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RESEARCH ARTICLE

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Comparative Anatomical, Palynological and Fruit Micromorphological Studies on the Endemic Species *Prangos abieticola* and *Prangos heyniae* (Apiaceae)

Endemik *Prangos abieticola* ve *Prangos heyniae* (Apiaceae) Türleri Üzerine Karşılaştırmalı Anatomik, Palinolojik ve Meyve Mikromorfoloji Çalışmaları

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ABSTRACT

In this study, the comparative anatomical, palynological, and fruit micromorphological characteristics of the endemic Türkiye species *Prangos abieticola* and *P. heyniae* were investigated. Anatomical analyses were carried out on transverse sections of the stem, peduncle, pedicel, ray, and fruit, and the structural features were evaluated in detail and presented in tables. Palynological investigations were conducted using light microscopy and scanning electron microscopy (SEM). Measurements of the polar and equatorial axes, colpus width and length, pore width and length, as well as exine and intine thicknesses were taken, and P/E ratios were calculated. The pollen grains of both species were perprolate in shape, with a trizonocolporate aperture type, and exhibited rugulate surface ornamentation. Fruit micromorphological features were examined using SEM, revealing distinct surface ornamentation patterns between the two species. The results indicate that palynological characters provide limited taxonomic resolution, whereas anatomical and especially fruit micromorphological characters offer reliable and diagnostic features for distinguishing *P. abieticola* and *P. heyniae*.

ÖZ

Bu çalışmada, Türkiye endemiği *Prangos abieticola* ve *P. heyniae* türlerinin karşılaştırmalı anatomik, palinolojik ve meyve mikromorfolojik özellikleri incelenmiştir. Anatomik analizler, gövde, pedunkul, pedisel, ray ve meyveye ait enine kesitler üzerinden gerçekleştirilmiş; yapısal özellikler ayrıntılı olarak değerlendirilerek tablolar hâlinde sunulmuştur. Palinolojik incelemeler, ışık mikroskobu ve taramalı elektron mikroskobu (SEM) kullanılarak yürütülmüştür. Polenlerin polar ve ekvatoral eksenleri, kolpus genişliği ve uzunluğu, por genişliği ve uzunluğu ile ekzin ve intin kalınlıkları ölçülmüş ve P/E oranları hesaplanmıştır. Her iki türün polenleri perprolat şekilli, apertür tipi trizonokolporat olup, yüzey ornamentasyonu rugulat olarak belirlenmiştir. Meyve mikromorfolojik özellikler SEM kullanılarak incelenmiş ve iki tür arasında farklı yüzey ornamentasyonlarının bulunduğu ortaya konulmuştur. Elde edilen sonuçlar, palinolojik karakterlerin taksonomik ayırımda sınırlı bir çözünürlük sağladığını; buna karşılık anatomik ve özellikle meyve mikromorfolojik karakterlerin P. abieticola ve P. heyniae türlerinin ayırt edilmesinde güvenilir ve tanılayıcı özellikler sunduğunu göstermektedir.

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1. INTRODUCTION

The Apiaceae family was first described by John Lindley in 1836 (Lindley, 1836). The family name is derived from the type genus *Apium* L. The name *Apium* was used for four plants resembling celery. The former name of the Apiaceae family, Umbelliferae, was used by A. L. de Jussieu in 1789 and is derived from the term *umbellula*, referring to the umbrella-like inflorescence structure (Gledhill, 2008). Today, the name Apiaceae is more widely used. Apiaceae (Umbelliferae) is one of the largest plant families worldwide and is represented by approximately 450 genera and 3700 species globally (Pimenov & Leonov, 1993). Members of the Apiaceae family have significant economic importance due to their widespread use in the pharmaceutical, cosmetic, and food industries (Kamte et al., 2018)

The genus *Prangos* Lindl., belonging to the Apiaceae family, is represented by 35 species worldwide (Herrnstadt & Heyn, 1977; Pimenov & Tikhomirov, 1983), with its main centre of diversification located in the Irano-Turanian phytogeographical region. Türkiye, Iran, and Central Asia are particularly prominent areas in terms of species richness of this genus. The genus *Prangos* was revised within the scope of the *Flora of Turkey and the East Aegean Islands* (Herrnstadt & Heyn, 1972; Davis et al., 1988), and following these studies, eight new taxa have been described from Türkiye (Duman & Watson, 1999; Duran et al., 2005; Pimenov et al., 2005; Şenol et al., 2011; Menemen, 2012; Aytaç & Duman, 2016). With the inclusion of these new taxa, a total of 21 *Prangos* taxa are currently recognized in Türkiye, 13 of which are endemic.

Anatomical studies on the Apiaceae family have demonstrated that characters such as stem structure and the arrangement of vascular bundles provide important information for systematic evaluations (Metcalfe, 1965). However, anatomical studies focusing on the genus *Prangos* within the Apiaceae family are rather limited, and existing investigations are generally restricted to a small number of species and specific organs. Consequently, the taxonomic value of anatomical characters and their role in species delimitation within the genus *Prangos* have not yet been sufficiently clarified. Among the limited anatomical studies conducted on the genus *Prangos*, some anatomical features related to the stem, peduncle, and ray anatomy of *P. heyniae* have been reported (Ahmed, 2008).

