ACTA BIOLOGICA CRACOVIENSIA Series Botanica 48/1: 33–43, 2006

MORPHOLOGY AND ANATOMY OF *SCROPHULARIA* L. (SCROPHULARIACEAE) TAXA FROM NE ANATOLIA

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Received October 25, 2005; revision accepted January 20, 2006

This study uses numerical methods to describe, illustrate and assess the taxonomic significance of morphological and anatomical features of *Scrophularia ilwensis* C. Koch, *S. capillaris* Boiss. & Ball., *S. nodosa* L., *S. libanotica* Boiss. var. *pontica* R. Mill, *S. lucida* L. and *S. cinerascens* Boiss. collected from NE Anatolia. Features related to peculiarities of the leaf, bracteole, alar pedicel and corolla were found to be important in separating the taxa morphologically, but principal component analysis of all characters showed some anatomical characters (mean number of stomata, diameter of vascular bundle and scleranchymatic sheath) to be more important than morphological ones in explaining the variation between the examined taxa.

Key words: *Scrophularia*, anatomy, idioblast, numerical analysis.

INTRODUCTION

Scrophularia L. (Scrophulariaceae), one of the most important genera of the flowering plants, consists of ~300 species. It is mainly Holartic, and species are found in both the Old and New Worlds (Lersten and Curtis, 1997). Their primary center of diversity is in Southeast Asia (Stiefelhagen, 1910). Many species belonging to this genus have been used as folk remedies since ancient times (Heather and Henderson, 1994).

Anatomical studies of *Scrophularia* are mainly focused on leaf features. The first brief descriptions of the idioblast in *Scrophularia* were made by Volkens (1887) and then Matcalfe and Chalk (1950). More recently, Lersten and Curtis (1997, 2001) investigated the distribution of idioblasts and internal secretory structures in many Scrophulariaceae taxa, and found many crucial differences between the examined taxa. Intercellular inclusions such as idioblasts and cellular cavities are useful new microcharacters used in taxonomic and systematic treatments. Pennel (1929, 1935) determined important differences in the leaf, stem and root anatomy of 25 Scrophulariaceae species and explained their taxonomic importance.

Scrophularia is represented by ~59 taxa in Turkey (Davis, 1978), some of which are endemic. Anatomical features are very important characters in *Scrophularia*, but there are insufficient data related to the Turkish species. The main object of this study is to explore the anatomical and morphological features of *Scrophularia* taxa distributed in NE Anatolia and to explain their systematic importance.

MATERIALS AND METHODS

The plants were collected from northeast Anatolia in 2002. The collection data for the examined specimens are given in Table 1. Specimens for morphological study were dried according to standard herbarium techniques and stored in the Herbarium of Karadeniz Technical University, Department of Biology (KTUB). The materials for anatomical study were fixed in FAA for 24 h and then preserved in 70% alcohol in the field.

Anatomical observations were performed on transverse sections of stem and leaves, and surface sections of leaves cut by hand. The material was stained with safranin/fast green for 24 h and mounted with glycerine-gelatine to make permanent slides

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PL ISSN 0001-5296

TABLE 1. Locality information of the examined *Scrophularia* taxa

No	Taxa	Locality
1	*S. ilwensis* C. Koch	A8 Rize: Cimil, 1800 m, 11.07.2001, Makbul 22, KTUB
2	*S. capillaris* Boiss. & Ball.	A8 Rize: İkizdere, 550 m, 20.06.2001, Makbul 18, KTUB
3	*S. nodosa* L.	A8 Rize: Anzer, 2150 m, 12.07.2001, Makbul 26, KTUB
4	*S. libanotica* Boiss. var. R. Mill *pontica*	A7 Gümüşhane: Köse Dağı, 1400 m, 21.06.2001, Makbul 20 KTUB
5	*S. lucida* L.	A9 Artvin: Şavşat, 2200 m, 28.06.2002, Makbul 29 KTUB
6	*S. cinerascens* Boiss.	A8 Rize: Çat-Çamlıhemşin, 1200m, 09.06.2001, Makbul 10, KTUB

(Vardar, 1987). Well-staining sections were photographed with an Olympus BX51 from permanent slides. All measurements and observations were made three or four times.

The 31 characters presented in Table 2 were assessed by numerical analysis: 14 related to vegetative structures and 17 to anatomical structures. Seventeen were quantitative, including linear measurements, ratios of linear measurements, and number of structures. The remaining 14 characters were qualitative, each divided into two discrete categories. All numerical analyses were performed using SYNTAX (Podani, 1994). A standardized data matrix was subjected to cluster analysis using the unweighted pair-group method with arithmetic averages (UPGMA), and principal components analysis (PCA). For UPGMA, the resemblance matrix was calculated from the standardized data matrix, using Gower's coefficient of resemblance for mixed data sets (Sneath & Sokal, 1973). For PCA, the standardized data were used to create a correlation matrix, and two eigenvectors were extracted, providing two axes onto which the standardized data were projected to give a two-dimensional plot of the taxa and characters. During this process it was found that some characters explain very low percentages of variance accounted for by each component. For this reason, these characters were removed from the matrix and the analysis was performed using X_{17}, X_{22}, X_{23} X_{27} and X_{28} (see Table 2) once again. Only the results of these characters are given in this paper.

