

ANATOMICAL STUDIES ON *SCORZONERA* (*ASTERACEAE*) SPECIES, SUBGENERA *PODOSPERMUM* AND *PSEUDOPODOSPERMUM* IN IRAN

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Abstract. The genus *Scorzonera* with approximately 175 species is the largest genus within the Cichorieae tribe. This genus includes 55 species distributed in different parts of Iran, 17 species of which are endemic. Due to morphological similarity, the recognition of species is comparatively difficult, thus the anatomical characters can be taken into consideration. To study anatomical structure, the leaf samples were taken off from herbarium specimens and handmade cross-sections were prepared and stained with methyl green and carmine. Several slides were studied and photographed with light microscope. The results obtained from this research confirm the usefulness of leaf anatomy characters in the identification of most of the species studied. The study of anatomical characters of midrib and lamina of *Podospermum* and *Pseudopodospermum* subgenera confirms classification of the series and subgenera of this genus.

Key words: *Scorzonera*, Asteraceae, Iran, anatomy, leaf

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Introduction

Scorzonera L. (Asteraceae) is the largest genus belonging to the subtribe Scorzonerinae Dumort. of the tribe Cichorieae, and is widespread in the more arid regions of Eurasia and Northern Africa (BREMER 1994; NAZAROVA 1997; MAKBUL 2006; COŞKUNÇELEBI *et al.* 2014). It grows mainly in dry areas throughout the Mediterranean region and Central Asia (RECHINGER 1977).

The first detailed arrangement of the genus *Scorzonera* was given by DE CANDOLLE (1805). According to the system developed by him, *Scorzonera* taxa are perennial herbs and shrubs with simple, entire, rarely pinnatifid leaves, phyllaries always deprived of horns, seeds mainly without or with hollow pedicels (DURAN & HAMZAÖGLU 2004). Then, the genus was revised again by BOISSIER (1875) and LIPSCHITZ (1935, 1939). Among these revisions, the work of LIPSCHITZ (1939) was more comprehensive (MAKBUL *et al.* 2011a).

Currently, *Scorzonera* is represented by 175 species in the world (MABBERLEY 2008), and by 55 species in Iran, 17 of which are endemic (SAFAVI *et al.* 2013).

This genus consists of several closely related species (CHAMBERLAIN 1975). One of the major taxonomic difficulties of the genus is the vast of morphological variation (BREMER 1994) which has not investigated well enough by experts (KOYUNCU *et al.* 2014; MAKBUL *et al.* 2011b). Anatomical characters are quite important in the systematics of *Scorzonera*. Although the classification of *Scorzonera* seems easy, too vast variation of the genus makes the identification hard (MAKBUL *et al.* 2011a, 2011b).

In general, there is little information about the leaf anatomy of this genus. Makbul (2006, 2011a, 2011b) offered anatomical features of some Turkish *Scorzonera*. However there is no comprehensive anatomical study in Iranian *Scorzonera*. Therefore, this research was aimed to study of Iranian *Scorzonera* species belonging

Tab. 1. List of *Scorzonera* species used in this study.

Subgenus	Species	Voucher specimens (TARI)
<i>Podospermum</i> (DC.) Lipsch.	<i>S. lachnostegia</i> (Woronow) Lipsch.	Azərbayjan province: Arasbaran, mount. of S of Kharil, 2000-2500 m, Assadi & Maassoumi 20268
	<i>S. laciniata</i> L.	Azərbayjan province: Tabriz, 9 Km Venyar road to Ahar, 1550 m, Maassoumi, Safavi & Ghahremani 82517
	<i>S. songorica</i> (Kar. & Kir.) Lipsch. & Vassilcz.	Sistan and Baluchestan province: Taftan Mnt., region, Kharestan, 2200 m Mozaffarian 53002
	<i>S. luristanica</i> Rech. f.	Kermanshah province: Tang-e Dalkushiar W. of Kerend, 1450 m, Wendelbo & Assadi 16764
	<i>S. meshhedensis</i> (Rech. f.) Rech. f.	Azərbayjan province: 14 km. W of Khoramdareh, 1560 m, Pabo 2718
	<i>S. armeniaca</i> (Boiss. & Huet) Boiss.	Tehran province: on the road of Qazvin to takestan, 1050 m, Dini & Bazargan 8428
	<i>S. cana</i> (C.A.Mey.) Hoffm.	Kordestan province: just east of bijar, 1920 m, Wendelbo, Assadi & Shirdelpur 12259
	<i>S. meyeri</i> (K.Koch) Lipsch.	Semnan province: ca. 20 km. N W of Shahroud, above Nekarman, Khoh-e Shahvar near the top, 3600-3900 m, Assadi & Mozaffarian 40914
	<i>S. radicata</i> Boiss.	Azərbayjan province: Shahbil. Koh-e Sabalan, 3450 m, Foroughi & Assadi 1 13929
	<i>S. persepolitana</i> Boiss.	Tehran province: 20 km from Saveh, Azgin, 1750 m, Dini & Bazargan 8240
<i>S. kandavanica</i> Rech. f.	Mazandaran province: Siahbisheh, Chalus valley, 2300 m, Foroughi 157	
<i>Pseudopodospermum</i> Lipsch. & Krasch.	<i>S. syriaca</i> Boiss. & C.I. Blanche	Bushehr province: 86 km on road from Genaveh to Dogonbadan, 350 m, Runemark & Mozaffarian 27298
	<i>S. turkeviczii</i> Krasch. & Lipsch.	Kermanshah province: 43 km. N of Kermanshah at right side of the road, above the village Meimoonabad, Parro mount., 1475 m, Fattahi & Lashkarbolooki 339
	<i>S. mucida</i> Rech. f., Aellen & Esfand.	Tehran province: Firuzkuh to Semnan, Torud village Miantange mount, 2300-2700 m, Safavi 80627
	<i>S. leptophylla</i> (DC.) Krasch. & Lipsch.	Kerman province: 59 km to Shahr-e Babak from Sirjan, 1800 m, Assadi & Sardabi 42239
	<i>S. tunicata</i> Rech. f. & Köie	Khorassan province: Birjand, W of Esfezar, village, 2080 m, Massoumi, Safavi & Sohrabi 83350
	<i>S. phaeopappa</i> (Boiss.) Boiss.	Esfahan province: Kashan, between Abyane and Vazvan around Maravand village, 1420 m, Mozaffarian 74412
	<i>S. raddeana</i> C. Winkl.	Azərbayjan province: Tabriz, Arpa, Darroci, ca. 6 Km N of Tabriz, 1681 m, Maassoumi, Safavi & Ghahremani 82498
	<i>S. stenocephala</i> Boiss.	Khorassan province: Torbat-e Heydariyeh to Mashhad, around Robat-e Sefid, 1740 m, Massoumi, Safavi, Sohrabi 83363
<i>S. szovitsii</i> DC.	Azərbayjan province: Urmiyeh, Ghassemlu village, 1500 m, Barri 7707	

to subgenera *Podospermum* (DC.) Lipsch. and *Pseudopodospermum* Lipsch. & Krasch.

Material and methods

In this study, 20 species belonging to 2 subgenera of *Scorzonera* were selected. The species sampled are listed in Tab. 1. Materials were based on the examination of herbarium specimens from the Institute of Forests and Rangelands herbarium (TARI).

For studying anatomical structure of species, the leaf samples were taken off from herbarium specimens and cross-sections of $\frac{1}{3}$ of the middle part of blade were prepared and stained by methyl green and carmine. Appropriate samples were photographed by light photomicroscope.

Results

Results revealed a number of interesting features, which are given in Tabs 2 & 3. It was found that anatomical study might provide useful characters for classifying and distinguishing species in the genus.

According to the Flora of USSR (BOBROV & TZVELEV 1964), members of this genus are set in 6 series. According to morphological features of these series we add some Iranian species to series. *S. lachnostegia* and *S. luristanica* were placed in ser. *Laciniatae*; *S. meshhedensis* was placed in ser. *Armeniaca*; *S. persepolitana* and *S. kandavanica* were placed in ser. *Alpignae*; and *S. mucida*, *S. tunicata*, *S. phaeopappa*, *S. stenocephala* and *S. szovitsii* were placed in ser. *Leptophyllae*. Investigation on anatomical features partially confirmed this division.

Series 1. *Laciniatae* Lipsch. Fl. URSS 29: 717. 1964 (Fig. 1).

Species: *S. lachnostegia*, *S. laciniata*, *S. songorica*, and *S. luristanica* (Fig. 7).

Morphological features: Biennials with well-developed leafy stems. Achenes cylindrical, glabrous.

Anatomical features: In this series the cross sections are V-shaped. Shape of vascular bundles of midrib is entire. The midrib diameter is *ca.* 320 to 560 μm . Xylem thickness is larger

than phloem thickness in all the species except *S. laciniata*. All species have one vascular bundle in midrib and lower collenchyma, however the number of the layers varies among the species.

The lamina thickness is 110-193 μm . Palisade parenchyma of both surfaces consists of 2 layers, sub-straight to crinkle. Spongy parenchyma in middle part of lamina is short and undulate (except of *S. luristanica*).

Series 2. *Armeniaca* Lipsch. Fl. URSS 29: 717. 1964 (Fig. 2).

Species: *S. armeniaca* and *S. meshhedensis* (Fig. 8).

