

Morphological and anatomical studies of annual taxa of *Sideritis* L. (Lamiaceae), with notes on chorology in Turkey

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Abstract: *Sideritis* L. (Lamiaceae) includes approximately 150 species of annual and perennial plants distributed mainly in the Mediterranean region. In Turkey, 44 species (55 taxa) are native. Three of these species (5 taxa) are annual and these taxa are included in *Burghdorffia* and *Hesiodia* sections. This study was undertaken to investigate the morphological and anatomical properties of 5 annual taxa of *Sideritis*. Full descriptions and illustrations of these taxa are given, along with some additional information regarding their ecology and phyto geography. The anatomy of the leaf blade, midrib, and stem of the taxa are described and illustrated.

Key words: *Sideritis*, morphology, anatomy, Labiatae

Türkiye'deki bir yıllık *Sideritis* L. (Lamiaceae) taksonlarının morfolojik ve anatomik özellikleri ile yayılışları

Özet: *Sideritis* L. (Lamiaceae) başlıca Akdeniz bölgesinde yayılım gösteren, bir ve çok yıllık yaklaşık 150 türe sahip bir cinstir. Türkiye'de 44 tür (55 takson) doğal olarak yetişir. Bu türlerden 3'ü (5 takson) bir yıllıktır ve bu taksonlar *Burghdorffia* ve *Hesiodia* seksiyonlarında yer alır. Bu çalışmada *Sideritis*'in bir yıllık 5 taksonunun morfolojik ve anatomik özellikleri incelenmiştir. Bu taksonların ayrıntılı tanımları ve şekilleri verilmiştir. Ayrıca, ekolojik ve fitocoğrafik bilgilerine de yer verilmiştir. Türaltı taksonlarla birlikte türlerin yaprak ve gövde anatomileri tanımlanmış ve resimlenmiştir.

Anahtar sözcükler: *Sideritis*, morfoloji, anatomi, Labiatae

Introduction

The genus *Sideritis* L. is represented by more than 150 species, distributed from the Bahamas to western

China and from Germany to Morocco, and mainly found in the Mediterranean basin. The *Sideritis* genus is divided into 2 subgenera as a *Marrubiastrum*

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(Moench) Benth and *Sideritis*. The subgenus *Marrubiastrum* contains 3 sections (*Marrubiastrum*, *Empedocleopsis* Huynk and *Creticae* P.Perez & L.Negrin). The subgenus *Sideritis* is divided into 2 annual [*Hesiodia* Benth. and *Burgsdorfia* (Moench) Briquet] and 2 perennial [*Sideritis* and *Empedoclia* (Rafin.) Benth.] sections (Barber et al., 2002). Three of these sections (*Hesiodia*, *Burgsdorfia*, and *Empedoclia*) are native to Turkey and include 44 species (55 taxa). Turkey is gene centre of the *Empedoclia* section (Huber-Morath, 1982, 1988; Duman, 2000), which includes 41 species, all perennial. Endemism of this genus is very high (almost 80%). Three species (5 taxa) are annual and these taxa are included in *Burgsdorfia* and *Hesiodia* sections. *S. lanata* L., *S. romana* L. subsp. *romana*, and *S. romana* subsp. *curvidens* (Staph) Holmboe are in *Burgsdorfia* section and *S. montana* L. subsp. *montana* and *S. montana* L. subsp. *remota* (d'Urv.) P.W.Ball ex Heywood in *Hesiodia* section.

Genera of *Sideritis* are called “Dağ çayı, Yayla çayı, Ada çayı, Alanya adaçayı or Balbaşı” in Turkey. The *Sideritis* species are widely used in the treatment of gastrointestinal disorders and for treatment of cough, common cold, and as diuretic, as well as in herbal tea and in folk medicine in Turkey (Sezik & Ezer, 1983;

Başer 1995; Baytop, 1999). Thirty-one taxa of *Sideritis*, of which 25 species are endemic to Turkey, are collected for exporting (Özhatay et al. 1997).

The objective of this work was to determine the morphological and anatomical properties of 5 annual taxa of *Sideritis* growing in Turkey.

Materials and methods

The aerial parts of *Sideritis* species used in this study were collected in the flowering season from the Mediterranean region of Turkey. Voucher specimens are deposited in the Botany Department Herbarium at Gazi University (GAZI), Turkey. The research material was collected from the locations shown in Table 1. For the distribution of the species in Turkey, we used Davis's grid system (Davis, 1965).

Stems, leaves, and flowers were preserved in 70% ethanol. Cross-sections of stem and leaf were performed by hand from preserved material in chloral hydrate solution and Sartur reagent. Sartur reagent contains KI-I, aniline, sudan III, lactic acid, alcohol, and water (Çelebioğlu & Baytop, 1949). In this study at least 50 cross-sections were investigated. Illustrations were made using a drawing prism

Table 1. Locations of annual *Sideritis* taxa.

| Taxa | Locations |
|--|---|
| <i>Sideritis lanata</i> | C2 Muğla: Yatağan-Çine, 20th km, in macchie, on schistose, in <i>Quercus coccifera</i> clearings, 28.4.2000, 350 m, N 37° 29', E 28° 11' <i>H.Duman</i> 7120; C5 Konya: Ereğli, Taşpınar village, 23.5.2000, 1100 m, tufa, <i>H.Duman</i> 7159. |
| <i>S. romana</i> subsp. <i>romana</i> | A2 İstanbul: Beykoz, bus station of Şahinkaya Municipality, on north facing, 05.06.2000, 100 m, in stony places, <i>H.Duman</i> 7251. |
| <i>S. romana</i> subsp. <i>curvidens</i> | C1 Muğla: Milas-Bodrum, 10th km, in calcareous olive trees places, 28.04.2000, 50 m, N 37° 15', E 27° 44', <i>H.Duman</i> 7119; C3 Antalya: Aksu, Perge, 26.05.2001, 70 m, in remains, N 36° 57' 59", E 30° 51' 206", <i>H.Duman</i> 8564. |
| <i>S. montana</i> subsp. <i>montana</i> | B3 Eskişehir: Sivrihisar-Polatlı road, around Oğlakçı, in calcareous steppe, 20.05.2000, 870 m, <i>H.Duman</i> 7127; C4 Konya: Beyşehir-Konya road, 40th km, <i>Pinus nigra</i> Arn. forest, 26.05.2001, 1300 m, <i>H.Duman</i> 8561. |
| <i>S. montana</i> subsp. <i>remota</i> | C2 Burdur: Around Burdur plantation field, in marl soils, 20.05.2000, 1030 m, <i>H.Duman</i> 7128. |

attached to a Leitz–Wetzlar (45°) microscope. Photographs from the preparations were taken with a camera adapted to a Olympus BX 50 microscope.

Results

Morphology

Sect. *Burgsdorfia* (Moench) Briquet

Annual. Bracts are ± entire and leaf-like. Calyx is 2-lipped, the upper tooth wider and larger than the lower 4 teeth.

Sideritis lanata L., Fl. Palaest. 22 (1756).

Type: Described from Palaestina (Hb. Linn. 729/17).

Annual, (5-) 10-30 (-60) cm, simple or branched from base, with densely white-villous and short glandular hairs. Leaves ovate-elliptic, obtuse, crenate or crenate-serrate; lamina 5-40 × 5-20 mm, loosely long villose and without stalk glandular hairs; petiole 3-20 (-30) mm, with long white-villous and short glandular hairs. Verticillasters 2-6 flowered; mostly distant below, to 1-2 cm, congested above. Bracts leaf-like, ovate-orbicular, ± sessile, crenate or crenate-serrate. Calyx 5-10 mm, densely long-villous, ± 2-lipped; teeth lanceolate, acuminate, curved, upper tooth 2.5-4 mm, lower teeth 1.5-3 mm. Pedicel 0.2-1 mm, erect or curved in fruiting time. Corolla cream, with purplish-black lips, 6-8 mm, ± subequal to calyx, with loose hairs. Nutlets ovate, light-brown, ± 2 mm.

Flowering time: April-June. It naturally grows in cultivated fields, limestone rocks, steppe, in macchie, schistose areas, and in *Quercus coccifera* L. clearings; at altitudes between 0–1650 m (Figure 1).

Distribution in Turkey: Marmara, Aegean, Mediterranean, and Central Anatolia (Figure 2).

Distribution in the world: Balkans and Turkey. East Mediterranean element.

S. romana L., Sp. Pl. 575 (1753).

Annual. Stem (3-) 10-35 (-50) cm, procumbent or erect, simple or branched at base, sparsely villous-lanate and rarely glandular hairs. Leaves ovate, oblong, oblanceolate, elliptic, obtuse or ± acute-mucronate, crenate-serrate or sometimes entire, loosely or densely villous-lanate; lamina 8-20 (-30) × 2-10 (-15) mm,

lowermost with petiolate, petiole (1-) 2-5 (-10) mm. Verticillasters (2-) 4-6-flowered, obviously distant, 1-4.5 cm. Bracts leaf-like, shortly petiolate or sessile. Bracteoles present or absent, if present then setaceous. Pedicel 0.5-2 mm, erect. Calyx 5-10 (-12) mm, obviously saccate at base or not, 2-lipped, obviously veined or not, villous-lanate and loose little glandular hairs; teeth usually erect, upper tooth broadly ovate, 3-6 mm, inner surface obviously 3-veined; 4 lower teeth triangular-lanceolate, curved or erect, 2-3 mm, teeth 1-2 mm spiny-aristate. Corolla white, 6-10 mm, equal to calyx, loose hairs. Nutlets ovate, light-brown, slightly rugose, ± 1.5 mm.

1. Calyx obviously veined, not saccate at base, calyx teeth usually erect. subsp. *romana*

1. Calyx not obviously veined, saccate at base, calyx teeth curved subsp. *curvidens*
subsp. *romana*

Type: Described from South Europe (Hb. Linn. 729/7, 8).

Flowering time: April-June. It naturally grows in cultivated fields, roadsides, limestone rocks, schistose soils; at altitudes between 5–100 m (Figure 3).

Distribution in Turkey: Marmara and Mediterranean (Figure 2).

Distribution in the world: Mediterranean. Mediterranean element.

subsp. *curvidens* (Staph) Holmboe, Veg. Cyprus 153 (1914).

Type: [Turkey C2 Antalya] in Acropoli urbis Xanthos (nr Kinik), 23 iv 1882, Luschan (holo. WU!).

Synonym: *S. curvidens* Staph in Denkschr. Akad. Wiss. Wien, Math.-Nat. Kl. 50(2): 100 (1885); *S. romana* L. var. *curvidens* (Staph) Bornm. In Mitt. Thür. Bot. Ver., N. S. 16:123 (1901); *S. romana* L. var. *mutica* Boiss., Fl. Or. 4:706 (1879); *S. curvidens* Staph f. *Mutica* (Boiss.) Greuter in Boissiera 13:115 (1967).

Flowering time: April-June. It naturally grows in cultivated fields, roadsides, limestone rocks, in macchie, calcareous rocks, in phrygana, schistose serpentine; at altitudes between 0–915 m (Figure 4).

Distribution in Turkey: Mediterranean and Aegean (Figure 2).