RESULTS

MORPHOLOGICAL CHARACTERS

Scrophularia ilwensis: Stem 25–90 cm, generally branched and glandular. Leaves rosette, alternate and shortly petiolate. Lamina ovate, entire, rarely pinnatifid. Inflorescence aphyllous, alar pedicel 2–5 mm and glandular. Calyx lobes glabrous with scarious margin. Corolla very dark red-brown, stamens exerted, staminode kidney-shaped, capsule ovoid, pedicel glandular.

Scrophularia capillaris: Stem 40–95 cm, leaves petiolate, opposite, lamina generally cordate. Inflorescence foliate, alar pedicel ~20 mm. Calyx lobes ovate with scarious margin. Corolla reddish-green, stamens included, staminode cordate to emarginate, capsule globose, pedicel glabrous. It is an endemic species and known only from the type locality.

Scrophularia nodosa: Stem 50–120 cm, quadrate, glabrous except in upper part. Leaves opposite, shortly petiolate. Lamina ovate, entire. Inflorescence subfoliate. Calyx lobes glabrous with narrow scarious margin. Corolla purple to yellowish, stamens included, staminode cordate to reniform, capsule ovoid, pedicel glandular.

Scrophularia libanotica var. *pontica*: Stem 15–85 cm. Leaves alternate, petiolate to sessile, lamina pinnatifid. Inflorescence aphyllous, pedicel glandular. Calyx lobes ovate with scarious margin ~0.5 mm wide. Corolla maroon, stamens generally included, staminode linear to ovate, capsule globose. It is an endemic taxon and known only from the type locality.

Scrophularia lucida: Stem length 30–150 cm, leaves opposite, petiolate. Lamina pinnatifid to pinnatisect. Inflorescence aphyllous, alar pedicel 0.6–0.8 mm. Calyx lobes glabrous with scarious margin ~1 mm wide. Corolla lobes brownish pink to whitish red. Stamens included, staminode reniform, capsule globose.

Scrophularia cinerascens: Stem 10–50 cm, plant densely glandular. Leaves opposite, ovate. Lamina pinnatifid. Inflorescence aphyllous, alar pedicel 2–3 mm. Calyx lobes glabrous with scarious margin 2–4 mm wide. Corolla purple, stamens included to exerted, staminode oblong to ovate, capsule subglobose.

ANATOMICAL CHARACTERS

Scrophularia ilwensis: A transverse section taken from the middle part of the stem was observed (Fig. 1). Cuticle layer is 2.8–3.5 μm thick and trichomes are obvious (Fig. 2). Epidermis consists of a single

TABLE 2. List of characters used in this study

Symbol	Character
X_1	Total plant height (cm)
X_2	Stem pubesence; glandular: 1; glabrous: 0
X_3	Median leaf shape; entire: 0; pinnatifid: 1
X_4	Leaf arrangement; opposite: 0; alternate:1
X_5	Length of cauline leaves (cm)
X_6	Width of cauline leaves (cm)
X_7	Length of petiole (cm)
X_8	Infloresence; foliate: 0; aphyllous: 1
X_9	Length of alar pedicel (mm)
X_{10}	Sepal pubescence; glandular: 1; glabrous: 0
X_{11}	State of stamens; exerted: 0; included:1
X_{12}	Staminode shape; linear: 0; ovate, reniform or cordate: 1
X_{13}	Capsule shape; globose: 0; ovoid: 1
X_{14}	Pedicel in fruit; glarous: 0; glandular: 1
X_{15}	Idioblast in leaf; present: 1; absent: 0
X_{16}	Stomata index of lower epidermis
X_{17}	Average number of stomata on lower epidermis (mm^2)
X_{18}	Width/length of upper epidermal stomata (μm/μm)
X_{19}	Peripheral surface of lower epidermal cells; smooth: 0 undulate: 1
X_{20}	Peripheral surface of upper epidermal cells; smooth: 0 undulate: 1
X_{21}	Width/length of upper epidermal cells μm/μm)
X_{22}	Average number of epidermal cells on lower epidermis (mm^2)
X_{23}	Average number of epidermis cells on upper epidermis (mm^2)
X_{24}	Trichomes on lower epidermis surface; present: 1; absent: 0
X_{25}	Average number of rows of palisade parenchyma on leaf (number)
X_{26}	Thickness of cuticle in stem (μm)
X_{27}	Diameter of vascular bundle (μm)
X_{28}	Thickness of intervascular sycleranchym μm)
X_{29}	State of sycleranchymatic cells in phloem; single: 0; cluster: 1
X_{30}	Diameter of paranchymatic cells in cortex (μm)
X_{31}	Idioblast in stem; present: 1; absent: 0