Morphological features: Perennials. Achenes often hairy, dimorphic – outer achenes broadened and winged, while inner ones narrower and wingless.

Anatomical features: In this series the cross sections are U-shaped. Shape of vascular bundles of midrib is entire to obovate. The midrib diameter is *ca.* 675 μm . Xylem thickness is larger than phloem thickness in all species. The number of vascular bundles in midrib is different (1 in *S. armeniaca* and 3 in *S. meshhedensis*); there is also lower collenchyma, but the number of its layers differs between species.

The lamina thickness is 131-260 μm . Palisade parenchyma of both surfaces consists of 2 layers, substraight to crinkle. Spongy parenchyma in middle part of lamina is short and undulate.

Series 3. *Canae* Lipsch. Fl. URSS 29: 718. 1964 (Fig. 3).

Species: *S. cana* (Fig. 9).

Morphological features: Perennials. Growing in foothills and foothill plains. Achenes in lower part truncate and broadened, "bottle-shaped"; outer achenes wider; inner ones narrow, terete.

Anatomical features: In this series the cross sections are V-shaped. Shape of vascular bundle of midrib is ovate. The midrib diameter is *ca.* 145 μm . Xylem thickness is larger than phloem thickness. The species have one vascular bundle in midrib and lower collenchyma is two layered.

The lamina thickness is 358 μm . Palisade parenchyma of lower and upper surfaces consists

Tab. 2. Midrib characteristics of *Scorzonera* species. **Scl** – shape of cross section of the leaves (**em** – embowed; **u** – u-shaped; **v** – v-shaped); **Shm** – shape of midrib (**e** – elliptic; **i** – irregular; **o'** – orbicular to semi elliptic; **t** – triangular); **Sem** – shape of vascular bundles of midrib (**e** – entire; **o** – orbicular; **ob** – obovate; **ov** – ovate); **Mth** – midrib thickness; **Xth** – xylem thickness; **Phth** – phloem thickness; **Ucth** – upper cortex thickness; **Lcth** – lower cortex thickness; **Vbn** – vascular bundle number; **Nlc** – number of layers of lower collenchyma.

Species	Scl	Shm	Sem	Mth (μm)	Xth (μm)	Phth (μm)	Ucth (μm)	Lcth (μm)	Vbn	Nlc
<i>S. lachnostegia</i>	v	e	o	561.29	23.5	11	77.06	106.56	1	2-3
<i>S. laciniata</i>	v	o'	ov	407.86	18.02	27.31	195.67	122.28	1	3
<i>S. songorica</i>	v	e	o	320.53	20.75	10.43	63.57	68.85	1	1
<i>S. luristanica</i>	u	e	o	469.24	33	17.5	114.97	80.68	1	3
<i>S. meshhedensis</i>	u	i	e	697.27	97.61	47.66	105.91	51.82	3	3-4
<i>S. armeniaca</i>	u	i	ob	654.38	31.38	12.8	207.36	149.20	1	2
<i>S. cana</i>	v	e	ov	145.35	32.94	13.26	169.43	76.00	1	1-2
<i>S. meyeri</i>	u	t	ob	732.04	28.15	19.54	427.63	98.53	3	2-3
<i>S. radicata</i>	u	i	ob	274.30	22	17	104.43	63.49	1	1-2
<i>S. persepolitana</i>	v	t	e	989.45	39.46	13.49	848.42	69.71	5	4-5
<i>S. kandavanica</i>	u	i	ob	569.02	39.36	28.03	601.66	199.38	1	2-3
<i>S. syriaca</i>	v	e	ov	309.18	24.12	18	47.04	30.78	1	2-3
<i>S. turkeviczii</i>	em	i	o	569.29	43.82	23.59	180.31	42.41	5	3-5
<i>S. mucida</i>	em	i	ov	665.57	51.82	33.05	211.64	91.02	1	5
<i>S. leptophylla</i>	u	e	ov	1803.1	31.6	36.29	490.16	94.83	1	5-6
<i>S. tunicata</i>	v	e	ov	509.22	89.96	25.87	249.43	54.42	3	3
<i>S. phaeopappa</i>	v	i	ov	884.89	47.20	29.87	566.32	75.48	5	5
<i>S. raddeana</i>	u	t	ov	605.36	38.65	22.54	111.73	78.45	4	6
<i>S. stenocephala</i>	u	i	ov	834.82	44.58	30.6	249.11	58.61	3	4-5
<i>S. szovitsii</i>	em	e	ov	316.81	29.82	16.28	42.18	35.58	3	3

of 2 layers, crinkle. Spongy parenchyma in middle part of lamina is short and undulate.

Series 4. *Alpigenae* Lipsch. Fl. URSS 29: 719. 1964 (Fig. 4).

= Ser. *Alpigenae* Grossh. generis *Podospermi* DC. in Zam. po Sist. i Geogr. Rast. Tbil. 13: 66. 1947.

Species: *S. meyeri*, *S. radicata*, *S. persepolitana*, and *S. kandavanica* (Fig. 10).

Morphological features: Forming tussock. Stem scape-like with few reduced leaves. Leaves predominantly basal. Capitula large, 1.5-2.5 cm long (at flowering). Outer involucre bracts usually comiculate. Achenes slender, cylindrical, glabrous.

Anatomical features: In this series the cross sections are U-shaped. Shape of vascular

bundles of midrib is obovate. The midrib diameter is 274-990 μm . Xylem thickness is larger than phloem thickness. The number of vascular bundles in midrib differs (3 in *S. meyeri* and 1 in *S. radicata*); numbers of the layers of lower collenchyma is different between species.

The lamina thickness is ca. 133 to 277 μm . Palisade parenchyma of lower and upper surfaces consists of 2 layers, substraight to crinkle. Spongy parenchyma in middle part of lamina is irregular.

Series 5. *Molles* Lipsch. Fl. URSS 29: 719. 1964 (Fig. 5).

Species: *S. syriaca* (Fig. 11).

Morphological features: Root tuberous, near soil surface or deeper. Stems are more

Tab. 3. Lamina characteristics of *Scorzonera* species. **St** – stomata type (**1** – hypoaiphistomatic; **2** – epiaiphistomatic); **Lth** – lamina thickness; **Cth** – cuticle thickness; **Hyth** – hypoderm thickness (**0** – absent; **1** – present); **Ueth** – upper epidermis thickness; **Leth** – lower epidermis thickness; **Cth** – cuticle thickness (**ab** – abaxial; **ad** – adaxial); **La** – leaf anatomy (**I** – isobilateral one-layered type of palisade parenchyma; **I2** – isobilateral two-layered type of palisade parenchyma); **Ppln** – number of layers of palisade parenchyma (the numbers from left to right show the number of lower and upper layers correspondingly, and the symbols show the comparison size of layers); **Spln** – number of layers of spongy parenchyma; **Ppcwsh** – palisade parenchyma cell wall shape (**2** – substraight; **3** – crinkle); **Spchs** – spongy parenchyma cell shape (**1** – short and undulate; **2** – irregular).

Species	St	Lth (μm)	Hyth	Ueth (μm)	Leth (μm)	Cth	La	Ppln	Spln	Ppcwsh	Spchs
<i>S. lachnostegia</i>	1	192.69	0	8.28	5.5	ad \geq ab	I	1=1	1	3	1
<i>S. laciniata</i>	1	158.51	0	6.99	6.10	ad \geq ab	I2	2=2	2	3	1
<i>S. songorica</i>	1	109.77	0	5.18	3.21	ad > ab	I2	2=2	2-3	2	1
<i>S. luristanica</i>	1	177	0	6.64	7.08	ab > ad	I2	2+2	2-3	3	2
<i>S. meshhedensis</i>	1	260.91	0	5.5	4.5	ab > ad	I2	2=2	2-3	2	1
<i>S. armeniaca</i>	1	131.57	0	5.42	6.30	ab \geq ad	I2	2>2	2	3	1
<i>S. cana</i>	1	357.94	0	5.09	8.09	ad > ab	I2	2=2	3	2	1
<i>S. meyeri</i>	1	217.54	0	5.20	5.54	ab > ad	I2	2=2	2-3	2	2
<i>S. radicata</i>	1	277.07	0	7	4	ab > ad	I2	2=2	2-3	2	2
<i>S. persepolitana</i>	2	236.25	0	9.35	6.68	ad > ab	I2	2=2	4-5	3	1
<i>S. kandavanica</i>	2	133.01	0	6.18	8.31	ad \geq ab	I2	2>2	3-4	2	2
<i>S. syriaca</i>	2	241.56	0	3.01	5.90	ab > ad	I	1=1	2	3	2
<i>S. turkeviczii</i>	1	220.23	0	8.27	6.37	ab > ad	I	1=1	2-3	3	1
<i>S. mucida</i>	2	316.02	1	4.66	6.04	ad > ab	I2	2=2	2	3	2
<i>S. leptophylla</i>	1	358.97	1	6.30	4.13	ad > ab	I2	2=2	1	2	2
<i>S. tunicata</i>	2	263.89	0	5.29	4.19	ad \geq ab	I2	2=2	1	2	2
<i>S. phaeopappa</i>	2	179.66	0	9.90	11.45	ab \geq ad	I2	2=2	1	2	2
<i>S. raddeana</i>	1	102.16	1	4.26	6.87	ab > ad	I2	2=2	1	2	2
<i>S. stenocephala</i>	1	146	0	7.05	7.24	ab > ad	I2	2=2	1-2	2	1-2
<i>S. szovitsii</i>	2	100.50	0	4.57	6.49	ab \geq ad		2=2	2-3	2	1-2

or less tall, sulcate, and leafy to apex. Ligulate florets yellow.

