

## Fruit anatomy of some *Ferulago* (Apiaceae) species in Turkey

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**Abstract:** The genus *Ferulago* W.Koch is represented with 49 species in the world and 34 species in Turkey. In this study, comparative fruit anatomical properties based on mericarp shape in transverse section of 27 *Ferulago* species grown in Turkey are given. A description of *Ferulago cypria* H.Wolff, which was mentioned as a new record in an unpublished postdoctoral thesis, is also given. As a result of this study, we are able to identify and classify the species of this genus by using anatomical features of the fruit. In addition, an identification key has been prepared to represent the similarities and differences between the species. The number of vittae distributed in the mesocarp demonstrates large differences between closely related species such as *F. pauciradiata* Boiss. & Heldr. (5–10 vittae) and *F. isaurica* Peşmen (97–102 vittae). Anatomical studies also confirm morphological classification, e.g., in sections *Aucheria* and *Anisotaenia*. According to this study, *F. glareosa* should be placed in a section other than *Anisotaenia*.

**Key words:** Apiaceae, *Ferulago*, fruit, anatomy, Turkey

### 1. Introduction

The family Apiaceae (Umbelliferae) is the third largest family in terms of genera in Turkey. It is also the eighth largest family with approximately 455 species, and 33% of these are endemic (Davis et al., 1988; Güner et al., 2000; Özhatay & Kültür, 2006; Özhatay et al., 2008–2009, 2009, 2011).

Turkey is an acknowledged centre of biodiversity in the middle-sized Apiaceae genus *Ferulago* W.Koch, and is most likely the main area of its origin and primary diversification (Peşmen, 1972; Bernardi, 1979; Tomkovich & Pimenov, 1987, 1989; Akalın & Özhatay, 2001). Forty-nine *Ferulago* species are distributed in Europe (except northern Europe), south-western and central Asia, Caucasia, and northern and north-western Africa (Tomkovich & Pimenov, 1981; Saya & Miski, 1985; Pimenov, 1993; Özhatay & Akalın, 2000; Solanas et al., 2000; Akalın, 2003; Akalın & Pimenov, 2004; Kandemir & Hedge, 2007). Thirty-four species are known in Turkey, but *Ferulago autumnalis* Thieb., which is accepted as a synonym of *Peucedanum autumnalis* (Bernardi, 1979), can be assessed as a member of the genus *Peucedanum* L. Eighteen of 34 *Ferulago* species are endemic (*F. antiochia* Saya & Miski, *F. aucheri* Boiss., *F. blancheana* Post., *F. bracteata* Boiss. & Hausskn., *F. glareosa* Kandemir & Hedge, *F. humilis* Boiss., *F. idaea* Özhatay & E.Akalın, *F. isaurica* Peşmen, *F. longistylis* Boiss., *F. macrosciadia* Boiss.

& Bal., *F. mughlae* Peşmen, *F. pachyloba* (Fenzl) Boiss., *F. pauciradiata* Boiss. & Heldr., *F. platycarpa* Boiss. & Bal., *F. sandrasica* Peşmen & Quézel, *F. silaifolia* (Boiss.) Boiss., *F. thirkeana* (Boiss.) Boiss., and *F. trojana* E.Akalın & Pimenov). In addition, 4 new species added to the flora of Turkey are given in this study. Three of these are new species [*F. idaea* (Özhatay & Akalın, 2000), *F. trojana* (Akalın & Pimenov, 2004), and *F. glareosa* (Kandemir & Hedge, 2007)], and *F. cypria* H.Wolff is a new record.

The first classification of the *Ferulago* species was made by Boissier, and the genus *Ferulago* is separated into 2 sections (Boissier, 1872). Peşmen (1972) examined the *Ferulago* species in 2 sections in *Flora of Turkey and the East Aegean Islands*. A revision of the *Ferulago* species was made by Bernardi (1979). The last study about the *Ferulago* species classification was made by Tomkovich and Pimenov (1987). In our study, we accept Tomkovich and Pimenov's classification (Table 1).

Apiaceae species have specific odours because they have secretory cavities (vittae), which are schizogenous oil ducts with resin, oil, or mucilage. They are found in the roots, petioles, stems, leaves, and fruits (Metcalf, 1979). In the family Apiaceae, morphological and anatomical fruit characteristics and the number of vittae have reliable diagnostic importance.

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**Table 1.** *Ferulago* species and sections according to Tomkovich and Pimenov's classification in Turkey (1987). The underlined species are within the scope of this study.

Sections	Turkish <i>Ferulago</i> species
Sect. <i>Anisotaenia</i> Boiss.	<i>F. angulata</i> , <i>F. antiochia</i> , <i>F. blanchiana</i> , <i>F. bracteata</i> , <i>F. glareosa</i> , <i>F. pachyloba</i> , <i>F. trachycarpa</i>
Sect. <i>Eutaenia</i> Bernardi	<i>F. cypria</i> , <i>F. galbanifera</i> , <i>F. latiloba</i> , <i>F. longistylis</i> , <i>F. setifolia</i> , <i>F. stellata</i> , <i>F. syriaca</i> , <i>F. trojana</i>
Sect. <i>Humiles</i> M.Pimen. & L.Tomkovich	<i>F. humilis</i> , <i>F. idaea</i> , <i>F. macrosciadia</i>
Sect. <i>Bernardia</i> M.Pimen. & L.Tomkovich	<i>F. amani</i> , <i>F. bernardii</i> , <i>F. platycarpa</i> , <i>F. sandrasica</i> , <i>F. thirkeana</i>
Sect. <i>Lophosciadium</i> (DC.) M.Pimen. & L.Tomkovich	<i>F. confusa</i>
Sect. <i>Aucheria</i> M.Pimen. & L.Tomkovich	<i>F. asparagifolia</i> , <i>F. aucheri</i> , <i>F. cassia</i> , <i>F. isaurica</i> , <i>F. kurdica</i> , <i>F. mughlae</i> , <i>F. pauciradiata</i>
Sect. <i>Uloptera</i> (Fenzl.) M.Pimen. & L.Tomkovich	<i>F. macrocarpa</i> , <i>F. silaifolia</i>

Anatomical characters are not always as useful as morphological characters for plant identifications. However, it is possible to use anatomical characters to distinguish between closely related species (Güvenç & Kendir, 2012; Karamian et al., 2012) and genera, especially in the family Apiaceae. This is because the anatomy of Apiaceae fruits varies strongly, even among closely related species in the same genus.