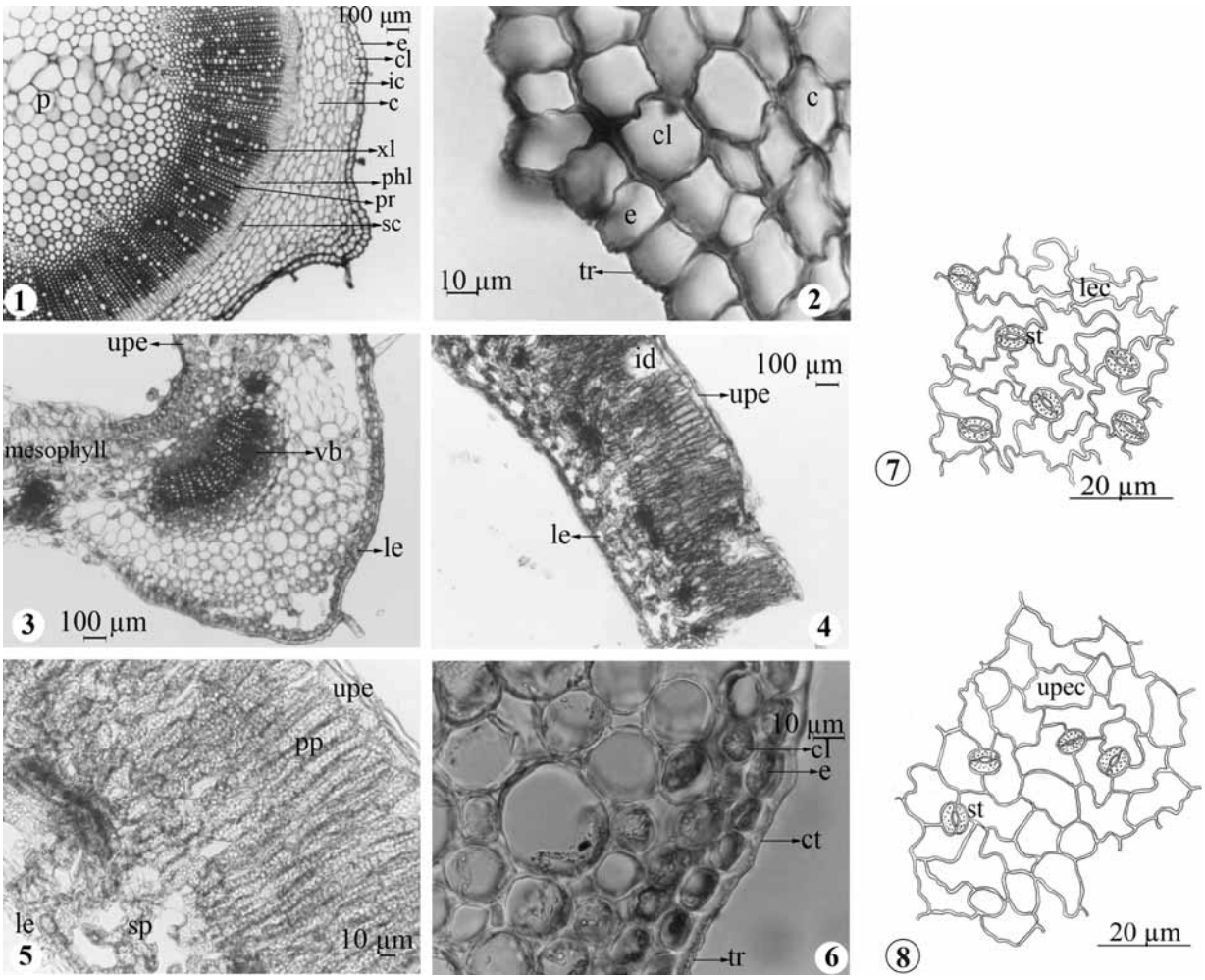
layer of rectangular or orbicular cells. Under the epidermis is a monolayer of collenchyma, but 2 or 3 layers of collenchyma can be seen below the epidermis at the stem ridges. Stem cortex (180–230 μm thick) consists of 6 or 7 layers of usually oval cells and makes up 20% of the stem. Cambium is not distinguishable. Xylem tissue, including solitary vessels or clustered vessels, is extensive and occupies 35% of the stem cortex. Pith cells are large and cylindrical, and occupied 36% of the stem radius.

A transverse section of the lamina, midrib and both epidermises was studied (Fig. 3). Midrib is triangular and has 1 or 2 layers of collenchyma under both the abaxial and adaxial epidermises. Upper epidermal cells are larger than lower ones. Idioblasts sparsely distributed between the palisade parenchyma cells (Fig. 4). Mesophyll consists of 4 or 5 layers of elongated palisade cells and 3 or 4 layers of isodiametric spongy parenchymatic cells with large intercellular cavities (Fig. 5). Solitary arc-shaped vascular bundles are surrounded ny parenchymatous and orbicular cells. There are many prominent trichomes on the lower epidermis (Fig. 6). Both epidermises have cuticle 3–3.5 μm thick and have undulate cell walls. Leaf is unifacial and has anomocytic stomata cells. Stomata occur on both epidermal surfaces, level with neighboring cells (Figs. 7, 8).

Scrophularia capillaris: A transverse section taken from the middle part of the stem was observed (Fig. 9). Cuticle layer is 2–2.5 μm (Fig. 10). Epidermal cells consist of a single layer and are plane, and are rectangular or orbicular. Stem cortex (150–200 μm thick) consists of 7 or 8 layers of usually oval cells, and occupies 25% of the stem. Cambium is not distinguishable. Xylem tissue, including solitary vessels or clustered vessels, is extensive at the sites of ridges and occupies 25% of the stem radius. There is a sclerenchymatic sheath (40–50 μm thick) between the bundles. Pith cells are large and cylindrical, and occupy 40% of the stem radius.