Anatomical features: In this series shape the cross sections are V-shaped. Shape of vascular bundles of midrib is ovate. The midrib diameter is *ca.* 309 μm . Xylem thickness is larger than phloem thickness. The species has one vascular bundle in midrib and 2-3 layers of lower collenchyma.

The lamina thickness is *ca.* 241 μm . Palisade parenchyma of both surfaces consist of 1 layer, substraight. Spongy parenchyma in middle part of lamina is irregular.

Series 6. *Leptophyllae* Lipsch. Fl. URSS 29: 719. 1964 (Fig. 6).

Species: *S. raddeana*, *S. szovitsii*, *S. mucida*, *S. leptophylla*, *S. turkeviczii*, *S. phaeopappa*, *S. stenocephala* (Fig. 12).

Morphological features: Stems scape-like, short, leafy only in lower part, less often with solitary leaves, never densely leafy. Tubers nut-shaped, oval or fusiform, at the soil surface or deeper. Ligulate florets yellow or red.

Anatomical features: In this series the cross sections are from U-shaped to embow shaped. Shape of vascular bundles of midrib is ovate. The midrib diameter is 316-1803 μm .

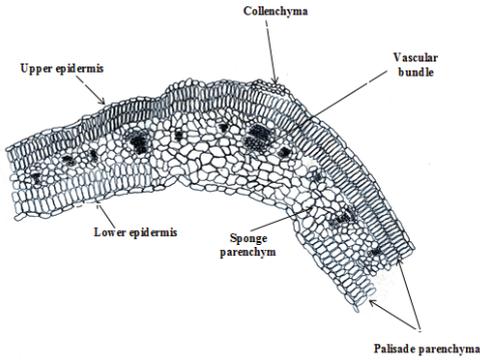


Fig. 1. Leaf transversal sections of series *Laciniatae* (drown from *Scorzonera laciniata*).

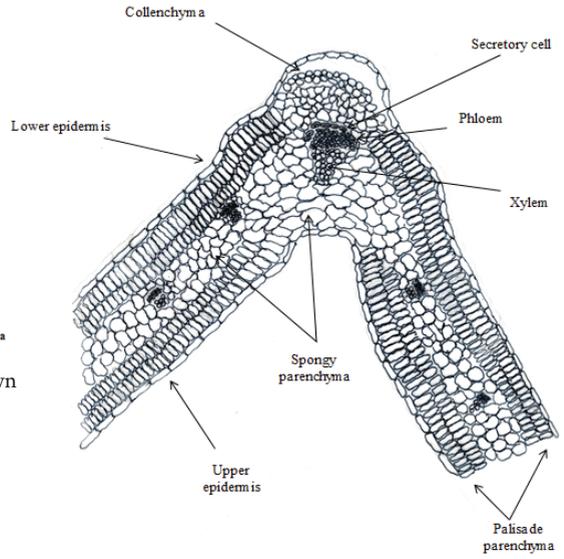


Fig. 3. Leaf transversal sections of series *Canae* (drown from *Scorzonera cana*).

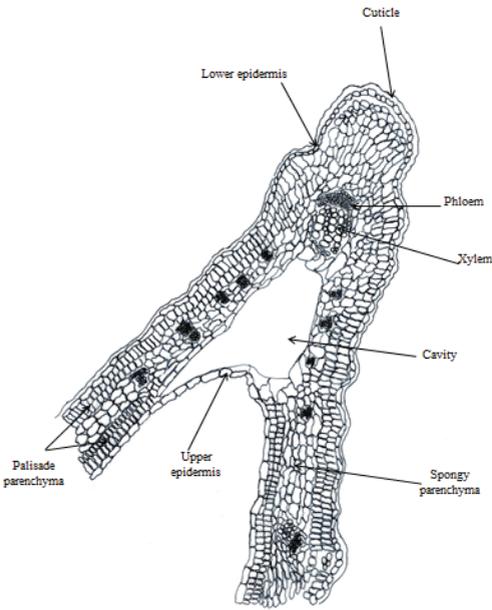


Fig. 2. Leaf transversal sections of series *Armeniacae* (drown from *Scorzonera armeniaca*).

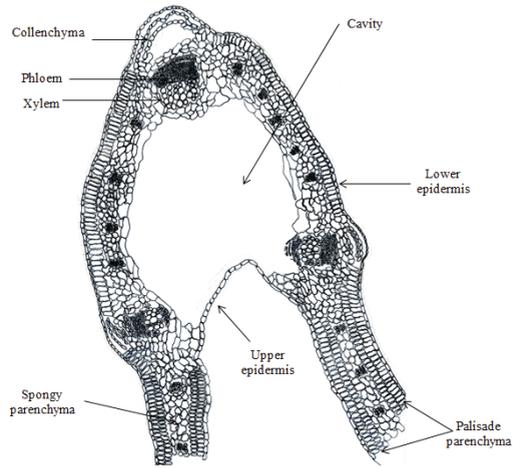


Fig. 4. Leaf transversal sections of series *Alpigenae* (drown from *Scorzonera meyeri*).

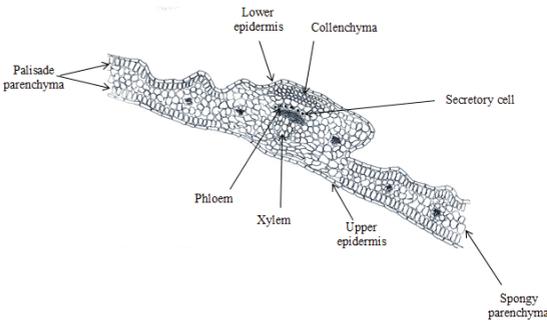


Fig. 5. Leaf transversal sections of series *Molles* (drown from *Scorzonera syriaca*).

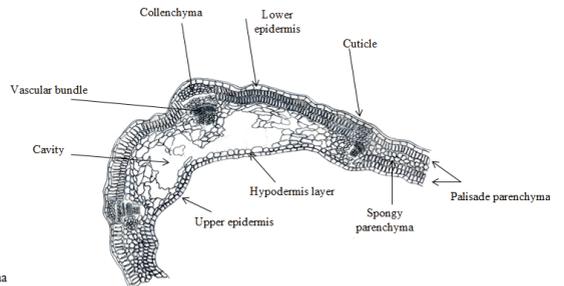


Fig. 6. Leaf transversal sections of series *Leptophyllae* (drown from *Scorzonera mucida*).

Xylem thickness is larger than phloem thickness (except of *S. leptophylla*). The number of vascular bundles in midrib differs from 1 to 5. The lower collenchyma was observed in all taxa of this series but the number of its layers differs from 3 to 6.

The lamina thickness is *ca.* 100-358 μm . Palisade parenchyma of lower and upper surfaces consists of 2 layers; straight, substraight or crinkle. Spongy parenchyma in middle part of lamina is short, from undulate to irregular.

Midrib. The average thickness of midrib was from 274 to 1803 μm . *S. radicata* had the thinnest and *S. leptophylla* had the thickest midribs.

The midrib is inserted in the central part of lamina. It shows some differences among the species, e.g. is singular in *S. lachnostegia*, *S. laciniata*, *S. songorica*, *S. luristanica*, *S. armeniaca*, *S. cana*, *S. meyeri*, *S. radicata*, *S. kandavanica*, *S. syriaca*, *S. mucida*, *S. leptophylla*, but usually consists of three bundles in *S. tunicata*, *S. stecocephala*, *S. szovitsii*, *S. meshhedensis* or five bundles – in *S. turkeviczii*, *S. raddeana*, *S. phaeopappa* and *S. persepolitana*.

The shape of vascular bundle of midrib is different between the two subgenera. In the subgenus *Podospermum* it is from orbicular to obovate, while in the subgenus *Pseudopodospermum* it is mostly obovate.

The distance of the vascular bundle from the lower epidermal layer varies from 30.78 μm in *S. syriaca* to 199.38 μm in *S. kandavanica*. The distance of the vascular bundle from the upper epidermal layer ranges from 42.18 μm in *S. szovitsii* to 848.42 μm in *S. persepolitana*.

The minimal ratio of xylem length was observed in *S. laciniata* (18.02 μm) and the maximal was observed in *S. meshhedensis* (97.61 μm). Phloem length was minimal in *S. songorica* (10.43 μm) and maximal in *S. meshhedensis* (47.66 μm).

The species studied only have lower collenchyma. The number of layers of lower collenchyma ranges from a thinnest (1 layer) in *S. songorica* to a thickest (6 layers) in *S. raddeana* (Tab. 2).

Lamina. The cross section of the leaves in subgenus *Podospermum* varies from V-shaped to U-shaped, and in subgenus *Pseudopodospermum* – mostly from V-shaped to embowed.

Lamina mostly had a regular shape and arrangement. The following layers could be seen from up to down respectively: cuticle layer, upper epidermis, palisade parenchyma, spongy parenchyma, palisade parenchyma, lower epidermis, cuticle layer. There are some exceptions such as the existence of a single lower hypodermis layer (Tab. 3)

The average lamina thickness was from 100 to 358 μm . *S. szovitsii* had the thinnest leaves, and *S. leptophylla* had the thickest.

