

FRUIT ANATOMY OF THE GENUS PRANGOS (APIACEAE) IN IRAN AND ITS SYSTEMATIC IMPLICATION

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The genus *Prangos* Lindl. belongs to the Apiaceae (Umbelliferae), subfamily Apioideae and tribe Apieae. This genus with about 45 species is one of the biggest genera of the family. *Prangos* includes 15 species in Iran, of which seven are endemics. In this study, the fruit anatomy of all species of the genus *Prangos* in Iran has been investigated comparatively based on the transverse sections of the mericarp. As a result, we could identify and group the species of this genus based on the anatomical features (similarities and differences among species) of the fruit. The species have been divided into four groups based on anatomical characteristics such as the mericarp structure, vallecular vittae, vascular bundle, and rib secretory ducts. Group I corresponds with two subgenera *Koelzella* (*P. pabularia*), and *Prangos* (sections *Latilobae* and *Ulopterae*), group II with subgenus *Prangos* sections *Meliocarpoides* and *Prangos*, group III subgenus *Prangos* with the remainder species of the section *Prangos*, and group IV with subgenus *Prangos* section *Alococarpum*. Anatomical studies also confirmed the morphological and anatomical differences among sections *Alococarpum*, *Latilobae*, *Ulopterae*, and other members of the genus. Furthermore, the anatomical features confirm the transformation of *P. eriantha* from *Alococarpum* to *Prangos*. In addition, based on fruit morphological and anatomical characteristics, a key for the identification of *Prangos* species has been provided.

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تشریح میوه جنس *Prangos* (Apiaceae) در ایران و اهمیت سیستماتیک آن

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جنس *Prangos* Lindl. به تیره چتریان (Apiaceae)، زیرتیره Apioideae و طایفه Apieae تعلق دارد. این جنس با ۴۵ گونه یکی از بزرگترین جنس‌های تیره چتریان به شمار می‌آید. *Prangos* شامل ۱۵ گونه در ایران است که ۷ گونه از آنها انحصاری هستند. در این تحقیق، میوه همه گونه‌های جنس *Prangos* در ایران براساس شکل مریکارپ در برش‌های عرضی به صورت مقایسه‌ای مورد بررسی قرار گرفت. در نتیجه می‌توان گونه‌های این جنس را با استفاده از ویژگی‌های تشریحی (شباهت‌ها و تفاوت‌های بین گونه‌ها) میوه شناسایی و گروه‌بندی کرد. گونه‌ها بر اساس ویژگی‌های تشریحی مانند ساختار مریکارپ، مجاری ترش‌جی بین پره‌ای، دستجات آوندی و مجاری ترش‌جی درون پره‌ای به چهار گروه تقسیم شدند. گروه اول با دو زیرجنس *Koelzella* (شامل *P. pabularia*) و *Prangos* (شامل بخش‌های *Latilobae* و *Uloptera*)، گروه دوم با زیرجنس *Prangos*

(شامل بخش‌های *Meliocarpoides* و *Prangos*)، گروه سوم با زیرجنس *Prangos* و دیگر گونه‌های بخش *Prangos* و گروه چهار با زیرجنس *Prangos* بخش *Alococarpum* مطابقت دارد. مطالعات تشریحی نیز تفاوت‌های ریخت‌شناسی و تشریحی بین بخش‌های *P. eriantha*، *Ulopterae*، *Latilobae*، *Alococarpum* و سایر اعضای این جنس را تایید کرد. همچنین ویژگی‌های تشریحی انتقال *P. eriantha* از *Alococarpum* به *Prangos* را تایید می‌کند. علاوه بر این، بر اساس خصوصیات ریخت‌شناسی و تشریحی میوه، کلید شناسایی گونه‌های جنس *Prangos* ارائه شده است.

INTRODUCTION

The Apiaceae family is cosmopolitan consisting of 466 genera and about 3820 species (Plunkett & al. 2018). One of the most important classifications of the Apiaceae which is generally based on fruit anatomy was made by Drude (1898), who divided the family into three subfamilies including Apioideae, Saniculoideae, and Hydrocotyloideae. Several studies investigated the differences in the fruit anatomy in the Apiaceae family (Yılmaz & al. 2016; Ghahremaninejad & al. 2014; Bani & al. 2016; Zakharova & al. 2016; Lee & al. 2018). Fruit anatomy and morphology in Apiaceae are mentioned as useful characters for the taxonomic treatment of the family, and for distinguishing between closely related genera and species (Ghahremaninejad & al. 2014). The fruits in the family are typically schizocarps with two-ribbed mericarps. The presence, size, and location of the mericarp wings, the absence or presence of vallecular vittae, and the presence of secretory ducts have been accepted as diagnostic characters in Apiaceae by many researchers (Pimenov & Leonov 1993; Liu & al. 2006; Liu & al. 2007; Calvino & al. 2008; Yılmaz & al. 2016; Ghahremaninejad & al. 2014; Lee & al. 2018). Furthermore, Çil (2010) studied the morphology and anatomy of *Heracleum* L. and indicated the importance of the size of the mericarps, vascular bundles, wings, and vittae. Also, Zakharova & al. (2016) used fruit anatomy to support molecular investigations to clarify the taxonomy of the genus *Hellenocarum*

Prangos comprises at least 45 species occurring from the west coast of Portugal to western Tibet (Lyskov & al. 2017b). Most species are found in Asia (Pimenov & Leonov 1993), and the center of the diversity of the genus is the Irano-Turanian region. *Prangos* is polymorphic and varies considerably in habitat, flower, fruit morphology, and anatomy that determine the boundaries of the genus (Lyskov & al. 2017b). The first classification of the *Prangos* species was made by Kuzjmina (1962), and the genus was divided into two sections with two subsections. Herrnstadt & Heyn (1977) conducted a study on the carpological characters that modified Kuzjmina's

classification and divided the genus *Prangos* into three sections. In the most recent revision of *Prangos*, Pimenov & Tikhomirov (1983) used multivariate statistics based on a large set of morphological characters. They proposed the subdivision of the genus into two subgenera, five sections, nine subsections, and two series. Based on the molecular and morphological evidence, Lyskov & al. (2017a), transferred the monotypic genus *Alococarpum*, endemic to Iran to the genus *Prangos* section *Alococarpum*. Iranian species of *Prangos* belong to two subgenera including *Prangos* and *Koelzella* (M.Hiroe) Lyskov & Pimenov (Lyskov & al. 2017b). The subgenus *Prangos* comprises sections *Prangos*, *Meliocarpoides* Herrnst. & Heyn, *Latilobae* Pimenov & V.N.Tikhom., *Alococarpum* (Riedl & Kuber) Lyskov & Pimenov, and *Ulopterae* (Pimenov & V.N.Tikhom.) Lyskov & Pimenov. *Prangos pabularia* is the only species known in subgenus *Koelzella* in Iran. The genus includes 15 species in Iran, of which seven are endemic (*P. tuerculata*, *P. gaubae* (Bornm.) Herrnst. & Heyn, *P. eriantha* (DC.) Lyskov & Pimenov, *P. crossoptera* Herrnst. & Heyn, *P. serpentinica* (Rech.f., K. Rasbach, Reichst. & Bennert) Herrnst. & Heyn, *P. calligonoides* Rech.f., *P. cheilanthifolia* Boiss.), (Mozaffarian 2007).

Several studies examining the molecular phylogeny and seed micromorphological features have helped the systematic classification of *Prangos* (Valiejo-Roman & al. 2006; Ajani & al. 2008; Downie & al. 2010; Lyskov & al. 2015, 2017a, & b; Lyskov & Samigullin 2017; Zarei & al. 2022). Due to the polymorphism in morphological characters, the genus *Prangos* is taxonomically the most problematic and the boundaries of its species are not clear. Meanwhile, the fruit anatomy of *Prangos* is poorly known and only a few occurrences of fruit features are available in published works (Pimenov & Tikhomirov 1983; Duran & al. 2005; Ajani & al. 2008; Lyskov & al. 2017a & b). Lyskov & al. (2017a) studied the fruit anatomy of *Prangos* taxa and emphasized diagnostic characteristics such as the size of the mericarp, the shape of the mericarp in the transverse section, exocarp,

mesocarp (including epimesocarp and inner mesocarp), vascular bundles, and vallecular vittae.

