

FOLIAR ANATOMY OF THE GENUS *SILENE* L. (CARYOPHYLLACEAE) AT SECTIONAL LEVEL IN IRAN

M. Nejati Edalatian, F. Ghahremaninejad & F. Attar

Received 2015. 06. 08; accepted for publication 2016. 11. 02

Nejati Edalatian, M., Ghahremaninejad, F. & Attar, F. 2016. 12. 30: Foliar anatomy of the genus *Silene* L. (Caryophyllaceae) at sectional level in Iran. -*Iran. J. Bot.* 22 (2): 138-158. Tehran.

In this research, Iranian species of 20 sections of the genus *Silene* L. have been anatomically studied for the first time. Some of the most important anatomical characters of leaf in this genus are listed here: general shape of leaves in transverse section, type of stomata cells, form of trichome, type of mesophyll (dorsiventral or isobilateral), presence or absence and type of collenchyma, thickness of sclerenchyma, existence or lack of water-storage, shape of vascular bundles, number of parenchyma layers in midrib, form and number of spongy and palisade parenchyma, presence or absence of parenchyma bundle sheath, number of vascular bundles in midrib. Based on our results we are able to identify and classify sections of this genus (tables 2, 3). In addition, we selected the most important characters related to midrib and lamina. All of these results confirm anatomical characters have taxonomic value for separating sections in the genus *Silene*.

Maliheh Nejati Edalatian & Farrokh Ghahremaninejad (correspondence <ghahremaninejad@khu.ac.ir>) Department of Plant Sciences, Faculty of Biological Sciences, Kharazmi University, 43 Dr. Mofatteh Avenue, Postal code 15719-14911, Tehran, Iran. -Farideh Attar, Tehran University, College of Sciences, School of Biology, Department of Botany, Central Herbarium, Tehran, Iran.

Key words: Anatomy; *Silenoideae*; taxonomy; SW Asia

آناتومی برگ جنس *Silene* (تیره میخکیان) در سطح بخش در ایران

ملیحه نجاتی عدالتیان: دانش آموخته کارشناسی ارشد سیستماتیک گیاهی، گروه علوم گیاهی، دانشکده علوم زیستی، دانشگاه خوارزمی

فرخ قهرمانی نژاد: استاد دانشگاه خوارزمی، گروه علوم گیاهی، دانشکده علوم زیستی، دانشگاه خوارزمی

فریده عطار: استاد دانشگاه تهران، پردیس علوم، دانشکده زیست شناسی، گروه علوم گیاهی، دانشگاه تهران

در این تحقیق، گونه‌هایی از جنس سیلن موجود در ایران، متعلق به ۲۰ بخش برای اولین بار از لحاظ آناتومی برگ مورد بررسی قرار گرفته است. برخی از مهمترین ویژگی‌های آناتومیکی مطالعه شده بر روی برگ این گونه‌ها عبارتند از: شکل کلی برگ‌ها در برش عرضی، تیپ سلولهای روزنه ای، شکل کرکها، نوع مزوفیل (پشتی-شکمی یا یک وجهی و مزوفیل دو طرف)، وجود یا عدم وجود کلانشیم و شکل آن، ضخامت اسکلرانشیم، وجود یا عدم وجود سلولهای ذخیره ای آب، شکل دستجات آوندی، تعداد لایه‌های پارانشیمی رگبرگ میانی، شکل و تعداد پارانشیم‌های اسفنجی و نردبانی، وجود یا عدم وجود غلاف آوندی، تعداد دستجات آوندی رگبرگ میانی. براساس نتایج حاصله، علاوه بر شناسایی و طبقه‌بندی بخش‌ها، مهمترین ویژگیهای مربوط به رگبرگ میانی و پهنک مشخص شده است. این نتایج تأیید می‌کند که صفات آناتومیکی در مجموع دارای ارزش تاکسونومیکی جهت جداسازی بخش‌های جنس سیلن از هم هستند.

INTRODUCTION

Caryophyllaceae, with 90 genera and nearly 3000 species in the world, is distributed in north temperate regions. In Flora Iranica this family includes three

subfamilies *Paronychioideae*, *Alsinoideae* and *Silenoideae*. The genus *Silene* L. belongs to subfamily *Silenoideae*.

Silene is the largest genus in the Caryophyllaceae

family with nearly 700 species world-wide (Melzheimer 1988). It is mainly distributed in temperate regions of the northern hemisphere, and has its main center of diversity in the Mediterranean and the Middle East. The circumscription of the genus has long been controversial, with an expanding tendency during the past decades (Chowdhuri 1957; McNeill, 1978; Greuter & al. 1984; Greuter, 1995; Šouková, 1978). At the infra-generic level, a lumping trend has also been prevalent, from the multi-level hierarchical classification of Rohrbach (1869) to Chowdhuri (1957), use of only section and subsection. In Iran, genus *Silene* includes around one hundred species (Nejati Edalatian & al. 2010 & 2011).

Metcalf (1957) in his book "*Anatomy of the dicotyledonous*" has indicated that species of this family have a number of anatomical characters in common. Hairs in various forms uni-cellular in certain species of *Herniaria*, *Paronychia*, *Siphonichia*; simple hairs in most genera; uniseriate hairs with a glandular cell at the apex recorded in *Dysphania*, *Habrosia*, *Loeflingia*, *Silene*, *Spergula*, *Spergularia* or branched hairs occur in *Achyronichia*, *Cerastium*, *Pollichia*, *Polycarpon* and *Stipulicida*. Epidermis composed of cells with straight or undulating anticlinal walls, cells elongated in species with long leaves. Stomata generally of the caryophyllaceous type but sometimes tending to be of the cruciferous type. Mesophyll centric or dorsiventral.

In this research, leaf anatomy of Iranian species of 20 sections of *Silene* was studied for the first time. In addition, the most important characters were selected. Some of the most important anatomical characters of leaves in this genus are as follows:

general shape of leaves in transverse section, type of stomata cells, form of trichome, type of mesophyll (dorsiventral or isobilateral), presence or absence and type of collenchyma, thickness of sclerenchyma, existence or lack of water-storage, form of vascular bundles, number of parenchyma layers in midrib, form and number of spongy and palisade parenchyma, presence or absence of parenchyma sheet, number of vascular bundles in midrib.

MATERIALS AND METHODS

Based on our project, herbarium specimens of the genus *Silene* collected from different places of Iran were examined and identified by relevant literatures (Komarove, 1970; Melzheimer, 1988). We have

chosen several species from any section and from any species 3 sheet. All materials were placed in FAA (Formalin-Acid-Alcohol) for 24-48 hours and then washed with distilled water. After this, leaves were transferred to 70% methanol for preservation. For the next step, materials were brought out from methanol and rinsed with distilled water. Thin transverse sections were cut by hand. These sections were placed in 50% Javelle water and after sitting for a required time (depending on each specimen) were washed by water and put into acetic-acid 10%. After this step, the sections were washed by water again and placed in carmine for 15 minutes. After another washing step with water, all sections were placed in methyl green for 15-20 minutes. Samples were studied using a ZEISS Standard 20 microscope and photographs were taken with a Canon G5 camera. All species studied are preserved in Kharazmi University (T), Tehran University (TUH) and Herbarium of Ferdowsi University of Mashhad (FUMH). List of studied species is presented in table 1.

RESULTS

The most important anatomical characters in the genus *Silene* L. will be described here as follows:

General shape of leaf in transversal section in some sections is V-shape (epidermis below central vascular bundle are wrinkled) (fig. 13A) or U-shape (epidermis below central vascular bundle are not wrinkled), (fig. 1).

Trichomes in this genus are different from unicellular, simple uniseriate (figs. 5, 10, 16) to multicellular (fig. 11) and or uniseriate trichomes with a glandular cell in head (fig. 1, 17). Also some sections are without trichome on epidermal surface (figs. 7, 10B, 18).

Mesophyll is mainly composed of short or tall palisade cells and generally dorsiventral. Sometimes mesophyll is isobilateral or centric or in some sections isobilateral and dorsiventral or both. Mesophyll consists of 1 or 2 rarely 3 layers of palisade parenchyma with smooth or sinuous walls. Length of palisade parenchyma cells are 25 to 200 μm . Spongy parenchyma is orbicular to irregular. Stomata present on both surfaces that are prominent and isoplanar.

Water-storage is observed in the mesophyll (figs. 8, 20). Numerous solitary and large crystals of oxalate are observed in the mesophyll and also vascular bundles, but with less or high density (figs 17, 18).

Table 1. voucher specimens.

section	Species	Voucher specimen
<i>Ampullatae</i>	<i>S. ampullata</i>	TUH16892
<i>Atocion</i>	<i>S. atocioides</i>	T 17990
<i>Auriculatae</i>	<i>S. aucheriana</i>	TUH 6197
<i>Bipartitae</i>	<i>S. arabica</i>	TUH 9529
<i>Chloranthae</i>	<i>S. viscosa</i>	TUH 17408
<i>Compactae</i>	<i>S. compacta</i>	TUH 17503
<i>Conoimorphae</i>	<i>S. conica</i>	TUH 27208
<i>Fimbriatae</i>	<i>S. multifida</i>	TUH17527
<i>Inflatae</i>	<i>S. odontopetala</i>	TUH18337
	<i>S. pungens</i>	TUH9673
	<i>S. vulgaris</i>	TUH9681
<i>Lasiocalycinae</i>	<i>S. dichotoma</i>	FAR45516
<i>Lasiostemones</i>	<i>S. macrowiczii</i>	TUH29572
	<i>S. tenella</i>	W 53182
<i>Lychnidiformes</i>	<i>S. coronaria</i>	FUMH15895
<i>Melandrifformes</i>	<i>S. noctiflora</i>	T 3162
<i>Otites</i>	<i>S. cyri</i>	FUMH33797
<i>Paniculatae</i>	<i>S. italic</i>	FAR 45512
<i>Rigidulae</i>	<i>S. arenosa</i>	W 14959
	<i>S. austro-iranica</i>	TUH 23960
<i>Saponarioides</i>	<i>S. nana</i>	TUH28488
<i>Schaftae</i>	<i>S. schafta</i>	TUH 33219
<i>Sclerocalycinae</i>	<i>S. bupleoroides</i>	TUH55157
<i>Spergulifoliae</i>	<i>S. spergulifolia</i>	TUH29574

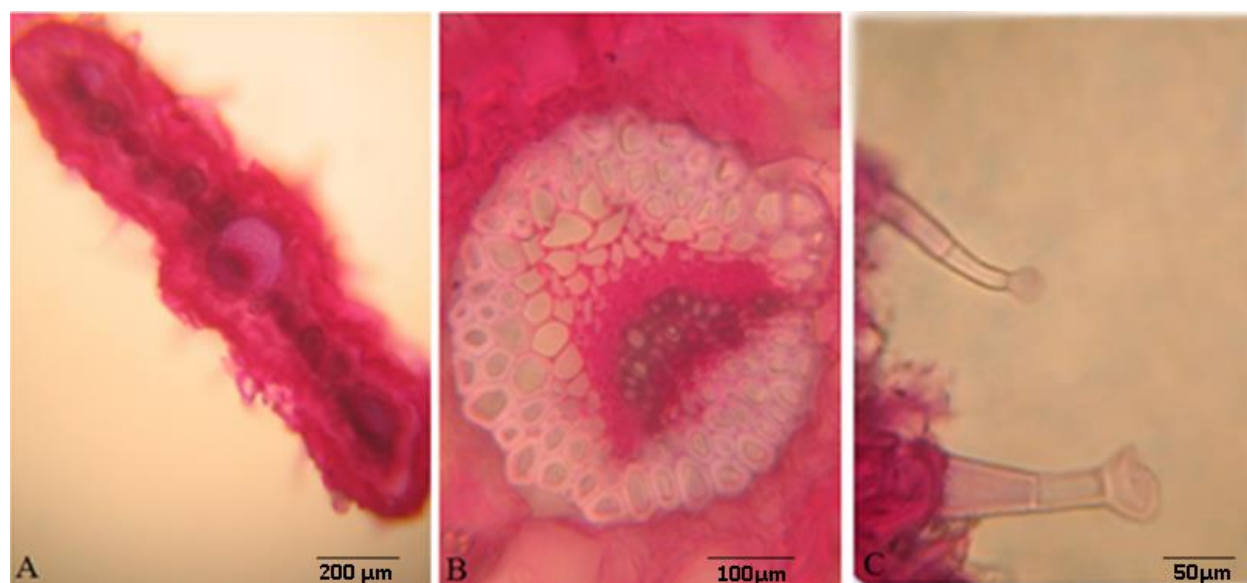


Fig. 1. *Silene ampullata* (Sect. *Ampullatae*). A, leaf transversal section and general aspect (200μm); B, midrib (100μm); C, trichomes (50μm).