In the species studied, single epidermal layer was observed. Epidermal cells of lower surface are usually larger than those in the upper surface of leaf lamina. The average thickness of the upper epidermal layer was between 3.01 μm (in *S. syriaca*) and 9.90 μm (in *S. phaeopappa*); and of lower epidermal layer – between 3.21 μm (in *S. songorica*) and 11.45 μm (in *S. phaeopappa*). The shape of epidermal cells on cross sections was mostly rectangular. Cuticle thickness and trichomes density in upper epidermis were more than that of lower epidermis in all of the studied species.

The structure of palisade and spongy mesophylls is important in the genus. Different types of lamina for the species are discussed by DIANE *et al.* (2003). In particular, in bifacial type (B) palisade parenchyma is located only in upper side of lamina, while the rest of the region is filled with spongy parenchyma. Isobilateral one-layered type (I) is characterized by presence of one-layered palisade parenchyma on both sides of lamina. Isobilateral two-layered type (I2) is characterized by 2-layered palisade parenchyma represented on both sides of lamina. Bifacial type was not observed. In most species we have found I2 type of organization of palisade parenchyma. However, in *S. lachnostegia*, *S. syriaca* and *S. turkeviczii* laminas represent I type (Tab. 3).

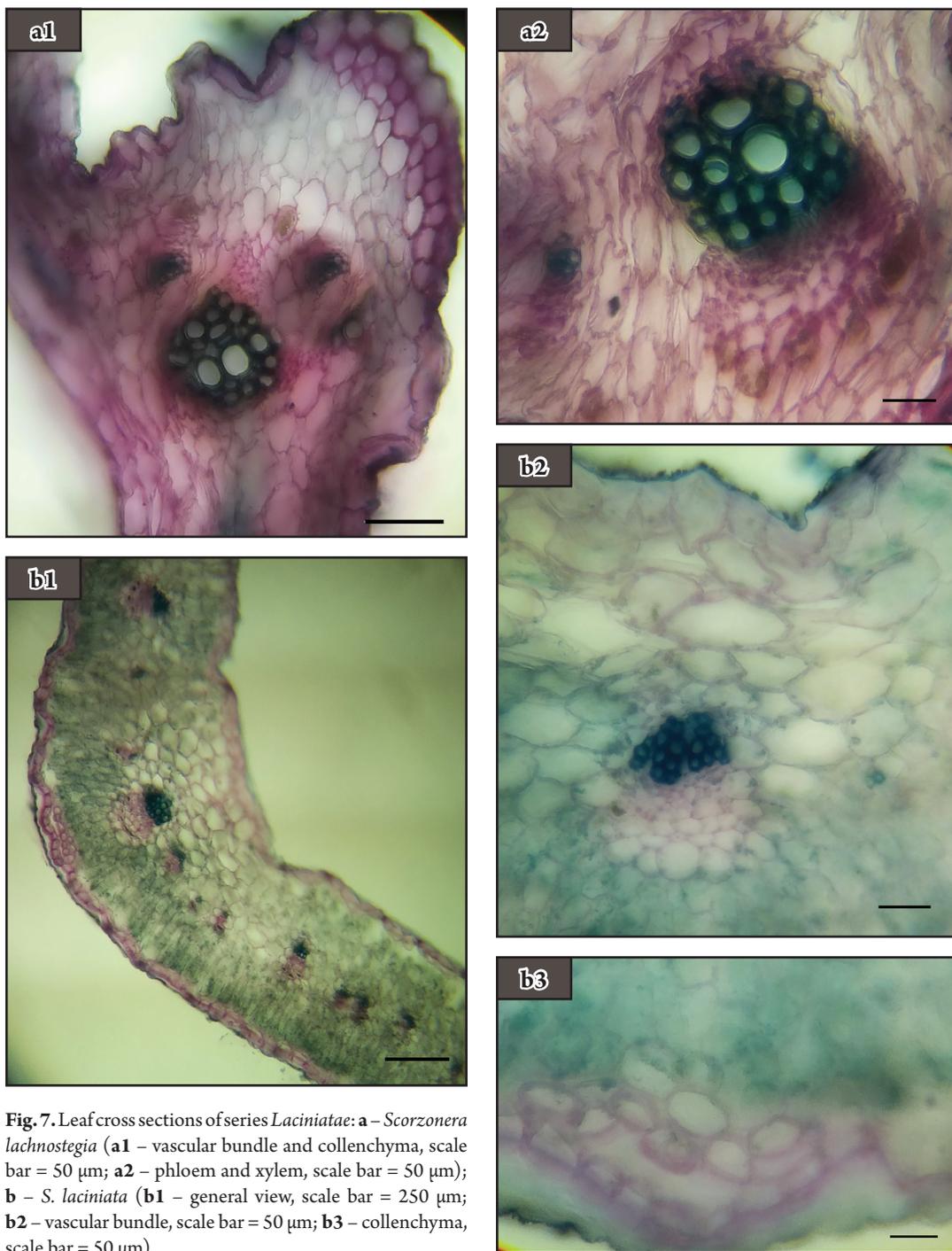


Fig. 7. Leaf cross sections of series *Laciniatae*: **a** – *Scorzonera lachnostegia* (**a1** – vascular bundle and collenchyma, scale bar = 50 μm ; **a2** – phloem and xylem, scale bar = 50 μm); **b** – *S. laciniata* (**b1** – general view, scale bar = 250 μm ; **b2** – vascular bundle, scale bar = 50 μm ; **b3** – collenchyma, scale bar = 50 μm)

Shape of the upper palisade parenchyma cell walls is a significant character too. It is substraight in *S. songorica*, *S. meshhedensis*, *S. cana*, *S. meyeri*, *S. radicata*, *S. kandavanica*, *S. leptophylla*, *S. tunicata*,

S. phaeopappa, *S. raddeana*, *S. stenocephala*, and *S. szovitsii*; and crinkled in *S. lachnostegia*, *S. laciniata*, *S. luristanica*, *S. armeniaca*, *S. persepolitana*, *S. syriaca*, *S. turkeviczii*, and

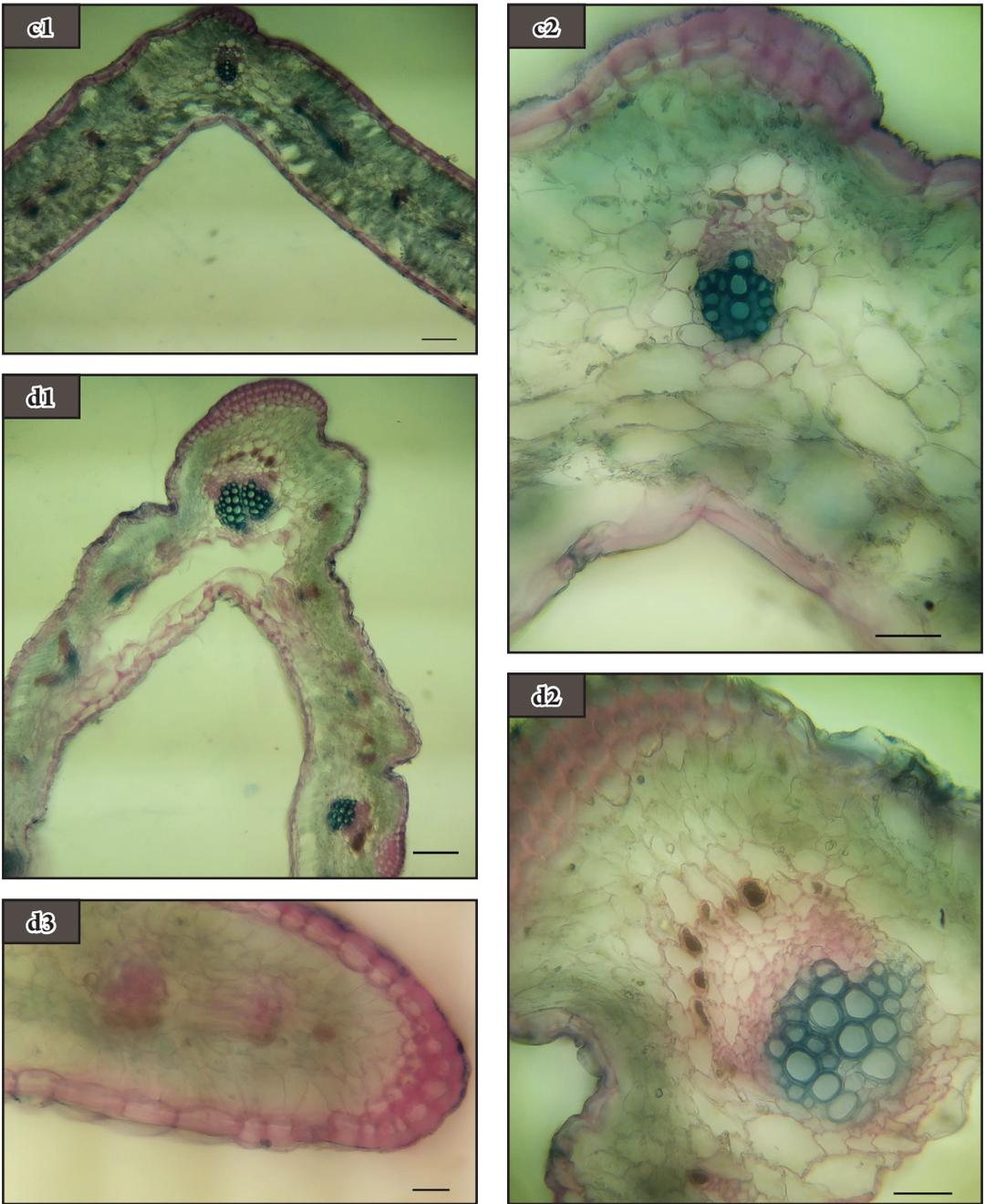


Fig. 7. Continued. Leaf cross sections of series *Laciniatae*: **c** – *Scorzonera songorica* (**c1** – general view, scale bar = 250 μ m; **c2** – midrib, scale bar = 50 μ m); **d** – *S. luristanica* (**d1** – general view, scale bar = 250 μ m; **d2** – midrib, scale bar = 50 μ m; **d3** – lamina fragment, scale bar = 50 μ m).