In this study, the morphological and anatomical characteristics of the fruit of *Prangos* species were investigated to determine the importance of the morphological and anatomical characteristics of the fruit as taxonomic characteristics. Among them, the anatomical features of 10 species are reported here for the first time. This article followed previous studies on the genus *Prangos* of Iran (Zarei & al. 2022) and aimed to investigate the morphological and anatomical characteristics of various species of *Prangos*. Also, useful fruit characteristics are introduced for the delimitation of closely related species. In addition, based on fruit morphological and anatomical characteristics, we provide a species identification key for the genus. Using fruit anatomical data from species of the genus *Prangos*, we address the following questions: Are there any fruit anatomical features that support the separation of sections *Meliocarpoides* and *Prangos*? Are there any anatomical features of the fruit that support the separation of *Prangos pabularia*, *P. latiloba*, and *P. uloptera*? What is the position of the *P. eriantha* based on anatomical features? Are there any morphological and anatomical data that support similarities between the two subgenera *Koelzella* and *Prangos*, and sections *Alococarpum*, *Latilobae*, and *Ulopterae*?

MATERIALS AND METHODS

Fifteen *Prangos* species that were collected from different locations in the west, south, and central parts of Iran were examined. A total of 55 quantitative/qualitative morphological and anatomical characters related to fruit were studied in 60 plants from four populations of *Prangos pabularia* subsp. *pabularia*, two populations of *P. gaubae*, two populations of *P. eriantha*, three populations of *P. crossoptera*, two populations of *P. serpentinica*, two populations of *P. calligonoides*, three populations of *P. cheilanthifolia*, six populations of *P. latiloba*, four populations of *P. acaulis*, three populations of *P. corymbosa*, three populations of *P. tuberculata*, 5 populations of *P. uloptera*, 5 populations of *P. longistylis*, 6 population of *P. asperula* subsp. *hausknechtii*, and 6 population of *P. ferulacea*. Collection details of the selected specimens are shown in Table 1. The work is based on studying the collections deposited at the Herbarium of Research Institute of Forests & Rangelands (TARI). The

specimens were then closely compared with various collections deposited in the E (<https://data.rbge.org.uk/search/herbarium>), K (<https://www.kew.org/science/collectionsand-resources/collections/herbarium>), and W (<https://herbarium.univie.ac.at/database/search.php>) herbaria, for identification.

All collections were critically studied for important taxonomic characters of the genus, including the fruit shape, color, size, mericarp, and the presence or absence of winged ribs of the fruits of each taxon. For morphological studies, observations were carried out in a Leica WILD M3Z stereomicroscope; and three to six fruits for each taxon were chosen to cover the range of variation.

Fruit samples were placed in tubes filled with distilled water, then transferred to bain-marie, at 60°C for 36 hours for rehydration. Then they were treated with FAA (formaldehyde-acetic acid-alcohol) for a minimum of 24h and transferred to 70% methanol for long-term preservation. After each step, specimens were washed with distilled water. Freehand sections were made using commercial razor blades. Sections were cleaned with 50% Javelle water for about 45 minutes, washed with distilled water, and treated with 10% acetic acid for 10 minutes. To stain the prepared samples, alum carmine solution and methyl green solutions were used. Samples were examined using Olympus BH2-RFCA standard light microscope and photographs were taken by a Cannon G5 Camera. The terminology of morphological characteristics is based on Kljuykov & al. (2004) and Swink & Wilhelm (1994). The values of the length and width of the fruits were calculated by the Simpson & Roe graphical test (Van der Pluym & Hideux 1997).

For data analysis, we chose 32 fruit anatomical and morphological characteristics to separate 15 taxa of the *Prangos* (Tables 2 & 3). The characteristics and their states have been subjected to numerical analysis under a program using the similarity and dissimilarity assessment percentage method (Kovach 1999). The taxa were grouped according to the variation of selected characters using the clustering analysis method (unweighted pair group method with arithmetic mean (UPGMA)). The MVSP software package version 3.2 (Kovach 1999) was used to calculate Jaccard's similarity coefficients among the taxa.

Table 1. The species of *Prangos* examined in this study.

Taxa	Collection data
Subgenus <i>Prangos</i>	
Section <i>Alococarpum</i>	
<i>P. eriantha</i> (DC.) Lyskov & Pimenov	West Azarbayejan: Urumieh, Salmas to Tasuj after Sadaghian, 38° 16' 02" N, 45° 01' 00" E, 1480 m, 25 Oct. 1991, Mozaffarian, 71622 TARI
Section <i>Latilobae</i>	
<i>P. latiloba</i> Korovin	Khorassan: Between Mashhad and Torbate-Heydarieh, Robat-Sefid, 35° 46' 26" N, 59° 22' 37" E, 1700-1900 m, Assadi & 16 Jun. 1972, Mozaffarian, 35966 TARI
Section <i>Meliocarpoides</i>	
<i>P. cheilanthifolia</i> Boiss.	Esfahan: 15km from Naein to Yazd, 32° 46' 42" N, 53° 13' 40" E, 1400 m, 15 May. 1999, Mozaffarian, 79243 TARI
Section <i>Prangos</i>	
<i>P. acaulis</i> (DC.) Bornm.	East Azarbyejan: Miyaneh Bozgoush Mount region Varankesh village, 37° 39' 26" N, 47° 27' 0.5" E, 1909 m, 2 Sep. 2007, Mozaffarian, 93429 TARI
<i>P. asperula</i> subsp. <i>haussknechtii</i> (Boiss.) Herrnst. & Heyn	Azarbayejan: 20 km Sardasht Baneh road, 36° 10' 58" N, 45° 41' 40" E, 1500 m, 9 Jul. 1974, Siami & Zehzad, 3012 TARI
<i>P. calligonoides</i> Rech.f.	Lorestan: ca. 20 km SW of Doroud at Bisheh, 33° 19' 43" N, 48° 53' 23" E, 1250-1600 m, 11 Jul. 1981, Assadi & Mozaffarian, 37022 TARI
<i>P. corymbosa</i> Boiss.	East Azarbayejan: Miyaneh, 30 km North of Miyaneh road to Khalkhal Neshagh village, 37° 41' 04" N, 47° 40' 39" E, 1500 m, 24 May. 1974, Babakhanlou, 23810 TARI
<i>P. crossoptera</i> Herrnst. & Heyn	Sanandaj: Narran village, 38 km from Sanandaj, Sanandaj-Kamyaran Route, 35° 07' 57" N, 46° 59' 04" E, 1500-2400 m, 15 Jun. 1986, Fattahi & Tavakoly & Khaleedian, 788 TARI
<i>P. ferulacea</i> Lindl.	Kordestan: 32 km from Baneh on the road to Marivan, 35° 43' 02" N, 46° 03' 25" E, 1640 m, 30 May. 1978, Runemark & Mozaffarian, 29301 TARI
<i>P. gaubae</i> (Bornm.) Herrnst. & Heyn	Zanjan: Zanjan-Dandi road: 3 km after Gharaei village, rocky slope, 36° 32' 27" N, 47° 55' 37" E, 1860 m, 29 May. 2014, Mahmoodi, 105328 TARI
<i>P. longistylis</i> (Boiss.) Pimenov & Kljuykov	Azarbayejan: kuh-e Sahand, 37° 48' 39" N, 46° 17' 34" E, 2200-2900 m, 3 Jul. 1978, Assadi & Mozaffarian, 30709 TARI
<i>P. serpentinica</i> (Rech.f., K. Rasbach, Reichst. & Bennert) Herrnst. & Heyn	Khorassan: Esferayen, N. slope of kuh-e Shah Jahan from Darparchin-e bala village, 37° 06' 21" N, 57° 43' 25" E, 1700-2500 m, 6 Jun. 1984, Mozaffarian, 48436 TARI
<i>P. tuberculata</i> Boiss. & Hausskn. ex Boiss.	Fars: Shiraz: Hossein-abad, Protected area, 29° 38' 15" N, 52° 11' 50" E, 1850 m, 3 Jun. 1983, Mozaffarian, 46677 TARI
Section <i>Ulopterae</i>	
<i>P. uloptera</i> DC.	Tehran: W Tehran, Suleghun valley, 35 48' 44" N, 51° 15' 48" E, 1500-2000 m, 31 Jun. 1979, Assadi & Mozaffarian, 32622 TARI
Subgenus <i>Koelzella</i>	
<i>P. pabularia</i> subsp. <i>pabularia</i> Lindl.	Kermanshah: Kermanshah to Kamyaran, Varmangeh, Padegan shahid Rajaice, 34° 8' 23" N, 46° 56' 37" E, 1915 m, 8 Jul. 2003, Hamzehee & Asri, 87681 TARI

RESULTS

Morphological studies

The results of this study showed that the morphological characteristics including eight quantitative/qualitative characters related to the shape and size of fruits are taxonomically valuable (Table 2, Fig. 1). They show variations in species of *Prangos*. The fruits were orbicular to elliptic, oblong, ovate, and pyriform. The orbicular to elliptic fruits were observed in *P. corymbosa*, *P. serpentinica*, *P. tuberculata*, *P. crossoptera*, *P. acaulis*, *P. calligonoides*, *P. latiloba*, and *P. eriantha* (Figs. 1A, 1C, 1D, 1F, 1H, 1I, 1M, 1O). The ovate to oblong fruits are characteristic of *P. longistylis*, *P. ferulacea*, *P. asperula* subsp. *haussknechtii*, *P. pabularia* subsp. *pabularia* and *P. uloptera* (Figs. 1B, 1E, 1J, 1K, 1L). The ovate to elliptic fruits were observed in *P. gaubae* (Fig. 1G). The fruits of *P. cheilanthifolia* were pyriform (Fig. 1N).