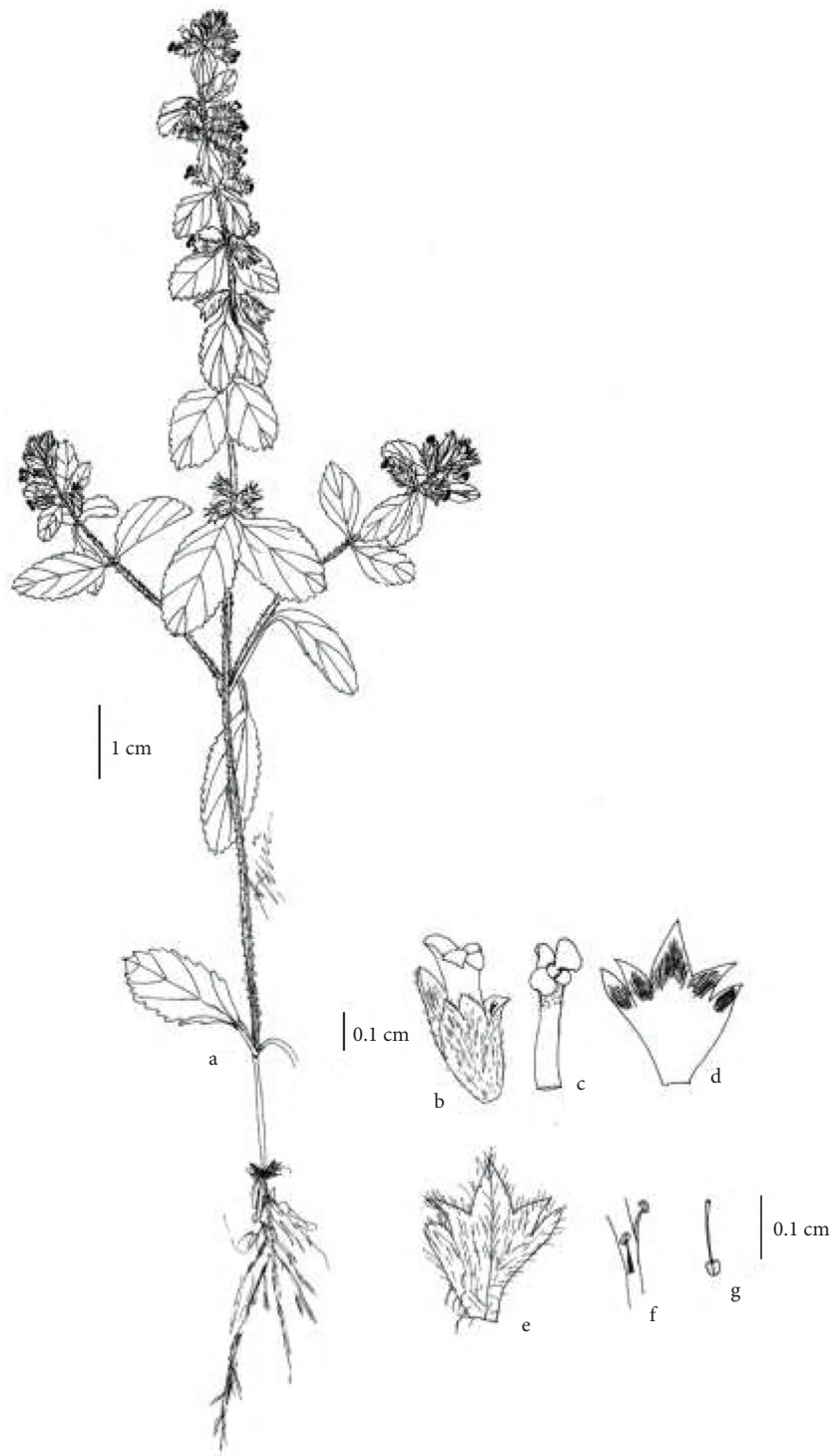


Figure 1. *S. lanata*. a- habitus, b- flower, c- corolla, d- inside of calyx, e- outside of calyx, f- stamens, g- gynoecium.

Distribution in the world: Turkey, Greece, Cyprus, Lebanon. East Mediterranean element.

Sect. *Hesiodia* (Moench) Benth

Annual. Bracts are \pm entire and leaf-like. Calyx is actinomorphic, teeth almost subequal.

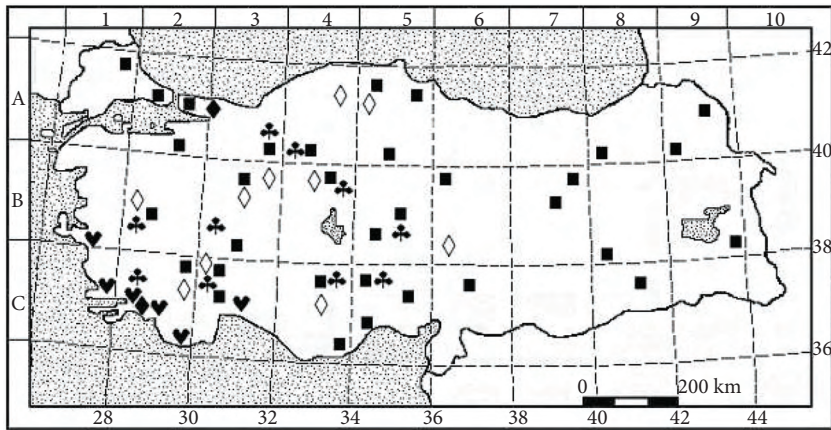


Figure 2. Distribution in Turkey of annual *Sideritis* taxa. ♣ *S. lanata*, ♦ *S. romana* subsp. *romana*, ♥ *S. romana* subsp. *curvidens*, ■ *S. montana* subsp. *montana*, ◇ *S. montana* subsp. *remota*.

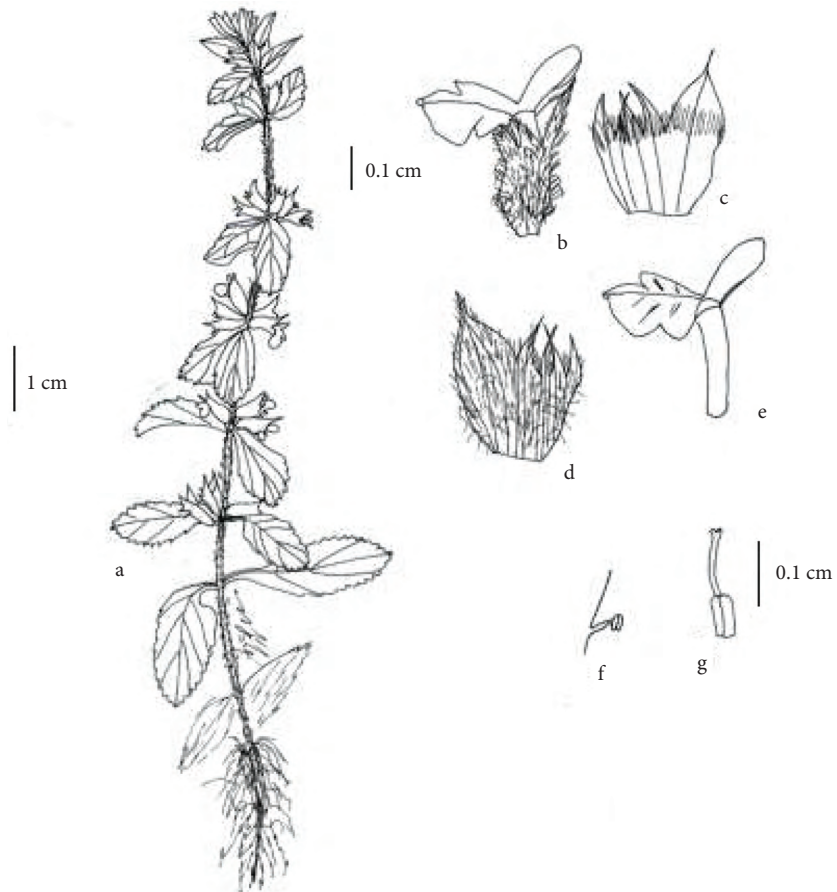


Figure 3. *S. romana* subsp. *romana* a- habitus, b- flower, c- inside of calyx, d- outside of calyx, e- corolla, f- stamen, g- gynoecium.

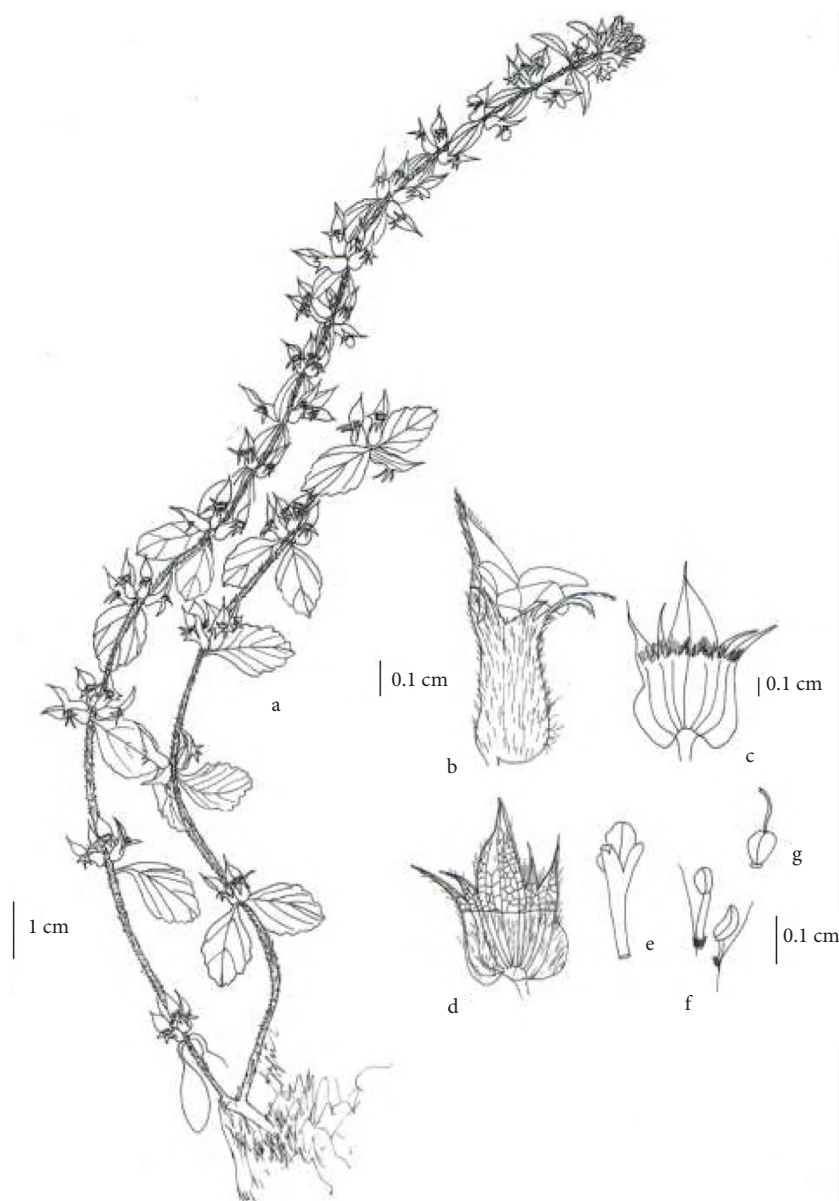


Figure 4. *S. romana* subsp. *curvidens*. a- habitus, b- flower, c- inside of calyx, d- outside of calyx, e- corolla, f- stamens, g- gynoecium.