Anatomical characters of fruits, especially the number of vittae, seem to have potential for evaluating infrageneric relationships in the genus *Ferulago*. As a difference from the fruits of related genera *Ferula* L. and *Peucedanum* L., *Ferulago* fruits have more vittae and have different numbers of vittae in the 2 surfaces of mericarp. The number of dorsal vittae is usually more than the commissural vittae of mericarps (Bernardi, 1979). Articles about the anatomy of *Ferulago* species are focused on determining the number of vittae in fruits. The most detailed studies about this were made with the fruit and peduncle's transverse sections by Tomkovich and Pimenov (1981, 1982a, 1982b).

In this study, the fruit anatomy of 27 *Ferulago* species found in Turkey was examined and anatomical characters were used in the taxonomy of the genus *Ferulago*. Microscopic studies revealed a distinct difference in number and position of vittae in the pericarp of fruits. This study closely supports the traditional classification system, which is based on morphology (plant height, leaf shape and size, involucre number, size, and shape).

## 2. Materials and methods

This study is part of a larger project ("Taxonomical studies on the *Ferulago* species growing in the central and western Taurus Mountains") and a PhD study ("Pharmaceutical botanical studies on the *Ferulago* species growing in western Anatolia"). The study materials, ripe fruits of 27 *Ferulago* species, were obtained from the voucher specimens of the ISTE herbarium. Names and herbarium register numbers of studied species are: *F. amani* (ISTE 81361), *F. antiochia* (ISTE 81355), *F. asparagifolia* (ISTE 81265), *F. aucheri* (ISTE 81269), *F. blanchiana* (ISTE 80772), *F. bracteata* (ISTE 80768), *F. cassia* (ISTE 80292), *F. confusa* (ISTE 68297), *F. cypria* (ISTE 80226), *F. galbanifera* (ISTE 72560), *F. glareosa* (unnumbered sample), *F. humilis* (ISTE 74432), *F. idaea* (ISTE 74485), *F. isaurica* (ISTE 81254), *F. longistylis* (ISTE 91461), *F. macrosciadia* (ISTE 72514), *F. mughlae* (ISTE 72536), *F. pachyloba* (ISTE 81342), *F. pauciradiata* (ISTE 81346), *F. platycarpa* (ISTE 85115), *F. sandrasica* (ISTE 74528), *F. setifolia* (ISTE 86968), *F. silaifolia* (ISTE 72530), *F. syriaca* (ISTE 80293), *F. thirkeana* (ISTE 72812), *F. trachycarpa* (ISTE 81223), and *F. trojana* (ISTE 72512).

First, mericarps were waited in warmish water, and then all transverse sections were cut by hand from the middle of the mericarps with a blade. Samples were investigated in Sartur reagent (a compound reagent of lactic acid, Sudan III, aniline, iodine, potassium iodide, alcohol, and water). The shapes of transverse sections of each mericarp were drawn schematically. All drawings were made using a Camera Lucida drawing tube attached

to a Leitz Wetzlar microscope. Photographs were taken with an Olympus BH-2 microscope. An identification key was made based on the anatomical characters of the mericarps to recognise species from each other. The number of vittae in a mericarp of the *Ferulago* species was determined. The present key of genus *Ferulago* in *Flora of Turkey* is based on morphological properties and there is a characterisation about the number of vittae only for one differentiation. We made an identification key that is based on only fruit anatomical properties of the *Ferulago* species.

### 3. Results and discussion

Although this study is based on fruit anatomical properties of 27 *Ferulago* species grown in Turkey, we consider it necessary to give a description of *F. cypria*, because it was mentioned as a new record in an unpublished postdoctoral thesis.

*Ferulago cypria* H. Wolff, in Feddes Rep. 20: 67 (1924).

Perennial, entirely glabrous or sparsely scabrid, root-stock oblique, solitary, woody, with petiolar remains. Stem 60–100 cm, slightly sulcate, angled. Leaves 4-pinnate, triangular in outline, mostly basal, 8–45 × 7–30 cm, petiole with an inconspicuous basal sheath; lobes setaceous, linear or narrow oblong, 3–8 × 0.5–1 mm, glabrous or sparse scabrid, acute, with 0.1–0.3 mm mucro. Inflorescence paniculate-corymbose, branched from the base, rays 4–7, unequal, 1.5–5 cm; bracts persistent, 3–6, ovate, lanceolate, 2.5–4 × 1–2 mm, margin ciliate; pedicel 4–8, shorter than 3 mm in flowers, 12 mm or more in fruits; bracteoles persistent, 3–8, ovate-lanceolate, 1–3 × 1–1.5 mm; sepals ovate, minute triangular, 0.2–0.7 × 0.3–0.5 mm, glabrous; petals yellow, 0.8–1.8 × 0.8–1.2 mm, glabrous; ovary 0.8–2.5 × 0.9–2 mm, glabrous; stylopodium flat or slightly convex, c. 1.8 mm diameter. Mericarps elliptic-oblong, rarely rotundate, 9–14 × 6–9 mm, yellow, brown, lateral wings

1.5–2.5 mm wide, dorsal ribs winged, 0.5–1 mm wide; dorsal vittae 18–20(-24), commissural vittae (9-)11–12, distributed in mesocarp (10-)11–14. *Fl.* 5–6, *Fr.* 6–7. *Habitat*: dry, rocky, limestone hills, phrygana, and maquis formations, sea level to 700 m.

**Type:** (Cyprus) in montibus prope Corignia, *Sintenis et Rigo* 1880.

**Distribution in Turkey:** C3 Antalya: Manavgat, 2 km from Side to Turtel Hotel, 10 m, *Hub.-Mor.* 17745; Akseki, 26 km from Akseki to Manavgat, 600 m, *Hub.-Mor.* 17253; between Alanya-Gazipaşa, 04.06.1950, *A. Attila* s.n.; Side, upwards of Turtel Hotel, 03.06.2001, *E. Akalın & U. Uruşak* ISTE 80226; C4 İçel: Anamur, 5 km west from town, sea level, *Hub.-Mor.* 15474; Anamur, around the town, 05.06.1950, *A. Attila* s.n.

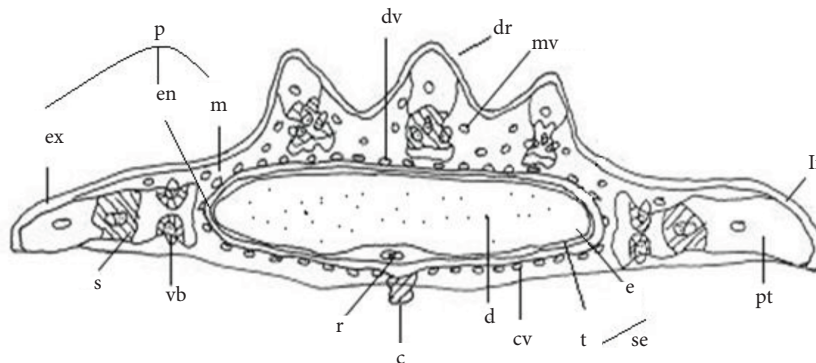
Mediterranean element, Cyprus.