The sizes of the fruits varied among the studied species; they ranged from 8–25 mm in length \times 5.5–20 mm in width. The longest fruit was 25 \times 15 mm, observed in *P. ferulacea*, while the smallest fruit (8 \times 8 mm) was found in *P. latiloba*. The fruit size was found useful to separate species of *Prangos* (Table 2). The fruit was winged or smooth. The winged fruit was further divided into two groups based on the shape of the wing. The wavy-winged fruits are easily recognized in six species including *P. crossoptera*, *P. calligonoides*, *P. asperula*, *P. pabularia*, *P. uloptera*, and *P. latiloba* (Figs. 1F, 1I, 1J, 1K, 1L, 1M). The straight-winged fruits were observed in five species including *P. corymbosa*, *P. longistylis*, *P. tuberculata*, *P. ferulacea*, and *P. acaulis* (Figs. 1A, 1B, 1D, 1E, 1H).

Anatomical studies

In this study, the fruit anatomy of *P. corymbosa*, *P. serpentinica*, *P. tuberculata*, *P. crossoptera*, *P. acaulis*, *P. calligonoides*, *P. latiloba*, *P. eriantha*, *P. longistylis*, *P. ferulacea*, *P. asperula* subsp. *haussknechtii*, *P. pabularia* subsp. *pabularia*, *P. uloptera*, *P. gaubae*, and *P. cheilanthifolia* were examined using both qualitative (18) and quantitative (14) characteristics. The fruits were mostly homomorphic, some of them had wings. In all studied species of *Prangos*, each mericarp had 3 dorsal ribs and 2 lateral ribs. The dorsal and lateral ribs did not show any variation (Figs 2–3 & Table 2).

The schizocarp fruits of *Prangos* had homomorphic or heteromorphic mericarps, pentagonal or orbicular which are strongly compressed dorsally and elliptical. The exocarp shows variation and is glabrous, pubescent, or tuberculate. The shape of the wings is straight or wavy, and the mesocarp is distinguished or undistinguished from the exocarp. Liu & al. (2006), and

Calvino & al. (2008) discussed the genera of Apiaceae according to the location and the development of the wings. The fruits of the studied species were of two main types: 1) with winged ribs, and 2) without winged ribs. The fruit of most studied species had winged ribs including *P. acaulis*, *P. asperula*, *P. calligonoides*, *P. corymbosa*, *P. crossoptera*, *P. ferulacea*, *P. latiloba*, *P. longistylis*, *P. pabularia*, *P. uloptera*, and *P. tuberculata*; and fruits without winged ribs were present in *P. cheilanthifolia*, *P. gaubae*, *P. eriantha*, and *P. serpentinica* (Table 2; Fig. 1). Fruits with winged ribs were further divided into two groups based on the shape of the wing (wavy-group, straight-group). The secondary ribs were an unusual feature in *Prangos*. The results of the present study indicated that the secondary ribs were present in *P. asperula*. Previously, the presence of secondary ribs had only been reported in *P. ferulacea* by Lyskov & al. (2016). *Prangos ferulacea* and *P. asperula* displayed great variations in the size of the fruits (Fig. 4B).

Also, the mericarp's size varied among the studied species. It ranged from 7.98–22.28 mm in length \times 5.87–17.04 mm in width. The largest mericarp size was 22.28 \times 17.04 mm, observed in *P. asperula*, while the smallest mericarp (8.25 mm \times 5.87 mm) was observed in *P. uloptera*. The shape of the mericarp in transverse sections showed variation. The mericarp of *Prangos* species were pentagonal (*P. tuberculata*, *P. calligonoides*, *P. corymbosa*, *P. asperula*, *P. longistylis*, *P. acaulis*, *P. crossoptera*), orbicular (*P. cheilanthifolia*), orbicular to semiorbicular or semiorbicular (*P. ferulacea*, *P. pabularia*, *P. uloptera*, *P. eriantha*, *P. serpentinica*), and ovate to elliptic (*P. gaubae*, *P. latiloba*). The mericarp size and shape were found useful to separate the species (Table 2; Fig. 1).

Regarding vallecular vittae, two fruit types could be defined. In the first type, the mesocarp was present and in the second type, the mesocarp was absent. In *Prangos*, vittae are dispersed in the mesocarp. The distribution of vittae in the mesocarp showed variations. The vittae in the subgenera *Koelzella* and *Prangos* (sections *Latilobae* and *Ulopterae*) were observed in the inner parts of the mesocarp and in the subgenus *Prangos* (sections *Alococarpum*, *Prangos*, and *Meliocarpoides*) in the marginal parts of mesocarp. The vallecular vittae are secretory ducts in the intervals (furrows) between the ribs. The results of the present study indicated that three types of endosperms are present in *Prangos*, and endosperms varied from flat, slightly emarginate to deeply emarginate among the studied species. The number of vittae showed variation in dorsal and lateral ribs. Two groups were observed based on the number of vittae in dorsal ribs: Group I

included *P. tuberculata* and *P. asperula* which differ from the other species by having 10–15 dorsal vittae, *P. asperula* was separated from *P. tuberculata* in having 7–8 lateral vittae. Group II included *P. cheilanthifolia*, *P. gaubae*, *P. serpentinica*, *P. pabularia*, *P. latiloba*, *P. uloptera*, *P. corymbosa*, *P. acaulis*, *P. longistylis*, *P. ferulacea*, *P. calligonoides*, *P. crossoptera*, and *P. eriantha* by having 3–9 dorsal vittae. Group II was further divided into two subgroups based on the number of vittae in lateral ribs. One subgroup included *P. cheilanthifolia*, *P. gaubae*, *P. serpentinica*, *P. latiloba*, *P. acaulis*, *P. longistylis*, *P. calligonoides*, and *P. eriantha* with less than 5 lateral vittae. Species belonging to sections *Alococarpum*, *Meliocarpoides*, *Latilobae*, and *Prangos* are in this subgroup. The other subgroup includes *P. pabularia*, *P. uloptera*, *P. corymbosa*, *P. ferulacea*, and *P. crossoptera* which differ from the first subgroup in having more than 5 lateral vittae. Species belonging to subgenus *Koelzella* and *Prangos* sections *Ulopterae*, and *Prangos* belong to this subgroup.

Dispersed vascular bundles were observed in the middle parts (subgenus *Koelzella* and subgenus *Prangos* sections *Latilobae* and *Ulopterae*), middle parts, and marginal part (section *Prangos*: *P. calligonoides*, *P. corymbosa*, *P. crossoptera*, *P. serpentinica*, *P. tuberculata*) and marginal parts (sections *Alococarpum*, *Meliocarpoides*, and *Prangos*: *P. ferulacea*, *P. gaubae*, *P. longistylis*, *P. acaulis*, *P. asperula*) of mesocarp. The results of the present study indicated that different sizes of vascular bundles were arranged regularly to irregularly. The large and regular vascular bundle was observed in subgenera *Koelzella* and *Prangos* (sections *Latilobae*, *Ulopterae*, and *Prangos*: *P. longistylis*). The large and irregular vascular bundle was observed in subgenus *Prangos* (sections *Alococarpum* and *Prangos* (*P. corymbosa*)). The small and regular vascular bundle is found in subgenus *Prangos* (sections *Meliocarpoides* and *Prangos*: *P. acaulis*, *P. asperula*, *P. gaubae*, *P. serpentinica*, *P. ferulacea*). The small and irregular vascular bundle is found in subgenus *Prangos* (section *Prangos*: *P. calligonoides*, *P. crossoptera*, *P. tuberculata*).

In general, the species of the genus *Prangos* can be divided into four groups based on the mericarp structure, vallecular vittae, vascular bundle, and rib secretory duct characteristics (Fig. 4A; see key).