A transverse section of the lamina, midrib and both epidermises was studied (Fig. 11). Idioblasts were clearly seen between the palisade cells (Fig. 12). Mesophyll consists of 1–3 layers of elongated palisade cells and 2 or 3 layers of isodiametric spongy parenchymatic cells with large intercellular cavities (Fig. 13). Midrib is triangular and has 1 or 2 layers of collenchyma located below the epidermal cells. Vascular bundle is solitary, arc-shaped, and surrounded by orbicular parenchymatous cells. Upper epidermal cells are larger than the lower ones. Both epidermises are covered with cuticle 2.5–3 μm thick and have undulate cell walls; there are no trichomes on the lower epidermis (Fig. 14). Leaf is unifacial and has anomocytic stomata cells. Stomata occur on the both surfaces, level with neighboring cells (Figs. 15, 16).

Scrophularia nodosa: A transverse section taken from the middle part of the stem was observed (Figs. 17, 18). Cuticle layer is 3–3.5 μm thick and trichomes are evident on the cuticle. Under the epidermis is a monolayer collenchyma, but 2 or 3 lay-

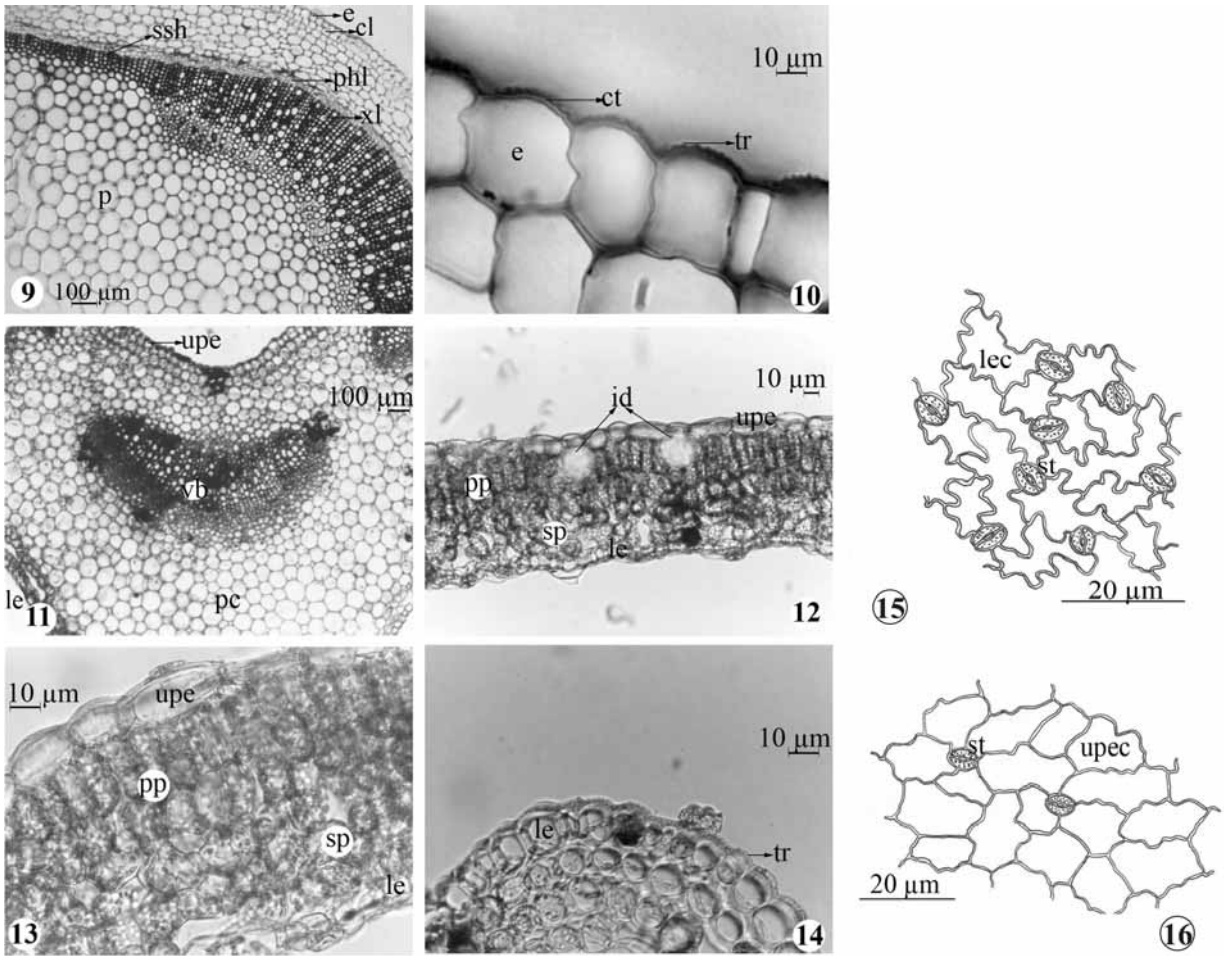


Figs. 1–8. *Scrophularia ilwensis*. **Figs. 1, 2.** Transverse section of stem. **Figs. 3–6.** Transverse section of leaf. **Figs. 7, 8.** Surface section of leaf. e – epidermis; c – cortex; vb – vascular bundle; phl – phloem; xl – xylem; p – pith; le – lower epidermis; upe – upper epidermis; sp – spongy parenchyma; pp – palisade parenchyma; tr – trichome; upec – upper epidermis cell; lec – lower epidermis cell; cl – collenchyma; st – stoma; id – idioblast; sc – sclerenchyma; pr – pith rays; ic – intravascular cavity; ct – cuticle.

ers of collenchyma can be seen below the epidermis at the stem ridges. Stem cortex (350–400 µm thick) consists of 7 or 8 layers of usually oval cells and occupies 25% of the stem. Bundles are of different sizes and occupy 25% of the stem. There is a sclerenchymatic sheath (150–200 µm thick) between these bundles. Pith cells are large and cylindrical, and occupy 55% of the stem radius.