***S. montana* L., Sp. Pl. 575 (1753).**

Annual. Stem 10-40 cm, usually ascending, branched from middle of stem or base, green or purple, eglandular, villous-lanate, hairs 1-6 mm. Leaves oblanceolate, lanceolate, oblong, linear or elliptic, acute-mucronate or obtuse, denticulate-serrate or sometimes entire, loosely or densely villous-lanate; lamina (5-) 15-30 (-42) × 2-10 mm, lowermost with petiolate, petiole 2-15 mm. Verticillasters

numerous, (3-) 4-6-flowered, 0.5-3.5 cm distant or congested at upper parts, moderately to densely villous-lanate. Bracts leaf-like, usually short petiolate or sessile, upper bracts yellow or violet. Pedicel absent or 0.5-1.5 (-2) mm. Calyx 6-10 mm, ± actinomorphic, usually green or purple, villous-lanate; teeth ± subequal, triangular-ovate, oblong, 2-3.5 mm, with 0.5-1 mm mucro. Corolla yellow, turning brownish-black when dry, 5-7 mm, hairy. Nutlets obovate, 1.5-2 × 1-1.5 mm, brown.

1. Calyx green, upper bracts usually yellow, verticillasters loosely villous-lanate
 subsp. *montana*
1. Calyx purple, upper bracts usually violet, verticillasters densely villous-lanate
 subsp. *remota*
 subsp. *montana*

Type: Described from Italy (Hb. Linn. 729/6).

Synonym: *S. montana* L. var. *comosa* Rochel ex Benth in DC., Prodr. 12:446 (1848); *S. comosa* (Rochel ex Benth) Stankov in Stankov & Taliev, Opred. Vyssh. Rast. Evrop. SSSR. Ed. 1, 861 (1949); *S. montana* L. subsp. *comosa* (Rochel ex Benth) Soo in Acta Bot. Acad. Sci. Hung. 10:371 (1964).

Flowering time: May-August. It naturally grows in cultivated fields, roadsides, steppe, limestone rocks, *Quercus* scrub, salt steppe, dune, schistose slopes, rocky terrain, high mountain meadow, serpentine rocks, volcanic tufa slopes; at altitudes between 0–2000 m (Figure 5).

Distribution in Turkey: Widespread and common (Figure 2).

Distribution in the world: Turkey, Europe, North Africa, South-West Asia. Mediterranean element.

subsp. *remota* (d'Urv.) P. W. Ball ex Heywood in Bot. J. Linn. Soc. 65:355 (1972).

Type: [Islands] in collibus insulae Sami (Samos), vi 1819, d'Urville (P).

Synonym: *S. remota* d'Urv. in Mem. Soc. Linn. Paris 1:322 (1822); *S. lycanica* Boiss. & Heldr. in Boiss., Diagn. Ser. 2(4):35 (1859); *S. remota* d'Urv. var. *lycanica* (Boiss. & Heldr.) Boiss., Fl. Or. 4:707 (1879).

Flowering time: April-July. It naturally grows in cultivated fields, roadsides, limestone rocks, *Quercus coccifera* L. shrubs, *Cistus laurifolius* L. shrubs, *Thymus* steppe, marly places, calcareous rocks; at altitudes between 5–2100 m (Figure 6).

Distribution in Turkey: Marmara, West Black Sea Region, Central Anatolia, Mediterranean and Aegean (Figure 2).

Distribution in the world: Turkey, Greece, Aegean Islands. East Mediterranean element.

Anatomy

Sideritis lanata

Leaf

Cross-section of leaf blade

Upper epidermis cells are usually rectangular, single layered, thin and long, with thin walls. Cuticle is thin. Plant contains eglandular and glandular trichomes. Eglandular trichomes are unicellular and simple. There are 2 types of glandular trichomes: 1) shorter glandular trichomes have a unicellular stalk and head and Lamiaceae type trichomes have a unicellular stalk and multicellular (2-8) head. 2) longer glandular trichomes consist of 2–4-celled stalk, and 2-4-celled head, pin-like. There are numerous covering simple eglandular trichomes, but few glandular trichomes. The leaf is bifacial. The palisade cells are usually 1-layered, thick, subequal long and cylindrical, and there are usually intercellular spaces. This parenchyma continues smooth. Spongy parenchyma consists of 3-4 layers, with the first layer like palisade cells and the others usually non-isodiametrical cells with intercellular space. Underneath the spongy parenchyma is lower epidermis. These epidermal cells are flattened and smaller than the upper cells and are covered with a thin cuticle. Both types of glandular trichomes are present on lower epidermis, and covering simple eglandular trichomes are more frequent than on upper epidermis. Stomata occur on both sides of the leaves. Palisade and spongy parenchyma contain starch granules. Mesophyll does not contain crystals of calcium oxalate (Figures 7, 8A).

Cross-section of the midrib

The upper surface of the midrib area is formed by 1 small cell and 2 large cells. As a result, the midrib area is slightly concave on this surface. Underneath the upper epidermis, there are 2 layers of small or large, a few almost cylindrical, colourless parenchyma cells. Palisade and spongy parenchyma are interrupted in this region. Vascular bundle is located in the area. Midrib area is deeply convexed on the lower surface. Inside this convex, spherical colourless parenchymatous cells are present. Lower epidermis cells are almost spherical and larger than the lamina epidermis (Figure 8B).

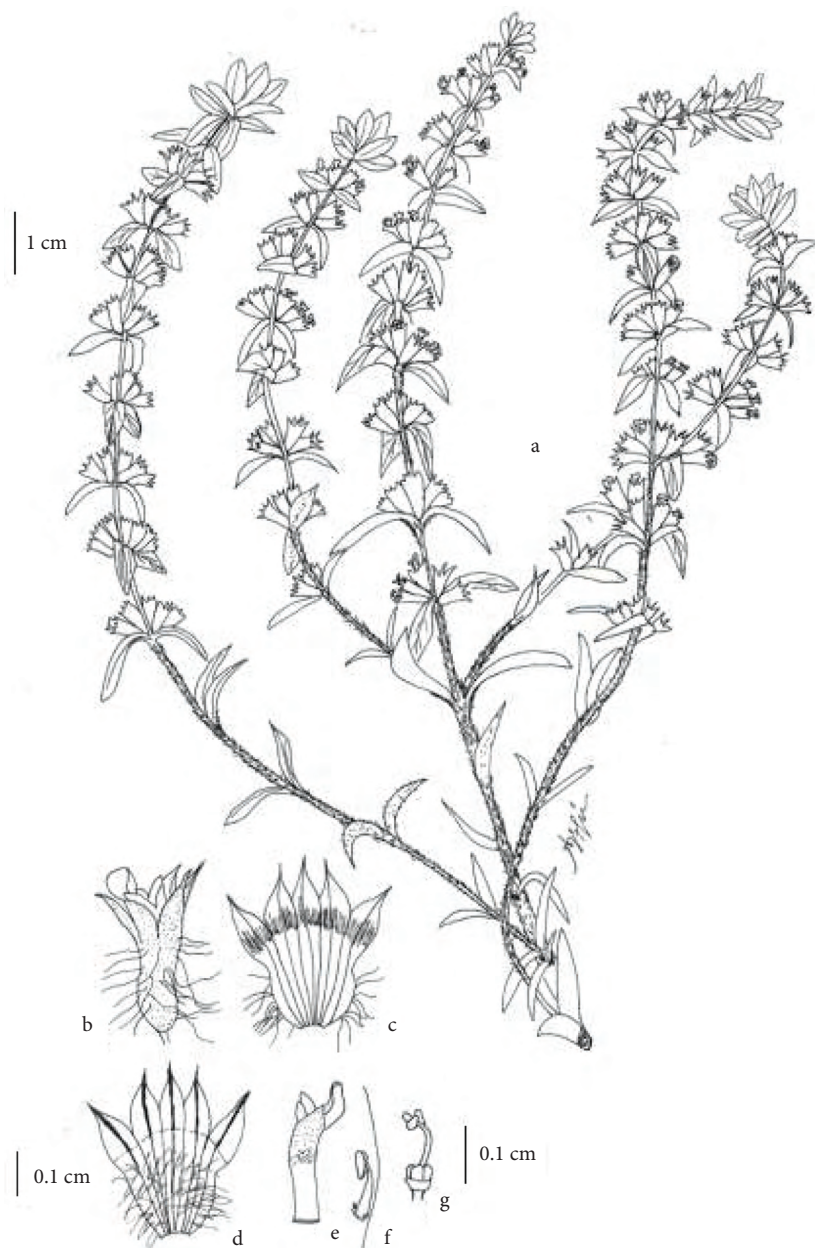


Figure 5. *S. montana* subsp. *montana*. a- habitus, b- flower, c- inside of calyx, d- outside of calyx, e- corolla, f- stamen, g- gynoecium.

Stem

Cross-section of the stem is 4-cornered (squared). Collenchyma is present in corners. Stem exhibits the following characteristics:

The cuticle is thin. Epidermis usually has rectangular, in corners square or multi-angled cells. Eglandular and glandular trichomes are seen on the whole surface. Covering simple eglandular trichomes

are strong, thick, unicellular, and simple or 2-4 celled. Glandular trichomes are short and long types. Short glandular trichomes have a unicellular stalk and head or 2-celled stalk and multicellular head. Long glandular trichomes consist of 2-4-celled stalk and 1-2-celled head. In corners underneath the epidermis there is narrow collenchyma. In intercorners, cortex parenchyma consists of 2-4 layers; however, underneath the collenchyma is 1-2 layers. This

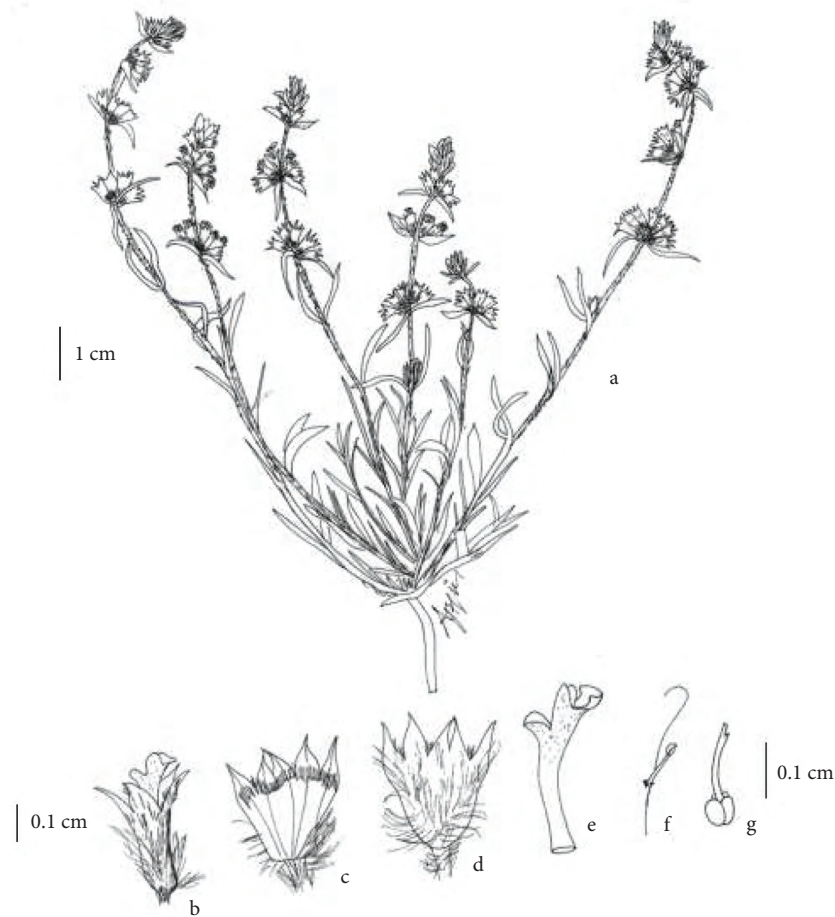


Figure 6. *S. montana* subsp. *remota*. a- habitus, b- flower, c- inside of calyx, d- outside of calyx, e- corolla, f- stamen, g- gynoecium.

parenchyma consists of cylindrical or oval cells containing starch granules and there are usually small intercellular spaces. Underneath the cortex parenchyma is endodermis, which consists of 1 layer, usually rectangular or oval and colourless cells, surrounding the stem. Pericycle is underneath the endodermis and in corners is usually sclerenchymatous and in intercorners is usually thin-walled with live cells. Phloem is obvious in corners, thin-walled, with irregularly shaped small cells; however, in intercorners there are irregular large cells containing druses. Cambium cells are not clear, generally collapsed but visible. Xylem is narrow in intercorners, but wide in corners. Xylem is observed as groups. Pith rays are usually 1-2 layers. The pith is massive and consists of round parenchyma cells. The pith cells next to the xylem are small, but in the centre are large and cylindrical and thin-walled. This region

does not contain crystals of calcium oxalate or starch granules (Figures 9, 10).