Group I: The first group included species belonging to two subgenera including *Koelzella* (*P. pabularia*) and *Prangos* (sections *Latilobae* and *Ulopterae*). This group has winged ribs, mericarp slightly compressed dorsally, wavy wings, exocarp wavy, mesocarp 5 parted, without vallecular vittae, vittae in mesocarp 2, vascular bundle regular and large, dorsal vittae 3–9, lateral vittae 2–6, and rib secretory ducts present in all ribs (*Prangos pabularia* subsp. *pabularia*, *P. latiloba*, *P. uloptera*).

Group II: The second group included species belonging to subgenus *Prangos* sections *Meliocarpoides* (*P. cheilanthifolia*) and *Prangos* (*P. gaubae*, *P. serpentinica*). They differed from the other species in having an obsolete rib, mericarp slightly compressed dorsally or not compressed, exocarp straight, mesocarp 4 parted relay single, vallecular vittae multiplex or absent, 1–4 vittae in mesocarp, vascular bundle regular and small, dorsal vittae 3–9, lateral vittae less than 5, and rib secretory ducts absent.

Group III: The third group included species belonging to subgenus *Prangos* section *Prangos* and included *P. corymbosa*, *P. acaulis*, *P. tuberculata*, *P. longistylis*, *P. ferulacea*, *P. asperula* subsp. *haussknechtii*, *P. calligonoides*, and *P. crossoptera*. This group can be distinguished from the other groups by winged, mericarp slightly compressed dorsally or not compressed, winged ribs, number of inner mesocarps 4–5, exocarp wavy, pubescent, tuberculate, mesocarp 4 parts relay 5 parts (in *P. acaulis*), vallecular vittae multiplex, vittae in mesocarp 1–2, vascular bundle variable, the number of vittae in ribs variable, and rib secretory ducts present in some ribs (relay in all).

Group IV: The fourth group included species belonging to subgenus *Prangos* section *Alococarpum*. In this group, *Prangos eriantha* has obsolete ribs, mericarp slightly compressed dorsally, exocarp straight, vittae 5, vallecular vittae multiplex, vittae in mesocarp 5, size of vascular bundle large and irregular in mesocarp, dorsal vittae 3–9, lateral vittae 3–5, and rib secretory ducts present in all ribs.



Fig. 1. Light microscope images of *Prangos* fruits. A, *P. corymbosa*; B, *P. longistylis*; C, *P. serpentinica*; D, *P. tuberculata*; E, *P. ferulacea*; F, *P. crossoptera*; G, *P. gaubae*; H, *P. acaulis*; I, *P. calligonoides*; J, *P. asperula* subsp. *haussknechtii*; K, *P. pabularia* subsp. *pabularia*; L, *P. uloptera*; M, *P. latiloba*; N, *P. cheilanthifolia*; O, *P. eriantha*. Scale Bar= 10 mm.

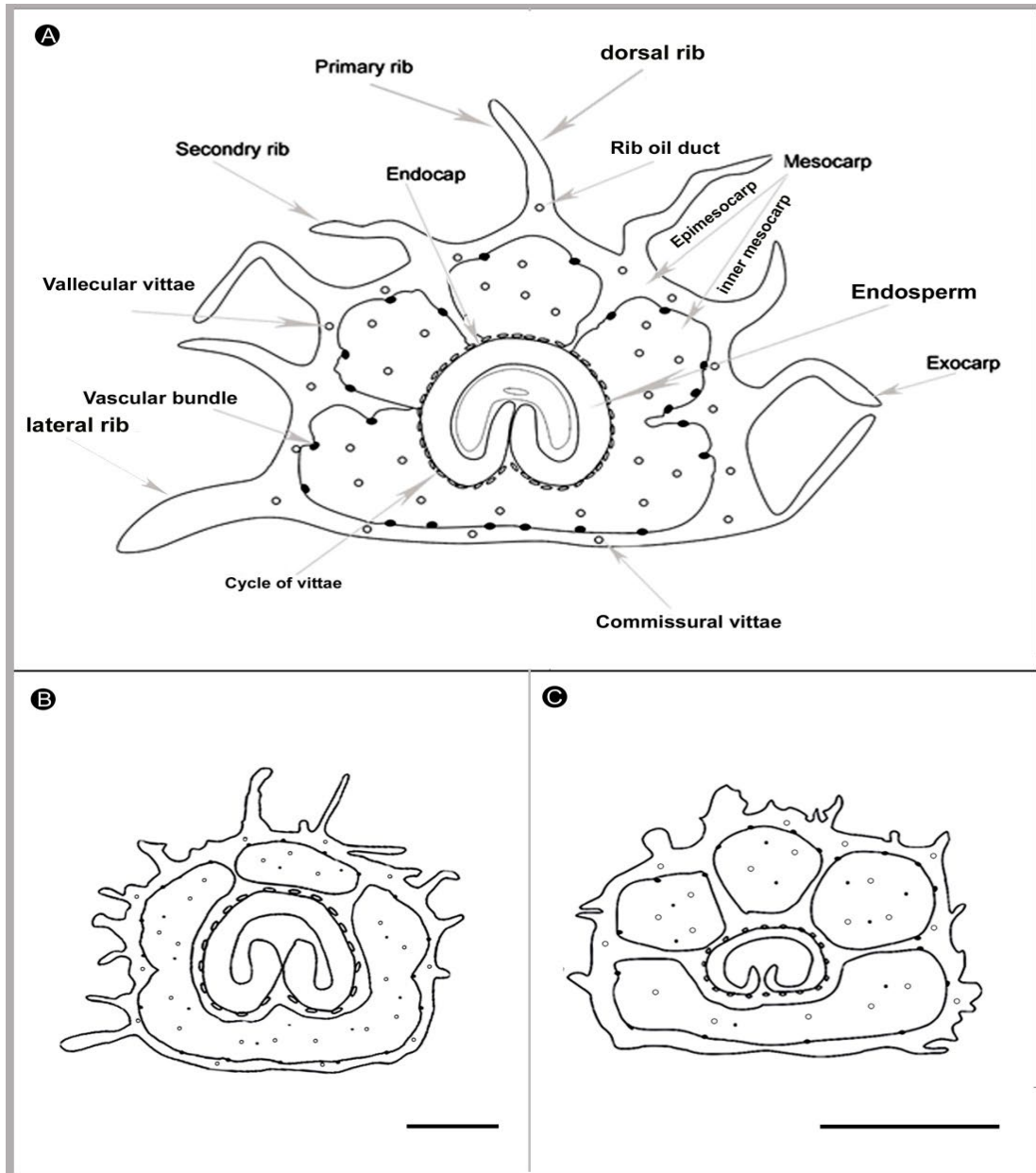


Fig. 2. Mericarp schematic structure of fruit of the genus *Prangos*, showing applied terminology. A, *P. asperula* subsp. *haussknechtii*; B, *P. crossoptera*; C, *P. calligonoides*. Scale Bar=5 mm.