A transverse section of the lamina, midrib and both epidermises was studied (Fig. 19). Vascular bundles are arc-shaped and surrounded by parenchymatous and orbicular cells. Mesophyll consists of 2 or 3 layers of elongated palisade cells and 2 or 3 layers of isodiametric, spongy parenchymatic cells with large intercellular cavities (Fig. 20). Both epidermises are covered by cuticle 4–4.5 µm thick (Fig. 21). Leaf is unifacial and has anomocytic stomata cells. Upper epidermal cells are larger than the lower ones; they have undulate cell walls and no trichomes (Figs. 22, 23).

Scrophularia libanotica var. *pontica*: A transverse section taken from the middle part of the stem was observed (Figs. 24, 25). Stem is woody (Fig. 24). Cuticle layer is 6–7 µm thick (Fig. 25). Epidermis consists of a single layer of plane, rectangular or orbicular cells. Collenchyma is a single layer under the epidermis, but 2 or 3 layers of collenchyma can be seen below the epidermis at the stem ridges. Stem cortex (220–300 µm thick) consists of 6 or 7 layers of usually oval cells and occupies 15% of the stem. Cambium is distinguishable. Sclerenchyma fibers are evident, grouped in the phloem tissue

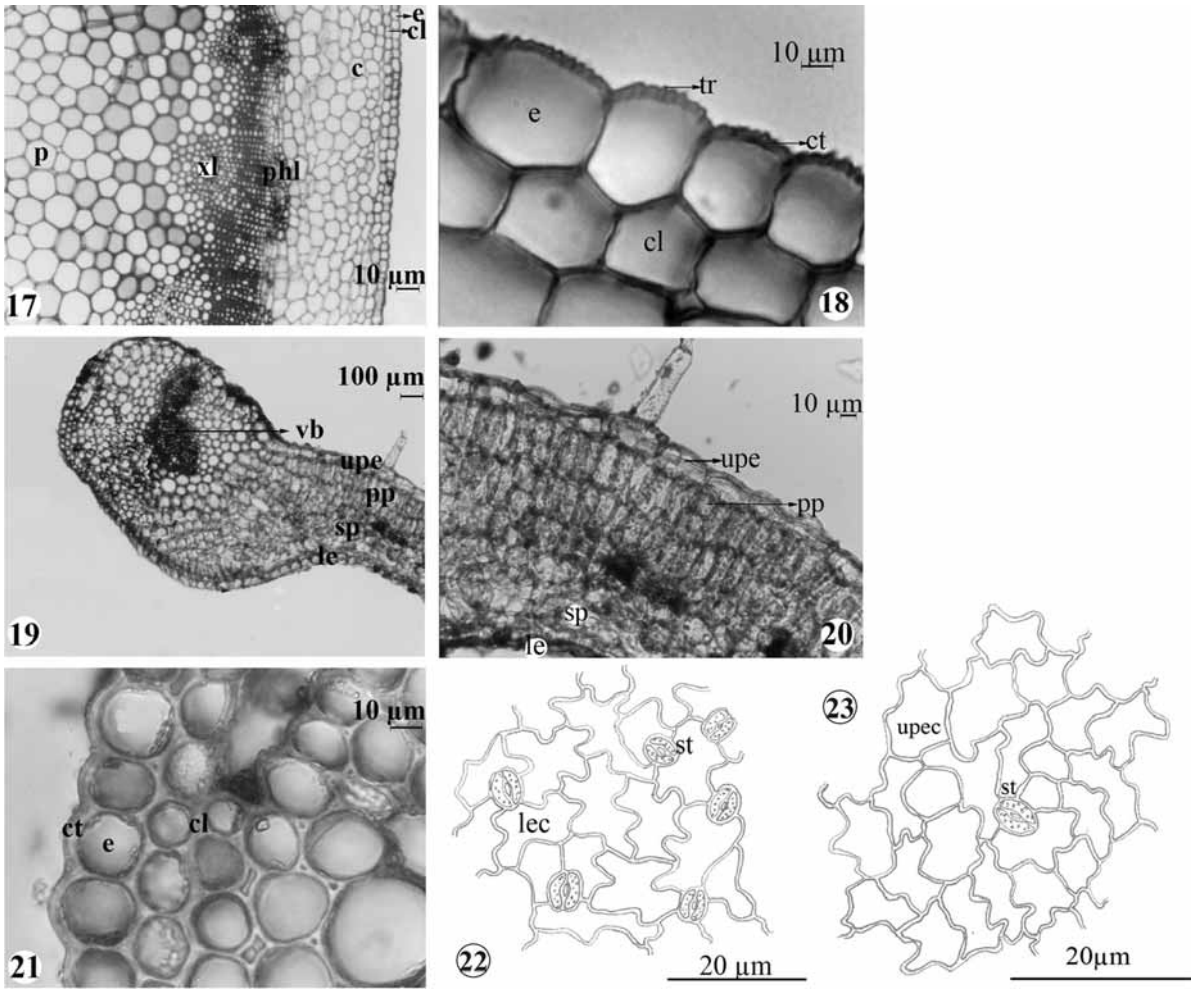


Figs. 9–16. *Scrophularia capillaris*. **Figs. 9, 10**. Transverse section of stem. **Figs. 11–14.** Transverse section of leaf. **Figs. 15, 16.** Surface section of leaf. e – epidermis; pc – parenchymatic cells; vb – vascular bundle; phl – phloem; xl – xylem; p – pith; le – lower epidermis; upe – upper epidermis; sp – spongy parenchyma; pp – palisade parenchyma; tr – trichome; upec – upper epidermis cell; lec – lower epidermis cell; cl – collenchyma; st – stoma; id – idioblast; ssh – sclerenchymatic sheath.

(Fig. 24). Xylem tissue is extensive and occupies 50% of the stem cortex. Because the bundles are arranged in rows along the stem, the sclerenchymatic sheath is not recognizable. Pith cells are large and cylindrical, and occupy 44% of the stem radius.