S. mucida. Spongy parenchyma in most of the species was 2-3-layered with small and irregularly undulated cells, but in *S. persepolitana* it was 4-5-layered with short and undulate cells.

There was sometimes a distinct layer of hypodermis adjacent to the epidermis. The hypodermis composed either of transparent parenchymatous cells or, more rarely, of

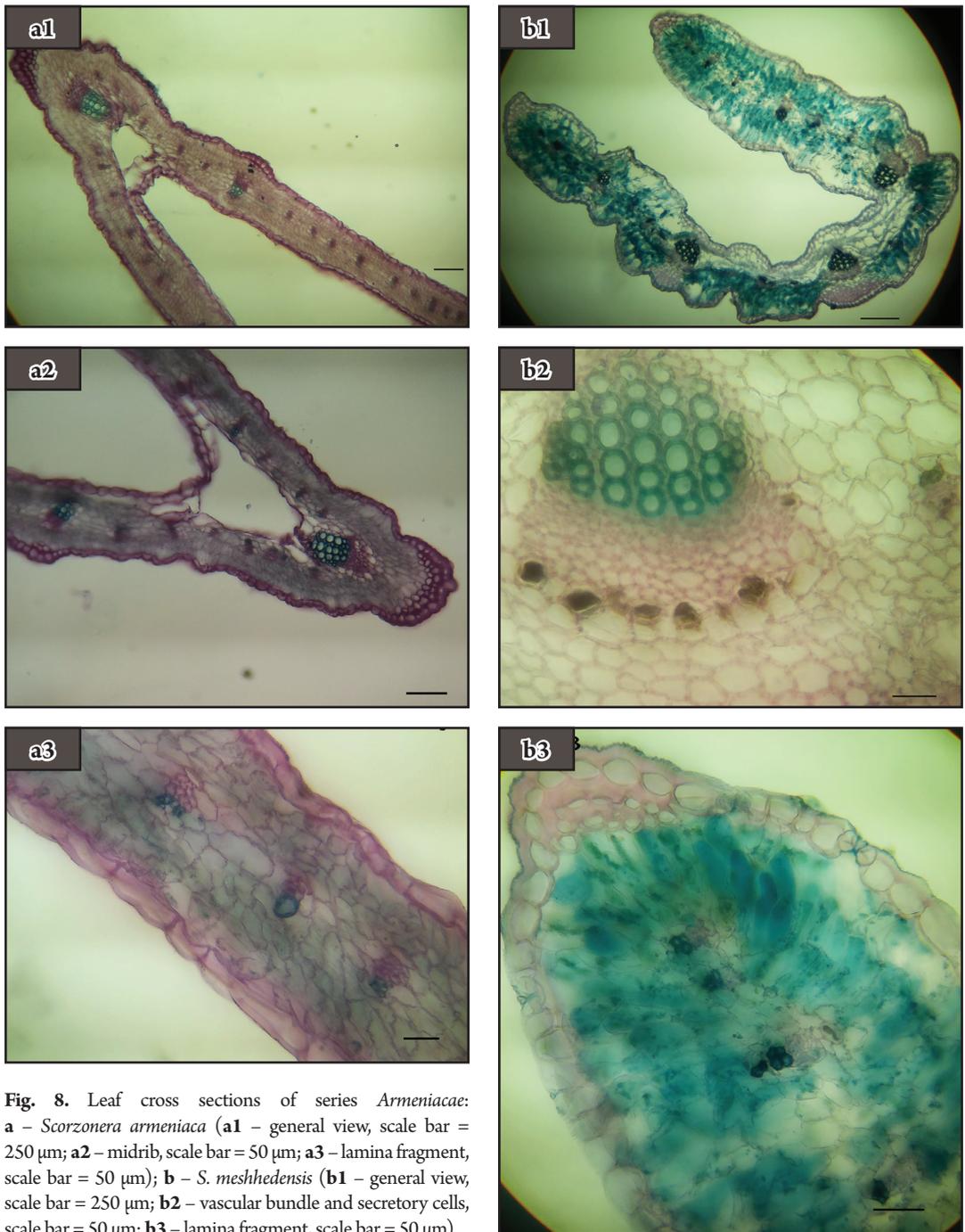


Fig. 8. Leaf cross sections of series *Armeniaceae*: **a** – *Scorzonera armeniaca* (**a1** – general view, scale bar = 250 μm; **a2** – midrib, scale bar = 50 μm; **a3** – lamina fragment, scale bar = 50 μm); **b** – *S. meshhedensis* (**b1** – general view, scale bar = 250 μm; **b2** – vascular bundle and secretory cells, scale bar = 50 μm; **b3** – lamina fragment, scale bar = 50 μm).

fibrous cells (METCALFE & CHALK 1957). Hypodermis was found within the lower epidermis in *S. mucida*, *S. leptophylla*, and *S. raddeana*.

Discussion and conclusions

Anatomical characters have a systematic value in many plants (LERSTEN & CURTIS

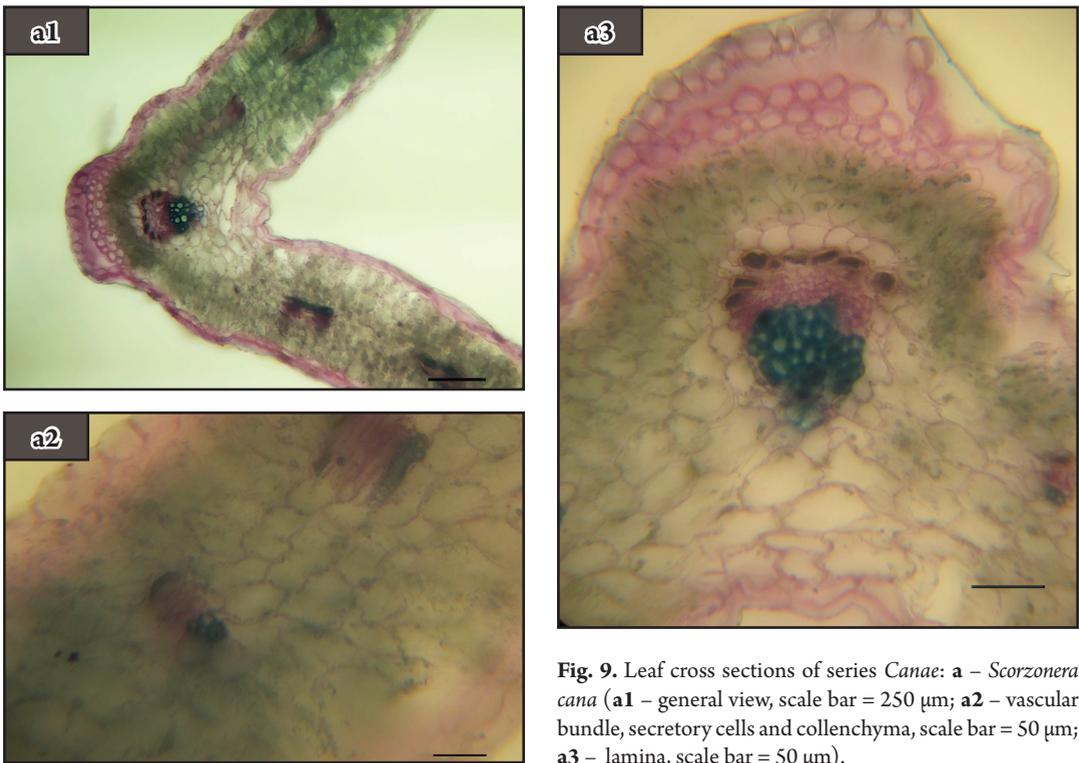


Fig. 9. Leaf cross sections of series *Canae*: **a** – *Scorzonera cana* (**a1** – general view, scale bar = 250 µm; **a2** – vascular bundle, secretory cells and collenchyma, scale bar = 50 µm; **a3** – lamina, scale bar = 50 µm).