Table 2. Anatomical characteristics of lamina in sections of *Silene* L.

Sect	General shape	Trichome	Type of mesophyll	Stomata of back face	Number of palisade parenchyma layers in adaxial surface	Number of palisade parenchyma layers in abaxial surface	Size of epidermal cells in adaxial and abaxial surface	Length palisade parenchyma in adaxial surface(μm)	Length palisade parenchyma in abaxial surface (μm)	Pallisade cells wall
<i>Ampullatae</i>	U	Glandular multicellular	Isobilateral	Prominent	2	2	Equal	50-100	50-100	Smooth
<i>Atocion</i>	U	Simple multicellular	Dorsiventral	Prominent	1-3	—	Adaxial>Abaxial	50-75	—	Sinous
<i>Auriculatae</i>	U	Glandular-eglandular	Isobilateral	Isoplanar	1-3	1-3	Equal	50-200	37.5-175	Sinous
<i>Bipartitae</i>	V	Simple multicellular	Isobilateral	Prominent	2	2	Equal	100-175	100-175	Sinous
<i>Chloranthae</i>	U	Simple multicellular	Dorsiventral	Prominent	1-3	—	Equal	37.5	—	Smooth-sionous
<i>Compactae</i>	U	Non trichome	Dorsiventral	Isoplanar	1	—	Equal	37.5-87.5	—	Smooth
<i>Conoimorphae</i>	V	Simple multicellular	Dorsiventral	Prominent	2-3	—	Adaxial>Abaxial	87.5-125	—	Smooth
<i>Fimbriatae</i>	U	Simple multicellular or non trichome	Dorsiventral	Prominent	1	—	Adaxial>Abaxial	25-50	—	Smooth
<i>Inflatae</i>	U	Simple multicellular or non trichome	Isobilateral or Dorsiventral	Prominent or Isoplanar	2	2-3	Equal	37.5-87.5	50-87.5	Smooth
<i>Lasiocalycinae</i>	V	Simple multicellular	Isobilateral or Dorsiventral	Prominent	2-3	2	Equal	50-162.5	62.5-125	Sinous
<i>Lasiostemones</i>	U	Simple multicellular	Isobilateral	Prominent	2-3	2	Equal	50-162.5	62.5-125	Sinous
<i>Lychnidiformes</i>	V	Glandular multicellular	Dorsiventral	Prominent	2	—	Adaxial>Abaxial	62.5-100	—	Smooth
<i>Melandrifformes</i>	V	Glandular multicellular	Dorsiventral	Prominent	2	—	Equal	50-75	—	Smooth
<i>Otites</i>	U	Simple uniseriate	Isobilateral	Prominent	1	1	Adaxial>Abaxial	87.5-150	62.5-87.5	Sinous
<i>Paniculatae</i>	U	Simple multicellular	Dorsiventral	Prominent	2	—	Equal	37.5-50	—	Smooth
<i>Rigidulae</i>	U	Glandular multicellular	Isobilateral	Isoplanar	2	2	Equal	37.5-212.5	50-175	Smooth
<i>Saponarioides</i>	U	Simple multicellular or non trichome	Dorsiventral	Isoplanar	3	—	Equal	50-75	—	Sinous
<i>Schaftae</i>	U	Simple multicellular	Dorsiventral	Prominent	1-2	—	Adaxial>Abaxial	62.5-75	—	Sinous
<i>Sclerocalycinae</i>	U	Non trichome	Dorsiventral	Prominent	2	—	Equal	62.5-125	—	Smooth
<i>Spergulifoliae</i>	U	Simple multicellular	Isobilateral or Dorsiventral	Prominent	2-3	2-3	Adaxial>Abaxial	37.5-150	62.5-100	Smooth

Table 3. Anatomical characteristics of midrib in sections of *Silene* L.

Sect	Type of central vascular bundle	Type of sclerenchyma	Type of collenchyma in abaxial surface	Type of collenchyma in adaxial surface	Number of central vascular bundle	Number of parenchyma cells in abaxial	Number of parenchyma cells in adaxial	Bundle sheath	Length/width of midrib	Type of midrib
<i>Ampullatae</i>	Semiorbicular	Complete sheath	—	—	1-2	—	—	—	1.1-1.2	Semiorbicular
<i>Atocion</i>	Semiorbicular	Non sheath	Angular	lamellar	1	1-3	4	—	0.5-0.6	Semiorbicular
<i>Auriculatae</i>	Semiorbicular	Complete sheath	Lacunar or angular	lamellar	1-2	1-3	3-4	+	1-1.5	Ovate-semiorbicular
<i>Bipartitae</i>	Reniform	Non sheath	Lacunar	lamellar	1	1-2	3-4	+	0.4-0.8	Semiorbicular
<i>Chloranthae</i>	Reniform	Non sheath	Angular	lamellar	1-2	2-3	4-6	+	1-1.3	Ovate
<i>Compactae</i>	Reniform	Non sheath	Angular	lamellar	1	1-2	3-4	—	1	Semiorbicular
<i>Coniomorphae</i>	Semiorbicular-reniform	Non sheath	Angular	lamellar	1	1	3	+	1-1.2	Semiorbicular
<i>Fimbriatae</i>	Reniform	Non sheath	Angular	lamellar	1	1	2	—	0.3-1	Semiorbicular
<i>Inflatae</i>	Semiorbicular-reniform	Complete sheath or only abaxial	Lamellar or angular	lamellar	1-2	2	4-8	—	0.8-1.1	Semiorbicular
<i>Lasiocalycinae</i>	Semiorbicular	Non sheath	Lacunar or Angular	lamellar	1	1	4	+	1-1.2	Ovate-semiorbicular
<i>Lasiostemones</i>	Semiorbicular-ovate	Non or complete sheath	Lacunar or angular	Lamellar	1	1	2	+	0.8-1	Semiorbicular
<i>Lychnidiformes</i>	Reniform	Non sheath	Angular	Lamellar	1-2	2	9	+	2	triangular
<i>Melandriformes</i>	Semiorbicular-ovate	Non sheath	Angular	Lamellar-angular	1-2	1-3	3-4	—	1-1.3	Ovate
<i>Otites</i>	Semiorbicular-ovate	Non sheath	Lacunar	Lamellar	1	2-3	4-8	+	0.7	Semiorbicular
<i>Paniculatae</i>	Reniform	Non sheath	Lamellar	Lamellar	1	1-2	5	+	1.3-1.8	Ovate
<i>Rigidulae</i>	Semiorbicular-ovate	Complete sheath	Lamellar	Lamellar	1-2	2	2-3	+	1-1.2	Semiorbicular
<i>Saponarioides</i>	Reniform	Only abaxial	Angular	Lamellar	1	3	4	—	1-1.4	Ovate
<i>Schaftae</i>	Semiorbicular	Non sheath	Angular	Lamellar	1-2	1-3	3	+	1	Ovate
<i>Sclerocalycinae</i>	Reniform	Non sheath	Lacunar or Angular	Lamellar	1-2	2-3	3-6	+	1-1.3	Ovate
<i>Spergulifoliae</i>	Semiorbicular-ovate	Complete sheath	Lacunar or Angular	Lamellar	1-2	2-3	3-4	+	1-1.3	Ovate

The most important characters inferred to midrib are as follow:

General shape of midrib is triangular (fig. 13A), semi orbicular (fig. 10A) or ovate (fig. 14). number of spongy tissue layers around central vascular bundle varies from 2 to 9 layers in abaxial surface and 1 to 3 layers in adaxial surface in different sections.

Vascular sheath cells in some sections have been different from neighbor parenchyma cells (spongy parenchyma) (fig. 4B).

Collenchyma that is present bellow or above of central vascular bundle, is lamellar or angular, rarely lacunars. Vascular bundles are reniform or semi orbicular or in some sections both shapes (reniform-semi orbicular) are observed. Preservative tissue around vascular bundle is sclerenchyma.

Thickness of sclerenchyma around vascular bundles has diagnostic value at sectional level as follows:

In some sections vascular bundles have wide sclerenchyma sheath (fig. 10D) and or have been limited to bellow of above of vascular bundles (fig. 10G, 12E, 18B).

Keshavarzi & al. (2014), measured other important characteristics such as cortex diameter, hair presence in dorsal and ventral surfaces of leaves, midrib diameter, thickness of upper and lower cuticle, fiber presence in midrib, stomata index and hair frequency.

Anatomical characteristics of different sections

1. *Silene* L. Sect. *Ampullatae* Boiss. (1867)

Lamina: general leaf form in transversal section U-shape; glandular multicellular trichomes; mesophyll

composed of palisade cells and dorsiventral; stomata are prominent; number of palisade parenchyma layers are two, with smooth cell wall; length of palisade parenchyma cells 50-100 μm with water-storage; size of epidermal cells in adaxial and abaxial more or less equal; crystals of oxalate calcium is scattered in mesophyll; epidermis in both surface having cuticle.

Midrib: central vascular bundle semi-orbicular; very wide sclerenchymatous sheath around vascular bundles, having one rarely two central vascular bundle; midrib semi-orbicular, without distinguished vascular sheath around vascular bundles; midrib length to width ratio almost 1. 1- 1. 2 (fig. 1).

2. *Silene* L. Sect. *Atocion* Otth in DC. (1824)

Lamina: general leaf form in transversal section U-shape; glandular multicellular trichomes; mesophyll is composed of palisade cells and isobilateral; stomata are prominent; number of palisade parenchyma layers are two with sinuous cell wall; length of palisade parenchyma cells 25-75 μm with water-storage; size of epidermal cells in adaxial surface larger than abaxial; crystals of calcium oxalate is scattered in mesophyll; epidermis in both surfaces have cuticle.