Leaf features in a transverse section taken from the lamina of *S. libanotica* var. *pontica* are seen in Figure 26. Midrib is triangular and has 1 or 2 layers of collenchyma located below epidermal cells. Cells of the upper epidermis are larger than those of the lower epidermis. Vascular bundles are surrounded by orbicular parenchymatic cells. Idioblasts with thin primary walls and large empty lumens are abundant in the mesophyll tissue (Fig. 27). Mesophyll consists of 3 or 4 layers of elongated palisade cells and 4 or 5 layers of isodiametric, spongy parenchymatic cells having large intercellular cavities (Fig. 28). Trichomes are evident on the lower epidermis cells (Fig. 29). Leaf is unifacial and has anomocytic stomata. Stomata occur on both surfaces. Epidermal cell walls are not undulate (Figs. 30, 31).

Scrophularia lucida: A transverse section taken from the stem was studied (Fig. 32). Cuticle layer is 6–7 μm thick (Fig. 34). Epidermis consists of a single layer of plane, rectangular or orbicular cells. Under the epidermis is a monolayer of collenchyma, but 2 or 3 layers of collenchyma can be seen below the epidermis at the stem ridges. Stem cortex (180–200 µm thick) consists of 7 or 8 layers of usually oval cells and occupies 13% of the stem. Cambium is distinguishable. Phloem has sclerenchyma fibers in groups (Fig. 33). Xylem tissue



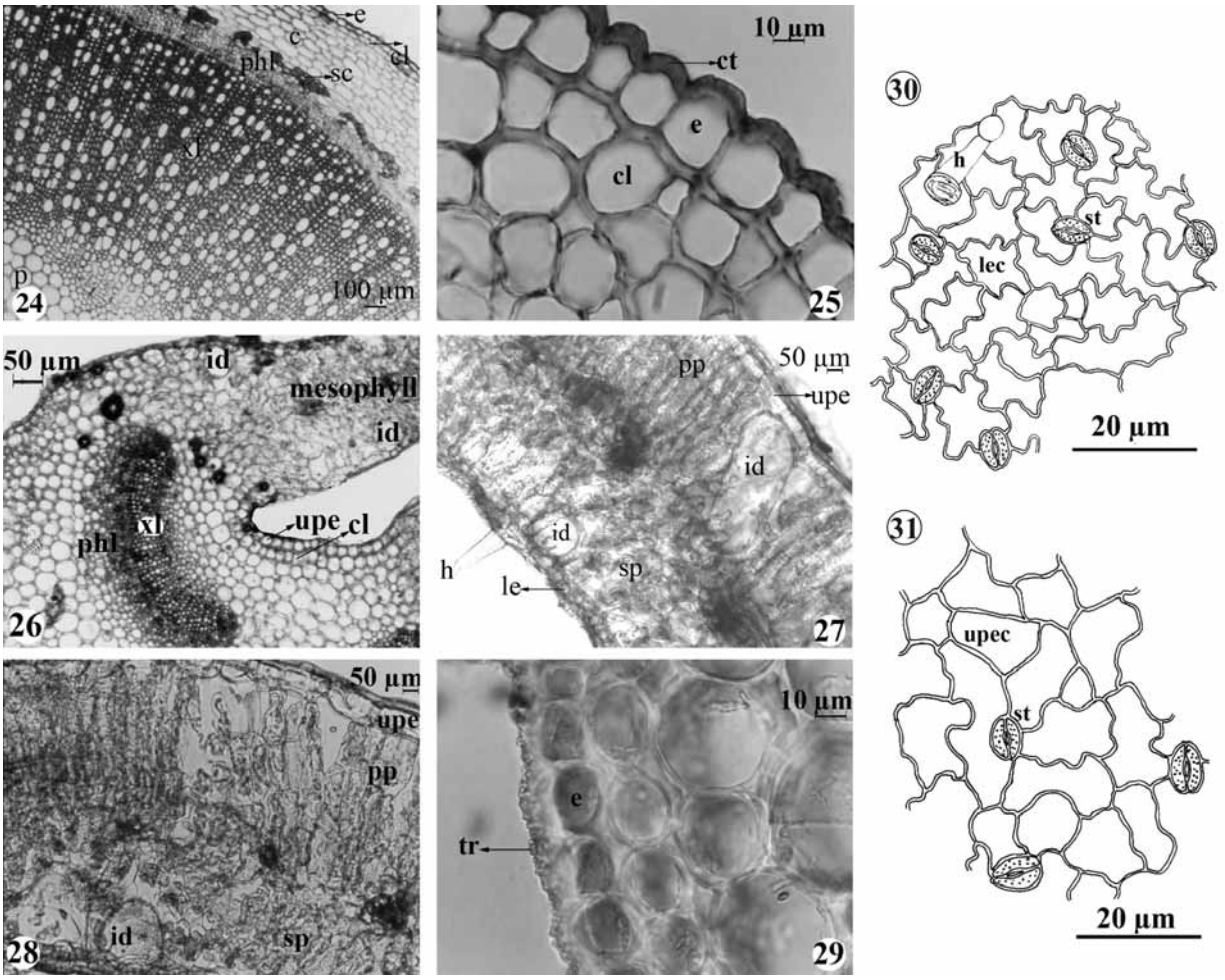
Figs. 17–23. *Scrophularia nodosa*. **Figs. 17, 18.** Transverse section of stem. **Figs. 19–21.** Transverse section of leaf. **Figs. 22, 23.** Surface section of leaf. e – epidermis; c – cortex; vb – vascular bundle; phl – phloem; xl – xylem; p – pith; le – lower epidermis; upe – upper epidermis; sp – spongy parenchyma; pp – palisade parenchyma; tr – trichome; upec – upper epidermis cell; lec – lower epidermis cell; cl – collenchyma; st – stoma.