2001), e.g. *Epilobium* L. (MAKBUL *et al.* 2008) and *Scrophularia* L. (Makbul *et al.* 2006; LERSTEN & CURTIS 2001; COŞKUNÇELEBI *et al.* 2012), and may also supply sufficient useful information in *Scorzonera* (MAKBUL *et al.* 2011a, 2011b). As indicated in the above literatures, the presence and distribution of hypodermis, main bundles, collenchyma, mesophyll, as well as surface features are particularly important in the taxa examined. Leaf characters among the morphological traits are generally considered as most important in the delimitation of *Scorzonera* species (MAKBUL 2006). According to MAKBUL (2006) leaf margin shapes vary among the taxa. CHAMBERLAIN (1975) also reported that the width of leaf lamina, type of pubescence, margin shape, as well as basal and upper leaf features are the most important phenetic characters in the genus *Scorzonera* (MAKBUL *et al.* 2011a). MAKBUL (2006) also indicated that anatomical properties of root, stem and achenes can also be used in conjunction with morphological ones in *Scorzonera* (MAKBUL *et al.* 2011a). In the

present study, it was found that foliar phenetic differences are generally in accordance with foliar anatomical peculiarities. MAKBUL *et al.* (2011a, 2011b) stressed that the distribution of the fibres in Turkish *Scorzonera* is taxonomically important. Surprisingly, however, fibers were not observed in any of studied Iranian *Scorzonera*.

BOBROV & TZVELEV (1964) in flora of USSR suggested 6 series for species of subgenera *Podospermum* and *Pseudopodospermum*. Our results showed that the anatomical characters are useful in determination of series and subgenera of the genus *Scorzonera* because species belonging to each series and subgenus show similar features.

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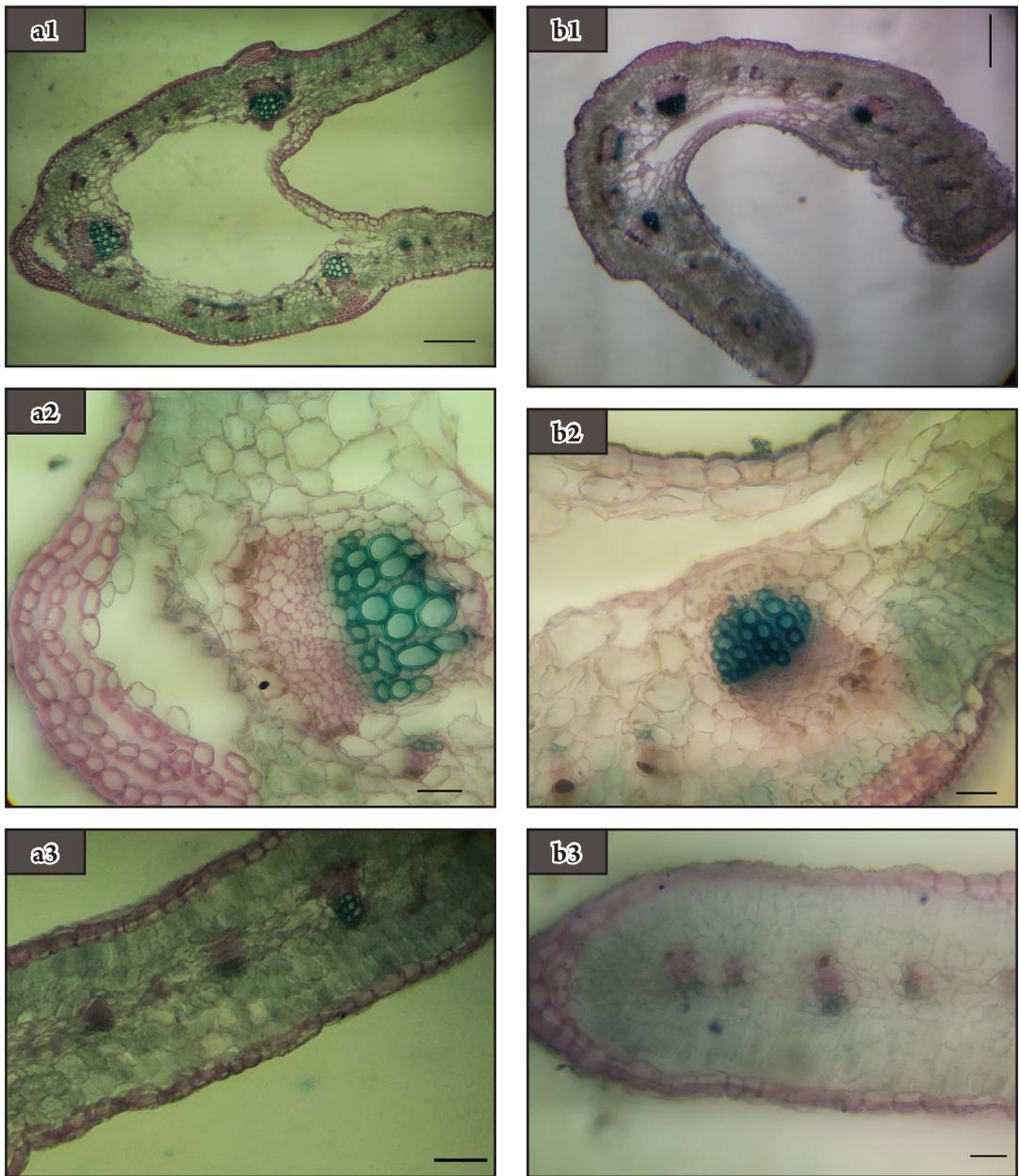


Fig. 10. Leaf cross sections of series *Alpiginae*: **a** – *Scorzonera meyeri* (**a1** – vascular bundles and central cavity, scale bar = 250 μm; **a2** – collenchyma, phloem and xylem, scale bar = 50 μm; **a3** – lamina fragment, scale bar = 50 μm); **b** – *S. radicata* (**b1** – vascular bundles and central cavity, scale bar = 250 μm; **b2** – collenchyma, phloem and xylem, scale bar = 50 μm; **b3** – lamina fragment, scale bar = 50 μm).

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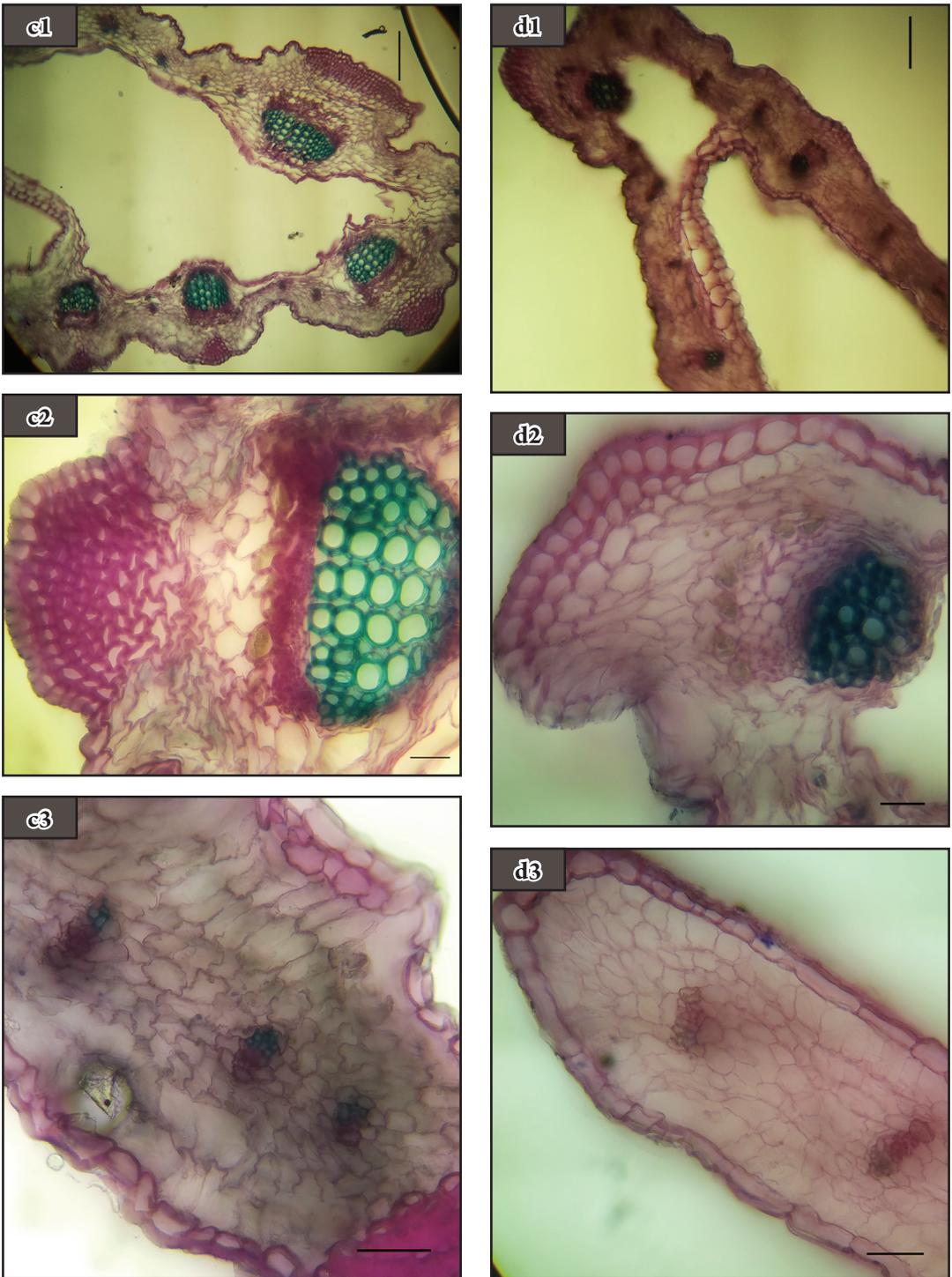


Fig. 10. Continued. Leaf cross sections of series *Alpignae*: **c** – *Scorzonera persepolitana* (**c1** – vascular bundles and central cavity, scale bar = 250 μm; **c2** – collenchyma, phloem and xylem, scale bar = 50 μm; **c3** – lamina, scale bar = 50 μm); **d** – *S. kandavanica* (**d1** – vascular bundles and central cavity, scale bar = 250 μm; **d2** – collenchyma, phloem and xylem, scale bar = 50 μm; **d3** – lamina fragment, scale bar = 50 μm).