**Conservation Status:** EN in Turkey

This species is related to *Ferulago galbanifera*. Some specimens that were indicated in the discussion part of *F. galbanifera* in *Flora of Turkey* (Peşmen, 1972) were identified as *F. cypria* by Peşmen in his unpublished postdoctoral thesis. Bernardi (1979) stated that this species was synonym of *F. syriaca*, but it is clearly different.

#### 3.1. Macromorphological and micromorphological characteristics of the *Ferulago* fruits

The fruits of *Ferulago* have 2 homomorphic mericarps that are strongly compressed dorsally and elliptical. Each mericarp has 3 dorsal and 2 lateral, at total 5 ribs, varying in width and length among species. Epidermal surface scabrous or glabrous. Vittae are 2 types in fruit. In the first type, they are present near the endocarp regularly, and at the surface of the seed-like cycle (circular vittae). In the second type, they spread in the mesocarp. Mericarp structure showing the terminology of genus *Ferulago* is given in Figure 1.



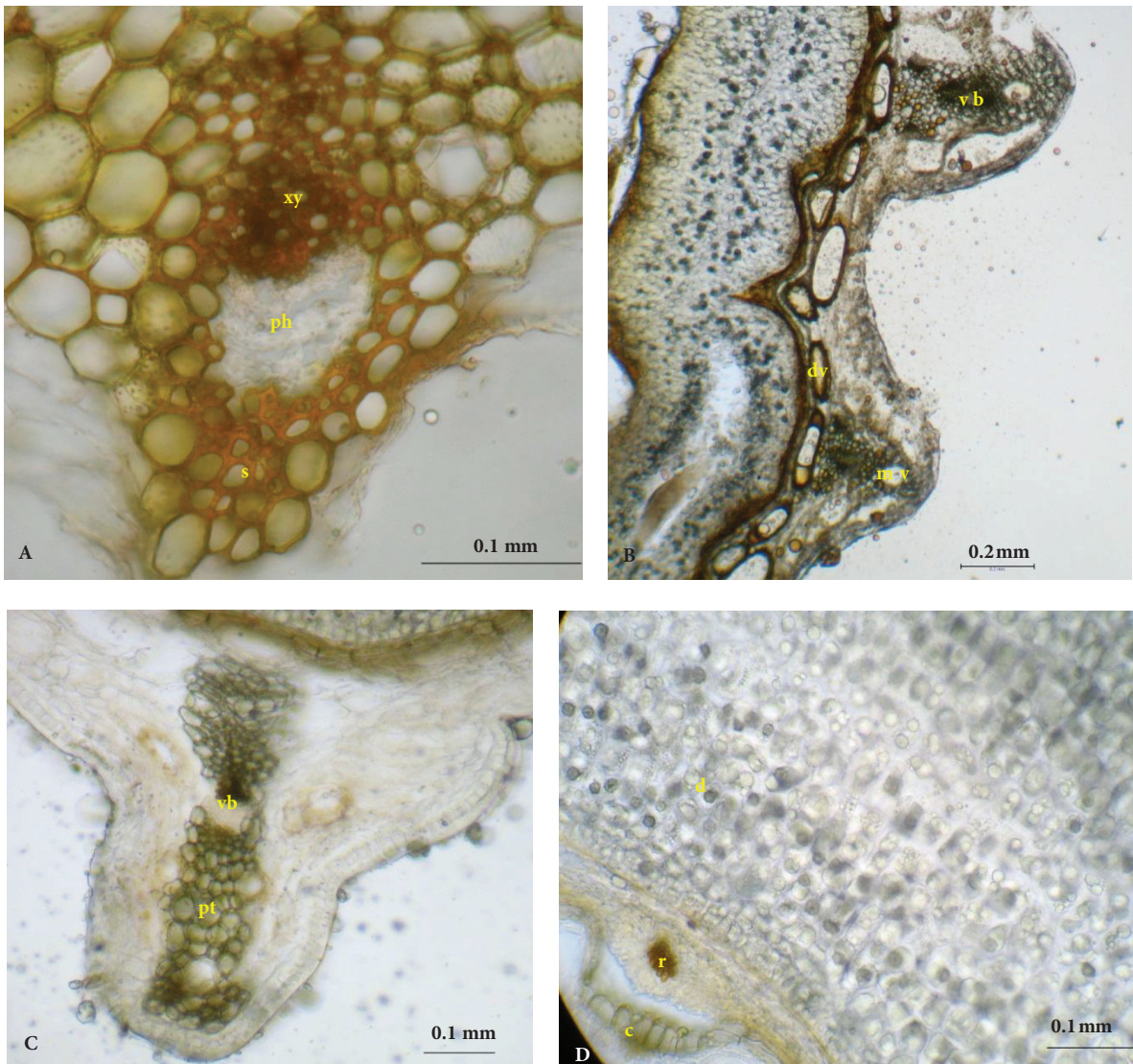
**Figure 1.** Mericarp structure showing the terminology of genus *Ferulago*. c- carpopore, cv- commissural vittae, d- druse, dr- dorsal rib, dv- dorsal vittae, en- endocarp, e- endosperm, ex- exocarp, Ir- lateral rib, m- mesocarp, mv- vittae distributed in mesocarp, p- pericarp, pt- thin-walled and nonlignified parenchymatic tissue, r- raphe, s- sclerenchyma, se- seed, t- testa, vb- vascular bundles.