occupies 20% of the stem cortex. Sclerenchymatic sheath (150–200 µm thick) is between the bundles. Pith cells are large and cylindrical, and occupy 36% of the stem radius.

Leaf features of the species are shown in Figure 35. Midrib is triangular and has 1 or 2 layers of collenchyma located below the epidermal cells. Upper epidermal cells are larger than the lower ones; trichomes are absent. Solitary arc-shaped vascular bundles are surrounded by orbicular parenchymatic cells. Cuticle is evident (Fig. 36). Mesophyll consists of 5 or 6 layers of elongated palisade cells and 5 or 6 layers of isodiametric, spongy parenchymatic cells having large intercellular cavities (Fig. 37). In surface preparations, cell walls of both epidermises are undulate. Leaf is unifacial and has anomocytic stomata (Figs. 38, 39).

Scrophularia cinerascens: A transverse section taken from the middle part of the stem was observed (Fig. 40). Cuticle layer is 4–5 µm thick. Under the epidermis is a monolayer of collenchyma. Stem cortex (200–250 µm thick) consists of 6 or 7 layers of usually oval cells and occupies 25% of the stem. Cambium is not distinguishable. Bundles are solitary or in clusters in the stem (Fig. 41). Xylem is large and occupies 25% of the stem cortex. Sclerenchymatic sheath is 100–120 µm thick. Pith cells are large and cylindrical, and occupy 36% of the stem radius.

A transverse section of the lamina, midrib and both epidermises was studied (Fig. 42). Midrib is triangular and has 1 or 2 layers of collenchyma. Vascular bundles are surrounded by orbicular parenchymatic cells. Mesophyll consists of 3 or 4