Studies focusing on fruit anatomy within the genus *Prangos* are relatively limited. Available investigations have indicated that fruit and mericarp anatomical characters can be useful for evaluating relationships among subgenera and sections within the genus. In this context, comparative studies on fruit anatomy of *Prangos* species have been conducted, emphasizing the taxonomic relevance of fruit anatomical characters in infrageneric classifications (Lyskov et al., 2017a; Lyskov et al., 2017b; Zarei et al., 2022). Palynological studies on the genus *Prangos* are extremely limited, and the available literature includes only a single study addressing the pollen morphology of *P. heyniae* (Pehlivan et al., 2009).

In recent systematic studies, anatomical, palynological, and micromorphological investigations have increasingly been integrated with classical morphological data to achieve more robust taxonomic evaluations. Variations in anatomical and palynological characters provide important support for species delimitation based on morphology, while micromorphological differences in seed and/or fruit surface ornamentation contribute significantly to the clarification of interspecific relationships. The aim of the present study is to investigate comparatively and in detail the anatomical (stem, peduncle, pedicel, ray, and fruit) and palynological and furit micromorpological characteristics of the endemic Türkiye species *Prangos abieticola* Aytaç & H. Duman and *P. heyniae* H. Duman & M. F. Watson, and to evaluate the taxonomic importance of these characters by addressing this significant gap in the literature.

2. MATERIALS AND METHODS

The plant materials examined in this study were collected from different localities in Konya Province and identified accordingly. Specimens of *P. abieticola* were collected from the Tınaztepe locality in Seydişehir district, Konya Province (grid square C4), at an altitude of 1650 m on 06 June 2020 (O. Tugay & E. Karahisar 17561; ESSE 15799, KNYA 26903). Specimens of *Prangos heyniae* were collected from the Hadim–Bozkır road in Konya Province (grid square C4), at an altitude of 1600 m on 31 May 2020 (O. Tugay & E. Karahisar 17533; ESSE 15797,

KNYA 26902). The specimens were collected with consideration of their suitability for subsequent laboratory analyses.

During field investigations, samples of stem and related organs (stem, peduncle, pedicel, ray, and fruit) were collected from the taxa at the flowering stage and fixed in 70% ethanol. Transverse sections were prepared using the paraffin embedding technique. The plant materials were embedded in paraffin wax and sectioned at a thickness of 5–10 µm using a Leica RM2125RT rotary microtome. The obtained sections were stained with safranin–fast green, and permanent microscope slides were mounted with Entellan following standard procedures (Johansen, 1940).

Microscopic observations and measurements were carried out using a Leica DM1000 light microscope fitted with a Leica DFC280 digital camera. For the comparative anatomical evaluation of stem, peduncle, pedicel, and ray structures, measurements were taken from at least 30 cells obtained from four individuals per taxon. The analyzed parameters included epidermal cell dimensions of the stem, peduncle, pedicel, and ray, as well as the diameters of tracheary elements, phloem cells, and pith parenchyma cells. Minimum, maximum, mean, and standard deviation values were calculated for all measured characters and are presented in Table 1.

Pollen samples obtained from herbarium specimens were prepared as permanent slides using the method described by Wodehouse (1935). For each pollen grain, measurements were taken of the polar axis (P), equatorial axis (E), colpus length (Clt), pore diameter, and the thicknesses of the exine and intine layers. P/E ratios were subsequently calculated based on these measurements. For each species, at least 30 pollen grains from four individuals were measured and the results are presented in Table 2. Additionally, exine sculpturing patterns were examined using scanning electron microscopy (SEM, TM303Plus tabletop scanning electron microscope). Pollen morphological terminology and descriptive criteria followed Punt et al. (2007). Fruit micromorphological analyses were performed using a SEM. Cleaned fruit samples were affixed to aluminum stubs using double-sided carbon adhesive tape and subsequently sputter-coated with a thin gold layer to improve electrical conductivity, following standard SEM preparation procedures (Barthlott, 1981). SEM observations were carried out to examine and document fruit surface micromorphological features in detail, and the identification and description of sculptural patterns were based on the terminology and criteria proposed by Simpson (2019).

3. RESULTS AND DISCUSSIONS

3.1. Anatomy

3.1.1. Stem anatomy

Transverse sections of the stem in *P. abieticola* (Fig. 1.A) and *P. heyniae* (Fig. 1.B) revealed that the stem outline is generally circular in both taxa. The stem of *P. heyniae* is pubescent, whereas no trichomes were observed on the stem of *P. abieticola*. In both species, the outermost layer consists of a thin cuticle followed by a single layer of rectangular epidermal cells, which locally becomes two-layered in *P. heyniae*. Beneath the epidermis, *P. abieticola* possesses 3–4 layers of parenchyma and 4–6 layers of collenchyma cells, while in *P. heyniae* this region is composed of 5–7 layers of parenchyma and 7–15 layers of collenchyma cells. In both taxa, embedded secretory ducts are present immediately below the collenchyma layer. The endodermis is indistinct in both species.