### 3.1.1 Pericarp

**Exocarp:** Cuticula is usually thin and smooth, exocarp consists of single line, thick-walled and isodiametric cells. Exocarp continues towards the commissural area of 2 mericarps. Stoma can be seen rarely. **Mesocarp:** Composed of big, thin-walled, and thickened above irregular parenchymatic cells. Small, 3 or 5 collateral vascular bundles are present in mid-bottom of dorsal and lateral ribs (Figures 2A and 2B). Trachea and tracheids are not distinguished from each other in xylem. They are formed in a group of 2–4 in dorsal and lateral ribs. Sclerenchymatic tissue covers vascular bundles regularly or is only present in upper and lower parts of the bundles. Thin-walled and

nonlignified parenchymatic tissue is present especially in dorsal and lateral ribs (Figure 2C), sometimes covering whole vascular bundles and sclerenchyma, rarely only 1 to 2 lines below and more lines above of them. This parenchymatic tissue can continue towards the edge of rib, or clipped after 1 to 2 lines. Two types of vittae are present in the mesocarp. In the first type, they are circular, regularly arranged, and present near endocarp, which we call dorsal and commissural vittae. In the second type, they are spread in the mesocarp irregularly and are especially more dense around vascular bundles. Both types of vittae are similar in shape (covered with small secretion cells) before forming secretion in young fruit. As fruit matures, the 2



**Figure 2.** A- Vascular bundles (xy- xylem, ph- phloem, other abbreviations as in Figure 1) in *Ferulago longistylis*, B- vascular bundles in dorsal ribs and dorsal vittae of *F. asparagifolia*, C- thin-walled and nonlignified parenchymatic tissue in dorsal ridge of *F. platycarpa*, D- druse crystals in *F. platycarpa*.

types of vittae differ from each other. Small secretion cells fragment in circularly arranged vittae and walls become lignified, although they preserve parenchymatic properties in vittae that are spreading in the mesocarp irregularly. One vitta of this type is usually present in thin-walled and nonlignified parenchymatic tissue of each of the ribs. The other smaller ones are present close to vascular bundles and inside the parenchymatic cells. **Endocarp:** Composed of single line, narrow-long and thin-walled cells. Endoderm cells are shortened between raphe (connecting seed to pericarp) and carpophore (connecting 2 mericarps to each other). Cell walls are lignified and sometimes it is possible to see them in 2–5 lines. Outside of this part, a little sclerenchymatic tissue is present.

### 3.1.2 Seed

Seeds are composed of a thick-walled testa and endosperm. Endosperm contains plenty of oil and protein. Druse crystals are usually present in endosperm (Figure 2D). Embryo is distally and small. Embryo cannot be seen in transverse sections taken from the middle of the mericarps. In the transverse section of carpophore, dense and highly thick-walled sclerenchymatic tissue is present.

An identification key was made based on the anatomical properties of the mericarps, and all anatomical characters of *Ferulago* fruits are given in Tables 2 and 3. The shapes of transverse sections of each mericarp were drawn schematically. The schematic drawings of 27 *Ferulago* species' mericarps are given in Figures 3–6.

**Table 2.** The general anatomical characters of *Ferulago* fruits.

Species	General appearance		Ratio of mericarp width to its length	Relative size of vascular bundles (Vb) and dorsal vittae (Dv)
	Dorsal ribs	Lateral ribs		
<i>F. confusa</i>	longer than seed, wavy	long, wavy	0.24	Dv equal to Vb or rarely larger
<i>F. mughlae</i>	longer than seed, broad	long, broad	0.33	Dv larger than Vb
<i>F. syriaca</i>	more than 2 times seed, broad, walls are thickened	long, broad, walls are thickened	0.32	Dv larger than Vb
<i>F. cypria</i>	longer than seed, distinct	2/3 of seed	0.35	Dv equal to Vb
<i>F. trojana</i>	longer than seed, narrow	longer than seed, narrow	0.18	Dv equal to Vb
<i>F. silaifolia</i>	longer than seed, narrow	longer than seed, narrow	0.36	Dv equal to Vb
<i>F. galbanifera</i>	shorter than seed	long	0.21	Dv equal to Vb
<i>F. trachycarpa</i>	shorter than seed	long	0.23	Dv larger than or rarely equal to Vb
<i>F. antiochia</i>	shorter than seed, broad	app. 1/2 of seed*	0.33	Dv larger than Vb
<i>F. pachyloba</i>	shorter than seed, narrow	2/3 of seed, wavy	0.33	Dv larger than Vb
<i>F. platycarpa</i>	shorter than or equal to seed	app. 1/2 of seed	0.23	Dv equal to Vb
<i>F. amani</i>	shorter than seed	1/2 of seed, smooth	0.22	Dv larger than or rarely equal to Vb
<i>F. setifolia</i>	shorter than seed	app. 1/3 of seed, smooth	0.18	Dv equal to or larger than Vb
<i>F. thirkeana</i>	shorter than seed	long, wavy	0.22	Dv larger than Vb
<i>F. blancheana</i>	slightly prominent, broad	shorter than 1/2 of seed	0.28	Dv larger than or rarely equal to Vb
<i>F. longistylis</i>	slightly prominent, broad	app. 1/2 of seed	0.35	Dv equal to Vb
<i>F. cassia</i>	slightly prominent	shorter than 1/2 of seed	0.18	Dv equal to or rarely larger than Vb
<i>F. glareosa</i>	slightly prominent, broad	app. 1/4 of seed	0.32	Dv equal to Vb
<i>F. aucheri</i>	slightly prominent	short	0.19	Dv equal to or rarely larger than Vb
<i>F. asparagifolia</i>	slightly prominent, narrow	app. 1/4 of seed	0.18	Dv larger than Vb
<i>F. macrosciadia</i>	slightly prominent, narrow	app. 1/2 of seed	0.17	Dv equal to Vb
<i>F. humilis</i>	slightly prominent	longer than 1/2 of seed	0.17	Dv equal to Vb
<i>F. idaea</i>	slightly prominent	app. longer than 1/2 of seed	0.21	Dv equal to Vb
<i>F. pauciradiata</i>	smooth	app. 1/3 of seed	0.23	Dv equal to Vb
<i>F. bracteata</i>	smooth	app. 1/3 of seed, distinct	0.27	Dv larger than Vb
<i>F. isaurica</i>	smooth	app. 1/3 of seed, not distinct	0.24	Dv larger than or rarely equal to Vb
<i>F. sandrasica</i>	smooth	short	0.25	Dv equal to or larger than Vb

\* app.: approximately.