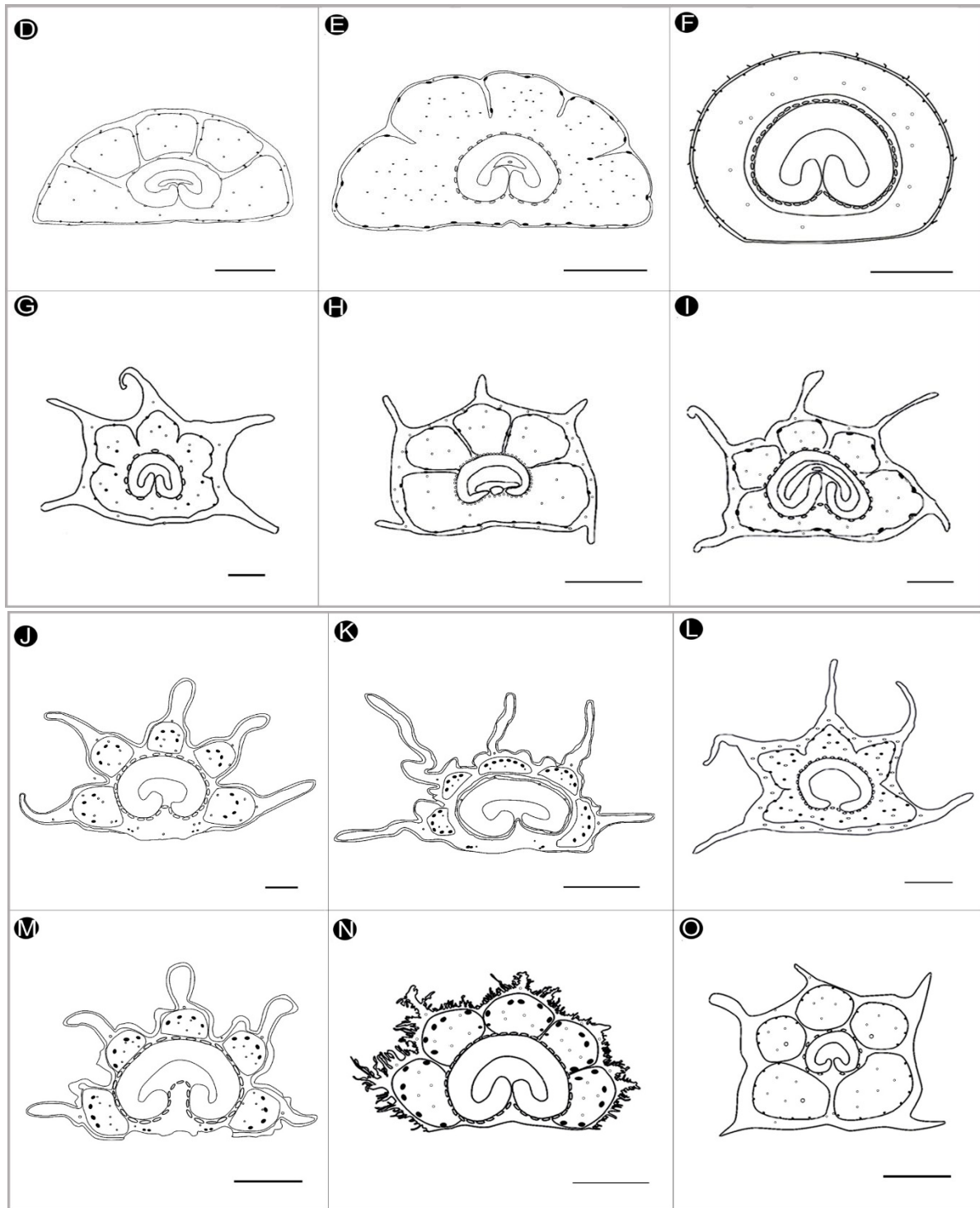


Fig. 2. Continued. D, *P. gaubae*; E, *P. serpentinica*; F, *P. cheilanthifolia*; G, *P. tuberculata*; H, *P. ferulacea*; I, *P. longistylis*. J, *P. uloptera*; K, *P. latiloba*; L, *P. corymbosa*; M, *P. pabularia* subsp. *pabularia*; N, *P. eriantha*; O, *P. acaulis*. Scale Bar = 5 mm.

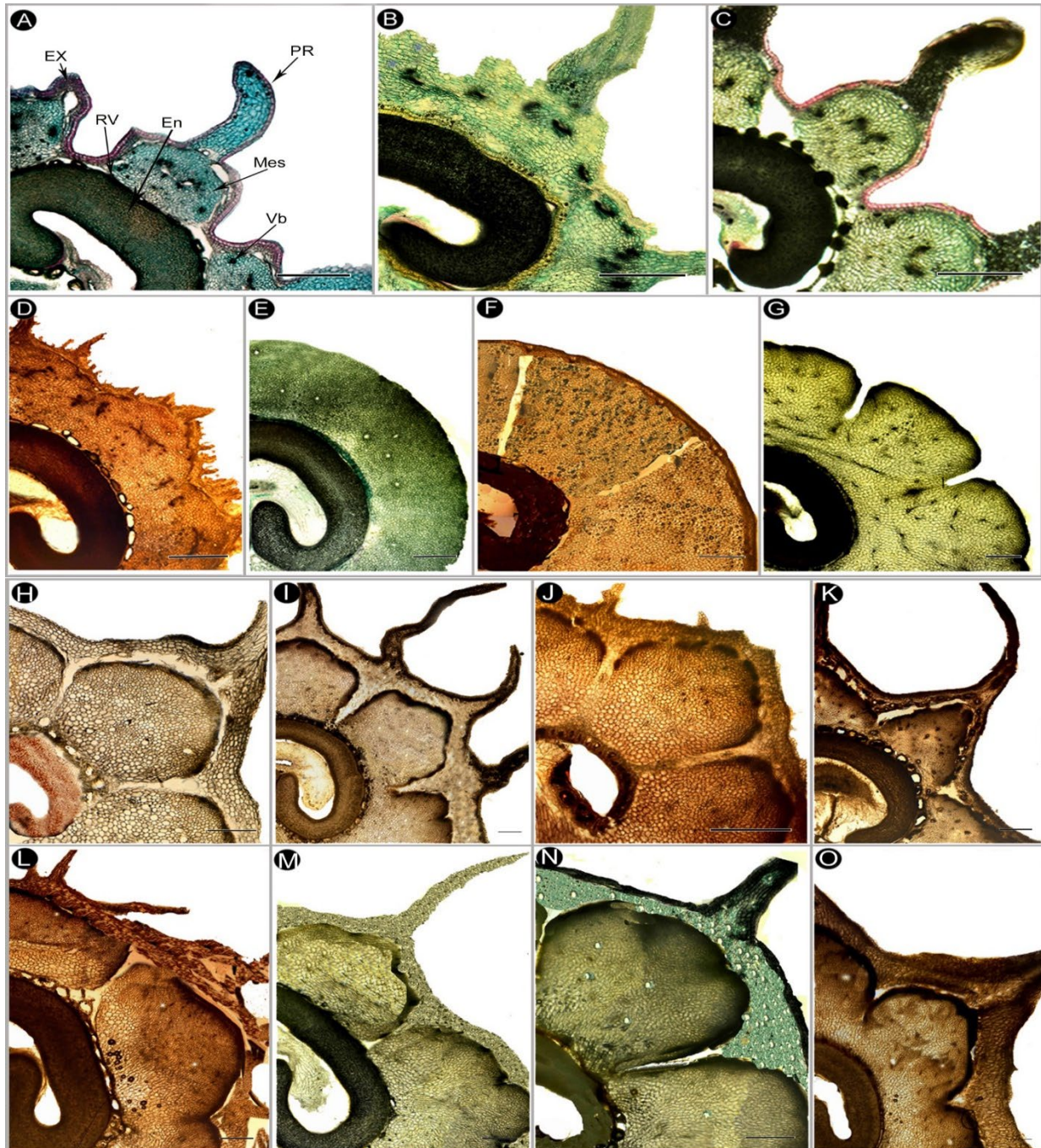


Fig. 3. Mericarp cross sections of the genus *Prangos*. A, *P. pabularia* subsp. *pabularia*; B, *P. latiloba*; C, *P. uloptera*; D, *P. eriantha*; E, *P. cheilanthifolia*; F, *P. gaubae*; G, *P. serpentinica*; H, *P. acaulis*; I, *P. asperula* subsp. *haussknechtii*; J, *P. calligonoides*; K, *P. corymbosa*; L, *P. crossoptera*; M, *P. longistylis*; N, *P. ferulacea*; O, *P. tuberculata*. Vb: Vascular bundle; Ex: Exocarp; PR: Primary ribs; En: Endocarp; Rv: Ring vittae; Mes: Mesocarp; Scale Bar= 1 mm.

Table 2. Summary of structural characters of mericarps in 15 examined species of *Prangos*. Fruit length (FL), Fruit width (FW), Fruit shape (FS), Mericarp length (ML), Mericarp width (MW), Mericarp width/length ratio (MW/ML), Mericarp shape in cross-section (MSC), Mericarp compressed (Mc), Primary ribs (PR), Prominency of rib (PRR), Shape wing (SW), Mericarps color (MCO), Dorsal ribs number (DR), Dorsal vittae number (DV).