Toward the pith region, *P. abieticola* exhibits vascular bundles arranged in 3–4 concentric rows, with the outermost bundles being smaller in size, whereas in *P. heyniae* the vascular bundles are freely distributed. In both species, a sclerenchymatous layer surrounds the phloem, consisting of 12–17 cell layers in *P. abieticola* and 5–7 layers in *P. heyniae*. The sclerenchyma surrounding the xylem comprises 3–7 layers in *P. abieticola* and 2–3 layers in *P. heyniae*. Secretory ducts are also observed between the vascular bundles in both taxa. The pith region is composed of parenchymatous cells in both species, and scattered secretory ducts are present within the pith.

3.1.2. Peduncul anatomy

Transverse sections of the peduncle in *P. abieticola* (Fig. 1.C) and *P. heyniae* (Fig. 1.D) showed that the peduncle outline is generally circular in both species. In *P. heyniae*, the peduncle surface is slightly wavy and sparsely pubescent, whereas no trichomes were observed on the

peduncle of *P. abieticola*. In both taxa, the overall peduncle anatomy is largely similar to that of the stem.

However, some differences were observed. In *P. abieticola*, the single-layered endodermis is more distinct in the peduncle compared to the stem, and the number of collenchyma and parenchyma cell layers is reduced. In *P. heyniae*, although the peduncle anatomy is generally similar to that of the stem, it differs by the absence of freely distributed vascular bundles toward the central region and by having a lower number of tracheary elements.

3.1.3. Pedicel anatomy

Transverse sections of the pedicel in *P. abieticola* (Fig. 1.E) and *P. heyniae* (Fig. 1.F) showed that the pedicel outline is slightly wavy in *P. abieticola* and distinctly wavy in *P. heyniae*. The pedicel anatomy of *P. abieticola* is generally similar to that of the peduncle, whereas in *P. heyniae* the cortex region, consisting of epidermal, collenchyma, and parenchyma cells, is similar to that observed in the stem.

Some differences were observed between the two species. In *P. abieticola*, the pedicel differs from the peduncle by the presence of a distinct single-layered endodermis and a single row of vascular bundles. In *P. heyniae*, a single-layered endodermis is present beneath the cortex parenchyma, and the vascular bundles are arranged in two concentric rows, with the outer vascular bundles being smaller than the inner ones.

3.1.4. Ray anatomy

Transverse sections of the ray in *P. abieticola* (Fig. 1.G) and *P. heyniae* (Fig. 1.H) revealed that the ray outline is generally circular and slightly wavy in both species. In *P. heyniae*, the ray surface is glabrous, while no trichomes were observed in either taxon. In general, the ray anatomy of both species shows similarities to that of the pedicel.

Some differences were observed between the two taxa. In *P. abieticola*, the ray differs from the pedicel by having a reduced number of collenchyma and parenchyma cell layers. In *P. heyniae*, although the ray anatomy is similar to that of the pedicel, it is distinguished by the presence of vascular bundles arranged in a single row.

3.1.4. Fruit anatomy

Transverse sections of the fruit in *P. abieticola* (Fig. 1.I) and *P. heyniae* (Fig. 1.J) revealed that the fruits of both species are glabrous and five-winged. In *P. abieticola*, the exocarp consists of a single layer of rectangular to subrounded parenchymatous cells, whereas in *P. heyniae* the exocarp is composed of two layers of rectangular parenchymatous cells. In both species, the mesocarp is thick and formed of reticulate parenchymatous cells.

In both taxa, vittae are present within the mesocarp and located above the endocarp, which consists of a single layer of elongated parenchymatous cells. In *P. abieticola*, vascular bundles are scattered throughout the mesocarp, while in *P. heyniae* the vascular bundles are dispersed within the mesocarp and display a crescent-shaped arrangement. Secretory ducts are observed scattered within the vallecular regions in *P. abieticola*. The endosperm in both species is composed of thin-walled, slightly rounded cells containing abundant oil droplets.

3.2. Pollen morphology

The pollen grains of *P. abieticola* and *P. heyniae* are monads. In both species, pollen shape is perprolate, with P/E ratios of 2.01 (1.90–2.24) in P. abieticola (Fig. 2. A,B) and 2.09 (1.96–2.30) in P. heyniae (Fig. 2. C,D). The polar axis (P) measures 42.29 µm (39.25–49.14 µm) in P. abieticola and 40.63 µm (37.51–43.21 µm) in P. heyniae, while the equatorial axis (E) is 20.25 µm (17.46–22.04 µm) and 19.44 µm (17.21–21.64 µm), respectively. Both taxa exhibit a trizonocolporate aperture type.