**Table 3.** The pericarp and seed characters of *Ferulago* fruits.

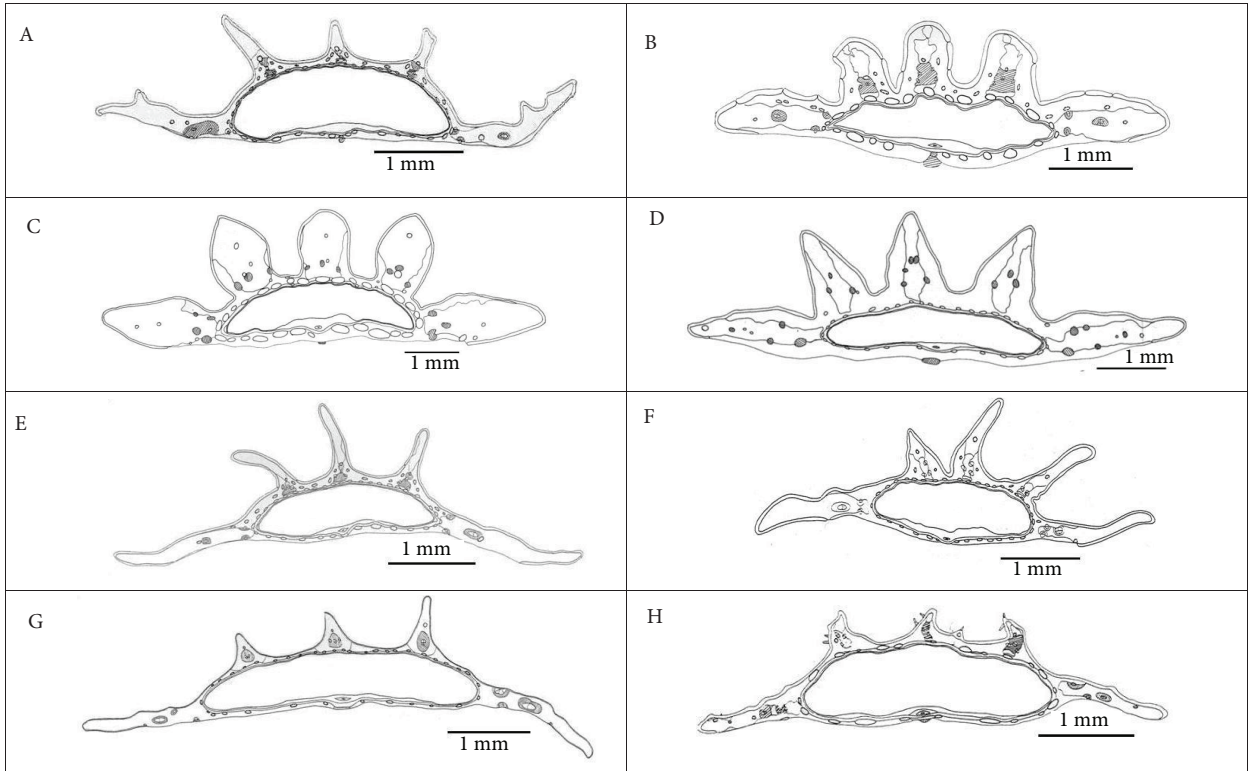
Species	Exocarp	Mesocarp		Endocarp	Seed
		Number of vittae*	Typical characters		
<i>F. confusa</i>	cuticula thin and smooth, epidermis cells are thickened above	A = (17-)19–23(-29) B = (10-)13–15(-18) C = (15-)25–30(-43)	-	endoderm cells are 2–3 lines above carpophore	general characters
<i>F. mughlae</i>	cuticula thin and smooth, epidermis cells are thickened above, starch present	A = (14-)16–19 B = 12–15(-17) C = (20-)24–27(-32)	-	general characters	general characters
<i>F. syriaca</i>	cuticula thin and smooth, epidermis cells are thickened above and below	A = (18-)20–22 B = 10–12 C = 15–19(-20)	-	general characters	general characters
<i>F. cypria</i>	cuticula thick, epidermis cells with thin walls	A = 18–20(-24) B = (9-)11–12 C = (10-)11–14	-	general characters	general characters
<i>F. trojana</i>	cuticula thin and smooth, epidermis cells are thickened above	A = (18-)21–24(-29) B = (10-)11–12(-17) C = (13-)17–26(-27)	-	general characters	general characters
<i>F. silaifolia</i>	cuticula thin and smooth, epidermis cells are thickened above	A = (17-)20–23(-25) B = (12-)13–14(-17) C = 6–12	-	general characters	general characters
<i>F. galbanifera</i>	cuticula app. 1/3 of epidermis	A = (15-)22–23(-33) B = (10-)11–13(-16) C = 5–7	thin-walled parenchyma fragmented	endoderm cells are 3–5 lines and narrowed above carpophore	general characters
<i>F. trachycarpa</i>	cuticula app. 1/5 of epidermis and wavy, single-celled hair is present, starch is present	A = (10-)14–15 B = 6–7(-9) C = 5–8	thin-walled parenchyma fragmented	endoderm cells are 3–5 lines above carpophore and shortened	druse crystals do not exist in endosperm
<i>F. antiochia</i>	cuticula thin and smooth	A = 12–13 B = 7–8(-9) C = 40–43(-45)	thin-walled and nonlignified parenchymatic tissue poor in dorsal ribs	general characters	general characters
<i>F. pachyloba</i>	cuticula thin and smooth	A = (10-)12–14 B = (4-)6–8 C = (30-)36–40	starch is dense under the epidermis; thin-walled and nonlignified parenchymatic tissue poor in dorsal ribs	general characters	general characters
<i>F. platycarpa</i>	cuticula thin and smooth	A = (14-)15–21(-32) B = 10–11(-17) C = 25–35(-36)	thin-walled and nonlignified parenchymatic tissue distinct in dorsal and lateral ribs	general characters	general characters
<i>F. amani</i>	cuticula smooth	A = 21–23(-30) B = 11–15 C = 28–38(-42)	thin-walled and nonlignified parenchymatic tissue distinct in dorsal ribs	general characters	general characters
<i>F. setifolia</i>	cuticula thin and smooth	A = 11–12(-14) B = 9–10(-12) C = 8–10	thin-walled and nonlignified parenchymatic tissue distinct in dorsal and lateral ribs	general characters	general characters
<i>F. thirkeana</i>	cuticula thin and smooth, epidermis cells are thickened above 2 times more than below	A = (15-)17–20(-21) B = (8-)10–14(-17) C = (8-)16–34(-43)	thin-walled and nonlignified parenchymatic tissue ends towards terminal of the dorsal ribs	general characters	general characters

Table 3. (Continued).