Midrib: central vascular bundle semi-orbicular; without sclerenchymatous sheath around vascular bundles, having one central vascular bundle; collenchyma in abaxial surface angular and in adaxial surface lamellar; number of parenchyma layers in abaxial surface 1-3 and in adaxial 4; midrib semi-orbicular, without distinguished vascular sheath around vascular bundles; midrib length to width ratio 0. 5- 0. 6 (fig. 2).

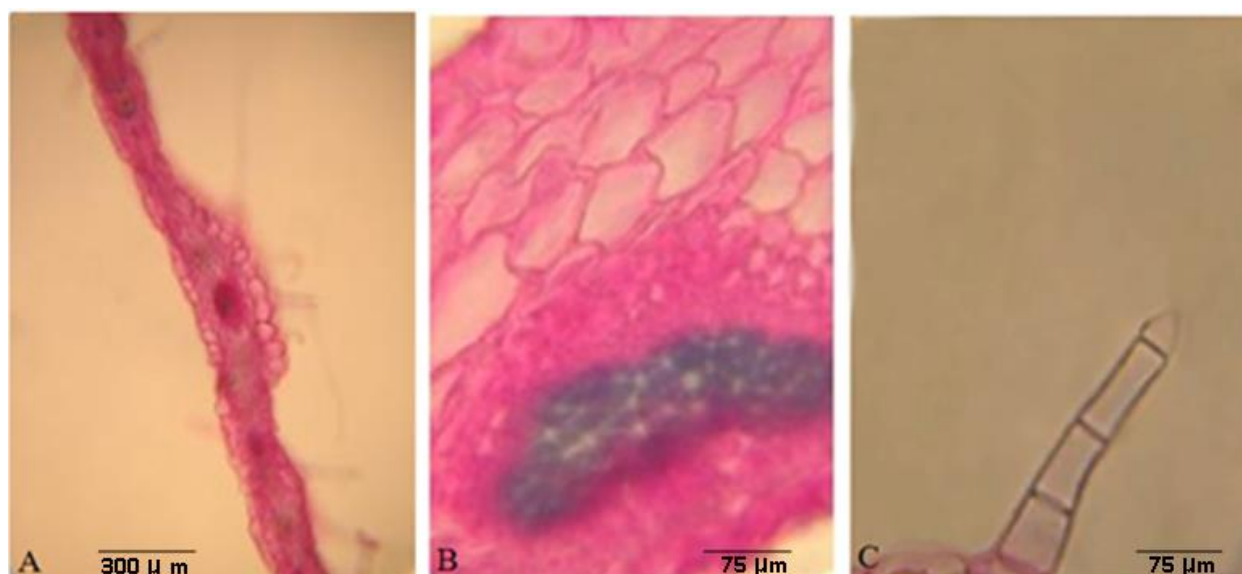


Fig. 2. *Silene atocioides* (Sect. *Atocion*). A, leaf transversal section and general aspect (300 μm); B, midrib (75 μm); C, trichomes (75 μm).

3. *Silene L. Sect. Auriculatae* Boiss. (1867)

Lamina: general leaf form in transversal section U-shape; glandular or eglandular multicellular trichomes, their surface tuberculoses; mesophyll composed of palisade cells and dorsiventral; stomata are isoplanar; number of palisade parenchyma layers are 2-3 with sinuous cell wall; length of palisade parenchyma cells 62.5-200 μm with water-storage; size of epidermal cells in adaxial and abaxial nearly equal; crystals of calcium oxalate scattered in mesophyll; having wide

cuticle in both epidermic surfaces.

Midrib: central vascular bundle semi-orbicular; with developed sclerenchymatous sheath around vascular bundles, having 1-2 central vascular bundle; collenchymas in abaxial surface angular or lacunar and in adaxial surface lamellar; number of parenchyma layers in abaxial surface 1-3 and in adaxial surface 3-4; midrib ovate to semi-orbicular, with distinguished vascular sheath around vascular bundles; midrib length to width ratio 1-1.5 (fig. 3).

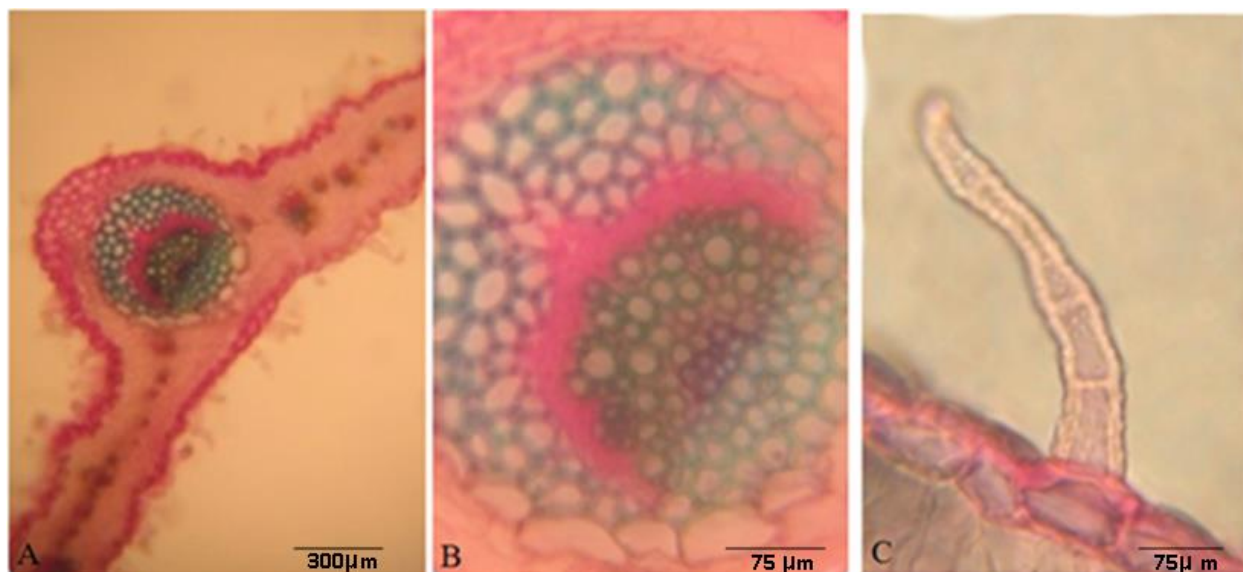


Fig. 3. *Silene aucheriana* (Sect. *Auriculatae*). A, leaf transversal section and general aspect (300 μm); B, midrib (75 μm); C: trichomes (75 μm).

4. *Silene L. Sect. Bipartitae* Boiss. (1867)

Lamina: general leaf form in transversal section V-shape; eglandular multicellular trichomes, their surface tuberculoses; mesophyll composed of palisade cells and dorsiventral; stomata are prominent; number of palisade parenchyma layers are two with sinuous cell wall; length of palisade parenchyma cells 100-170 μm with water-storage; size of epidermal cells in adaxial and abaxial more or less equal; crystals of calcium oxalate scattered in mesophyll; having wide cuticle in both epidermic surfaces.

Midrib: central vascular bundle reniform; without sclerenchymatous sheath around vascular bundles, having one central vascular bundle; collenchymas in abaxial and adaxial lacunar; number of parenchyma layers in abaxial 1-2 and in adaxial 3-4; midrib semi orbicular, with distinguished vascular sheath around vascular bundles; midrib length to width ratio 0.4-0.8 (fig. 4).

5. *Silene L. Sect. Chloranthae* (Rohrb.) Schischk. (1868)

Lamina: general leaf form in transversal section U-shape; eglandular multicellular trichomes; mesophyll isobilateral; stomata are prominent; number of palisade parenchyma layers are 2-3 with sinuous cell wall; length of palisade parenchyma cells 37.5 μm with water-storage; size of epidermal cells in adaxial and abaxial nearly equal; crystals of calcium oxalate scattered in mesophyll; have cuticle in both epidermic surfaces.

Midrib: central vascular bundle reniform; without distinguished sclerenchymatous sheath around vascular bundles, having 1-2 central vascular bundle; collenchymas in abaxial angular and in adaxial lamellar; number of parenchyma layers in abaxial 2-3 and in adaxial 4-6; midrib ovate, with distinguished vascular sheath around vascular bundles; midrib length to width ratio 1-1.3 (fig. 5).

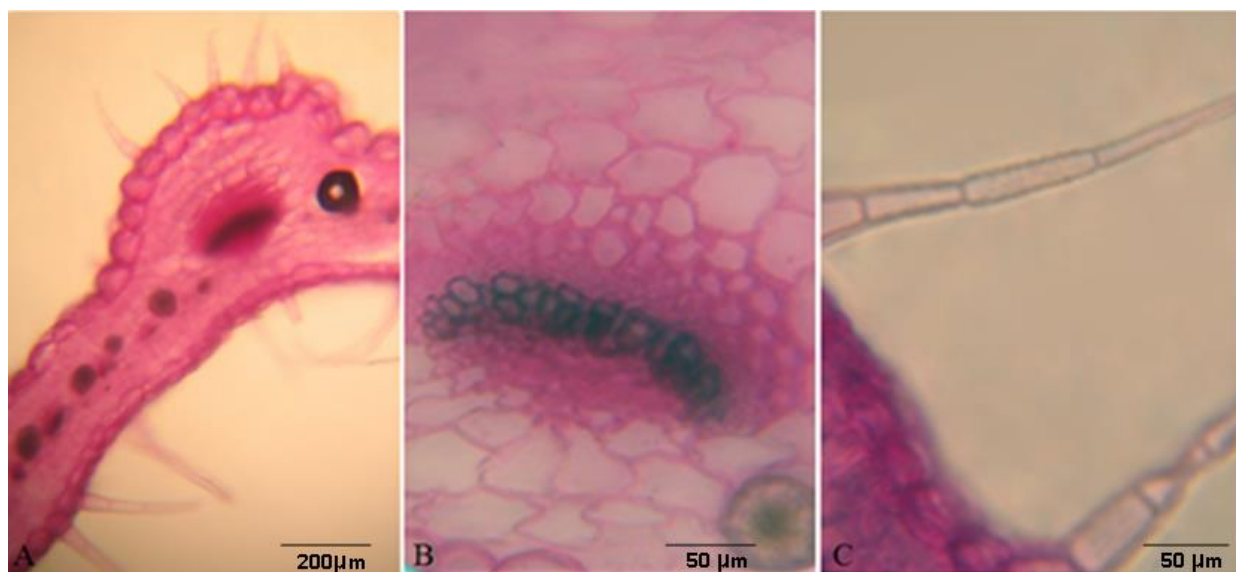


Fig. 4. *Silene arabica* (Sect. *Bipartitae*). A, leaf transversal section and general aspect (200µm); b, midrib (50µm); C, trichomes (50µm).