The colpus width (Clt) is 3.31 µm (2.09–4.14 µm) in P. abieticola and 3.35 µm (2.12–5.51 µm) in P. heyniae, whereas the colpus length (Clg) is 32.51 µm (23.70–35.17 µm) and 32.49 µm (29.05–36.38 µm), respectively. Pore dimensions in P. abieticola are 4.92 µm (3.20–7.74 µm) in width and 4.85 µm (2.72–7.00 µm) in length, while in P. heyniae they measure 5.05 µm (3.03–6.95 µm) in width and 5.50 µm (4.43–7.32 µm) in length. Exine thickness ranges from 0.93 µm (0.57–1.36 µm) in P. abieticola to 0.95 µm (0.71–1.20 µm) in P. heyniae, whereas intine thickness is 0.64 µm (0.21–1.02 µm) and 0.59 µm (0.20–0.92 µm), respectively. SEM observations revealed a rugulate exine sculpturing pattern in both species (Fig. 3.A, 3.B).

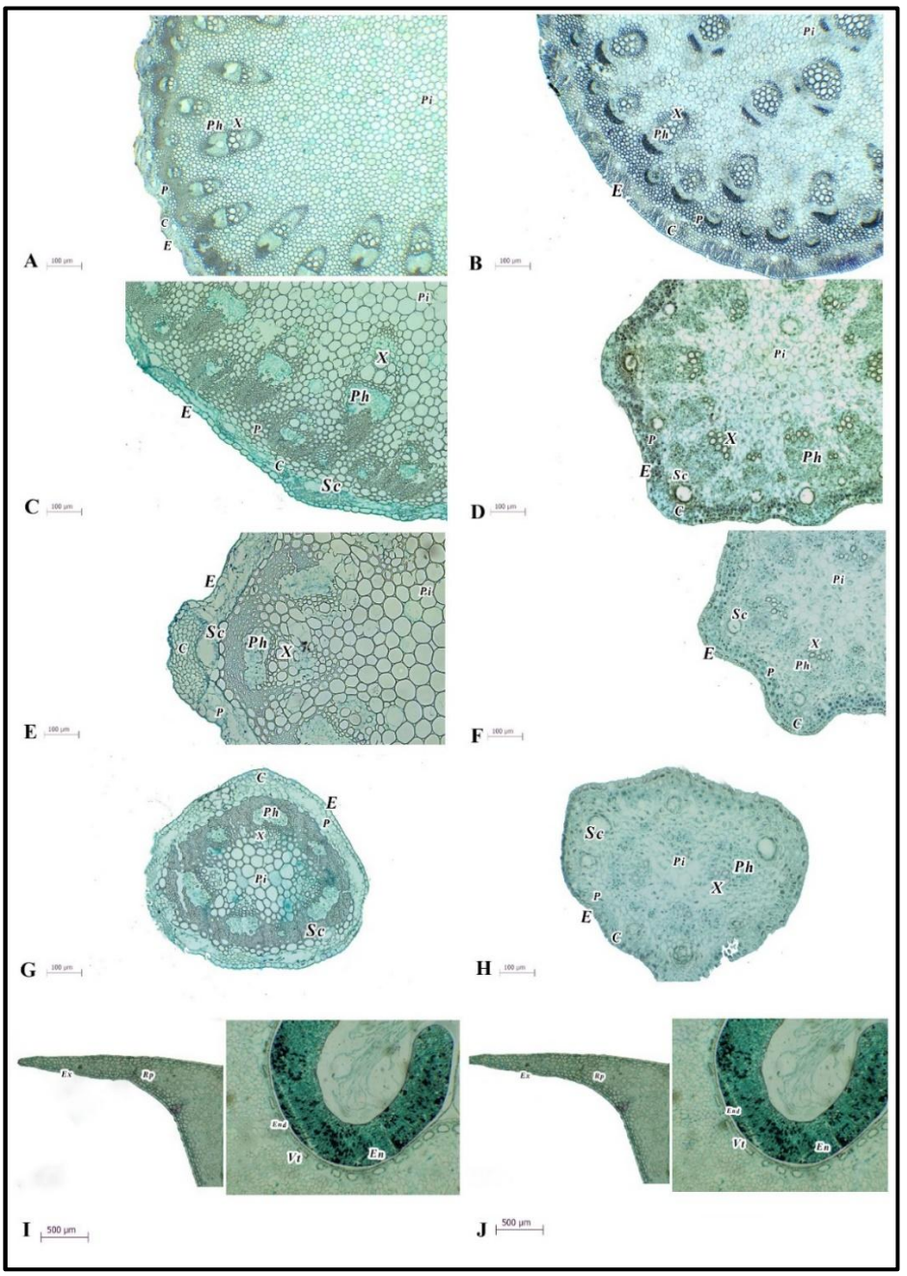

Figure 1. Anatomical structures of *P. abieticola* and *P. heyniae*. *P. abieticola*: A, stem; C, peduncle; E, pedicel; G, ray; I, fruit anatomy. *P. heyniae*: A, stem; C, peduncle; E, pedicel; G, ray; I, fruit anatomy. E, epidermis; C, collenchyma; P, parenchyma; Sc, secretory canal; Ph, phloem; X, xylem; Pi, pith.