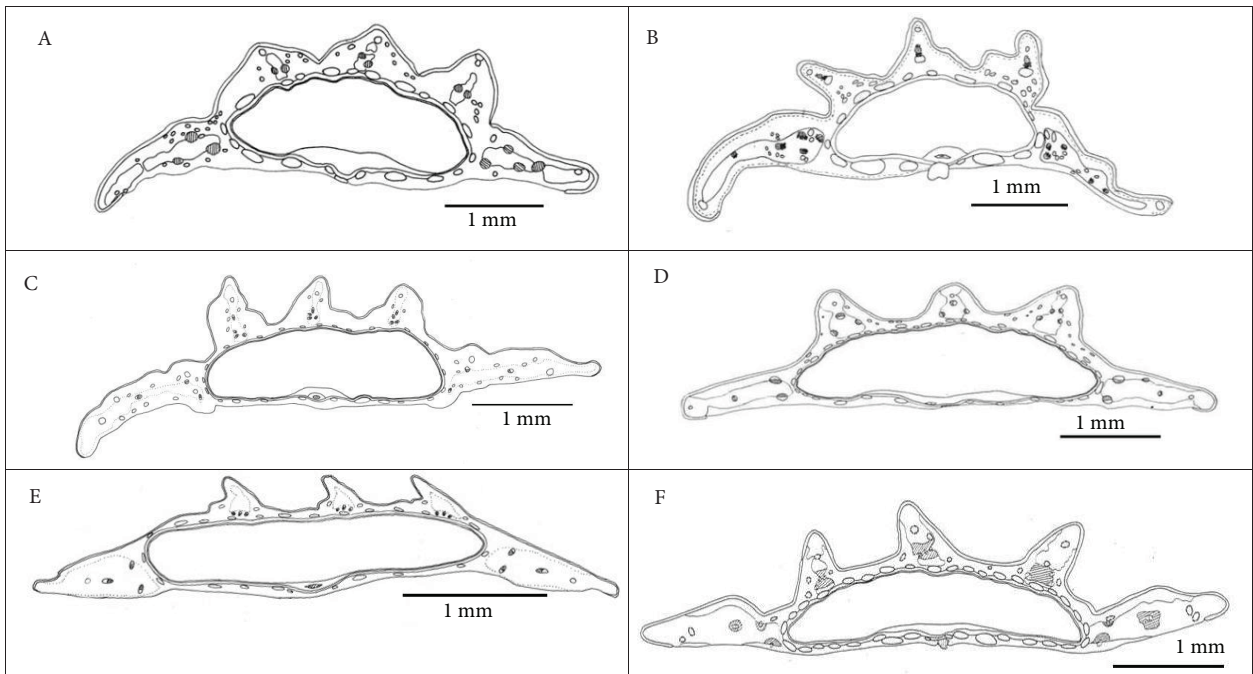
<i>F. blancheana</i>	cuticula thin and smooth	A = 8-10(-12) B = 4-7(-8) C = 10-12(-20)	starch is dense under the epidermis; thin-walled and nonlignified parenchymatic tissue poor in dorsal ribs	general characters	general characters
<i>F. longistylis</i>	cuticula thin and smooth	A = (10-)11-13 B = 9-10 C = 43-45(-47)	thin-walled and nonlignified parenchymatic tissue distinct in dorsal and lateral ribs	general characters	general characters
<i>F. cassia</i>	cuticula smooth	A = 20-27(-28) B = (18-)21-24 C = (55-)56-60	thin-walled and nonlignified parenchymatic tissue distinct in dorsal ribs	general characters	general characters
<i>F. glareosa</i>	cuticula smooth	A = 18-24 B = 12-14 C = 5-6(-7)	thin-walled and nonlignified parenchymatic tissue poor in dorsal and lateral ribs	general characters	general characters
<i>F. aucheri</i>	cuticula thin and smooth, epidermis cells are thickened above	A = (12-)14-21(-29) B = (15-)19-22(-29) C = (35-)36-44(-45)	-	general characters	general characters
<i>F. asparagifolia</i>	cuticula thin and smooth, epidermis cells are thickened above 3 times more than other parts	A = 16-21(-23) B = 12-15(-17) C = (53-)74-84(-86)	thin-walled and nonlignified parenchymatic tissue poor in dorsal ribs	general characters	general characters
<i>F. macrosciadia</i>	cuticula thin and smooth, epidermis cells are much thickened above and below	A = (22-)26-28 B = (15-)17-18(-20) C = (17-)20-24(-27)	sclerenchyma dense	general characters	general characters
<i>F. humilis</i>	cuticula thin and smooth, epidermis cells are thickened above and below, lumen narrow	A = (24-)31-36(-40) B = (13-)21-25(-29) C = (9-)20-25(-40)	-	general characters	general characters
<i>F. idaea</i>	cuticula thin and smooth, epidermis cells are thickened more above	A = (20-)22-27(-37) B = (13-)19-21(-24) C = 4-10	-	general characters	general characters
<i>F. pauciradiata</i>	cuticula thin and smooth	A = (20-)22-25 B = 13-16 C = 4-5	thin-walled and nonlignified parenchymatic tissue only below vascular bundles in dorsal ribs	general characters	general characters
<i>F. bracteata</i>	cuticula thin and smooth, epidermis cells are not distinct because of dense starch	A = 10-15 B = (6-)7-8 C = 25-30(-35)	thin-walled and nonlignified parenchymatic tissue poor in dorsal ribs	general characters	general characters
<i>F. isaurica</i>	cuticula thin and smooth, epidermis cells are thickened above	A = (20-)22-32 B = (20-)21-25 C = 97-100(-102)	thin-walled and nonlignified parenchymatic tissue only below vascular bundles in dorsal ribs or none	general characters	general characters
<i>F. sandrasica</i>	cuticula thin and smooth, epidermis cells are thickened above and below, lumen narrow	A = (21-)28-30(-34) B = (19-)20-21(-29) C = (-40)50-64(-96)	-	endoderm cells are 2 lines above carpophore with different lengths (usually width longer than length)	general characters

\*A: number of dorsal vittae, B: number of commissural vittae, C: vittae distributed in mesocarp.