	FL (mm)	FW (mm)	FS	ML (mm)	MW (mm)	MW/M L (mm)	MSC	Mc	PR	PRR	SW	MCO	DR	DV
Subgenus Prangos														
Section Alococarpum														
<i>P. eriantha</i>	18	10	Oblong-elliptic	13.36	8.95	0.64	Orbicular to semiorbicular	Slightly dorsally	Present	Obsolete	Without wing	Yellow	0	8-9
Section Latilobae														
<i>P. latiloba</i>	8	8	Orbicular	10.84	7.42	0.68	Ovate to elliptic	Slightly dorsally	Present	Winged	Wavy	Light yellow	3	4-5
Section Meliocarpoides														
<i>P. cheilanthifolia</i>	9	8	Pyriform	13.18	11.13	0.84	Orbicular	Not compressed	Absent	Obsolete	Without wing	Light yellow	3	5-7
Section Prangos														
<i>P. acaulis</i>	14	13	Elliptic-orbicular	11.78	10.53	0.89	Pentagonal	Not compressed	Present	Winged	Straight	Yellow	3	8-9
<i>P. asperula</i> subsp. <i>haussknechtii</i>	23	20	Elliptic-orbicular	22.28	17.04	0.76	Pentagonal	Not compressed	Present	Winged	Wavy	Dark brown	3	10-12
<i>P. calligonoides</i>	13	10	Elliptic-orbicular	9.48	6.93	0.73	Pentagonal	Not compressed	Present	Winged	Wavy	Yellow	3	7-8
<i>P. corymbosa</i>	12	11	Elliptic-orbicular	13.18	10.37	0.78	Pentagonal	Not compressed	Present	Winged	Straight	Yellow	3	7-8
<i>P. crossoptera</i>	11.5	8	Elliptic-orbicular	15.49	13.43	0.86	Orbicular	Not compressed	Present	Winged	Wavy	Light yellow	0	5-6
<i>P. ferulacea</i>	23	13	Ovate-oblong	12.04	10.69	0.88	Orbicular to semiorbicular	Slightly dorsally	Present	Winged	Straight	Dark brown	3	5-6
<i>P. gaubae</i>	13	9.25	Elliptic- orbicular	20.08	13.62	0.67	Ovate to elliptic	Slightly dorsally	Absent	Obsolete	Without wing	Light yellow	0	3-4
<i>P. longistylis</i>	14.5	6	Ovate-oblong	19.27	13.69	0.71	Orbicular to Semiorbicular	Slightly dorsally	Present	Winged	Straight	Light yellow	3	5-6
<i>P. serpentinica</i>	14	10	Elliptic-orbicular	20.28	11.58	0.57	Semiorbicular	Slightly dorsally	Absent	Obsolete	Without wing	Light yellow	3	5-7
<i>P. tuberculata</i>	14	7	Orbicular	17.60	15.02	0.85	Pentagonal	Not compressed	Present	Winged	Straight	Yellow	5	10-15
Section Ulopterae														
<i>P. uloptera</i>	13	13	Oblong-elliptic	8.25	5.87	0.71	Orbicular to semiorbicular	Slightly dorsally	Present	Winged	Wavy	Yellow	3	7-8
Subgenus Koelzella														
<i>P. pabularia</i> subsp. <i>pabularia</i>	12.25	5.25	Oblong-elliptic	11.11	7.35	0.66	Orbicular to semiorbicular	Slightly dorsally	Present	Winged	Wavy	Yellow	3	7-8

Table 2. Continued. Lateral ribs number (LR), Lateral vittae number (LV), Secondary ribs (SR), Endocarp in the form of distinct layers (EL), Number of inner mesocarp (NIM), Exocarp (EX), Mesocarp separated from exocarp (MSE), Surface of exocarp (SEX), Vallecular vittae number (VV), Size of vallecular vittae (SVV).

	LR	LV	SR	EL	NIM	EX	MSE	SEX	VV	SVV
Subgenus Prangos										
Section Allocarpum										
<i>P. eriantha</i>	0	3-5	Absent	No	5	Straight	No	Pubescent	Multiplex	Medium
Section Latilobae										
<i>P. latiloba</i>	2	2-3	Absent	Yes	5	Wavy	Yes	Glabrous	Absent	Absent
Section Meliocarpoides										
<i>P. cheilanthifolia</i>	0	3-4	Absent	No	1	Straight	No	Tuberculate	Absent	Absent
Section Prangos										
<i>P. acaulis</i>	2	2-3	Absent	No	5	Straight	No	Glabrous	Multiplex	Medium
<i>P. asperula</i> subsp. <i>haussknechtii</i>	4	7-8	Present	No	4	Straight	No	Glabrous	Multiplex	Small
<i>P. calligonoides</i>	2	3-5	Absent	No	4	Straight	No	Pubescent	Multiplex	Small
<i>P. corymbosa</i>	2	7-8	Absent	No	4	Straight	No	Glabrous	Multiplex	Medium
<i>P. crossoptera</i>	2	5-6	Absent	No	4	Straight	No	Tuberculate	Multiplex	Small
<i>P. ferulacea</i>	2	5-6	Absent	No	4	Straight	No	Glabrous	Multiplex	Medium
<i>P. gaubae</i>	0	4-5	Absent	No	4	Straight	No	Glabrous	Multiplex	Small
<i>P. longistylis</i>	2	3-4	Absent	No	4	Straight	No	Glabrous	Multiplex	Small
<i>P. serpentinica</i>	0	2-3	Absent	No	4	Straight	No	Glabrous	Multiplex	Medium
<i>P. tuberculata</i>	2	3-4	Absent	No	4	Straight	No	Glabrous	Multiplex	Small
Section Ulopterae										
<i>P. uloptera</i>	2	5-6	Absent	No	5	Wavy	Yes	Glabrous	Absent	Absent
Subgenus Koelzella										
<i>P. pabularia</i> subsp. <i>pabularia</i>	2	5-6	Absent	No	5	Wavy	Yes	Glabrous	Absent	Absent

Table 2. Continued. Commissural vittae number (CV), Vascular bundle (VB), Size vascular bundle (SVB), Vittae near endocarp formed cycle (VEC), Oil duct in the rib (ODR), Endosperm shape (ES), Dorsal wings wide (DWW), Lateral wings wide (LWW), The ratio of the size of the vittae to the vascular bundle (RSVVB), Dispersion vascular bundles in mesocarp (M).

	CV	VB	SVB	RSVVB	M	VEC	ODR	ES	DWW (mm)	LWW (mm)
Subgenus Prangos										
Section Alococarpum										
<i>P. eriantha</i>	0	Irregular	Large	Unequal	Margin	Numerous	Present at all ribs	Slightly emarginate	0	0
Section Latilobae										
<i>P. latiloba</i>	2	Regular	Large	Unequal	Middle	Low	Present at all ribs	Slightly emarginate	5 (4-6)	4 (3-5)
Section Meliocarpoides										
<i>P. cheilanthifolia</i>	1	Regular	Very small	Equal	Margin	Medium	Absent	Slightly emarginate	0	0
Section Prangos										
<i>P. acaulis</i>	2	Regular	Small	Equal	Margin	Medium	Present in some ribs	Slightly emarginate	3 (2-4)	2 (1-3)
<i>P. asperula</i> subsp. <i>hausknechtii</i>	2	Regular	Small	Equal	Margin	Numerous	Present in some ribs	Slightly emarginate	5 (4-6)	4 (3-5)
<i>P. calligonoides</i>	2	Irregular	Small	Equal	Margin/Middle	Numerous	Present in some ribs	Flat	3 (2-4)	2 (1-3)
<i>P. corymbosa</i>	1	Irregular	Large	Equal	Margin/Middle	Numerous	Present at all ribs	Flat	2 (1-3)	2 (1-3)
<i>P. crossoptera</i>	2	Irregular	Small	Equal	Margin/Middle	Numerous	Present in some ribs	Slightly emarginate	2 (1-3)	2 (1-3)
<i>P. ferulacea</i>	3	Regular	Small	Equal	Margin	Numerous	Present in some ribs	Slightly emarginate	3 (2-4)	2 (1-3)
<i>P. gaubae</i>	1	Regular	Small	Equal	Margin	Numerous	Absent	Slightly emarginate	0	0
<i>P. longistylis</i>	1	Regular	Large	Equal	Margin	Numerous	Present in some ribs	Slightly emarginate	2 (1-3)	2 (1-3)
<i>P. serpentinica</i>	2	Regular	Small	Equal	Margin/Middle	Numerous	Absent	Flat	0	0
<i>P. tuberculata</i>	1	Irregular	Small	Equal	Margin/Middle	Numerous	Present in some ribs	Slightly emarginate	5 (4-6)	4 (3-5)
Section Ulopterae										
<i>P. uloptera</i>	2	Regular	Large	Unequal	Middle	Numerous	Present at all ribs	Slightly emarginate	2 (1-3)	2 (1-3)
Subgenus Koelzella										
<i>P. pabularia</i> subsp. <i>pabularia</i>	2	Regular	Large	Unequal	Middle	Numerous	Present at all ribs	Deeply emarginate	2 (1-3)	2 (1-3)

Table 3. Quantitative and qualitative characters and character states used in the analysis of *Prangos* species.