S. romana subsp. *romana*

Leaf

Cross-section of leaf blade

Upper epidermis consists of big or small rectangular cells and is covered with a thin cuticle. Covering glandular trichomes are unicellular or multicellular and simple. There are 2 types of glandular trichomes: 1) shorter ones have a unicellular stalk and head and a unicellular stalk and multicellular head. 2) longer ones consist of 2-4 celled stalk, and 2-4-celled head, pin-like. The leaf is monofacial. Palisade cells are usually 1, sometimes 2-layered, thick, long, and cylindrical. Spongy parenchyma consists of 2-3 layers of usually

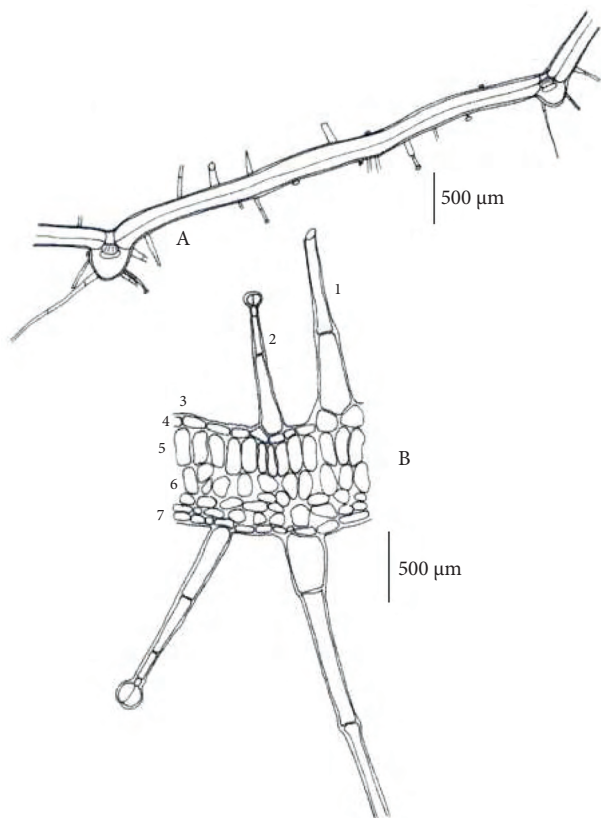


Figure 7. *S. lanata* – cross section of leaf blade; A. general view, B. anatomic properties, 1- eglandular trichomes, 2- glandular trichomes, 3- cuticle, 4- upper epidermis, 5- palisade parenchyma, 6- spongy parenchyma, 7- lower epidermis.

isodiametrical cells with intercellular space. Underneath the spongy parenchyma there is 1 layer of palisade parenchyma. These palisade cells are longer than the upper palisade cells and sometimes have wide intercellular spaces. Palisade and spongy parenchyma contain abundant starch granules. Lower epidermis cells are shaped similarly to upper epidermis cells and covered with a thin cuticle. Both types of glandular trichomes are present on lower epidermis, and covering simple eglandular trichomes are more frequent than on upper epidermis. Stomata occur on both sides of the leaves. Mesophyll does not contain crystals of calcium oxalate (Figures 11, 12A).

Cross-section of the midrib

Midrib area is slightly concave on the upper surface. Underneath the upper epidermis, there are 2-3 layers of small or wide, cylindrical, colourless parenchyma cells. Palisade and spongy parenchyma

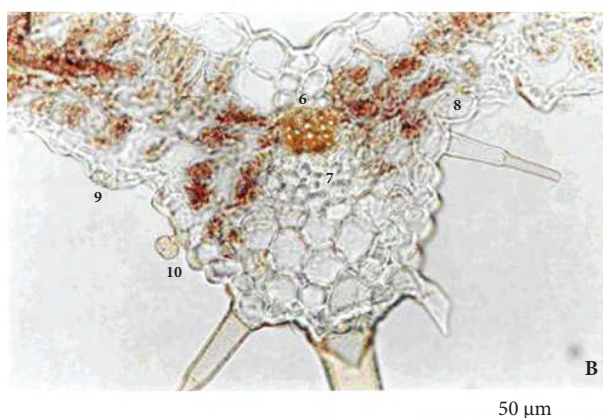
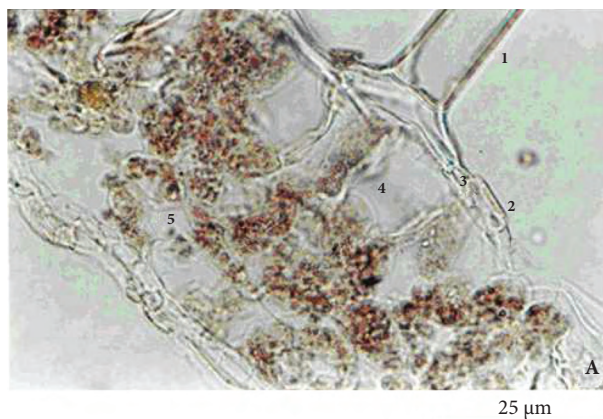


Figure 8. *S. lanata* – A. cross section of leaf blade, B. cross section of the midrib. 1- eglandular trichomes, 2- cuticle, 3- upper epidermis, 4- palisade parenchyma, 5- spongy parenchyma, 6- vascular bundle, 7- parenchyma, 8- lower epidermis, 9- stoma, 10- glandular trichomes.

are interrupted in this region, which contains vascular bundle. Midrib area is a wide convex on the lower surface, inside of which, 3-4 layers of spherical, colourless parenchymatous cells are present. Lower epidermal cells are almost square and smaller than in the lamina epidermis (Figure 12B).

Stem

Cross-section of the stem is 4-cornered (squared). Collenchyma is seen in corners as wide and shallow. Stem exhibits the following characteristics:

The protective tissue consists of a single-layered epidermis. These cells are square, outer and inner walls are rather thickened compared to side walls. Cuticle is thin. Eglandular and glandular trichomes are seen on the entire epidermal surface. Covering

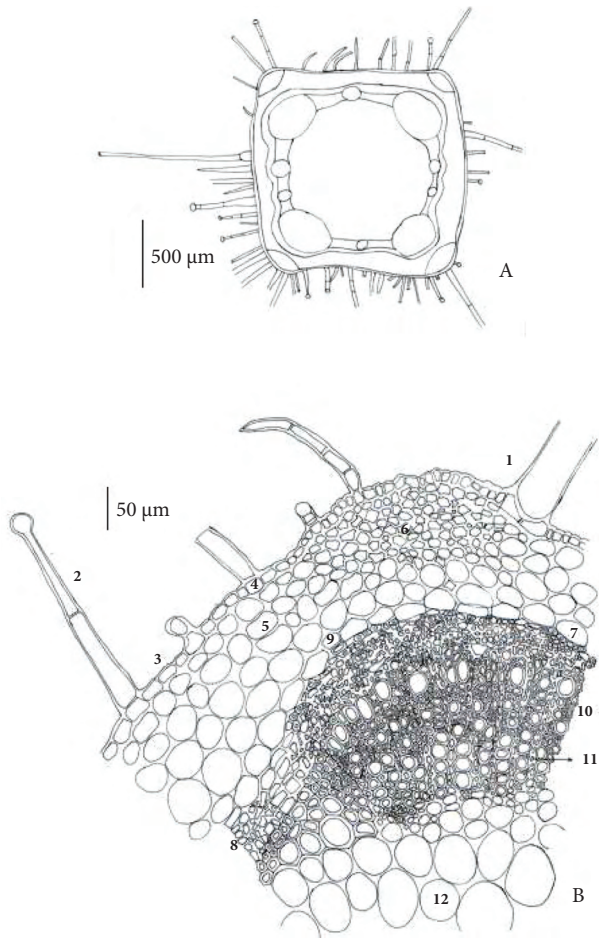


Figure 9. *S. lanata* – cross section of stem; A. general view, B. anatomic properties. 1- eglandular trichome, 2- long glandular trichome, 3- cuticle, 4- epidermis, 5- parenchyma, 6- collenchyma, 7- endodermis, 8- phloem, 9- sclerenchyma, 10- xylem, 11- pith ray, 12- pith.

eglandular trichomes are usually 2-celled and simple, but can sometimes be multicellular, and long. Glandular trichomes are short and long types, with short type having unicellular stalk and 2-celled head or multicellular stalk and head. Long glandular trichomes consist of multicellular stalk and head, pin-like. There are numerous short glandular trichomes in the stem, and stomata are present. Collenchyma is present in corners, underneath the epidermis, and is composed of 5-7 layers, usually with irregular walls and big cells in the upper side of collenchyma, but with small cells near the endodermis. In intercorners, cortex parenchyma consists of 3-5 layers, and is

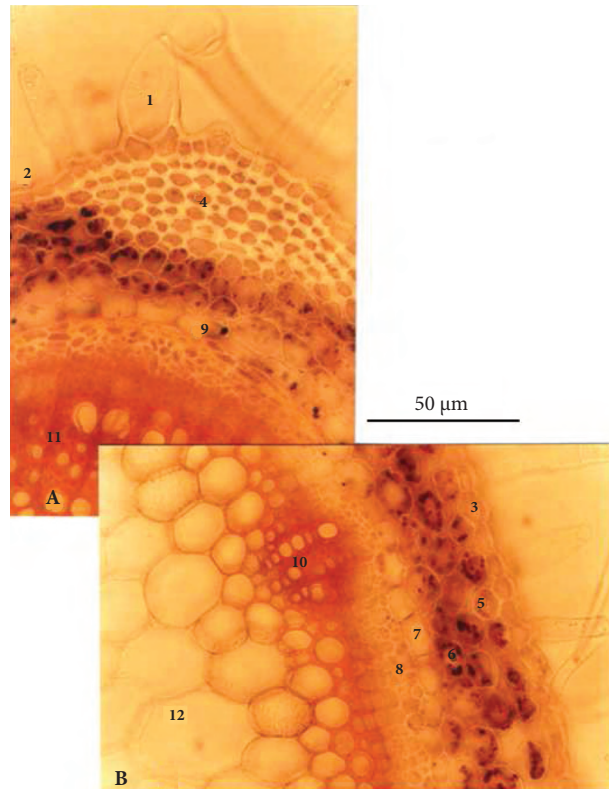


Figure 10. *S. lanata* – cross section of stem of anatomical properties. A. corner, B. intercorner. 1- eglandular trichome, 2- cuticle, 3- epidermis, 4- collenchyma, 5- parenchyma, 6- starch granules, 7- endodermis, 8- phloem, 9- sclerenchyma, 10- pith ray, 11- xylem, 12- pith.