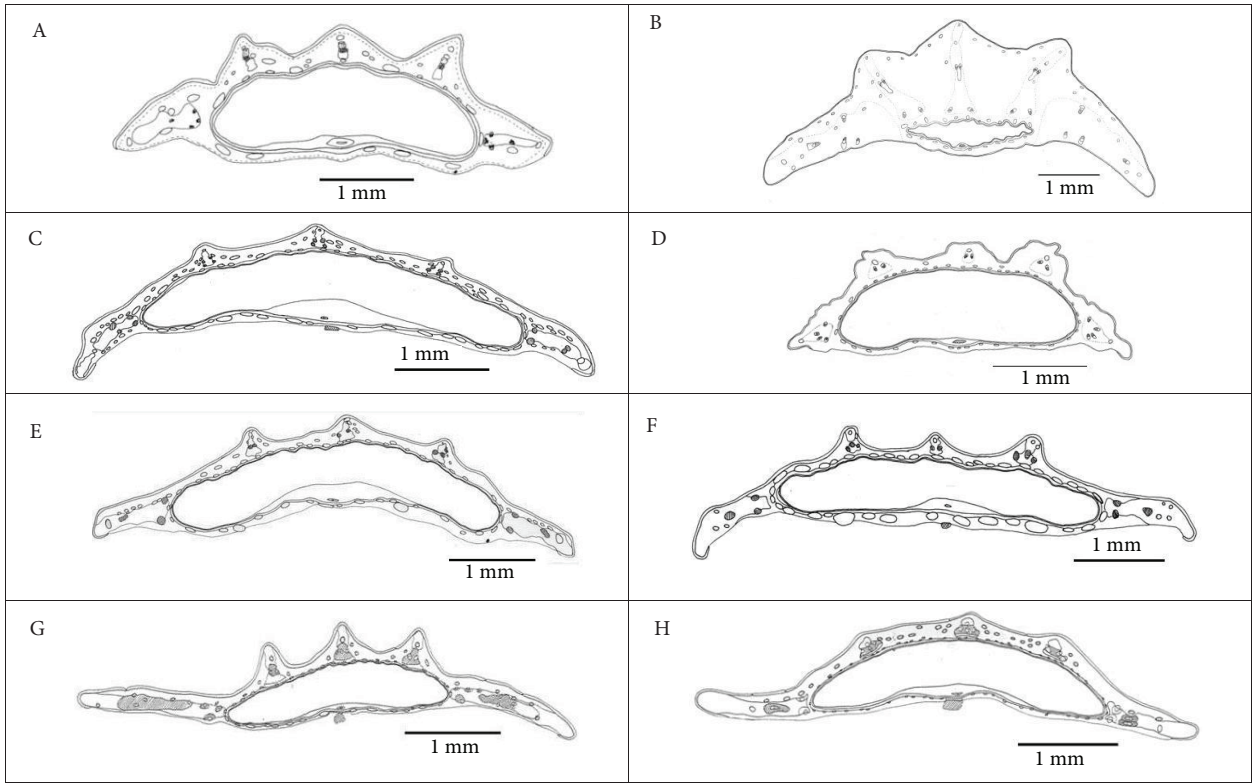


**Figure 3.** The schematic drawings of *Ferulago* species' mericarps (Group 1). A- *Ferulago confusa*, B- *F. mughlae*, C- *F. syriaca*, D- *F. cyprica*, E- *F. trojana*, F- *F. silaifolia*, G- *F. galbanifera*, H- *F. trachycarpa*.

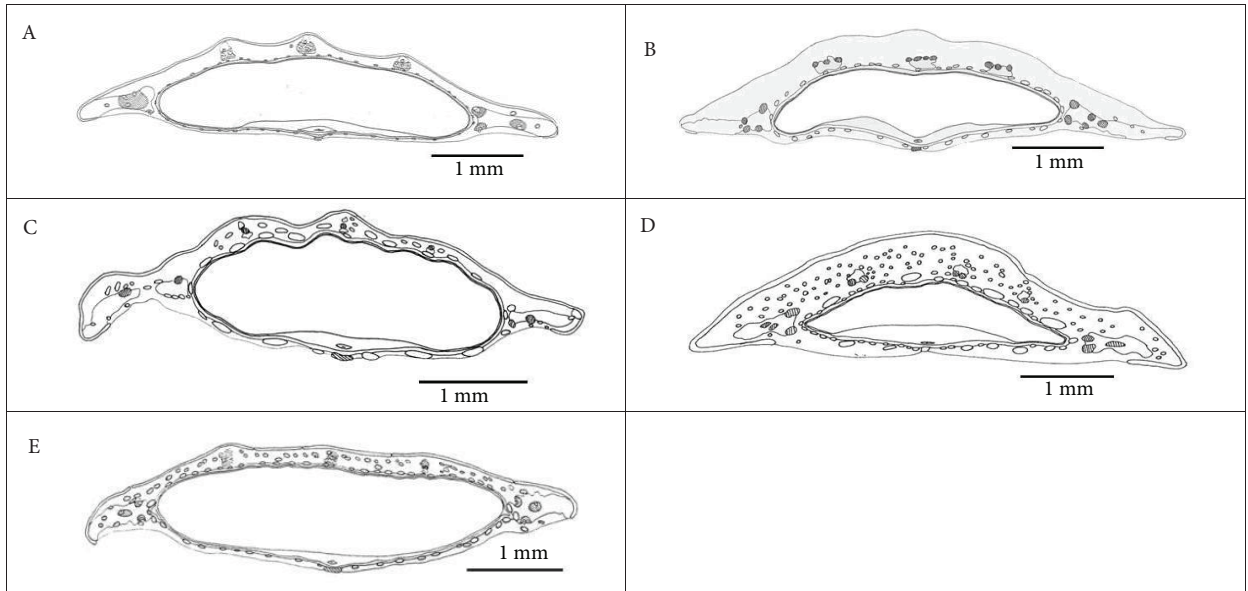


**Figure 4.** The schematic drawings of *Ferulago* species' mericarps (Group 1). A- *Ferulago antiochia*, B- *F. pachyloba*, C- *F. platycarpa*, D- *F. amani*, E- *F. setifolia*, F- *F. thirkeana*.





**Figure 5.** The schematic drawings of *Ferulago* species' mericarps (Group 2). A- *Ferulago blancheana*, B- *F. longistylis*, C- *F. cassia*, D- *F. glareosa*, E- *F. aucheri*, F- *F. asparagifolia*, G- *F. macrosciadia*, H- *F. humilis*.



**Figure 6.** The schematic drawings of *Ferulago* species' mericarps (Group 2). A- *Ferulago idaea*, B- *F. pauciradiata*, C- *F. bracteata*, D- *F. isaurica*, E- *F. sandrasica*.