Characters	Character state	Character	Character state
Qualitative characteristics			
1. Fruit shape	Elliptic- orbicular (0); oblong (1); ovate (2); ovate-oblong (3); pyriform (4)	10. Exocarp b	Pubescent (0); glabrous (1); tuberculate (2)
2. Mericarp shape in cross-section	Orbicular to semiorbicular (0); ovate to elliptic (1); orbicular (2); pentagonal (3)	11. Vascular bundle a	Small (0); very small (1)
3. mericarp compressed	Not compressed (0); slightly dorsally (1)	12. Vascular bundle b	Regular (0); irregular (1)
4. Primary ribs	Presence (0); absent (1)	13. Rib oil duct	In some (0); at all (1); absent (2)
5. Prominency of rib	Obsolete (0); winged (1)	14. Endosperm shape	Slightly emarginated (0); deeply emarginated (1); flat (2)
6. Shape of wing	Without wing (0); wavy (1); straight (2)	15. Dispersion vascular bundles in mesocarp	Margin (0); margin/middle (1); middle (2)
7. Mericarps color	Yellow (0); light yellow (1); dark brown (2)	16. Vallecular vittae a	Multiplex (0); absent (1)
8. Secondary ribs	Presence (0); absent (1)	17. Vallecular vittae b	Small (0); medium (1)
9. Exocarp a	Straight (0); wavy (1)	18. Cyclic vittae	Low (0); medium (1); numerous (2)
Quantitative characteristics			
19. Fruit length (mm)		26. Number of inner mesocarp	
20. Fruit width (mm)		27. Commissural vittae number	
21. Mericarp length (mm)		28. Vallecular vittae number	
22. Mericarp width (mm)		29. Lateral ribs number	
23. Lateral wings wide (mm)		30. Lateral vittae number	
24. Dorsal wings wide (mm)		31. Dorsal ribs number	
25. Compression of mericarp		32. Dorsal vittae number	

Identification key to the species based on fruit morphological and anatomical characteristics

1. Obsolete ribs (smooth ribs), exocarp straight 2
 - Winged ribs (winged ribs), exocarp straight or wavy 5
2. Mericarp not compressed, vallecular vittae absent in mesocarp, vittae less than 4, *P. cheilanthifolia*
 - Mericarp slightly compressed dorsally, vallecular vittae present in mesocarp, vittae more than 4, 3
3. Exocarp pubescent, size of vascular bundle large and irregular in mesocarp, rib secretory ducts present *P. eriantha*
 - Exocarp glabrous, size of vascular bundle small and regular in mesocarp, rib secretory ducts absent 4
4. Endosperm slightly emarginate, dispersed vascular bundles in middle parts of mesocarp, with small vallecular vittae *P. gaubae*
 - Endosperm flat, dispersed vascular bundles in margin and middle parts of mesocarp, with medium vallecular vittae *P. serpentinica*
5. Wings straight 6
 - Wings wavy 10
6. Endosperm flat, rib secretory ducts present in all ribs *P. corymbosa*

- Endosperm slightly emarginate, rib secretory ducts present in some ribs 7
- 7. Mericarp not compressed, vittae equal to vascular bundles 8
 - Mericarp slightly compressed dorsally, vittae unequal to vascular bundles 9
- 8. Mericarp length less than 15 mm, endocarp covered with regularly vallecular vittae with medium size, vallecular vittae more than 5 in mesocarp, vascular bundle regularly in mesocarp *P. acaulis*
 - Mericarp length more than 15 mm, endocarp covered with irregular vallecular vittae with small size, vallecular vittae less than 5 in mesocarp, vascular bundle irregular in mesocarp *P. tuberculata*
- 9. Fruits ovate to oblong, mericarp length more than 15 mm, size of vallecular vittae small in mesocarp, commissural vittae less than 2, size of vascular bundle large *P. longistylis*
 - Fruits oblong, mericarp length less than 15 mm, size of vallecular vittae medium in mesocarp, commissural vittae more than 2, size of vascular bundle small *P. ferulacea*
- 10. Exocarp glabrous and wavy, vallecular vittae

absent, size of vallecular vittae large in mesocarp, rib secretory ducts present in all ribs, mericarp slightly compressed dorsally 11
 - Exocarp straight and pubescent or glabrous, vallecular vittae present, size of vallecular bundle small in mesocarp, rib secretory ducts present in some ribs, mericarp not compressed 13
 11. Endosperm deeply emarginated
 *P. pabularia* subsp. *pabularia*
 - Endosperm slightly emarginate 12
 12. Fruits elliptic to orbicular, endocarp with distinct layer *P. latiloba*

- Fruits ovate to oblong, endocarp without distinct layer *P. uloptera*
 13. Fruits ovate to oblong, mericarp length more than 20 mm, vascular bundle regular and in marginal parts of mesocarp *P. asperula*
 - Fruits elliptic to orbicular, mericarp length less than 20 mm, vascular bundle irregular and in marginal and middle parts of mesocarp 14
 14. Fruits length less than 15 mm, mericarps pentagonal, endosperm flat *P. calligonoides*
 - Fruits length more than 15 mm, mericarps orbicular, endosperm slightly emarginate *P. crossoptera*

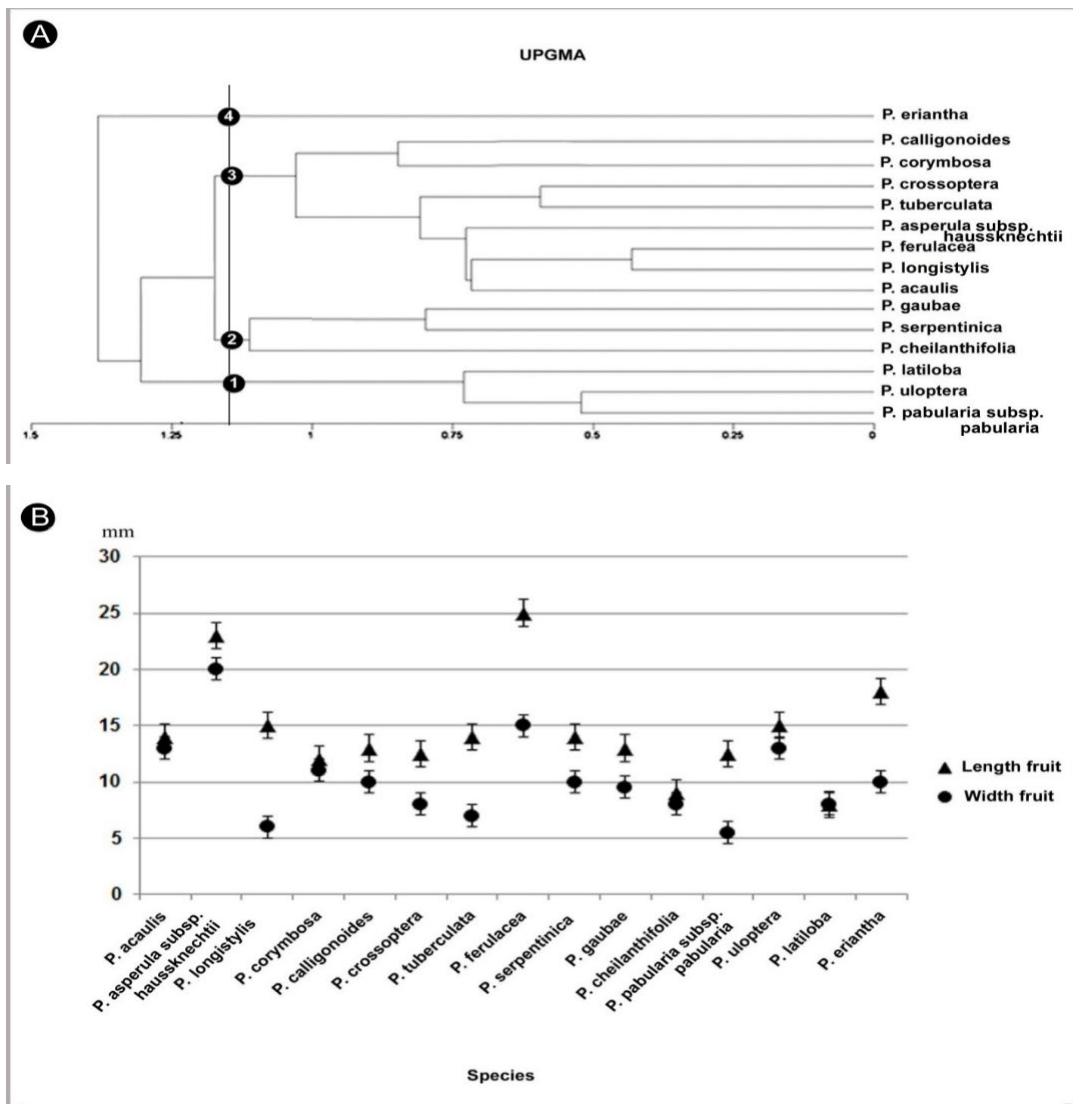


Fig. 4. A, UPGMA clustering of the examined taxa based on fruit characters; B, Simpson and Roe test for *Prangos* fruit length and width.