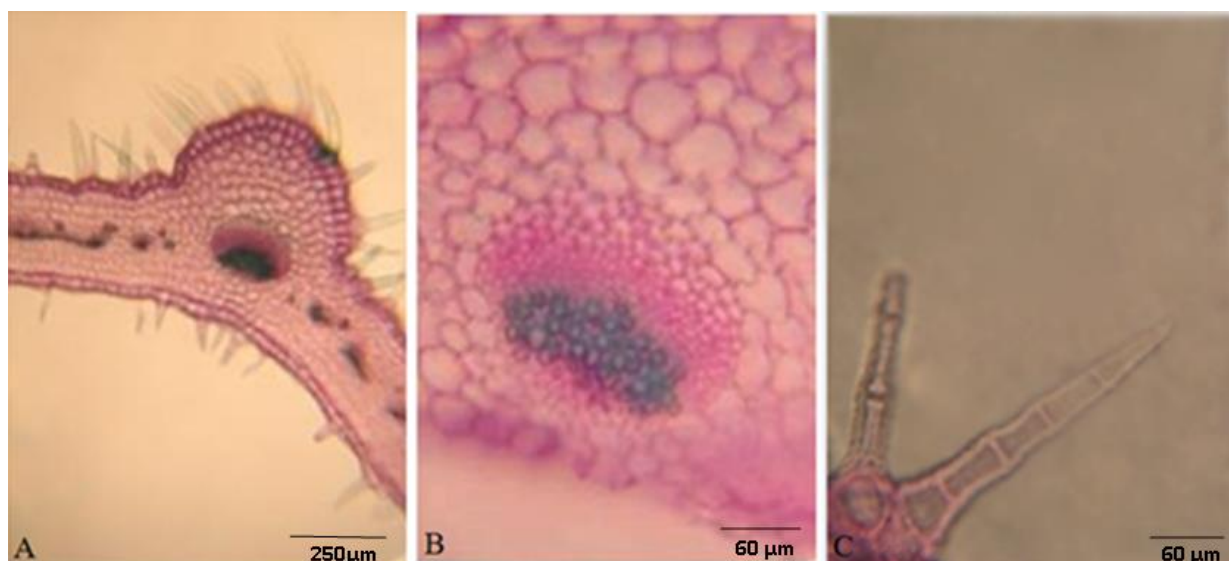


Fig. 5. *Silene viscosa* (Sect. *Chloranthae*). A, leaf transversal section and general aspect (250µm); b, midrib (60µm); C, trichomes (60µm).

6. *Silene* L. Sect. *Compactae* Boiss. (1867)

Lamina: general leaf form in transversal section U-shape; without trichome; mesophyll isobilateral; Stomata are isoplanar; number of palisade parenchyma layers is one; length of palisade parenchyma cells 62.5 µm with water-storage; size of epidermal cells in adaxial and abaxial nearly equal; crystals of calcium oxalate scattered in mesophyll; both epidermic surfaces have cuticle

Midrib: central vascular bundle reniform; without

distinguished sclerenchymatous sheath around vascular bundles, having one central vascular bundle; collenchymas in abaxial angular and in adaxial lamellar; number of parenchyma layers in abaxial 1-2 and in adaxial 3-4; midrib semi orbicular, without vascular sheath around vascular bundles; midrib length to width ratio 1 (fig. 6).

7. *Silene* L. Sect. *Conoimorpha* Otth in DC. (1824)

Lamina: general leaf form in transversal section V-shape; long multicellular trichomes; mesophyll

isobilateral; stomata are prominent; number of palisade parenchyma layers are 2-3; length of palisade parenchyma cells 87. 5-125 μm with water-storage; size of epidermal cells in adaxial larger than abaxial; crystals of calcium oxalate scattered in mesophyll; both epidermis surfaces have cuticle

Midrib: central vascular bundle reniform- semi orbicular; without sclerenchymatous sheath around

vascular bundles, having one central vascular bundle; collenchyma in abaxial surface angular and in adaxial surface lamellar; number of parenchyma layers in abaxial surface three and in adaxial surface is one; midrib semi orbicular, with distinguished vascular sheath around vascular bundles; midrib length to width ratio 1- 1.2 (fig. 7).

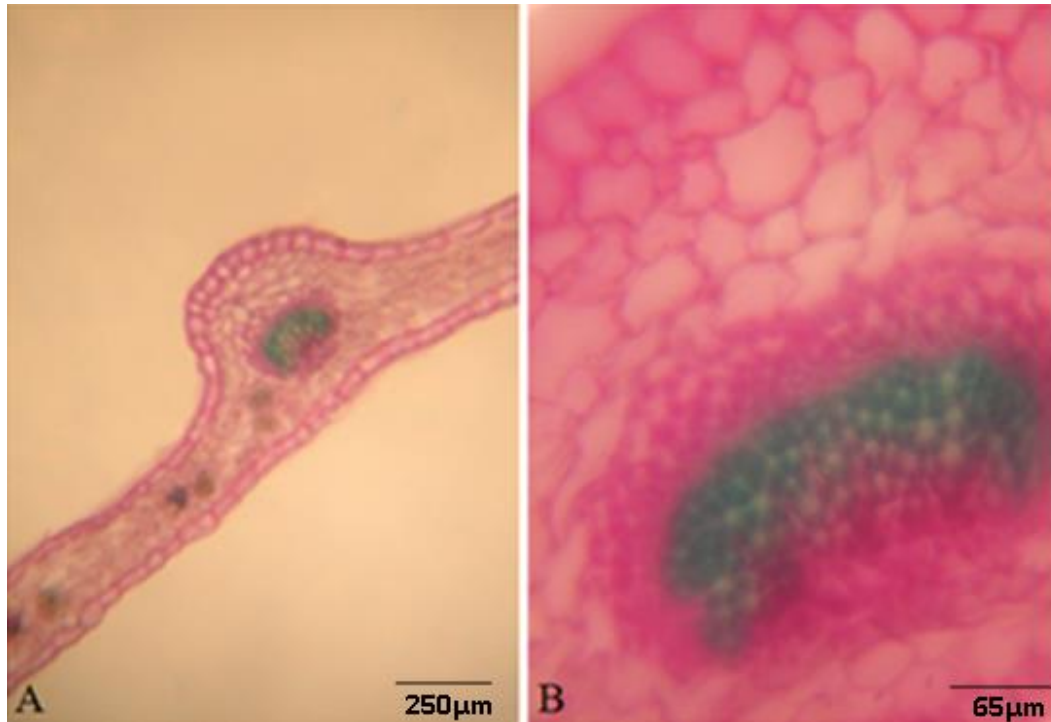


Fig. 6. *Silene compacta* (Sect. *Compactae*). A, leaf transversal section and general aspect (250 μm); b, midrib (65 μm).

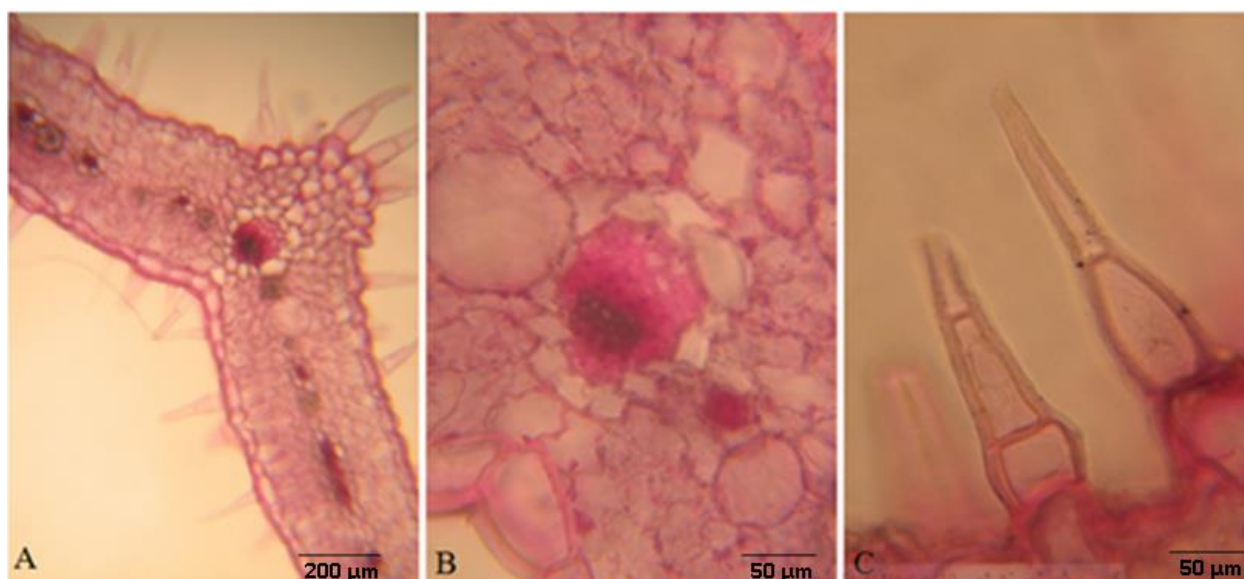


Fig. 7. *Silene conica* (Sect. *Conoimorphae*). A, leaf transversal section and general aspect (200μm); b, midrib (50μm); C, trichomes (50μm).

8. *Silene* L. Sect. *Fimbriatae* Boiss. (1867)

Lamina: general leaf form in transversal section U-shape; multicellular trichome; mesophyll isobilateral; stomata are prominent; number of palisade parenchyma layers is one; length of palisade parenchyma cells 25-50 μm with water-storage; size of epidermal cells in adaxial surface larger than abaxial; crystals of calcium oxalate scattered in mesophyll; epidermis have cuticle in both surfaces.

Midrib: central vascular bundle reniform; without sclerenchymatous sheath around vascular bundles, having one central vascular bundle; collenchymas in abaxial surface angular and in adaxial lamellar; number of parenchyma layers in abaxial surface one and in adaxial up to two; midrib semi-orbicular, without vascular sheath around vascular bundles; midrib length to width ratio 0.3-1 (fig. 8).