**Identification key based on the anatomical characteristics of 27 *Ferulago* fruits**

- 1- Dorsal ribs winged
- 2- Dorsal ribs more than 2 times longer than seeds
- 3- Endodermal cells 2-3 lines above carpophore, wings wavy ..... *F. confusa*
- 3- Endodermal cells single line above carpophore, wings smooth
- 4- Dorsal and lateral ribs broad (0.6–1 mm)
- 5- Dorsal vittae larger than vascular bundles
- 6- Starch is present under the epidermis; thin-walled and nonlignified parenchymatic tissue limited in ribs ..... *F. mughlae*
- 6- Starch is absent under the epidermis; thin-walled and nonlignified parenchymatic tissue covers whole wings in ribs ..... *F. syriaca*
- 5- Dorsal vittae equal to vascular bundles ..... *F. cypria*
- 4- Dorsal and lateral ribs narrow (less than 0.5 mm)
- 7- Vittae in mesocarp (13-)17–26(-27) ..... *F. trojana*
- 7- Vittae in mesocarp up to 12 ..... *F. silaifolia*
- 2- Dorsal ribs equal to or shorter than seed
- 8- Epidermis fragmented, cuticula approximately 1/3 of epidermis ..... *F. galbanifera*
- 8- Cuticula approximately 1/5 of epidermis
- 9- Epidermis scabrous, druse crystals absent in endosperm ..... *F. trachycarpa*
- 9- Epidermis glabrous, druse crystals present in endosperm
- 10- Size of circular vittae considerably bigger than vittae distributed in mesocarp
- 11- Circular vittae fewer than 20
- 12- Dorsal ribs broad, lateral ribs 1/2 of seed ..... *F. antiochia*
- 12- Dorsal ribs narrow, lateral ribs 2/3 of seed ..... *F. pachyloba*
- 11- Circular vittae more than 20 ..... *F. platycarpa*
- 10- Size of circular vittae equal to vittae distributed in mesocarp (size of circular vittae not as big as above)
- 13- Lateral ribs smooth
- 14- Vittae in mesocarp more than 10 ..... *F. amani*
- 14- Vittae in mesocarp fewer than 10 ..... *F. setifolia*
- 13- Lateral ribs wavy ..... *F. thirkeana*
- 1- Dorsal ribs slightly prominent or smooth
- 15- Dorsal ribs slightly prominent
- 16- Dorsal ribs broad (0.3–0.8 mm)
- 17- Size of dorsal vittae bigger than vittae distributed in mesocarp (rarely some vittae distributed in mesocarp equal to dorsal vittae in *F. blancheana*)
- 18- Circular vittae fewer than 20 ..... *F. blancheana*
- 18- Circular vittae more than 20 ..... *F. longistylis*
- 17- Size of dorsal vittae equal to vittae distributed in mesocarp
- 19- Vittae in mesocarp many (55 or more) and everywhere ..... *F. cassia*
- 19- Vittae in mesocarp rare (7–45) and usually in lateral and dorsal ribs
- 20- One vitta in lateral and dorsal ribs ..... *F. glareosa*
- 20- More than 4 vittae in lateral and dorsal ribs ..... *aucheri*
- 16- Dorsal ribs narrow (less than or rarely equal to 0.3 mm)
- 21- Lateral ribs 1/4 of seed ..... *F. asparagifolia*
- 21- Lateral ribs 1/2 of seed or longer
- 22- Lateral ribs 1/2 of seed ..... *F. macrosciadia*
- 22- Lateral ribs longer than 1/2 of seed
- 23- Vittae in mesocarp (9-)20–25(-40) ..... *F. humilis*
- 23- Vittae in mesocarp max. 10 ..... *F. idaea*
- 15- Dorsal ribs smooth
- 24- Vittae in mesocarp 4–5 only in lateral ribs ..... *F. pauciradiata*
- 24- Vittae in mesocarp numerous
- 25- Endoderm cells' width same as length and single line
- 26- Lateral ribs distinct, vittae in mesocarp about 30 ..... *F. bracteata*
- 26- Lateral ribs not distinct, vittae in mesocarp about 100 ..... *F. isaurica*
- 25- Endoderm cells' width longer than length ..... *F. sandrasica*

Twenty-seven species of *Ferulago* can be separated first into 2 groups according to their dorsal ribs. The first group has winged dorsal ribs (*F. confusa*, *F. mughlae*, *F. syriaca*, *F. cypria*, *F. trojana*, *F. silaifolia*, *F. galbanifera*, *F. trachycarpa*, *F. antiochia*, *F. pachyloba*, *F. platycarpa*, *F. amani*, *F. setifolia*, and *F. thirkeana*). Among these species, *F. confusa*, *F. mughlae*, *F. syriaca*, *F. cypria*, *F. trojana*, and *F. silaifolia* have dorsal ribs more than 2 times longer than seeds, while the other species, *F. mughlae*, *F. galbanifera*, *F. trachycarpa*, *F. antiochia*, *F. pachyloba*, *F. platycarpa*, *F. amani*, *F. setifolia*, and *F. thirkeana* have dorsal ribs equal to or shorter than seeds. Among all of these 27 species, druse crystals do not exist in the endosperm only in *F. trachycarpa*, and single-celled hairs are present in the exocarp only in *F. trachycarpa*.

The second group has slightly prominent or smooth dorsal ribs (*F. blancheana*, *F. longistylis*, *F. cassia*, *F. glareosa*, *F. aucheri*, *F. asparagifolia*, *F. macrosciadia*, *F. humilis*, *F. idaea*, *F. pauciradiata*, *F. bracteata*, *F. isaurica*, and *F. sandrasica*).

All seeds of the 27 *Ferulago* species show general characters. Endocarp properties are different only in *F. confusa*, *F. galbanifera*, *F. trachycarpa*, and *F. sandrasica*.

The number, shape, and location of vittae in fruits are distinguishing properties in the *Ferulago* species. Dispersed vittae in the mesocarp sometimes may differ between related species *F. pauciradiata* (5–10 vittae) and *F. isaurica* (97–102 vittae).

According to our results, anatomy of the fruits of 27 *Ferulago* species supports the traditional classification system, which was based on morphology (plant height; leaf shape and size; involucre number, size and shape). For example, in the section *Anisotaenia*, the number of vittae around the seed (both dorsal and commissural vittae) is less than in other sections. However, some anatomical properties are different between related species. For example, druse crystals do not exist in the endosperm of *F. trachycarpa* and this causes a difference between

anatomically related species of *F. trachycarpa* and *F. bracteata*.

*F. glareosa* is in section *Anisotaenia*, but it distinctly differs from other species in the same section. *F. glareosa* has more vittae around the seed (both dorsal and commissural vittae) and fewer vittae spread in the mesocarp than other species in the same section. *F. glareosa* is markedly different from all known *Ferulago* species because of its slender stems with an absent or poorly developed fibrous collar, according to Kandemir and Hedge (2007). Its numbers of vittae are also very different from the other 5 Turkish species recognised in that section. Our result supports these contradictions. In our opinion, *F. glareosa* must be in another section, differentiated from other *Ferulago* species.

In section *Aucheria*, the number of vittae distributed in the mesocarp is greater than in other sections (Tomkovich & Pimenov, 1987). Only *F. pauciradiata* has 4–5 vittae in the mesocarp in this section.

In section *Humiles*, all species have more dorsal vittae than in other sections. *F. humilis*, *F. macrosciadia*, and *F. idaea* are in the second group, in which dorsal ribs are slightly prominent and narrow. They are related species according to our identification key, like in Tomkovich and Pimenov's classification.

In the family Apiaceae, the classification of genera and generic groupings is largely based on the morphology and anatomy of the fruit. According to our results, anatomy of the fruits of the *Ferulago* species supports the traditional classification system, which was based on morphology. We suggest that advanced studies, such as chemical and molecular research, are also needed to clarify the similarities and differences between the species.

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