cylindrical or oval with intercellular spaces; however, underneath corners this parenchyma is 2-layered without intercellular gaps. Cortex parenchyma cells do not contain starch granules. Cortex parenchyma cells above the endodermis are usually ovoid and large, and are irregularly shaped and generally collapsed in corners. Endodermis consists of 1 layer of usually oval or rectangular colourless cells surrounding the stem. Pericycle is underneath the endodermis and is usually sclerenchymatous in corners, and occasionally sclerenchymatous in intercorners. Phloem is 2-4 layers, thin-walled, with irregularly shaped small cells. Cambium cells are not clear. Xylem is often divided by pith rays and has 9-10 layers in corners and 5-6 layers in intercorners. Primary xylem is behind the pith parenchyma. Xylem parenchyma is present in this region. Pith rays are usually 1 layer. The pith is massive and consists of

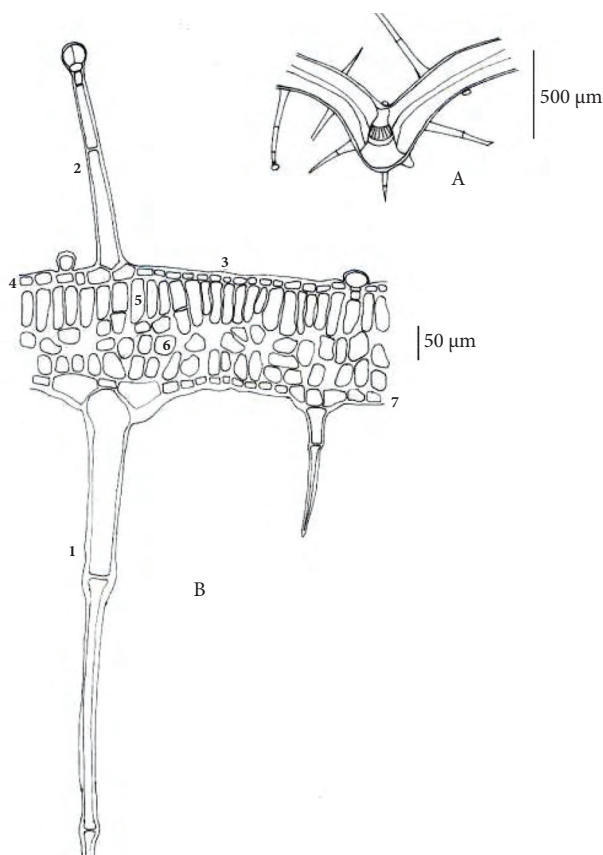


Figure 11. *S. romana* subsp. *romana* – cross section of leaf blade; A. general view, B. anatomic properties, 1– eglandular trichomes, 2– glandular trichomes, 3– cuticle, 4– upper epidermis, 5– palisade parenchyma, 6– spongy parenchyma, 7– lower epidermis.

round and big parenchymal cells. The pith cells next to the xylem are small. These cells contain no crystals of calcium oxalate or starch granules (Figures 13, 14).

S. romana* subsp. *curvidens

Leaf

Cross-section of leaf blade

Upper epidermis usually consists of rectangular cells and is covered with a thin cuticle. This species contains eglandular and glandular trichomes. Covering eglandular trichomes are multicellular and simple. There are 2 types of glandular trichomes: 1) shorter ones are Lamiaceae type trichomes with a unicellular stalk and head. This species includes a few



Figure 12. *S. romana* subsp. *romana* – A. cross section of leaf blade; B. cross section of the midrib. 1– eglandular trichomes, 2– cuticle, 3– upper epidermis, 4– palisade parenchyma, 5– spongy parenchyma, 6– vascular bundle, 7– parenchyma, 8– lower epidermis, 9–stoma.

trichomes with unicellular stalk and multicellular head, 2) longer glandular trichomes consist of 1–2-celled stalk, and 1-2-celled head, pin-like. The leaf is bifacial. The palisade cells are 3(-4) layers, thick, subequal long and cylindrical. Spongy parenchyma consists of 3-4 layers usually of isodiametrical cells with intercellular space. Underneath the spongy parenchyma there is 1 layer of lower epidermis in which cells are rectangular or square, narrower than upper epidermis cells and covered with a thin cuticle. Both types of glandular trichomes are present on lower epidermis. Mesophyll contains abundant starch granules. Stomata occur on both sides of the leaves. Mesophyll does not contain crystals of calcium oxalate (Figures 15,16A).

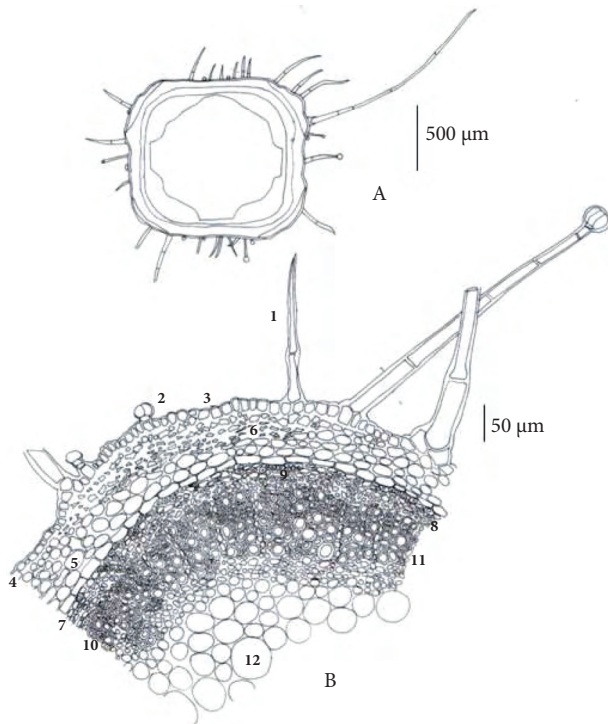


Figure 13. *S. romana* subsp. *romana* – cross section of stem; A. general view, B. anatomic properties. 1- eglandular trichome, 2- glandular trichome, 3- cuticle, 4- epidermis, 5- parenchyma, 6- collenchyma, 7- endodermis, 8- phloem, 9- sclerenchyma, 10- xylem, 11- pith ray, 12- pith.

Cross-section of the midrib

Midrib area is narrow on the upper surface and is not convex on the lower surface. Upper epidermal cells in this region are smaller than the laminal epidermal cells. Mesophyll is interrupted in this region. Underneath the upper epidermal cells there is 1 layer of almost cylindrical, colourless parenchyma, with few cells, and containing a vascular bundle. One layer of spherical, colourless parenchymatous cells is present underneath the phloem. One layer of collenchyma is located between these parenchymatous cells and the lower epidermis. Upper epidermal cells are almost square and smaller than the lamina epidermis (Figure 16B).

Stem

Cross-section of the stem is 4-cornered (squared). Collenchyma is narrow in corners. Stem exhibits the following characteristics:



Figure 14. *S. romana* subsp. *romana* – cross section of stem of anatomical properties; A. corner, B. intercorner. 1- eglandular trichome, 2- cuticle, 3- epidermis, 4- stoma, 5- collenchyma, 6- parenchyma, 7- endodermis, 8- phloem, 9- sclerenchyma, 10- xylem.

The protective tissue consists of a single layered epidermis. These cells are almost square, with walls forming convex projections outside. Cuticle is thin and penetrates toward the border between the epidermis cells. Eglandular and glandular trichomes are abundant on the whole epidermal surface. Covering simple eglandular trichomes are 1- or 2-celled, usually short (0.01-0.05 mm), sometimes long (0.5-0.6 mm), with 4-5 cells and simple; some of them have a swollen base. Glandular trichomes are short and long types. Short type trichomes have unicellular stalk and head; long type trichomes have 2-celled stalk and 1- or 2-celled head, pin-like. Stomata are present in stem. A group collenchyma is present underneath the epidermis in corners. Here, cortex parenchyma is 1 layer, and in intercorners this parenchyma consists of 3-4 layers of big and isodiametric cells. Cortex parenchyma cells contain starch granules.

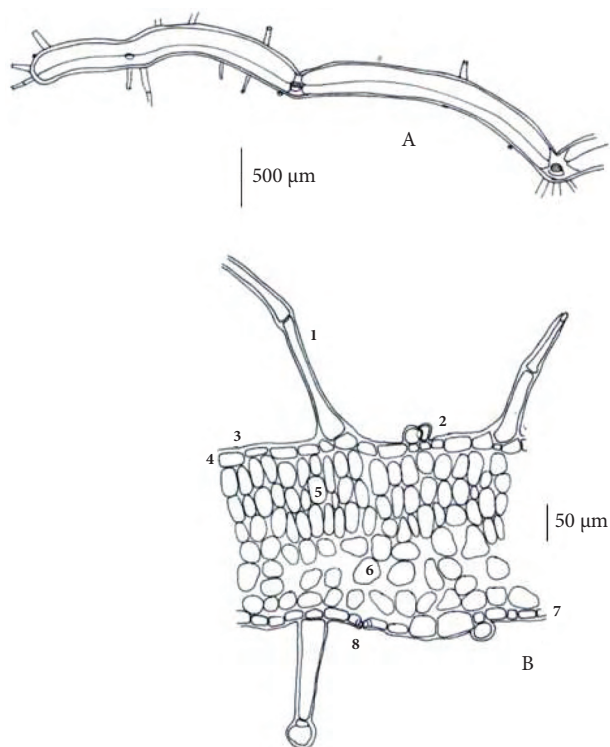


Figure 15. *S. romana* subsp. *curvidens* – cross section of leaf blade; A. general view, B. anatomic properties, 1-eglandular trichomes, 2-glandular trichomes, 3-cuticle, 4-upper epidermis, 5-palisade parenchyma, 6-spongy parenchyma, 7-lower epidermis, 8-stoma.

Endodermis consists of 1 layer of rectangular and colourless cells surrounding the stem. Pericycle is underneath the endodermis and is occasionally sclerenchymatous, especially in corners. Phloem is thin-walled, irregularly shaped and usually with big cells. Cambium is not clear. Xylem is observed as groups in corners. Pith rays are usually 1 layer and rare. The pith cells next to the xylem are small and thick-walled; however, pith parenchyma cells are big and sclerenchymatous in the centre. These cells contain no crystals of calcium oxalate or starch granules (Figures 17, 18).

S. montana* subsp. *montana

Leaf

Cross-section of leaf revealed the following characteristics:

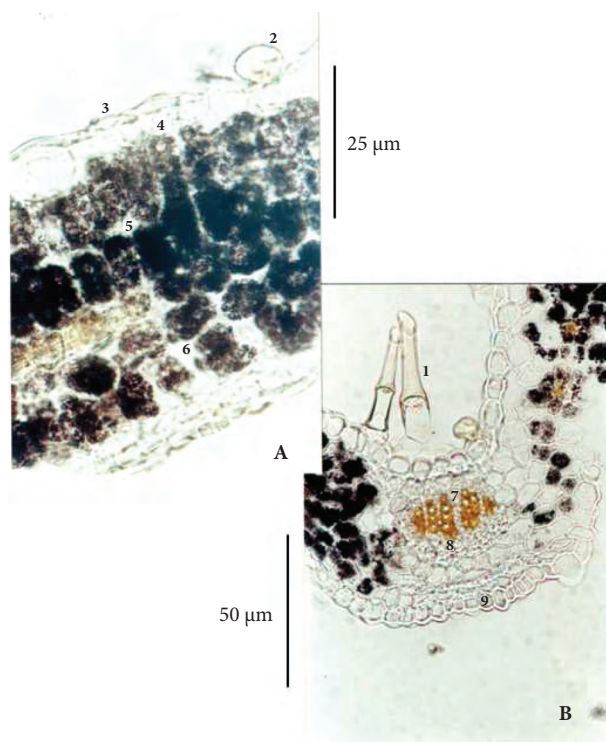


Figure 16. *S. romana* subsp. *curvidens* – A. cross section of leaf blade. B. cross section of the midrib. 1- eglandular trichomes, 2- glandular trichomes, 3 - cuticle, 4- upper epidermis, 5- palisade parenchyma, 6- spongy parenchyma, 7- vascular bundle, 8- parenchyma, 9- lower epidermis.