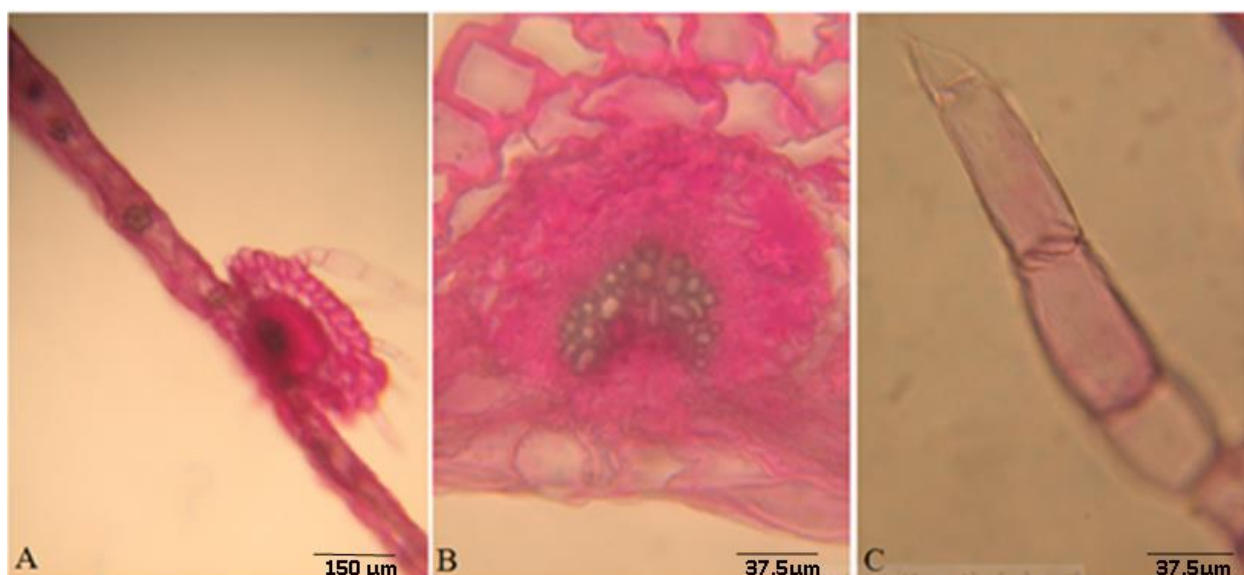


Fig. 8. *Silene multifida* (Sect. *Fimbriatae*). A, leaf transversal section and general aspect (150μm); b, midrib (37.5μm); C, trichomes (37.5μm)

9. *Silene* L. Sect. *Inflatae* Boiss. (1867)

Lamina: general leaf form in transversal section U-shape; multicellular trichome or non- trichome, their surface tuberculoses; mesophyll dorsiventral; or isobilateral; stomata are prominent or isoplanar; number of palisade parenchyma layers are two; length of palisade parenchyma cells 37. 5- 87. 5 μm with water-storage; size of epidermal cells in adaxial surface and abaxial surface more or less equal; crystals of calcium oxalate scattered in mesophyll; both epidermis surfaces have cuticle

Midrib: central vascular bundle reniform; sclerenchymatous sheath around vascular bundles or just in abaxial surface, having 1-2 central vascular bundle; collenchyma in abaxial surface angular and in adaxial lamellar; number of parenchyma layers in abaxial two and in adaxial 4-8; midrib semi orbicular, without distinguished vascular sheath around vascular bundles; midrib length to width ratio 0.8- 1. 1 (fig. 9).

10. *Silene* L. Sect. *Lasiocalycinae* Boiss. (1867)

Lamina: general leaf form in transversal section V-shape; multicellular trichome; mesophyll isobilateral; stomata are prominent or isoplanar; number of palisade parenchyma layers are 2-3; length of palisade parenchyma cells 37. 5- 100 μm with water-storage; Size of epidermal cells in adaxial and abaxial almost equal; crystals of calcium oxalate scattered in mesophyll; both epidermic surfaces have cuticle

Midrib: central vascular bundle semi-orbicular; without sclerenchymatous sheath around vascular bundles, having one central vascular bundle; collenchymas in abaxial surface angular and in adaxial lamellar; number of parenchyma layers in abaxial surface one and in adaxial to 4; midrib semi orbicular or ovate, with distinguished vascular sheath around vascular bundles or without sheath; midrib length to width ratio 1- 1.2 (fig 10).



Fig. 9. A-B: *Silene vulgaris*. C-E, *S. pungens*. F-G, *S. odontopetala* (Sect. *Inflatae*); A, C, F, leaf transversal section and general aspect (200μm, 220μm); B, D, G, midrib (50μm, 55μm); E, trichomes (50μm)

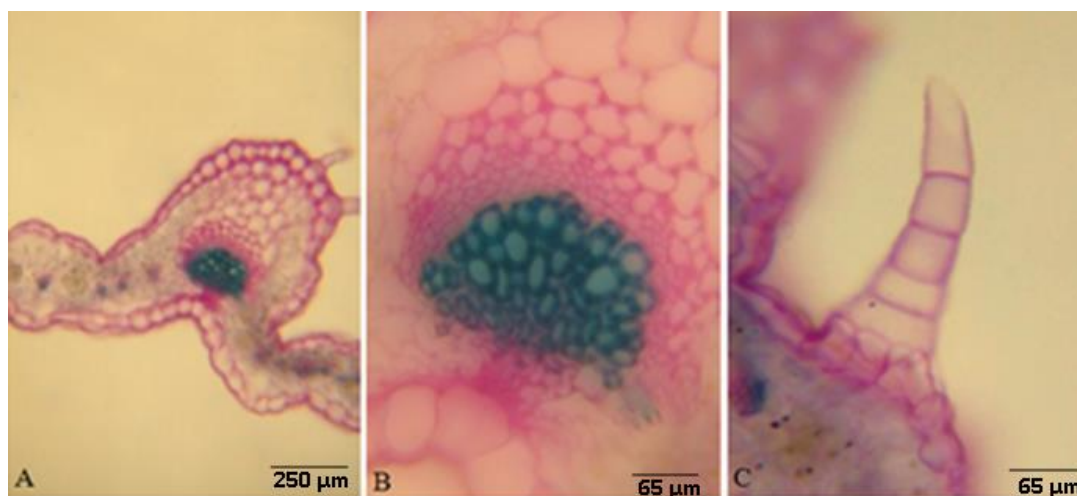


Fig. 10. *Silene dichotoma* (Sect. *Lasiocalycinae*). A, leaf transversal section and general aspect (250μm); B, midrib (65μm); C, trichomes (65μm).

11. *Silene* L. sect. *Lasiostemon* Boiss. (1867)

Lamina: general leaf form in transversal section U-shape; multicellular trichome, their surface tuberculoses; mesophyll dorsiventral or isobilateral; stomata are prominent; number of palisade parenchyma layers are two; length of palisade parenchyma cells 50-162. 5 μm with water-storage; Size of epidermal cells in adaxial and abaxial surface more or less equal; crystals of calcium oxalate scattered in mesophyll; both epidermis surfaces have cuticle

Midrib: central vascular bundle semi-orbicular to reniform; without complete sclerenchymatous sheath around vascular bundles, having 1-2 central vascular bundle; collenchymas in abaxial surface lamellar and in adaxial angular or lacunar; number of parenchyma layers in abaxial surface two and in adaxial three; midrib semi orbicular, with distinguished vascular sheath around vascular bundles; midrib length to width ratio 0.8-1 (Fig. 11).

12. *Silene* L. sect. *Lychnidiformes* Melzh. (1988)

Lamina: general leaf form in transversal section V-shape; multicellular glandular trichome; mesophyll isobilateral; stomata are prominent; number of stomata in adaxial more than abaxial surface; number of palisade parenchyma layers are two; length of palisade parenchyma cells 62. 5- 100 μm with water-storage; size of epidermal cells in abaxial surface larger than adaxial; crystals of calcium oxalate scattered in mesophyll; both epidermic surfaces have cuticle

Midrib: central vascular bundle reniform; without sclerenchymatous sheath around vascular bundles, having 1-2 central vascular bundle; collenchyma in abaxial surface angular and in adaxial lamellar; number

of parenchyma layers in abaxial surface two and in adaxial up to nine; midrib triangular, with distinguished vascular sheath around vascular bundles; midrib length to width ratio 2 (fig. 12).

13. *Silene* L. sect. *Melandrifformes* Boiss. (1867)

Lamina: general leaf form in transversal section V-shape; multicellular glandular trichome; mesophyll isobilateral; stomata are prominent; number of palisade parenchyma layers are two; length of palisade parenchyma cells 50- 75 μm with water-storage; size of epidermal cells in abaxial surface and adaxial nearly equal; crystals of calcium oxalate scattered in mesophyll; both epidermis surfaces have cuticle

Midrib: central vascular bundle semi-orbicular to reniform without sclerenchymatous sheath around vascular bundles, having 1-2 central vascular bundle; collenchyma in abaxial surface angular and in adaxial lamellar rarely angular; number of parenchyma layers in abaxial surface 1-3 and in adaxial 4-8; midrib triangular, with distinguished vascular sheath around vascular bundles; midrib length to width ratio 2 (fig. 13).

14. *Silene* L. sect. *Orites* (Adans.) Oth in DC. (1824)

Lamina: general leaf form in transversal section U-shape; unicellular trichome, their surface tuberculoses; mesophyll dorsiventral; stomata are prominent; number of palisade parenchyma layers 1-2 with sinuous cell walls; length of palisade parenchyma cells 37. 5- 125 μm with water-storage; size of epidermal cells in abaxial surface larger than abaxial surface; crystals of calcium oxalate scattered in mesophyll; both epidermis surfaces have cuticle

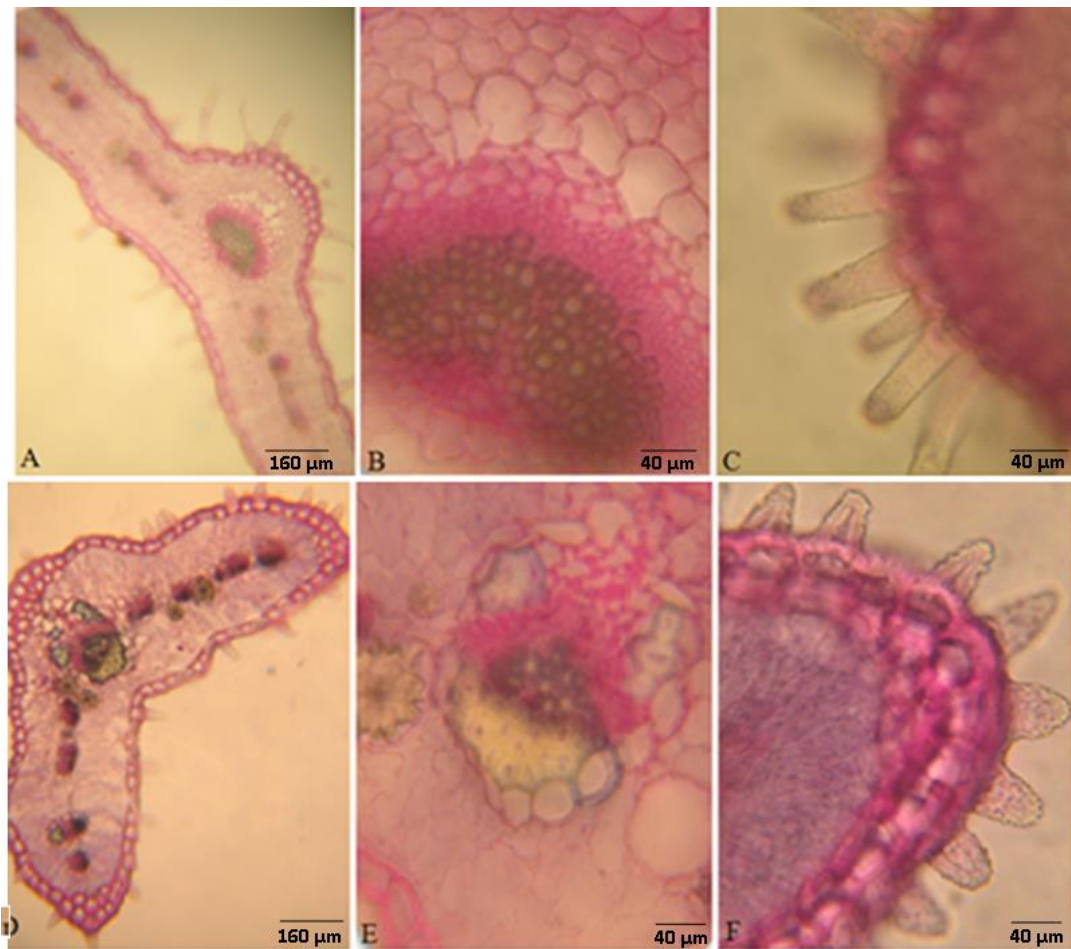


Fig. 11. A-C, *Silene macrowiczii*. D-F, *S. tenella* (Sect. *Lasiostemones*). A, D, leaf transversal section and general aspect (160μm); B, E, midrib (40μm); C, F, trichomes (40μm).