Table 1. Biometric measurements of stem, peduncle, pedicel and ray anatomy in *P. abieticola* and *P. heyniae*

	Character (µm)	*P. abieticola*	*P. heyniae*		*P. abieticola*	*P. heyniae*		*P. abieticola*	*P. heyniae*		*P. abieticola*	*P. heyniae*
Stem	Epidermal cell width	16.5 ± 3.8 (9.7–12.4)	17.9 ± 4.1 (12.4–26.5)	Peduncul	15.6 ± 3.4 (8.5-20.4)	16 ± 3.1 (11.8-24.4)	Pedicel	14.2 ± 2.7 (10.6-18.8)	12.3 ±1.5 (9.1-15.4)	Ray	15.4 ± 3.2 (10.7-21.9)	13 ± 0.9 (10.9-15.2)
	Epidermal cell length	31.9 ± 6.3 (19.5–51.2)	27.1 ± 6.4 (20.6–44.7)		32.2 ± 9,1 (19.2-54.8)	20.3 ± 5.6 (10.6-12.1)		14.6 ± 3.9 (8.6-25.2)	12 ±2.2 (7.9-17.3)		17.9 ± 4.9 (10-25.1)	12.6 ± 2.2 (9.2-17.7)
	Phloem cell width	7.3 ± 1.6 (4.2–9.5)	9.3 ± 2.3 (4.6–14.3)		8.4 ± 1.4 (5.7-10.6)	5.5 ± 1.8 (3.2-9.1)		4.8 ± 1.8 (2.1-8.6)	3.8 ± 0.7 (2.8-4.9)		5.7 ± 18 (3.5-9.7)	7 ± 1.6 (7.3-9.4)
	Phloem cell length	10.6 ± 2.6 (6.1–15.9)	9.2 ± 2.1 (6.2–13.3)		9.1 ± 2.2 (6-12.4)	6.9 ± 2 (4.5-12.1)		5.7 ± 2.4 (2.1-10.7)	4.4 ± 0.9 (3.1-6)		6.8 ± 1.3 (4.6-9.2)	5.2 ± 1 (4.1-8.6)
	Tracheary element width	35.3 ± 8.6 (21.5–54.1)	29.8 ± 5.6 (17.8–38.0)		35.3 ± 13.7 (12.8-59.8)	17.6 ± 3 (12.8-22.2)		20.2 ± 2.9 (11.4-27.7)	10.6 ± 1.8 (7.4-13.5)		12.5 ± 3.6 (6.8-18.2)	6.9 ± 1 (4.7-8.5)
	Tracheary element length	35.9 ± 9.7 (14.9–49.4)	32.4 ± 6.4 (21.4–46.4)		28.5 ± 8.6 (13.9-40.6)	17.5 ± 3.1 (10.8-23.4)		18.3 ± 3.6 (12.6-23.9)	10.4 ± 1.3 (8.7-12.3)		12.5 ± 4 (6.8-21.4)	6.9 ± 1.7 (4.7-10.1)
	Pith parenchyma cell width	54.0 ± 10.1 (29.3–74.7)	43.2 ± 6.5 (32.5–58.1)		72.2 ± 11.5 (48.1-107.1)	30.7 ± 6.8 (17.1-44.7)		41.8 ± 9.9 (20.3-61.9)	18.9 ± 3.9 (11.4-24.5)		41.5 ± 9.2 (23.5-51.9)	17.8 ± 5.5 (8.2-26)
	Pith parenchyma cell length	54.2 ± 14.1 (21.4–82.4)	51.7 ± 7.6 (42.5–69.3)		63.3 ± 10.1 (45.9-87.2)	27.3 ± 7.5 (15.2-44.8)		40.4 ± 8.1 (16-62.1)	20.2 ± 3.5 (12.7-25.5)		42.1 ± 9.4 (23-54.4)	20.6 ± 5.6 (11.8-30.9)

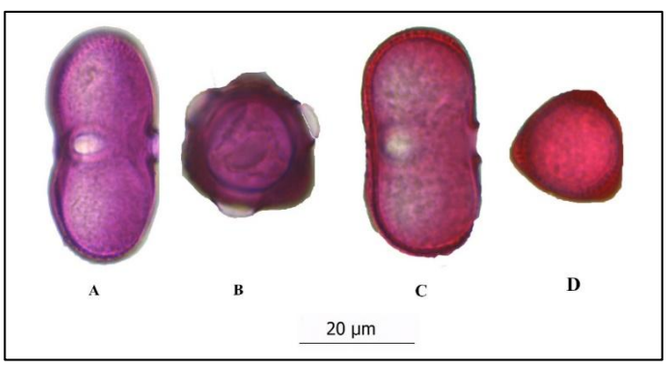

Figure 2. Pollen morphology of *P. abieticola* and *P. heyniae*. *P. abieticola*: A, equatorial view; B, polar view. *P. heyniae*: C, equatorial view; D, polar view.

