14</td>
<td>25.71±0.93</td>
<td>24.76±0.38</td>
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<td>Polar axes</td>
<td>21.74±0.29</td>
<td>27.11±0.62</td>
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<td>Pollen shape</td>
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<td>Oblate-spheroidal</td>
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<tr>
<td>Exine thickness</td>
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<td>0.94±0.11</td>
<td>1.25±0.09</td>
<td>0.94±0.06</td>
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<td>(M±SD)</td>
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<tr>
<td>Intine thickness</td>
<td>0.57±0.07</td>
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<tr>
<td>Pore diameter</td>
<td>3.02±1.64</td>
<td>2.78±0.31</td>
<td>2.31±0.40</td>
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</tr>
<tr>
<td>Number of pore</td>
<td>14±3</td>
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<tr>
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<tr>
<td>Operculum diameter</td>
<td>1.39±0.30</td>
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</tr>
<tr>
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<td>15-18</td>
<td>12-15</td>
<td>13-15</td>
<td>16-18</td>
<td>10-12</td>
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<tr>
<td>(10µm²)</td>
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<td>5-7</td>
<td>4-6</td>
<td>7-9</td>
<td>7-9</td>
</tr>
<tr>
<td>on operculum</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Number of punctum</td>
<td>4-6</td>
<td>4-6</td>
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<td>9-11</td>
<td>4-6</td>
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<td>(10µm³)</td>
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</table>

Abbreviations: M – mean value; SD – standard deviation.
Figure 1 SEM photos of pollen grains of studied *Bolanthus* taxa: 1a-1b-1c: *B. spergulifolius*, 2a-2b-2c: *B. hubermorathii*, 3a-3b-3c: *B. frankenioides*, 4a-4b-4c: *B. frankenioides* var. *fasciculatus*, 5a-5b-5c: *B. minuartioides*, 6a-6b-6c: *B. cherlerioides*, 7a-7b-7c: *B. turcicus*, 8a-8b-8c: *B. mevlanae*, 9a-9b-9c: *B. thymoides*, 10a-10b-10c: *B. aziz-sancarii*, 11a-11b-11c: *B. stenopetalus*
Figure 2 LM photos of pollen grains of studied *Bolanthus* taxa: 1a-1b: *B. spergulifolius*, 2a-2b: *B. hubermorathii*, 3a-3b: *B. frankenioides*, 4a-4b: *B. frankenioides* var. *fasciculatus*, 5a-5b: *B. minuartioides*, 6a-6b: *B. cherlerioides*, 7a-7b: *B. turcicus*, 8a-8b: *B. mevlanae*, 9a-9b: *B. thymoides*, 10a-10b: *B. azizsancarii*, 11a-11b: *B. stenopetalus*
4. CONCLUSION

The findings of the study shows, pollen ornamentations and pollen shape to be important morphological characteristics for the systematics of the taxa. Pollen grains are isopolar symmetrical. The pollen grains of the Bolanthus taxa are oblate spheroidal and prolate spheroidal. The pollen grains are polipantoporate. The pollen ornamentation of all taxa is scabrate-perforate. Morphological structures of pollen seem to be useful for distinguish taxa. The outcomes of the study could be benefited in taxonomical studies.

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The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by the authors.

Authors’ Contribution

Y.C: Literature research, data collection, organize the execution of the study, contribution
to article writing and study, data entry and measurement, create an idea.

M.N.T: Contribution to article writing and study, data entry and measurement.

M.K: Provision of the plant material, provide a working environment and tools, create an idea.

The Declaration of Ethics Committee Approval

The authors declare that this document does not require an ethics committee approval or any special permission.

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REFERENCES