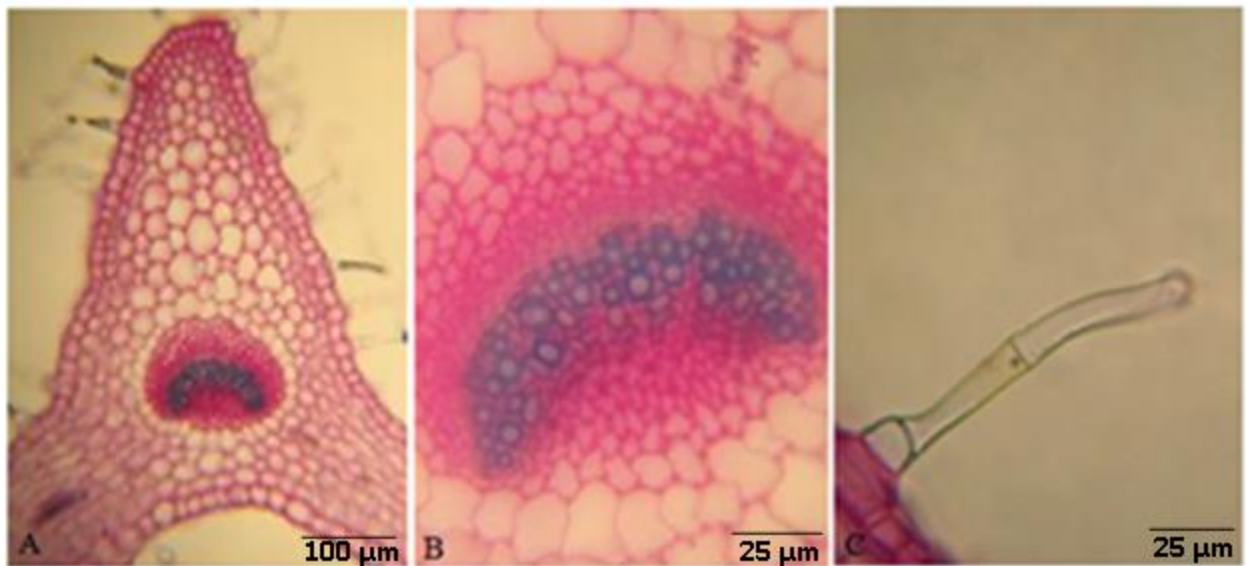


Fig. 12. *Silene coronaria* (Sect. *Lychnidiformes*). A, Leaf transversal section and general aspect (100μm); B, midrib (25μm); C, trichomes (25μm).

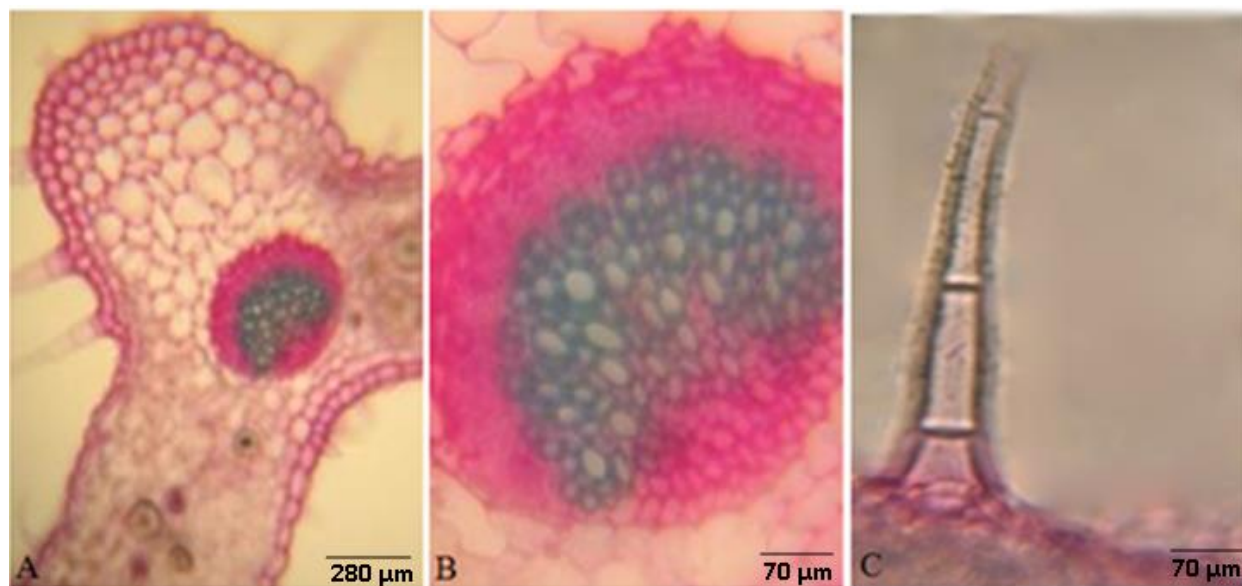


Fig. 13. *Silene noctiflora* (Sect. *Melandriiformes*). A, Leaf transversal section and general aspect (280μm); B, midrib (70μm); C, trichomes (70μm).

Midrib: central vascular bundle semi-orbicular to reniform; without sclerenchymatous sheath around vascular bundles, having one central vascular bundle; collenchymas in abaxial surface and adaxial lamellar; number of collenchymas layers in adaxial to two and abaxial surface is one; number of parenchyma layers in

abaxial surface 2-3 and in adaxial up to 5; midrib semi orbicular, with distinguished vascular sheath around vascular bundles; midrib length to width ratio 0.7; epidermal cells in abaxial surface ovate- elliptical (fig. 14).

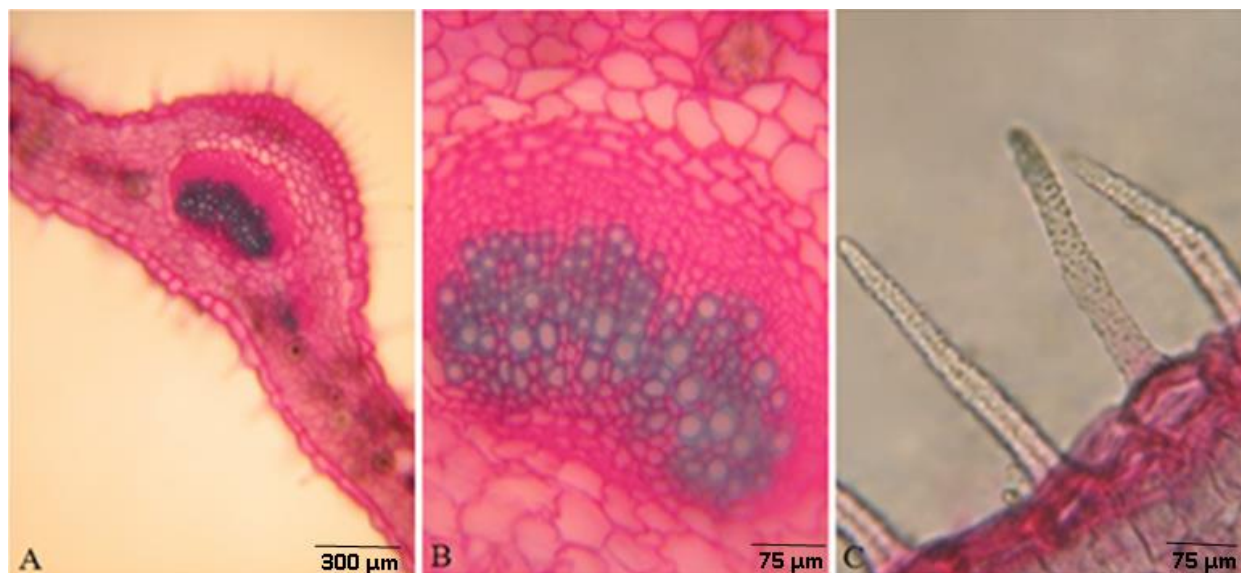


Fig.14. *Silene cyri* (Sect. *Otites*). A, leaf transversal section and general aspect (300μm); B, midrib (75μm), C, trichomes (75μm)

15. *Silene* L. sect. *Paniculatae* Boiss. (1867)

Lamina: general leaf form in transversal section U-

shape; long multicellular trichome with short hairs, their surface tuberculous; mesophyll isobilateral; stomata are prominent; number of palisade parenchyma layers are two; length of palisade parenchyma cells 37. 5- 50 μm with water-storage; size of epidermal cells in abaxial surface and abaxial surface almost equal; crystals of calcium oxalate scattered in mesophyll; both epidermic surfaces have cuticle

Midrib: central vascular bundle reniform; without sclerenchymatous sheath around vascular bundles, having one central vascular bundle; collenchyma in abaxial surface angular and in adaxial lamellar; Number of parenchyma layers in abaxial surface 1-2 and in adaxial up to 4; midrib ovate, with distinguished vascular sheath around vascular bundles; midrib length to width ratio 1.3- 1.8 (fig. 15).

16. *Silene* L. sect. *Rigidulae* Boiss. (1867)

Lamina: general leaf form in transversal section U-shape; glandular multicellular trichome; mesophyll dorsiventral; stomata are isoplanar; number of palisade parenchyma layers are two; length of palisade parenchyma cells 62. 5- 175 μm with water-storage; size of epidermal cells in abaxial surface and abaxial surface almost equal; crystals of calcium oxalate scattered in mesophyll; both epidermis surfaces have cuticle

Midrib: Central vascular bundle reniform to semi-orbicular; with advanced sclerenchymatous sheath around vascular bundles, having one rarely two central vascular bundle; collenchyma in abaxial surface and adaxial lamellar; number of parenchyma layers in abaxial surface two and in adaxial 2-3; midrib semi orbicular, with distinguished vascular sheath around vascular bundles; midrib length to width ratio 1- 1.2 (fig. 16).

17. *Silene* L. sect. *Saponariodeae* Boiss. (1867)

Lamina: general leaf form in transversal section U-shape; Unicellular trichome or non; mesophyll isobilateral; stomata are isoplanar; number of palisade parenchyma layers are three with sinuous cell walls; length of palisade parenchyma cells 37. 5- 100 μm with water-storage; size of epidermal cells in abaxial surface and abaxial surface nearly equal; crystals of calcium oxalate scattered in mesophyll; both epidermis surfaces have cuticle

Midrib: Central vascular bundle reniform; having sclerenchymatous sheath in adaxial; having one central vascular bundle; collenchymas in abaxial surface and adaxial lamellar; number of parenchyma layers in abaxial surface three and in adaxial up to four; midrib ovate; without distinguished vascular sheath around vascular bundles; midrib length to width ratio 1- 1.4

(fig. 17).