Fig. 11. Leaf cross sections of series *Molles*: **a** – *Scorzonera syriaca* (**a1** – general view, scale bar = 250 μ m; **a2** – collenchyma, secretory cells, phloem and xylem, scale bar = 50 μ m).

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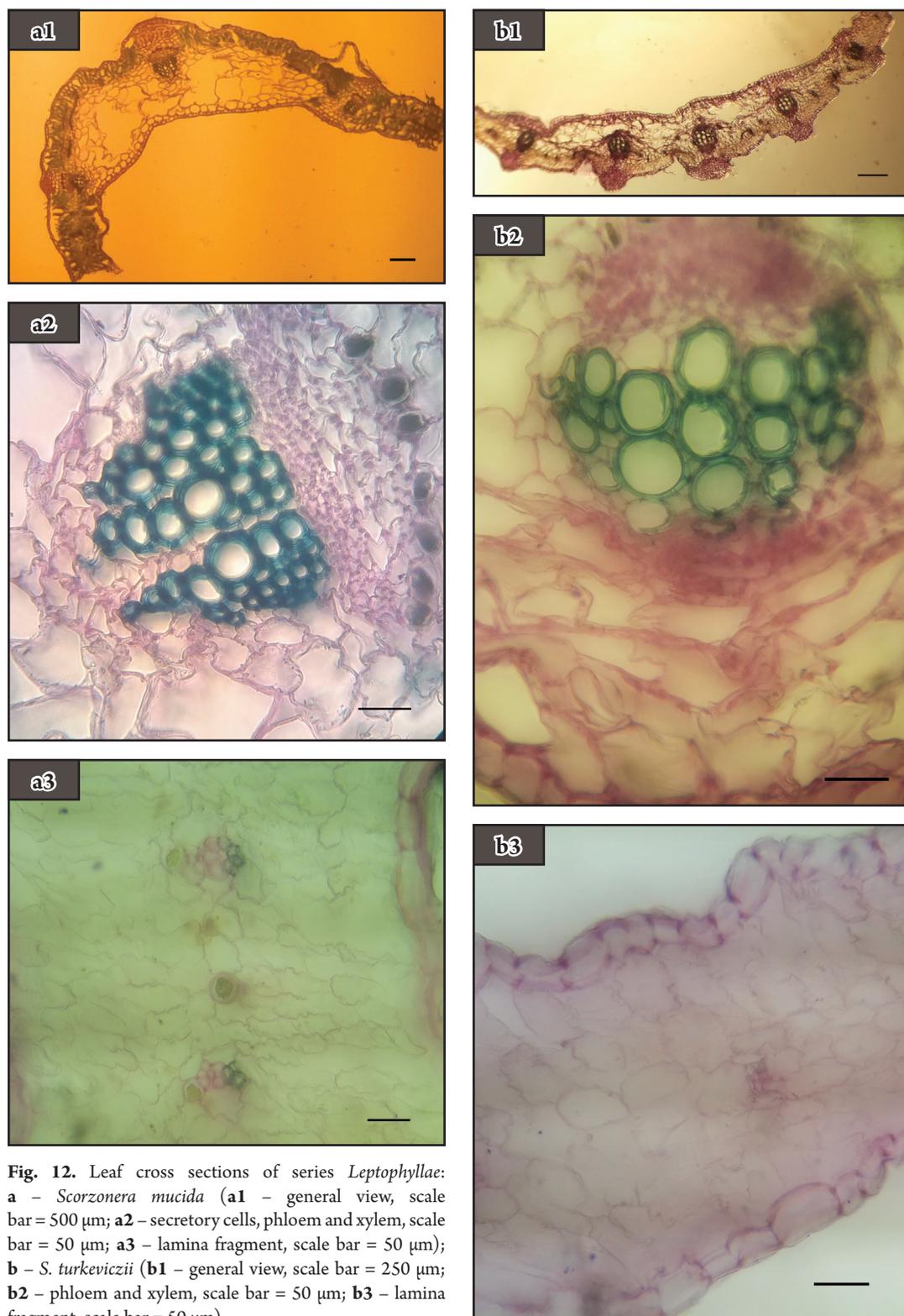


Fig. 12. Leaf cross sections of series *Leptophyllae*:
a – *Scorzonera mucida* (**a1** – general view, scale bar = 500 μm ; **a2** – secretory cells, phloem and xylem, scale bar = 50 μm ; **a3** – lamina fragment, scale bar = 50 μm);
b – *S. turkeviczii* (**b1** – general view, scale bar = 250 μm ; **b2** – phloem and xylem, scale bar = 50 μm ; **b3** – lamina fragment, scale bar = 50 μm).

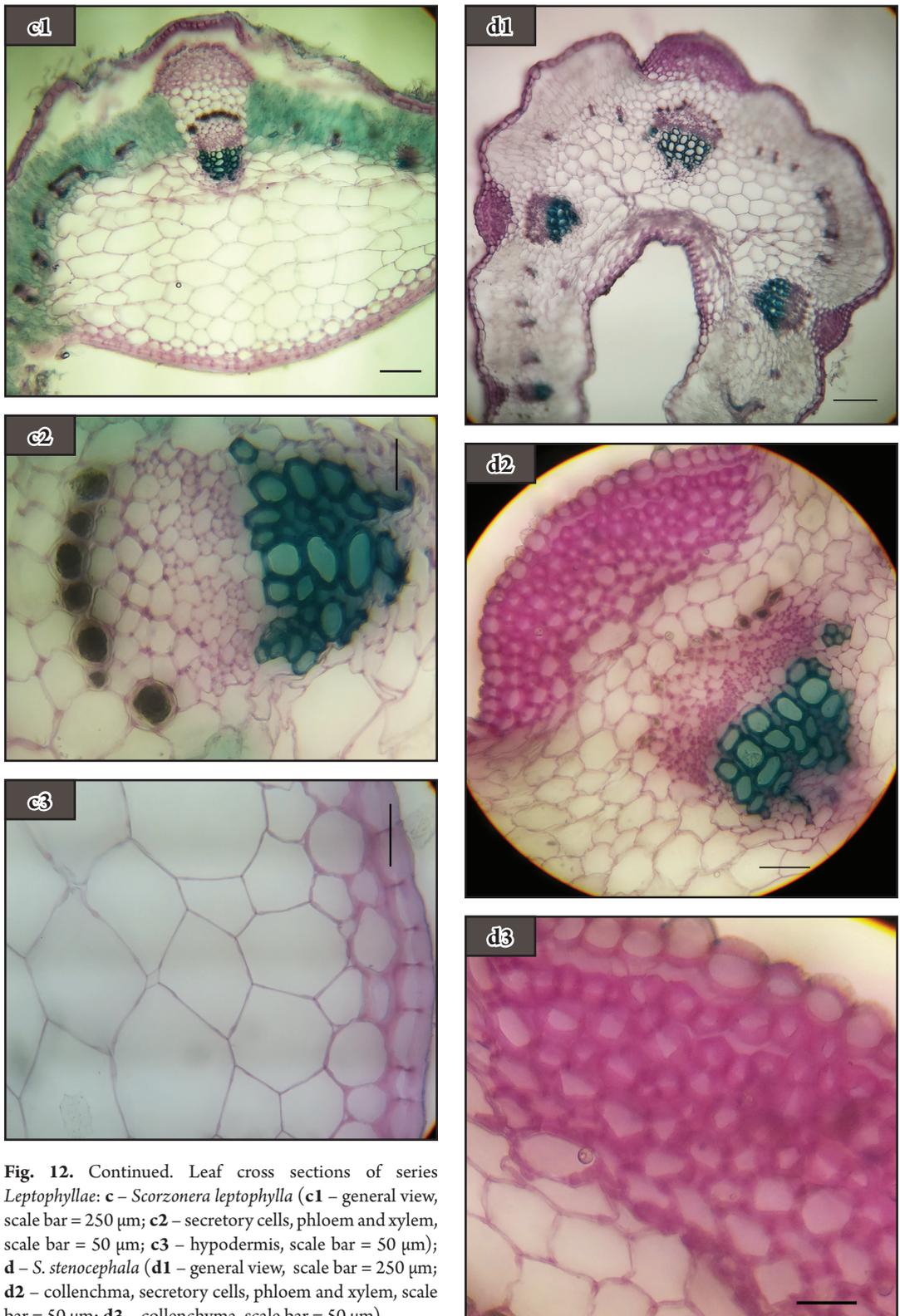


Fig. 12. Continued. Leaf cross sections of series *Leptophyllae*: **c** – *Scorzonera leptophylla* (**c1** – general view, scale bar = 250 μm; **c2** – secretory cells, phloem and xylem, scale bar = 50 μm; **c3** – hypodermis, scale bar = 50 μm); **d** – *S. stenocephala* (**d1** – general view, scale bar = 250 μm; **d2** – collenchma, secretory cells, phloem and xylem, scale bar = 50 μm; **d3** – collenchyma, scale bar = 50 μm).