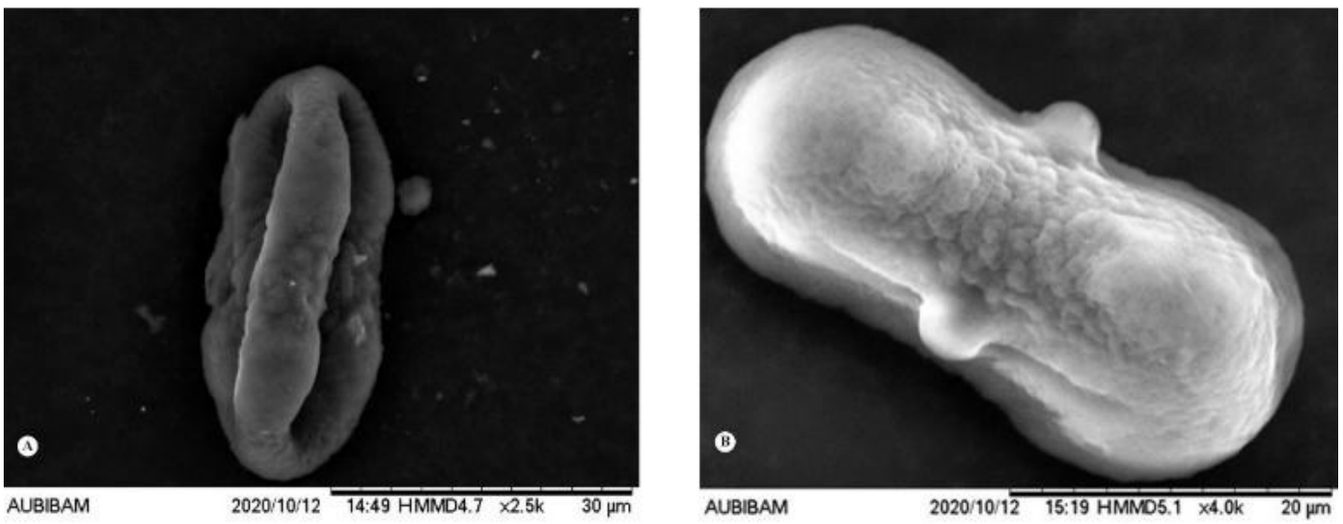

Figure 3. SEM images of pollen grains of *P. abieticola* and *P. heyniae.* A, pollen SEM image of *P. abieticola*; B, pollen SEM image of *P. heyniae*.

Table 2. Palynological characteristics of *P. abieticola* and *P. heyniae*

	P. abieticola	***P. heyniae***
Pollen shape	Perprolate, P/E= 2.01 µm	Perprolate P/E= 2.09 µm
Polar axis (P)	42.29 (39.25-49.14) µm.	40.63 (37.51-43.21) µm.
Equatorial axis (E)	20.25 (17.46-22.04) µm.	19.44 (17.21-21.64) µm.
Colpus width (Clt)	3.31 (2.09-4.14) µm.	3.35 (2.12-5.51) µm.
Colpus length (Clg)	32.51 (23.7-35.17) µm.	32.49 (29.05-36.38) µm.
Aperture type	Trizonocolporate	Trizonocolporate
Exine thickness	0.93 (0.57-1.36) µm.	0.95 (0.71-1.20) µm.
Intine thickness	0.64 (0.21-1.02) µm.	0.59 (0.2-0.92) µm.
Pore width	4.92 (3.20-7.74) µm.	5.05 (3.03-6.95) µm.
Pore length	4.85 (2.72-7.0) µm.	5.50 (4.43-7.32) µm.
Exine sculpturing	Rugulate	Rugulate

3.3. Fruit micromorphology

The fruits of *P. abieticola* and *P. heyniae* differ in shape, size, and surface ornamentation. In *P. abieticola* (Fig. 4. A,B), the fruits are dorsally compressed and vary in shape from oblong to ellipsoid. Fruit size ranges from 20–26 mm in length and 10–17 mm in width, and the wings are distinctly wavy. SEM observations revealed a foveolate–reticulate surface ornamentation pattern.

In P*. heyniae* (Fig. 4. C,D), the fruits are narrowly ellipsoid to globular in shape. Fruit length ranges from 11–20 mm, while the width varies between 12–16 mm. SEM examination showed a reticulate–pitted surface ornamentation pattern.