DISCUSSION

Relationship between subgenera *Koelzella* and *Prangos* (sections *Latilobae* and *Ulopterae*)

The genus *Prangos* is classified into the subgenera *Koelzella* and *Prangos*, of which subgenus *Koelzella* contains one species, *Prangos pabularia*. This species is widespread and found in Iran (Lyskov & al. 2017b). Pimenov & Tikhomirov (1983) placed *Prangos pabularia* in subgenus *Koelzella* because of the morphological characters. This is in agreement with the results of phylogenetic and seed micromorphological studies (Lyskov & al. 2015 & 2017b; Zarei & al. 2022). The subgenus *Prangos* is classified into five sections, *Alococarpum* (*P. eriantha*), *Latilobae* (*P. latiloba*), *Meliocarpoides* (*P. cheilanthifolia*), *Prangos* (other species), and *Ulopterae* (*P. uloptera*). Recently, *P. uloptera* has been transferred from the sect. *Prangos* to a new section *Ulopterae* (Lyskov & al. 2017b). *Prangos latiloba* was separated from the other *Prangos* species and was placed in a new section *Latilobae* (Pimenov & Tikhomirov 1983). *Prangos pabularia* and *P. uloptera* are closely related according to anatomical, morphological, and phylogenetic studies (Pimenov & Tikhomirov 1983; Valiejo-Roman & al. 2006, Ajani & al. 2008, Lyskov & al. 2015 & 2017b). Also, Lyskov & al. (2015 & 2017a) showed that one clade consisted of sections of *Latilobae*, *Ulopterae*, and *Prangos*.

In addition, recently, seed micromorphological studies showed a very close relationship among subgenus *Koelzella*, and subgenus *Prangos* sections *Latilobae* and *Ulopterae* within one subclade (Zarei & al. 2022). Our results showed that *P. pabularia*, *P. latiloba*, and *P. uloptera* share some features of fruit anatomy such as mericarps slightly compressed dorsally, exocarp glabrous and wavy, equal primary ribs, dorsal and lateral ribs, presence of rib secretory ducts, large and regular vascular bundles, absence of vallecular vittae, and commissural vittae, which confirm the results of previous studies (Lyskov & al. 2017a; Zarei & al. 2022). *Prangos pabularia* differed from *P. uloptera* in some characteristics such as vascular bundles distribution and endosperm shape. Also, *Prangos latiloba* differs from *P. pabularia* by its mericarp that is ovate to elliptic in transverse section, dorsal wings wide, dorsal and lateral vittae, endocarp, and endosperm shape. Lyskov & al. (2017b) reported mericarps with wavy ribs, equal, dorsal ribs 3, lateral ribs 2, exocarp glabrous, vallecular vittae distributed in inner parts, vascular bundles large and regular, endosperm deeply emarginate (slightly emarginate in *P. uloptera*), and rib secretory ducts present in all ribs in the *P. pabularia* and *P. uloptera*. Their results are in agreement with our results in the anatomical structure

of mericarps. Our results indicated that subgenus *Koelzella* is almost similar in the fruit anatomical characteristics to subgenus *Prangos* section *Ulopterae*, but these species differ in their biogeographical range.

Relationship between sections *Prangos* and *Ulopterae*

Lyskov & Samigullin (2017c) conducted a phylogenetic study and found that the species of sect. *Ulopterae* are clustered together and have a close relationship with the species of section *Prangos*. They believed that *P. uloptera* should be separated from the section *Prangos*, which is in agreement with the results from previous studies (Lyskov & al. 2017a & b). In addition, previous phylogenetic studies have proposed that *P. ferulacea* is close to section *Ulopterae*, and is in the same clade (Lyskov & al. 2017a). Ajani & al. (2008) studied the fruit anatomy of *Prangos uloptera* and *P. ferulacea* of sections *Prangos* and mentioned that the fruit was slightly lateral compressed, and ribs on the dorsal surface of the mericarp were prominent and wavy winged. Similar results were also reported by the anatomical studies of *Prangos* (Özdemir & Kültür 2014; Lyskov & al. 2017a). The results indicated that in *P. ferulacea* mericarps are slightly compressed dorsally, 12.04 × 10.69 mm, primary ribs are present, ribs winged, equal, and the endocarp covered with medium vallecular vittae, which is in agreement with the results of the latest phylogenetic study by Lyskov & al. (2017a). According to the results of our research, the fruit anatomical characteristics support the separation of section *Ulopterae* from the section *Prangos*, and these should be considered independent sections.

Relationship between subgenera *Koelzella* and *Prangos* (section *Alococarpum*)

Alococarpum erianthum was transferred from the genus *Alococarpum* to *Prangos* by Lyskov & al. (2017a) and considered as sect. *Alococarpum*. The section *Alococarpum* consists of one species (*Prangos eriantha*) that is endemic to Iran and occurs at low elevations (1400-1480 m). Similar results were also reported by the seed micromorphological studies of *Prangos* (Zarei & al. 2022). Furthermore, Lyskov & al. (2017a) studied the fruit anatomy of *P. eriantha* and showed its similarities to members of the subgenus *Prangos*. The results of the present study indicated that *P. eriantha* (subgenus *Prangos* section *Alococarpum*) differs from *P. pabularia* (subgenus *Koelzella*) by its obsolete ribs (vs. winged ribs) and vascular bundle irregular (vs. regular), which agrees with the results of previous studies (Lyskov & al. 2017a; Zarei & al. 2022). The fruit anatomical characteristics support

considering the genus *Alococarpum* as *Prangos* and recognizing its species in section *Alococarpum*.

Relationship between sections *Prangos* and *Meliocarpoides*

The sections *Prangos* and *Meliocarpoides* belong to the subgenus *Prangos* (Lyskov & al. 2017a), section *Meliocarpoides* contains one species (*P. cheilanthifolia*), and section *Prangos* contains 10 species (*P. corymbosa*, *P. serpentinica*, *P. tuberculata*, *P. crossoptera*, *P. acaulis*, *P. calligonoides*, *P. longistylis*, *P. ferulacea*, *P. asperula* subsp. *haussknechtii*, and *P. gaubae*), all present in Iran. *Prangos cheilanthifolia* occurs at low elevations (1400-1480 m), and other species occur at elevations above 1500 m. The phylogenetic study showed a very close relationship between *Prangos cheilanthifolia* and *P. crossoptera* (Lyskov & al. 2017b). The fruit anatomy supports this (Lyskov & al. 2017a). Our results indicated that in *P. cheilanthifolia* mericarp not compressed, ca. 13.18 × 11.13 mm, without wing, obsolete, endocarp covered with medium vallecular vittae, which is in agreement with their results in the shape of mericarp in transverse section and vallecular vittae. According to our results, *Prangos cheilanthifolia* differed from *P. crossoptera* in some characteristics such as the rib shape, mesocarp shape, vallecular vittae, and exocarp shape.

In addition, according to a study by Zarei & al. (2022), based on cell outlines and cell arrangement, two groups of seed surfaces were identified. One group consisted of *Prangos cheilanthifolia*, *P. gaubae*, and *P. serpentinica*, which is in agreement with the results of this research which indicates these three species (placed in Group II) are very similar in mericarp morphological characteristics. However, the fruit anatomical characteristics support the separation of *P. cheilanthifolia* from section *Prangos* and its placement in a separate section recognized as *Meliocarpoides*. Based on the results of this research, *P. gaubae* and *P. serpentinica* (of section *Prangos*) are very similar to *P. cheilanthifolia* (of section *Meliocarpoides*) and may be considered in the same section, but further studies are needed to prove the change. Meanwhile, these species differ in their biogeographical ranges.

In general, in the family Apiaceae, the classification of genera and subgeneric groupings is largely based on the morphology and anatomy of the fruit. Fruit features of taxonomic importance include the developmental origin of the wings, carpel shape, presence of vittae, woodiness of the endocarp, and type of carpophores (Liu & al. 2006). The results of our study support the molecular and seed micromorphological studies (Lyskov & al. 2017a & b; Zarei & al. 2022).

According to the current results, the anatomy of the fruits of the *Prangos* species supported the molecular and seed micromorphological classification studies (Lyskov & al. 2017a & b; Zarei & al. 2022).

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