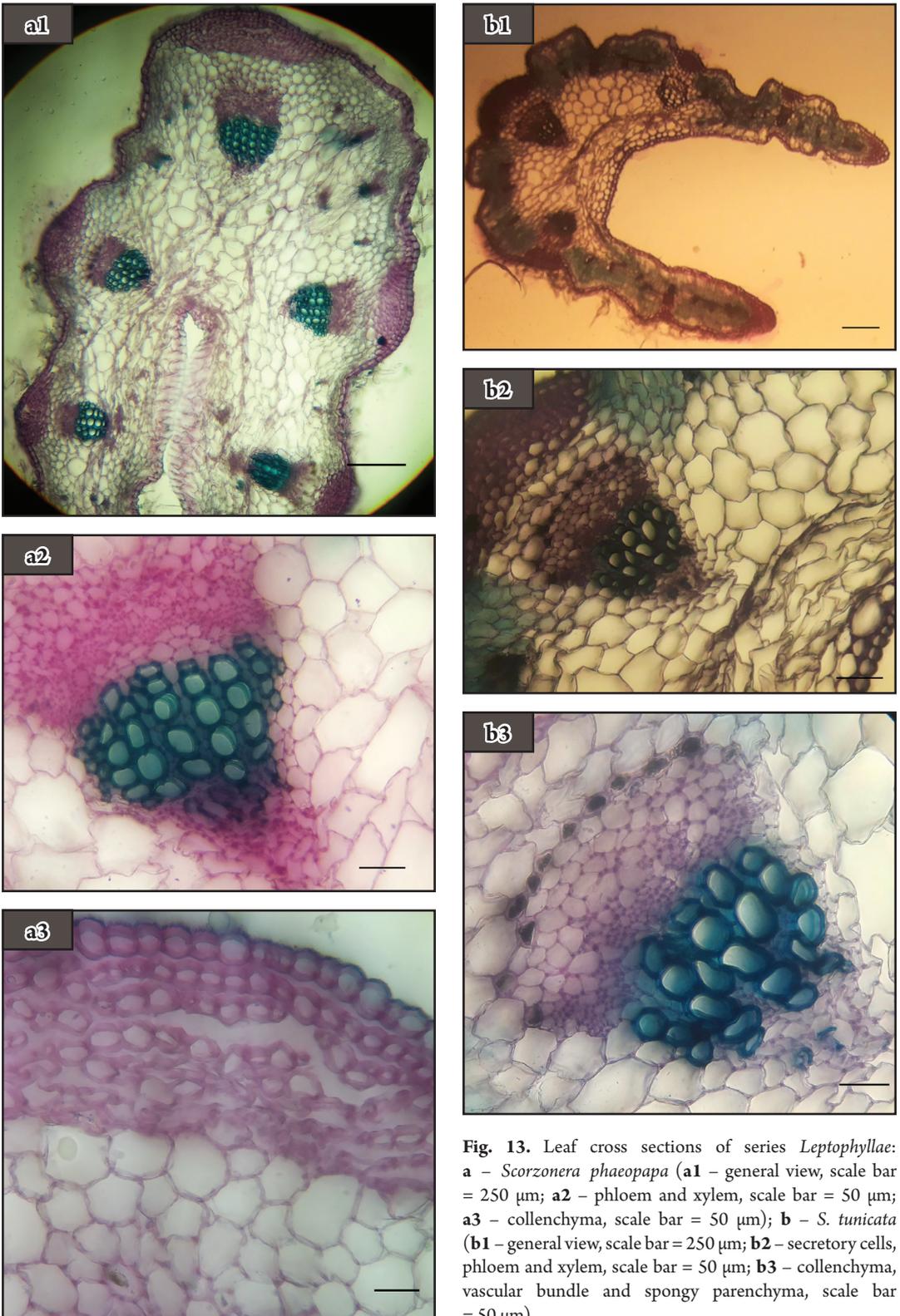


Fig. 13. Leaf cross sections of series *Leptophyllae*: **a** – *Scorzonera phaeopapa* (**a1** – general view, scale bar = 250 μm ; **a2** – phloem and xylem, scale bar = 50 μm ; **a3** – collenchyma, scale bar = 50 μm); **b** – *S. tunicata* (**b1** – general view, scale bar = 250 μm ; **b2** – secretory cells, phloem and xylem, scale bar = 50 μm ; **b3** – collenchyma, vascular bundle and spongy parenchyma, scale bar = 50 μm).

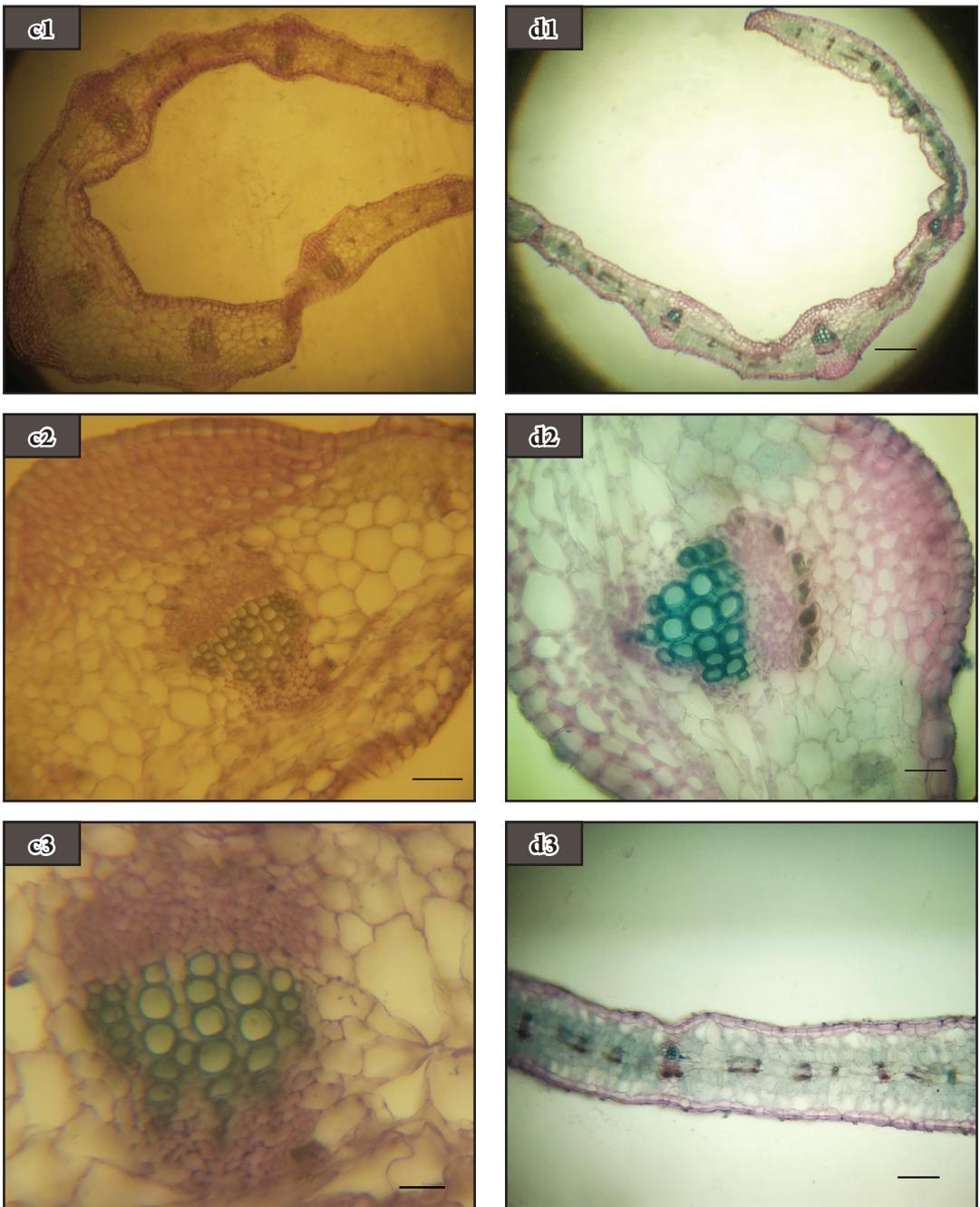


Fig. 13. Continued. Leaf cross sections of series *Leptophyllae*: **c** – *Scorzonera raddeana* (**c1** – general view, scale bar = 250 μm ; **c2** – collenchyma, vascular bundle and spongy parenchyma, scale bar = 50 μm ; **c3** – phloem and xylem, scale bar = 50 μm); **d** – *S. szovitsii* (**d1** – general view, scale bar = 500 μm ; **d2** – collenchyma, secretory cells, phloem and xylem, scale bar = 50 μm ; **d3** – lamina, scale bar = 50 μm).