18. *Silene* L. sect. *Schaftae* Boiss. (1867)

Lamina: general leaf form in transversal section U-shape; short multicellular trichome s; Mesophyll isobilateral; Stomata are prominent; number of palisade parenchyma layers 1-2 with sinuous cell walls; length of palisade parenchyma cells 50- 75 μm with water-storage; size of epidermal cells in adaxial larger than abaxial surface; crystals of calcium oxalate scattered in mesophyll; both epidermis surfaces have cuticle

Midrib: central vascular bundle semi-orbicular; without sclerenchymatous sheath around vascular bundles; having one rarely two central vascular bundle; collenchyma in adaxial lamellar and in abaxial surface is angular; number of parenchyma layers in abaxial surface 1-3 and in adaxial up to three; midrib ovate; with distinguished vascular sheath around vascular bundles; midrib length to width ratio nearly 1 (fig. 18).

19. *Silene* L. sect. *Sclerocalycinae* Boiss. (1867)

Lamina: general leaf form in transversal section U-shape; non- trichome; mesophyll isobilateral; Stomata are isoplanar; number of palisade parenchyma layers are two; length of palisade parenchyma cells 62. 5- 125 μm with water-storage; size of epidermal cells in adaxial and abaxial surface more or less equal; crystals of calcium oxalate scattered in mesophyll; both epidermis surfaces have cuticle

Midrib: central vascular bundle reniform; without sclerenchymatous sheath around vascular bundles; having one rarely two central vascular bundle; collenchyma in adaxial surface lacunar and in abaxial surface is lamellar; number of parenchyma layers in abaxial surface 2-3 and in adaxial surface 3-6; midrib ovate; with distinguished vascular sheath around vascular bundles; midrib length to width ratio nearly 1- 1.2 (fig. 19).

20. *Silene* L. sect. *Spergulfoliae* Boiss. (1867)

Lamina: general leaf form in transversal section U-shape; long multicellular trichome with small pili, their surface tuberculous; mesophyll isobilateral rarely dorsiventral; Stomata are prominent; number of palisade parenchyma layers are two; length of palisade parenchyma cells 37.5- 75 μm with water-storage; size of epidermal cells in adaxial surface and abaxial surface more or less equal rarely epidermal cells of adaxial surface larger than abaxial surface; crystals of calcium oxalate scattered in mesophyll; both epidermis surfaces have cuticle

Midrib: central vascular bundle semi-orbicular; with advanced sclerenchymatous sheath around vascular bundles; having one rarely two central vascular bundle; collenchyma in adaxial surface lamellar and in abaxial

surface is lacunar or angular; number of parenchyma layers in abaxial surface 2-3 and in adaxial surface 2-4; midrib ovate; with distinguished vascular sheath around

vascular bundles; midrib length to width ratio nearly 1-1.3 (fig. 20)

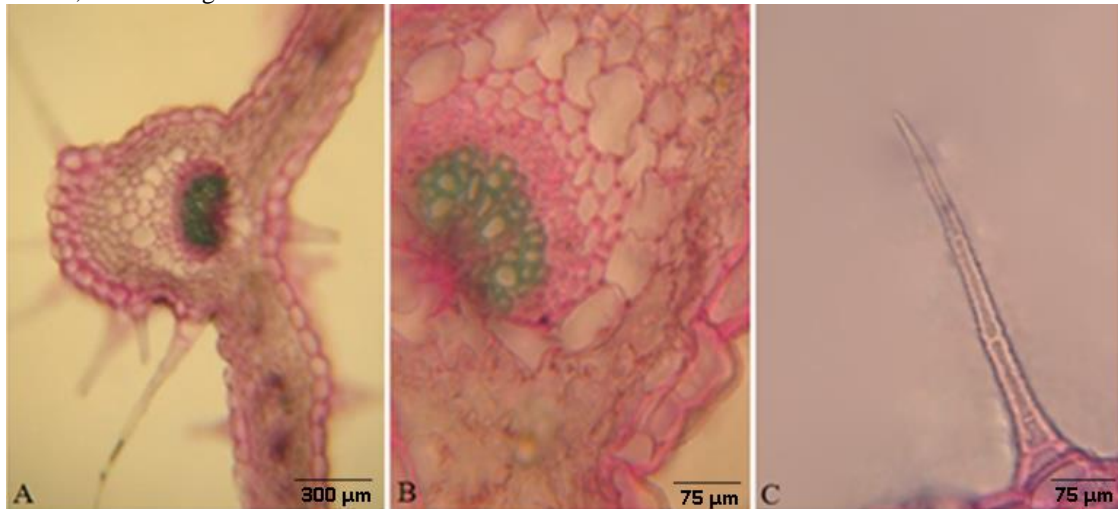


Fig. 15. *Silene italica* (Sect. *Paniculatae*). A, leaf transversal section and general aspect (300μm); B, midrib (75μm); C, trichomes (75μm)

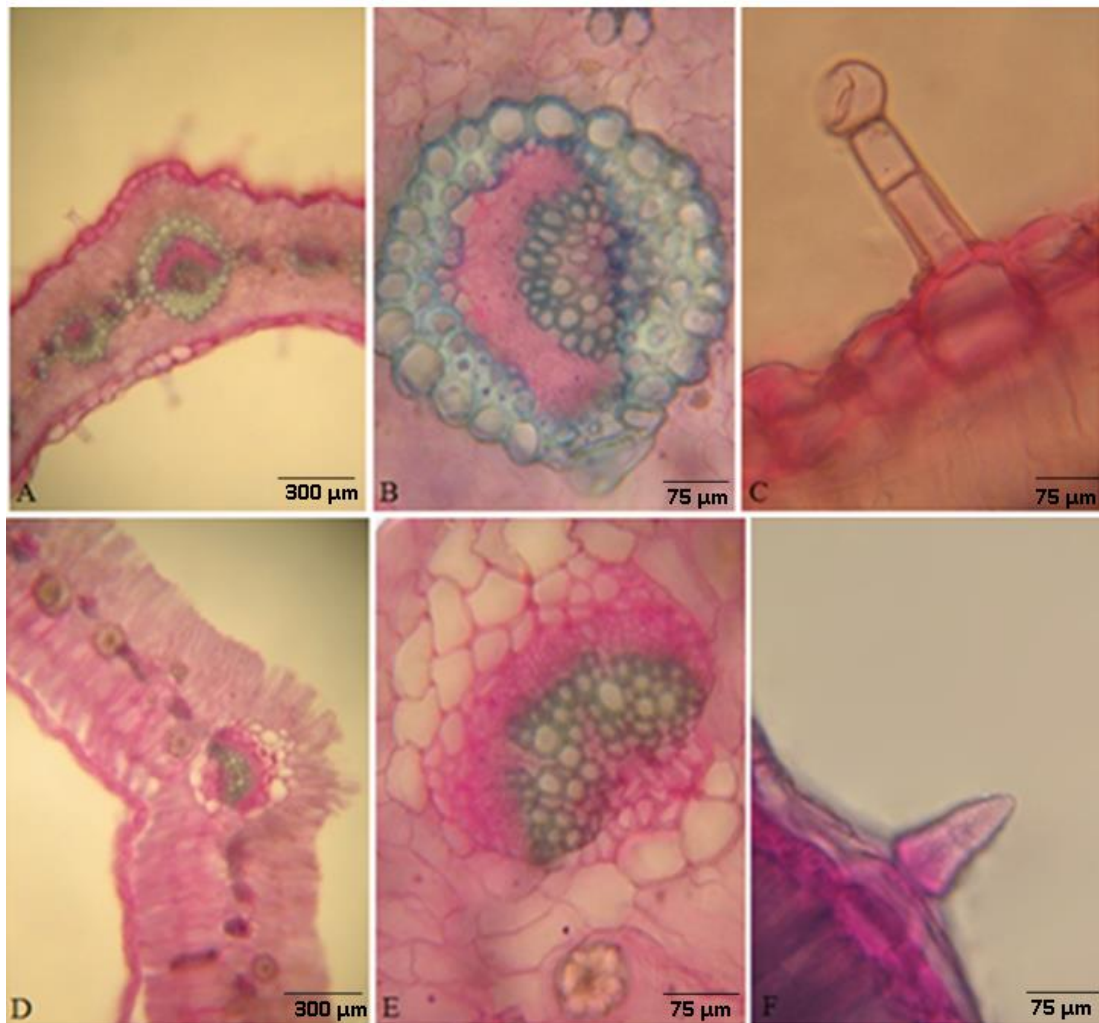


Fig. 16. A-C: *Silene arenosa* and D-F: *S. austro-iranica* (Sect. *Rigidulae*). A, D, leaf transversal section and general aspect (300μm); B, E, midrib (75μm); C, F, trichomes (75μm).

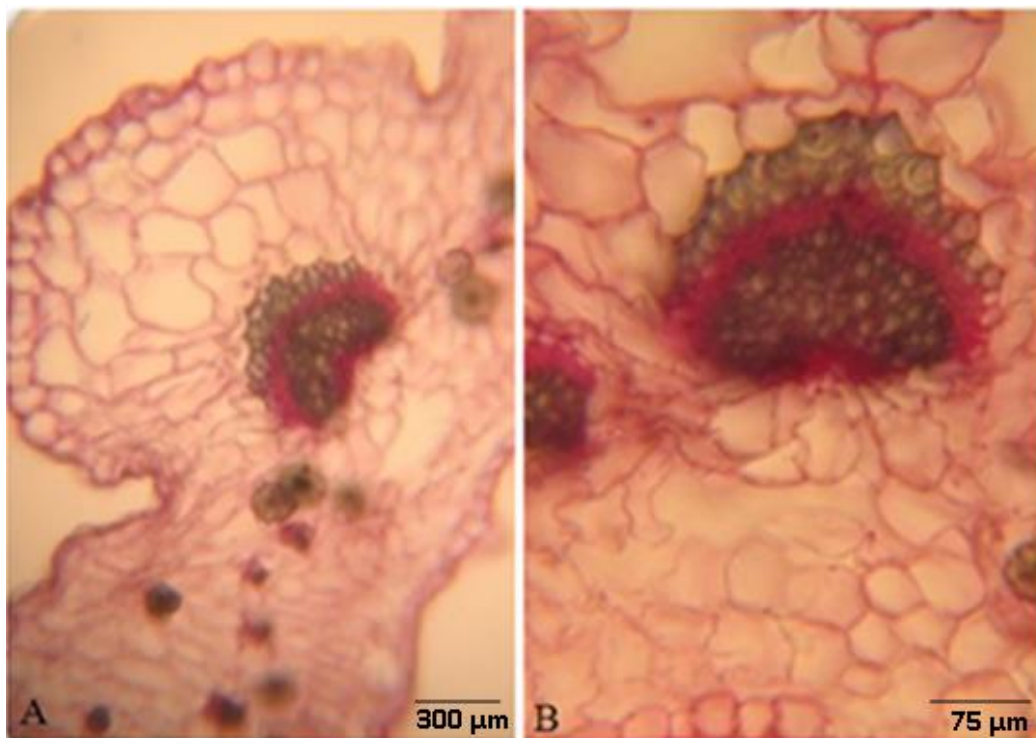


Fig. 17. *Silene nana* (Sect. *Saponarioides*). A, leaf transversal section and general aspect (300μm); B, midrib (75μm).