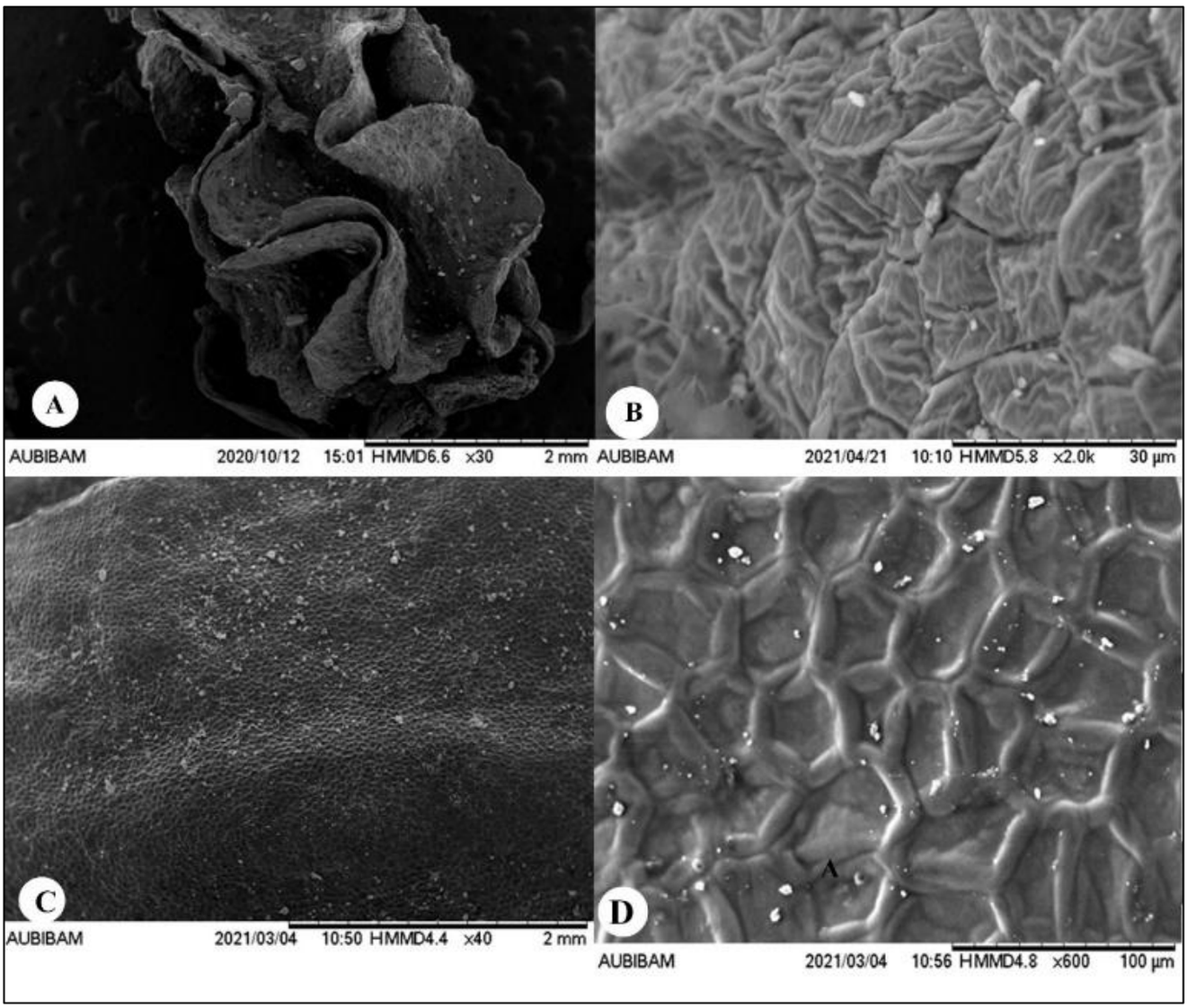

Figure 4. SEM images of fruits of *P. abieticola* and *P. heyniae*. A, general view of the fruit of *P. abieticola*; B, surface ornamentation of *P. abieticola*; C, general view of the fruit of *P. heyniae*; D, surface ornamentation of *P. heyniae*.

4. DISCUSSION

In this study, transverse sections of the stem, peduncle, pedicel, ray, and fruit of *P. abieticola* and *P. heyniae* were prepared, and their anatomical structures were examined in detail and documented photographically (Fig. 1). The anatomical characteristics of *P. abieticola* are presented for the first time in this thesis, while the available anatomical information on *P. heyniae* in the literature is limited; moreover, the biometric measurements of the anatomical structures of this species were also conducted for the first time within the scope of the present study.

In the Apiaceae (Umbelliferae) family, the general features of stem anatomy are described as having a mostly undulate transverse outline, the presence of collenchyma and occasionally sclerenchyma tissues in the protruding regions, and vascular bundles arranged either in a circular fused pattern or as free bundles (Metcalfe, 1965). The stem anatomical structures of both *Prangos* species examined in this study are, in general terms, consistent with the characteristics reported for the Apiaceae family.

However, some distinct anatomical differences were identified between the two species. In *P. abieticola*, the vascular bundles toward the pith region are arranged in 3–4 regular rows, whereas in *P. heyniae*, the vascular bundles are freely and irregularly distributed within the stem. This feature represents a notable difference in the stem anatomy of *P. heyniae* and constitutes an important diagnostic character for distinguishing the species. Indeed, a thesis study conducted by Ahmed (2008) also reported that the vascular bundles in the stem of *P. heyniae* exhibit a scattered arrangement distinct from the typical dicotyledonous pattern, and this finding is in agreement with the results of the present study.

An examination of the biometric measurements related to stem anatomy presented in Table 1 indicates that there is generally no marked difference between the two species in terms of quantitative values. In contrast, differences were observed between the species with respect to the number of parenchyma and collenchyma cell layers, as well as the thickness and number of layers of the sclerenchyma tissue surrounding the vascular bundles. These structural differences appear to be more decisive for species delimitation in terms of tissue organization rather than biometric measurements.