Cross-section of leaf blade

Upper epidermal cells are rectangular, large and thin-walled. Cuticle is thin. Both eglandular and glandular trichomes are present, but there are more eglandular trichomes on the whole epidermal surface. Eglandular trichomes are multicellular, long and simple; their hairs are usually broken. Glandular trichomes are short type with a unicellular stalk and head, and Lamiaceae type trichomes have a unicellular stalk and multicellular head. Long glandular trichomes are not seen in this species. The leaf is monofacial. Palisade parenchyma is 2-3-layered, with short, thick and cylindrical cells, and this parenchyma contains starch granules. Underneath the palisade parenchyma there is spongy parenchyma with 3-4 layers, and usually circular, sometimes ovoid cells. Underneath the spongy parenchyma there is 1(-

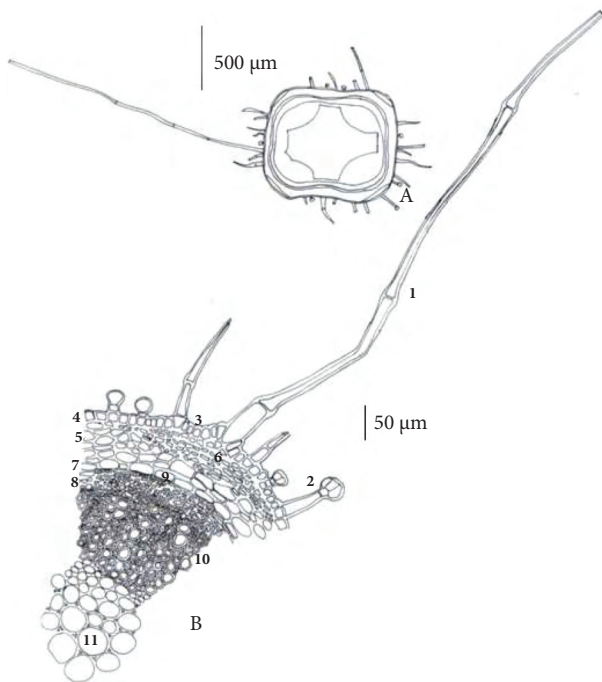


Figure 17. *S. romana* subsp. *curvidens* – cross section of stem; A. general view, B. anatomic properties. 1- eglandular trichome, 2- glandular trichome, 3- cuticle, 4- epidermis, 5- parenchyma, 6- collenchyma, 7- endodermis, 8- phloem, 9- sclerenchyma, 10- xylem, 11- pith.

2) layer of palisade parenchyma; these parenchyma cells are similar to the upper epidermis. Lower epidermis cells are 1 layer, flattened and smaller than the upper epidermal cells and are covered with a thin cuticle. Both types of glandular trichomes are present on lower epidermis, and covering simple eglandular trichomes are more frequent than on upper epidermis. Stomata occur on both sides of the leaves. Mesophyll contains no crystals of calcium oxalate (Figures 19, 20A).

Cross-section of the midrib

Midrib area is slightly concave on the upper surface. Upper epidermis cells are smaller than the lamina epidermis cells. Underneath the upper epidermis, there is narrow colourless parenchyma, with a vascular bundle in the area. Midrib area is a convex on the lower surface. Inside this convex, 1-2 layers of spherical colourless parenchymatous cells are

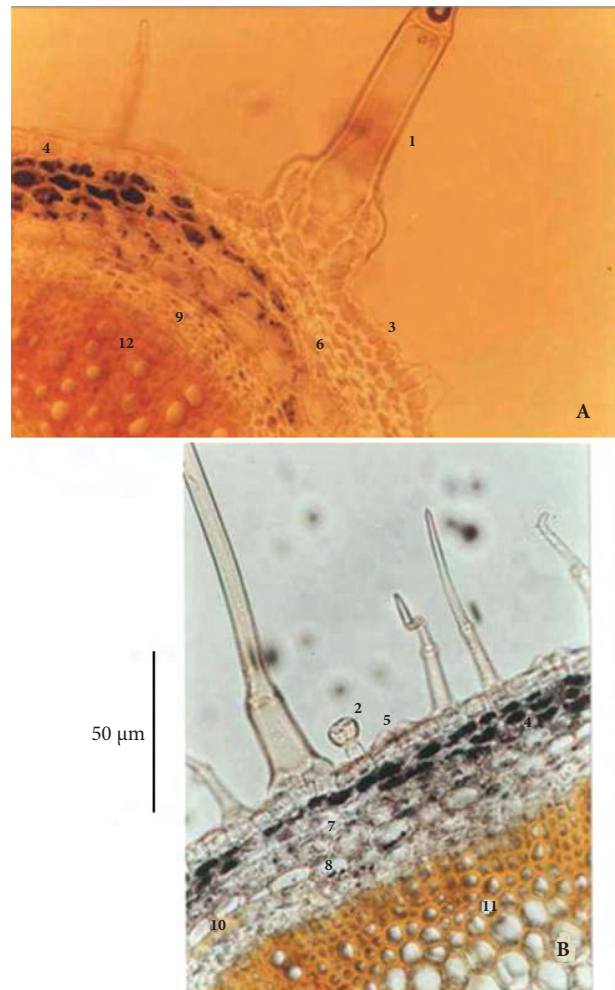


Figure 18. *S. romana* subsp. *curvidens* – cross section of stem of anatomical properties; A. corner, B. intercorner. 1- eglandular trichome, 2- glandular trichome, 3- cuticle, 4- epidermis, 5- stoma, 6- collenchyma, 7- parenchyma, 8- endodermis, 9- phloem, 10- sclerenchyma, 11- xylem, 12- pith ray.

present. Lower epidermal cells are almost square and smaller than the lamina epidermal cells (Figure 20B).

Stem

Cross-section of the stem is 4-cornered (squared). Collenchyma is present in corners. Stem exhibits the following characteristics: epidermis has usually square or rectangular cells with thickened outer and inner walls. The cuticle is thin. Eglandular and glandular trichomes are seen in abundance on the whole surface. Covering simple eglandular trichomes are unicellular and simple. Glandular trichomes are short

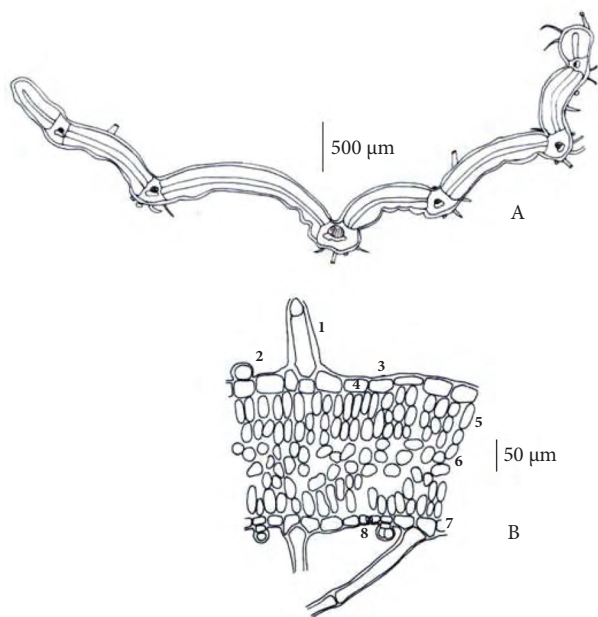


Figure 19. *S. montana* subsp. *montana* – cross section of leaf blade; A. general view, B. anatomic properties, 1– eglandular trichomes, 2–glandular trichomes, 3– cuticle, 4– upper epidermis, 5– palisade parenchyma, 6– spongy parenchyma, 7– lower epidermis, 8– stoma.

and long types. Short glandular trichomes have a unicellular stalk and head or 2-celled stalk and head. Long glandular trichomes consist of 2–4 celled stalk, 1-2 celled head, pin-like. Stomata are present in stem. Wide and shallow collenchyma is present in corners underneath the epidermis. Underneath this, cortex parenchyma consists of 1 layer and big cells; however, underneath the epidermis in intercorners it is 3-4 layers and with small cells. Cortex parenchyma cells are cylindrical or oval and there are usually intercellular spaces. This parenchyma rarely contains starch granules. Endodermis consists of 1 layer of rectangular cells. Pericycle is underneath the endodermis and in corners is occasionally sclerenchymatous; in intercorners it is usually thin-walled with live cells. Phloem is 2-4 layers, thin-walled, with irregular shaped small or big cells. Cambium is not clear. Xylem is narrow in intercorners, but wide in corners. Pith rays are usually 1 layer. The pith is massive and consists of round parenchyma cells. The pith cells next to the xylem are small and with thickened walls, but are big and cylindrical and thin-walled in the centre. This region

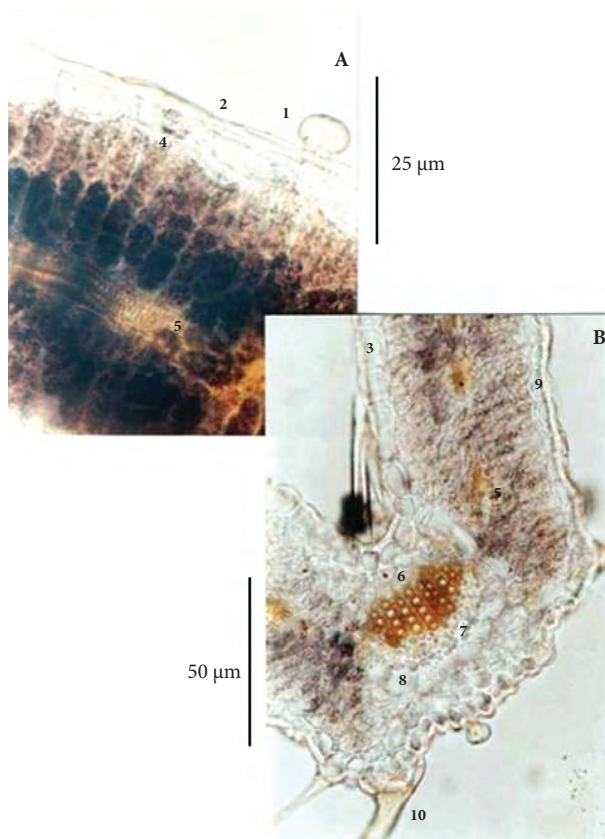


Figure 20. *S. montana* subsp. *montana* – A. cross section of leaf blade. B. cross section of the midrib. 1– glandular trichomes, 2– cuticle, 3– upper epidermis, 4– palisade parenchyma, 5– spongy parenchyma, 6– xylem, 7– phloem, 8– parenchyma, 9– lower epidermis. 10– eglandular trichomes.

contains no crystals of calcium oxalate or starch granules (Figures 21, 22).