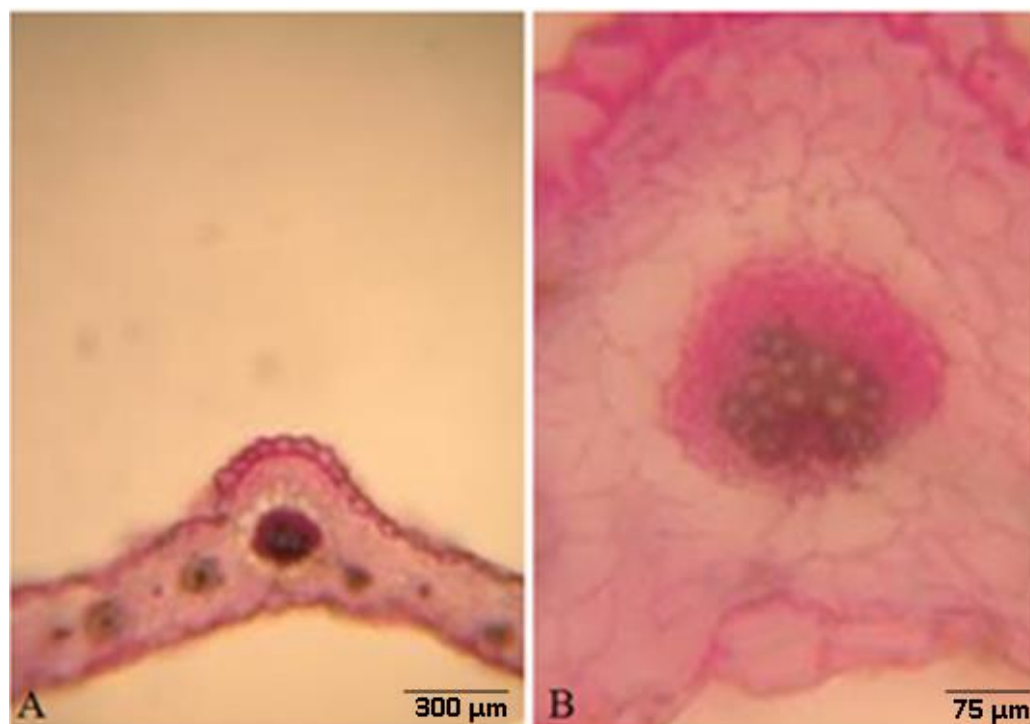


Fig. 18. *Silene schafta* (Sect. *Schaftae*). A, leaf transversal section and general aspect (300μm); B, midrib (75μm).

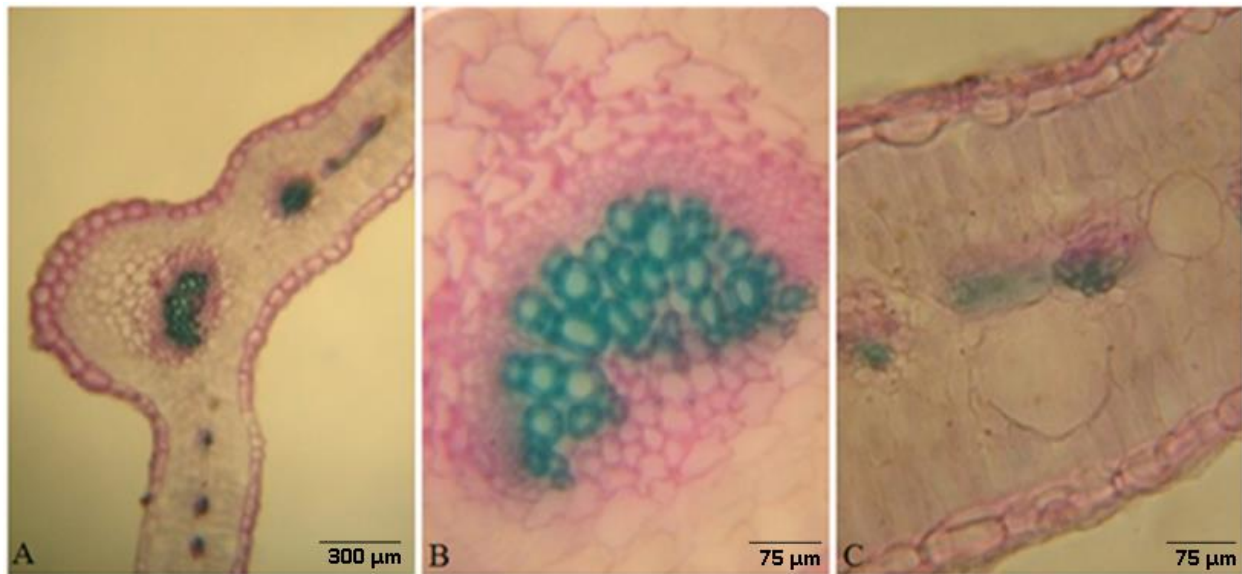


Fig.19. *Silene bupleoroides* (Sect. *Sclerocalycinae*). A, leaf transversal section and general aspect (300μm); B, midrib (75μm); C, lacuna (75μm).

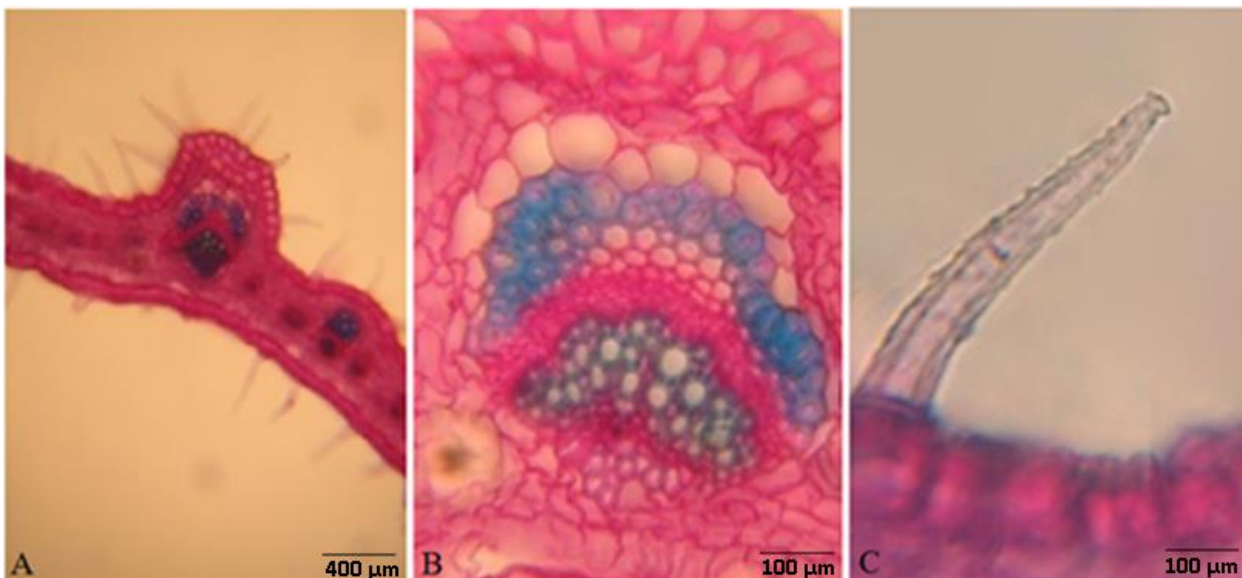


Fig. 20. *Silene spergulifolia* (Sect. *Spergulifoliae*). A, Leaf transversal section and general aspect (400μm); B, midrib (100 μm); C, trichomes (100 μm).

DISCUSSION

The study of the comparative anatomy of genus *silene* in sectional level has revealed interesting anatomical characters. All of these results show anatomical characters have taxonomic value for separating sections in genus *Silene*. Some sections have easily been separated from each other.

The most important character that has separated sections *Atocion* and *Rigidulae* from each other is the presence of sclerenchyma sheath and bundle sheath around vascular bundles in *Rigidulae* and absence of them in *Atocion*. These two sections are very similar taxonomically.

Sect *Lasioclycinae* and *Bipartitae* that have close relationship, have been separated based on adaxial surface collenchyma type and length of palisade parenchyma.

The most important differences between sect *Lychnidiformes* and *Otites* is form of midrib, which in *Lychnidiformes* is triangular but in *Otites* is semi-ovate.

Sometimes species of a section are so different from each other too. For example in section *Inflatae*, *Silene pungen* has very wide sclerenchyma sheath around vascular bundles that for this reason this species has been different from *S. vulgaris* and *S. odontopetala*. In addition, in section *Rigidulae*, *S. arenosa* has sclerenchyma sheath around vascular bundles, glandular trichome and bundle sheath.

REFERENCES

- Boissier, E. 1867: "Flora Orientalis, Caryophyllaceae", Geneva et Basieer Apath. Georg, Bibliopolam vol. 1: 567-656.
- Candolle, A. P. 1830: *Prodromus systematis naturalis regni vegetabilis*. Paris.
- Chowdhuri, P. K. 1957: Studies in the genus *Silene*. Notes from Royal. Bot. Garden. Edinburgh 22: 221-278.
- Nejati Edalatiyan, M., Joharchi, M. R. & Ghahremaninejad, F. 2011: *Silene ferdowsii* (Caryophyllaceae), a New Species from Iran. *Annales Botanici Fennici* 48: 155-158.
- Nejati Edalatiyan, M., Ghahremaninejad, F., Attar, F. & Joharchi, M. R. 2010: A taxonomic study on genus *Silene* L. (Caryophyllaceae) in Iran. *Rostaniha* 11: 133-149.
- Greuter, W., Burdet, H. M. & Long, G. 1984: *Med-Checklist*, 1. Geneve & Berlin.
- Greuter, W. 1995: *Silene* (Caryophyllaceae) in Greece: A subgeneric and sectional classification. *Taxon* 44: 543-581.
- Keshavarzi, M., Mahdavejad, M., Sheidai, M., and Gholipour, M: Anatomical study of some *Silene* L. species of *Lasiostemon* Boiss. Section in Iran. *Acta Biologica Szegediensis* 58 (1): 15-19
- Melzaimer, V. 1988: Caryophyllaceae: *Silene* L. in: Rechinger, K. H. (ed.). *Flora Iranica* 163: 341-508. Akad. Druke- u. Verlagsanstalt, Graz, Austria.
- Metcalf, C. R. & Chalk L. 1957: "Anatomy of the dicotyledones" vol. 1, Oxford university press.
- McNeill, J. 1978: *Silene alba* and *Silene dioica* in North America and the generic delimitation of *Lychnis*, *Melandrium*, and *Silene* (Caryophyllaceae). *Canad. J. Bot.* 56: 297-308.
- Oth, A., 1824: *Silene* L. In: *Prodromus systematis naturalis regni vegetabilis* vol. 1: 341-385.
- Rohrbach, P. 1869. *Monographie der Gattung Silene*. Leipzig.
- Shishkin, B. K. 1936: Caryophyllaceae: *Silene*. – In Komarov, V. L. (ed.) *Flora of the U. S. S. R* vol. 6: 578-691. Moskaova & Leningrad.
- Šourková, M. 1971: *Leconax* Rafin. –eine bis heuteun beachtete Silenoideen- Gattung. *Österr. Bot. Z.* 119: 577- 581.