Metcalfe (1965) reported that, in the Apiaceae family, secretory canals may occur in the cortical region of the stem, the pericycle, the pith tissue, and occasionally within the secondary phloem. In the present study, secretory canals were also observed in the stem transverse sections of both species in the aforementioned regions (Fig. 1.A, B). These findings indicate that the stem anatomy of *Prangos* species conforms to the general anatomical characteristics of the Apiaceae family.

In conclusion, although the stem anatomy of *P. abieticola* and *P. heyniae* reflects the general features of the family, the differences observed in the distribution of vascular bundles and the organization of supporting tissues enable a clear anatomical distinction between the two species. In particular, the free and scattered arrangement of vascular bundles in *P. heyniae* may be regarded as a key diagnostic anatomical character for this species.

A comparative evaluation of the biometric measurements of the peduncle anatomical structures was carried out (Table 1). Examination of the obtained biometric data revealed differences between the species in terms of the size of tracheary elements and pith parenchyma cells. The tracheary elements and pith cells in the peduncle anatomy of *P. abieticola* were found to be larger than those of *P. heyniae*. In addition, the overall shape of the transverse section of the peduncle being more circular in *P. abieticola* represents another anatomical feature distinguishing this species from *P. heyniae* (Fig. 1. C,D).

Ahmed (2008) reported that the vascular bundles of *P. heyniae* are arranged in 2–3 rows and that the peduncle anatomy closely resembles the anatomical structure of the stem. These observations are consistent with the findings obtained in the present study.

The biometric measurements of the pedicel and ray (Table 1.) anatomies of *P. abieticola* and *P. heyniae*, as well as the comparative evaluations of pedicel and ray anatomical structures, are presented. Examination of the pedicel anatomy and the associated biometric measurements revealed structural differences between the two species. According to the obtained results, the

less undulate transverse section of the pedicel, the arrangement of vascular bundles in a single row, and the larger sizes of tracheary elements and pith parenchyma cells distinguish *P. abieticola* from *P. heyniae* (Fig. 1. E,F).

Evaluation of the ray anatomy and its biometric measurements likewise indicated that the tracheary elements and pith parenchyma cells in *P. abieticola* are larger than those observed in *P. heyniae*. In addition, secretory canals were observed beneath the cortex and between the vascular bundles in *P. abieticola*, whereas in *P. heyniae*, secretory canals were present not only in these regions but also within the pith (Fig. 1. G,H). The presence of secretory canals in the pith region of *P. heyniae* has also been reported by Ahmed (2008), and this finding is consistent with the results of the present study.

Examination of the fruit anatomy of *P. abieticola* and *P. heyniae* revealed that the exocarp of *P. abieticola* consists of a single layer of rectangular to subrounded parenchymatic cells, whereas the exocarp of *P. heyniae* is composed of two layers of rectangular parenchymatic cells (Fig. 1. I,J).

As a result of the palynological investigations, the pollen morphological measurements of the two species are presented in Table 2. Examination of these data indicates that there are no pronounced quantitative differences between the pollen measurements of the two taxa. The fact that both species possess perprolate pollen grains, a trizonocolporate aperture type, and rugulate exine sculpturing (Fig. 2, 3.) demonstrates that the palynological characters investigated in this study do not provide clear diagnostic features for distinguishing between the two species.

In a previous study conducted by Pehlivan et al. (2009), the pollen grains of *P. heyniae* were examined and the exine sculpturing was described as rugulate–striate. In the present study, however, the exine sculpturing of *P. heyniae* was determined to be rugulate.

The fruit micromorphological characteristics of *P. abieticola* and *P. heyniae* are reported for the first time in this thesis. The presence of distinct surface ornamentation patterns in the fruits of the two species allows them to be readily distinguished from one another. Therefore, fruit micromorphological characters appear to constitute reliable and diagnostic features for the taxonomic delimitation of these species.

Overall, the combined evaluation of anatomical, palynological, and fruit micromorphological data demonstrates that, although palynological characters provide limited taxonomic resolution, anatomical features—particularly the organization of vascular bundles—and fruit micromorphological characters offer reliable diagnostic criteria for distinguishing *P. abieticola* and *P. heyniae*.

5. CONCLUSION

In this study, the anatomical (stem, peduncle, pedicel, ray, and fruit), palynological, and fruit micromorphological characteristics of the endemic Türkiye species *P. abieticola* and *P. heyniae* were investigated in detail and comparatively. The anatomical and palynological features of *P. abieticola*, as well as the fruit micromorphology of both species, are reported for the first time within the scope of this study. The results indicate that palynological characters provide limited contribution to species discrimination, whereas anatomical features—particularly the organization of vascular bundles—and micromorphological characters related to fruit surface ornamentation offer more reliable and diagnostic criteria for the taxonomic delimitation of the species. In this respect, the present study contributes to the clarification of species boundaries within the genus *Prangos* and provides an important data basis for future systematic and taxonomic studies.

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