S. romana* subsp. *remota

Leaf

Cross-section of leaf revealed the following characteristics:

Cross-section of leaf blade

Upper epidermal cells are rectangular, thin-walled and covered with a thin cuticle. There are eglandular and glandular trichomes. Eglandular trichomes are multicellular, long and simple. Glandular trichomes are short type with a unicellular stalk and head and Lamiaceae type trichomes have a unicellular stalk and multicellular (2-8) head. Long type glandular

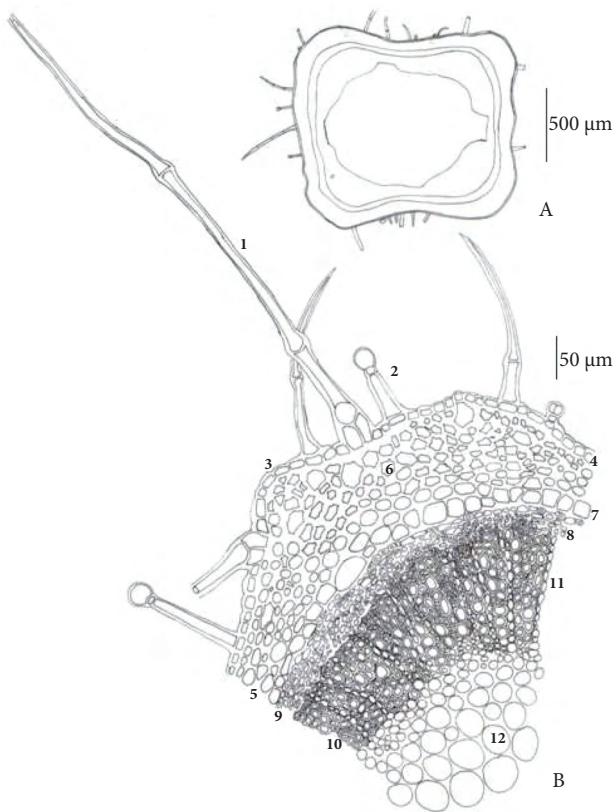


Figure 21. *S. montana* subsp. *montana* – cross section of stem; A. general view, B. anatomic properties. 1– eglandular trichome, 2– glandular trichome, 3– cuticle, 4– epidermis, 5–parenchyma, 6– collenchyma, 7– endodermis, 8– phloem, 9– sclerenchyma, 10– xylem, 11– pith ray, 12– pith.

trichomes consist of 2-celled stalk, 1-2-celled head, pin-like. The leaf is monofacial. Palisade parenchyma has 2-3 layers with cylindrical cells; this parenchyma contains starch granules. Spongy parenchyma is 3-4 layered, with usually circular, sometimes ovoid cells. Underneath the spongy parenchyma there are usually 2 layers of palisade parenchyma; these parenchyma cells are similar to the upper epidermis. Lower epidermis cells are 1 layer, flattened and smaller than the upper epidermal cells and covered with a thin cuticle. Both types of eglandular and glandular trichomes are present on lower epidermis, and covering simple eglandular trichomes are more frequent than on upper epidermis. Stomata occur on both sides of the leaves. Mesophyll contains no crystals of calcium oxalate (Figures 23, 24A).

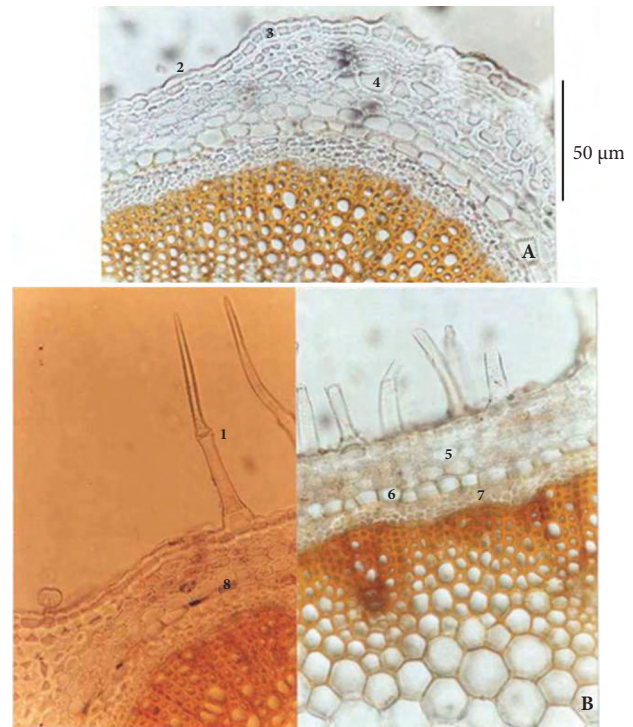


Figure 22. *S. romana* subsp. *montana* – cross section of stem of anatomical properties; A. corner, B. intercorners. 1– eglandular trichome, 2– cuticle, 3– epidermis, 4– collenchyma, 5– parenchyma, 6– endodermis, 7– phloem, 8– sclerenchyma.

Cross-section of the midrib

Midrib area is clearly concave on the surface. Upper epidermis cells are smaller than the lamina epidermis cells. Underneath the upper epidermis, there are 2-3 layers of colourless parenchyma. Vascular bundle is located in this area and is seen as wide and shallow. Midrib area is a convex on the lower surface. Inside this convex, 1-2 layers of spherical colourless parenchymatous cells are present. Lower epidermal cells are almost square and smaller than the lamina epidermal cells. Mesophyll is interrupted in the primary and secondary vascular bundle (Figure 24B).

Stem

Cross-section of the stem is 4-cornered (squared). Collenchyma is present in corners. Stem exhibits the following characteristics: epidermis has rectangular cells. The cuticle is thin. Eglandular and glandular trichomes are seen in abundance on the whole

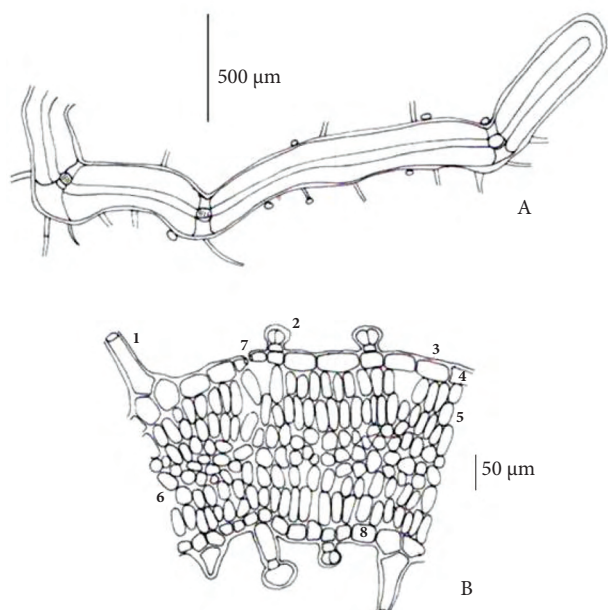


Figure 23. *S. montana* subsp. *remota* – cross section of leaf blade; A. general view, B. anatomic properties, 1– eglandular trichomes, 2–glandular trichomes, 3– cuticle, 4– upper epidermis, 5– palisade parenchyma, 6– spongy parenchyma, 7– stoma, 8– lower epidermis.

surface. Covering eglandular trichomes are unicellular and simple, and some have a swollen base. This type is seen especially in corners. Glandular trichomes have a unicellular stalk and 2-8-celled head; or 2-3-celled stalk and (1-) 2-4-celled head, pin-like. Stomata are present in stem. There is wide and shallow collenchyma in corners underneath the epidermis; this region is seen forming convex projections. Underneath the collenchyma in corners, cortex parenchyma consists of 1 layer; however, underneath the epidermis in intercorners there are 3-4 layers. Cortex parenchyma cells are cylindrical or oval, small and there are usually intercellular spaces. This parenchyma contains abundant starch granules. Endodermis consists of 1 layer of rectangular cells. Pericycle is underneath the endodermis and sclerenchymatous in the whole stem, but is sometimes parenchymatous in interconers. Phloem consists of very narrow, usually collapsed, thin-walled, irregularly shaped, small or big cells. Cambium is not clear. Xylem is in small pieces in intercorners, but wide in corners. Pith rays are usually 1 layer. The pith is massive and consists of round parenchyma cells.

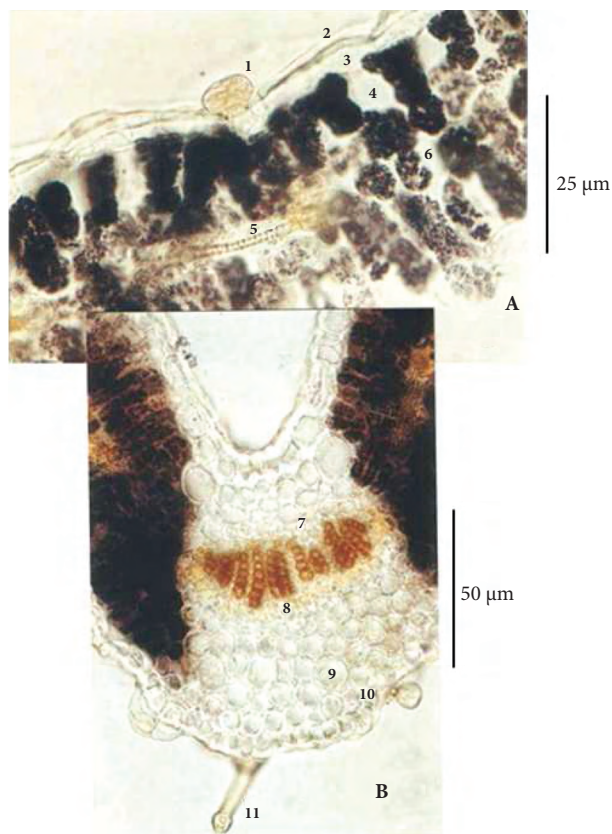


Figure 24. *S. montana* subsp. *remota* – A. cross section of leaf blade; B. cross section of the midrib. 1– glandular trichomes, 2– cuticle, 3 – upper epidermis, 4– palisade parenchyma, 5– vasculer bundle, 6– spongy parenchyma, 7– xylem, 8–phloem,9– parenchyma, 10– lower epidermis 11– eglandular trichomes.

The pith cells next to the xylem are small and thin-walled, but are big and cylindrical in the centre. This region contains no crystals of calcium oxalate or starch granules (Figures 25, 26).

Discussion

In this study, detailed morphological characteristics and anatomical structure of the Turkish annual *Sideritis* species are given.

S. lanata is a very distinct species, with no obvious allies in Turkey with respect to morphologic characteristics. It differs from other annual species, with its densely long villous stem, ovate-elliptic leaf lamina, and purplish-black lips corolla.

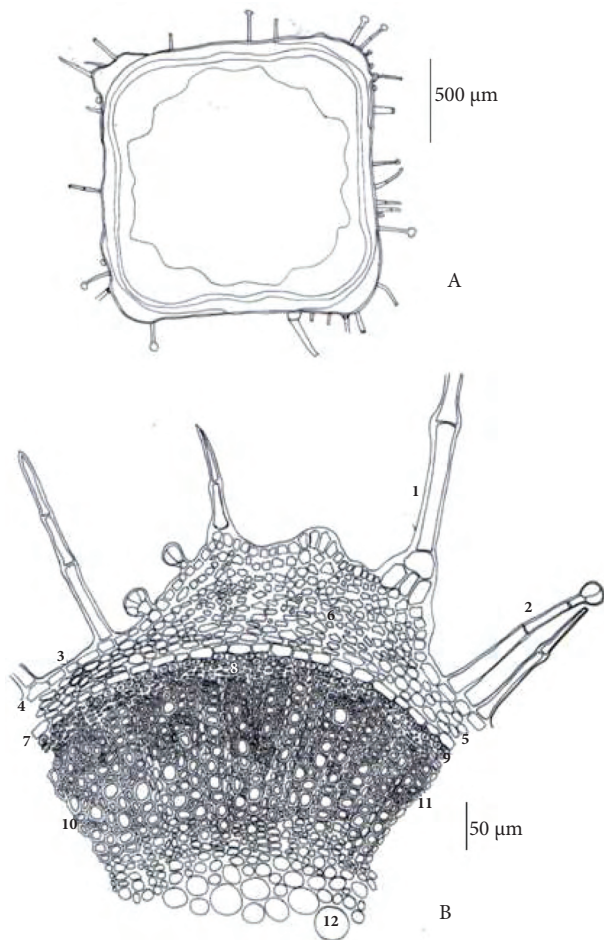


Figure 25. *S. montana* subsp. *remota* – cross section of stem; A. general view, B. anatomic properties. 1– eglandular trichome, 2– glandular trichome, 3– cuticle, 4– epidermis, 5– parenchyma, 6– collenchyma, 7– endodermis, 8– phloem, 9– sclerenchyma, 10– xylem, 11– pith ray, 12– pith.

According to Flora of Turkey (Huber-Morath 1982), *S. romana* and *S. curvidens* are 2 different species. Following a comparison study of the 2 related species, we decided that *S. curvidens* and *S. romana* were very similar. Thus, we accept Holmboe classification in which *S. curvidens* is reduced to subspecies level of *S. romana*. *S. romana* subsp. *curvidens* is allied to subsp. *romana*, but differs with respect to its calyx tube with less prominent veins and saccate base (versus prominent and non-saccate in subsp. *romana*), and usually curved teeth of calyx (versus erect in subsp. *romana*) (Huber-Morath 1982).

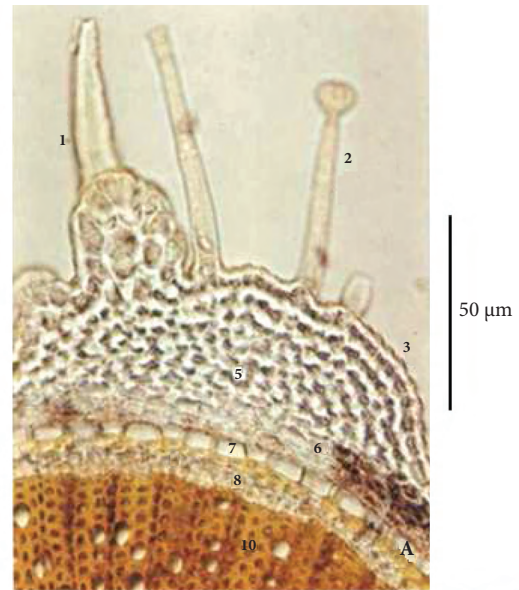


Figure 26. *S. romana* subsp. *remota* – cross section of stem of anatomical properties; A. corner, B. intercorner. 1– eglandular trichome, 2– glandular trichome, 3– cuticle, 4– epidermis, 5– collenchyma, 6– parenchyma, 7– endodermis, 8– phloem, 9– sclerenchyma, 10– xylem.

S. montana is a distinct species, with yellow corolla and calyx teeth all subequal, while other annual species of Turkish *Sideritis* have unequal teeth and 2-lipped calyx. *S. montana* subsp. *montana* is close to subsp. *remota*, but differs by its verticillasters sparsely to moderately villous-lanate, calyx green, and upper bracts usually yellow (versus verticillasters covered with long densely villous-lanate, and upper bracts and calyx usually purple in subsp. *remota*).

The anatomical structure of *S. congesta* Davis and Hub.-Mor. (Sezik & Ezer, 1983), *S. arguta* Boiss. et

Heldr. (Ezer & Sezik, 1988), *S. libanotica* Labill. subsp. *linearis* (Benth) Born. (Ezer, 1991), *S. trojana* Bornm. (Uysal et al., 1991), *S. germanicopolitana* Bornm. subsp. *germanicopolitana*, *S. germanicopolitana* subsp. *viridis* Hausskn. ex Bornm. (Koca et al., 1994) and *S. stricta* Boiss. et Heldr. (Şahin et al., 2005) were investigated previously in Turkey. These species are in *Empedoclia* section and perennial. Metcalfe and Chalk (1965) reported general anatomical structures for Lamiaceae. For example, the stem is usually rectangular in cross-section, and there is often a considerable development of collenchyma in the corners. In the leaf collenchyma is supporting tissue along the veins on one or both sides. Species are densely covered with a variety of trichomes. Stomata are on one or both surfaces. Crystals, although not very frequent, occur in many forms. Rays are sometimes 2- up to 4-12 cells wide (Metcalfe & Chalk, 1965). Our observations show that annual *Sideritis* species have the general anatomical characteristics of Lamiaceae with respect to leaf and stem. However, the anatomical structure of the leaf and stem of various

Sideritis species differ significantly. A comparison of the anatomical characteristics of the leaf and stem of the species under study is given in Tables 2 and 3.

Though Metcalfe and Chalk (1965) reported that the branched or tufted multicellular eglandular hairs are seen in *Sideritis* species, we did not observe these eglandular trichomes in leaves or stem of these 5 taxa, as also reported by other researchers (Sezik & Ezer, 1983; Ezer & Sezik, 1988; Ezer, 1991; Uysal et al., 1991; Koca et al., 1994; Şahin et al., 2005). In the *Sideritis* genus, leaves have been observed to be monofacial, bifacial, or centric form (Metcalfe & Chalk 1965; Sezik & Ezer, 1983; Ezer & Sezik, 1988; Ezer, 1991; Uysal et al., 1991; Koca et al., 1994; Şahin et al., 2005). Leaf structures were monofacial in *Hesiodia* section (*S. montana* subsp. *montana* and *S. montana* subsp. *remota*) and bifacial or monofacial in *Burgsdorfia* section (*S. lanata*, *S. romana* subsp. *romana* and *S. romana* subsp. *curvidens*). In the *Burgsdorfia* section, the leaf has numerous multicellular and long glandular trichomes, but few short glandular

Table 2. Comparison of leaf cross-sections in 5 annual *Sideritis* taxa growing in Turkey.

| Taxa | Leaf structure | Epidermal cells | Covering trichomes | Glandular trichomes | Palisade parenchyma | Spongy parenchyma |
|--|----------------|-----------------------------|------------------------------------|--|--|--|
| <i>Sideritis lanata</i> | monofacial | rectangular, thin and long | unicellular, multicellular, simple | short: unicellular stalk and head and unicellular stalk with 2-8-celled head; long: 2-4-celled stalk, 2-4-celled head | 1 layer, thick, subequal long and cylindrical, starch (+) | 3-4 layers, first layer like palisade, nonisodiametric, starch (+) |
| <i>S. romana</i> subsp. <i>romana</i> | monofacial | rectangular, usually small | unicellular, multicellular, simple | short: unicellular stalk and head, unicellular stalk with multicellular head; long: 2-4-celled stalk, 2-4-celled head | usually 1-, sometimes 2-layered, thick, long and cylindrical, starch (+) | 2-3 layers, usually isodiametric, starch (+) |
| <i>S. romana</i> subsp. <i>curvidens</i> | bifacial | rectangular, large | multicellular, simple | unicellular stalk and head, a few with unicellular stalk and multicellular head; long: 1-2-celled stalk, 1-2-celled head | 3(-4) layers, thick, subequal long and cylindrical, starch (+) | 3-4 layers, usually isodiametric, starch (+) |
| <i>S. montana</i> subsp. <i>montana</i> | monofacial | rectangular, large and long | multicellular, simple, long | short: unicellular stalk and head, unicellular stalk with multicellular head; long glandular trichomes are not seen | 2-3 layers, short, thick, cylindrical, starch (+) | 3-4 layers, usually circular, sometimes ovoid, starch (+) |
| <i>S. montana</i> subsp. <i>remota</i> | monofacial | rectangular, large | multicellular, simple, long | short: unicellular stalk and head; unicellular stalk with 2-8-celled head; long: 2-celled stalk and 1-2-celled head | 2-3 layers and cylindrical, starch (+) | 3-4 layers, usually circular, sometimes ovoid, starch (+) |

Table 3. Comparison of stem cross-sections in 5 annual *Sideritis* taxa growing in Turkey.

| Taxa | Epidermal cells | Covering trichomes | Glandular trichomes | Cortex parenchyma | Pericycle |
|---|--|--|---|--|--|
| <i>Sideritis lanata</i> | rectangular, in corners square or multi-angled | strong, thick, unicellular and simple or 2-4 cells | short: unicellular stalk and head or 2-celled stalk and multicellular head; long: 2-4 celled stalk, 1-2 celled head | intercorners 2-4 layers; corners 1-2 layers; cylindrical or oval cells; starch (+) | in corners sclerenchymatous; in intercorners thin walls |
| <i>S. romana</i> subsp. <i>romana</i> | square, outer and inner walls thickened | usually 2 cells and simple; sometimes multicellular, simple and long | short: unicellular stalk and 2-celled head or multicellular stalk and head; long: multicellular stalk and head | intercorners 3-5 layers, cylindrical or oval and with intercellular spaces; underneath the corners 2 layers and without intercellular gaps; starch (-) | in corners usually sclerenchymatous; in intercorners occasionally sclerenchymatous |
| <i>S. romana</i> subsp. <i>curvidens</i> | square, walls forming convex projections outside | 1 or 2 cells, usually short sometimes long, 4-5 cells and simple; some with swollen base | short: unicellular stalk and head; long: 2-celled stalk and 1- or 2-celled head | in corners 1 layer, in intercorners 3-4 layers, big and isodiametric cells; starch (+) | occasionally sclerenchymatous, especially in corners |
| <i>S. montana</i> subsp. <i>montana</i> | square or rectangular cells, thickened outer and inner walls | unicellular and simple | short: unicellular stalk and head or 2-celled stalk and head; long: 2-4-celled stalk, 1-2-celled head | in corners 1 layer, large; in intercorners 3-4 layers, small; cylindrical or oval cells, usually intercellular spaces; starch (+) | in corners occasionally sclerenchymatous, in intercorners usually thin walls |
| <i>S. montana</i> subsp. <i>remota</i> | rectangular, in corners multi-angled | unicellular and simple, some with swollen base | unicellular stalk and 2-8-celled head; or 2-3-celled stalk and (1-)-2-4-celled head | in corners cortex parenchyma 1 layer; in intercorners 3-4 layers, cylindrical or oval, small and usually intercellular spaces; starch (+) | sclerenchymatous in the whole stem, sometimes parenchymatous in intercorners |

trichomes. In the *Hesiodia* section, short glandular trichomes are observed more often than long glandular trichomes. Leaf structures of *S. romana* subsp. *romana* and *S. romana* subsp. *curvidens* were differentiated with respect to eglandular and glandular trichomes, palisade parenchyma, and spongy parenchyma. Stem structures of these 2 subspecies were differentiated. Anatomical characteristics of these 2 subspecies are not supported by morphological characteristics for plant

identification. However, anatomical characteristics of *S. montana* subsp. *montana* and *S. montana* subsp. *remota* are similar and are supported by morphological characteristics of these 2 species.

Although many of perennial *Sideritis* species, a.k.a. “Dağ çayı”, are commonly used in Turkey, annual *Sideritis* species are not used as herbal tea or medicinal plant. Therefore, annual *Sideritis* species growing in Turkey do not have any economical value.

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