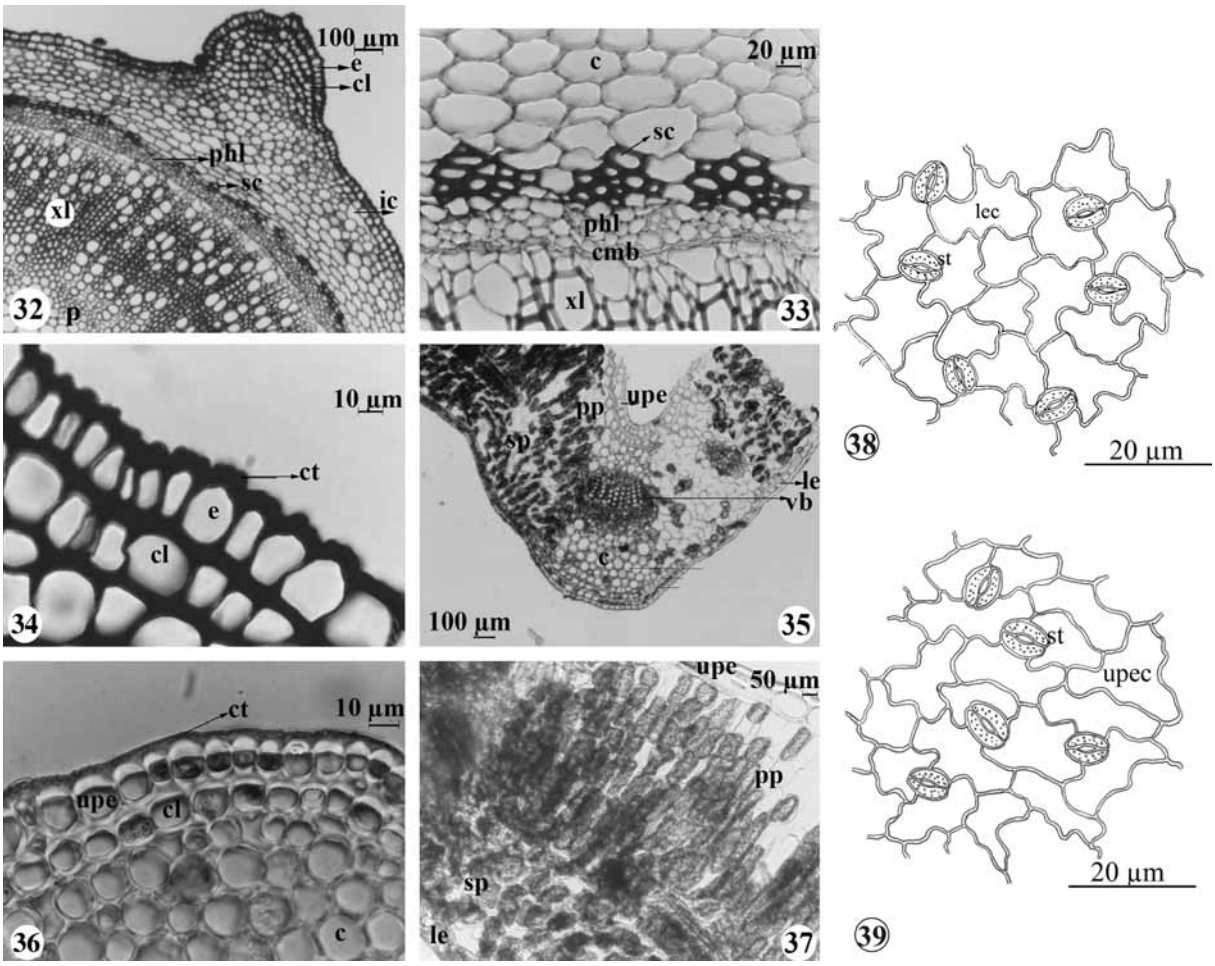
Figs. 24–31. *Scrophularia libanotica* var. *pontica*. **Figs. 24, 25.** Transverse section of stem. **Figs. 26–29.** Transverse section of leaf. **Figs. 30, 31.** Surface section of leaf. e – epidermis; c – cortex; sc – sclerenchyma; phl – phloem; xl – xylem; p – pith; le – lower epidermis; upe – upper epidermis; sp – spongy parenchyma; pp – palisade parenchyma; tr – trichome; upec – upper epidermis cell; lec – lower epidermis cell; cl – collenchyma; st – stoma; id – idioblast; h – hair.

layers of palisade cells and 4 or 5 layers of isodiametric, spongy parenchymatic cells having large intercellular cavities (Fig. 43). Many prominent trichomes are on the lower epidermis (Fig. 44). Upper epidermal cells are larger than the lower ones; cells of both epidermises have undulate walls. Leaf is unifacial and has anomocytic stomata (Figs. 45, 46).

NUMERICAL ANALYSIS

The dendrogram resulting from UPGMA is represented in Figure 47. To determine the congruence between the dendrogram and the underlying resemblance matrix, the cophenetic correlation coefficient (r_{cs}) was also calculated. It has generally been found to vary from 0.6 to 0.95, depending on the methods used to produce the dendrogram and the nature of the differences between the specimens classified. Our dendrogram had a cophenetic correlation of 0.72, suggesting that the dendrogram provides an accurate representation of the resemblances. A cross line at the 0.4 dissimilarity level divided the dendrograms into six groups corresponding to the six taxa of *Scrophularia* conventionally identified. Hence, we suggest that these clustering methods are more suitable than other methods for classifying the genus at the species level. As seen in Figure 47, while *S. ilwensis* and *S. nodosa* are linked to each other at a low dissimilarity level, *S. capillaris* and *S. libanotica* are linked at a high dissimilarity level.

PCA results using five characters are shown in Figure 48, which shows the taxa and the variables for the first two components. There are six taxa groups corresponding to the six examined taxa sep-



Figs. 32–39. *Scrophularia lucida*. **Figs. 32–34.** Transverse section of stem. **Figs. 35–37.** Transverse section of leaf. **Figs. 38, 39.** Surface section of leaf. e – epidermis; c – cortex; sc – sclerenchyma; phl – phloem; xl – xylem; ic – intracellular cavity; p – pith; le – lower epidermis; upe – upper epidermis; sp – spongy parenchyma; pp – palisade parenchyma; cmb – cambium; upec – upper epidermis cell; lec – lower epidermis cell; cl – collenchyma; st – stoma; vb – vascular bundle; ct – cuticle.

arated from each other by the first two PCs. Table 3 gives the results of principal component analysis showing eigenvalues as percentages of explained variance, and cumulative percentages. Only the first three components were taken into account because of their eigenvalues. The three components account together for 99.70% of the variation. The first component accounts for 60.33% of it, the second accounts for 27.46%, and together they account for 87.79%.

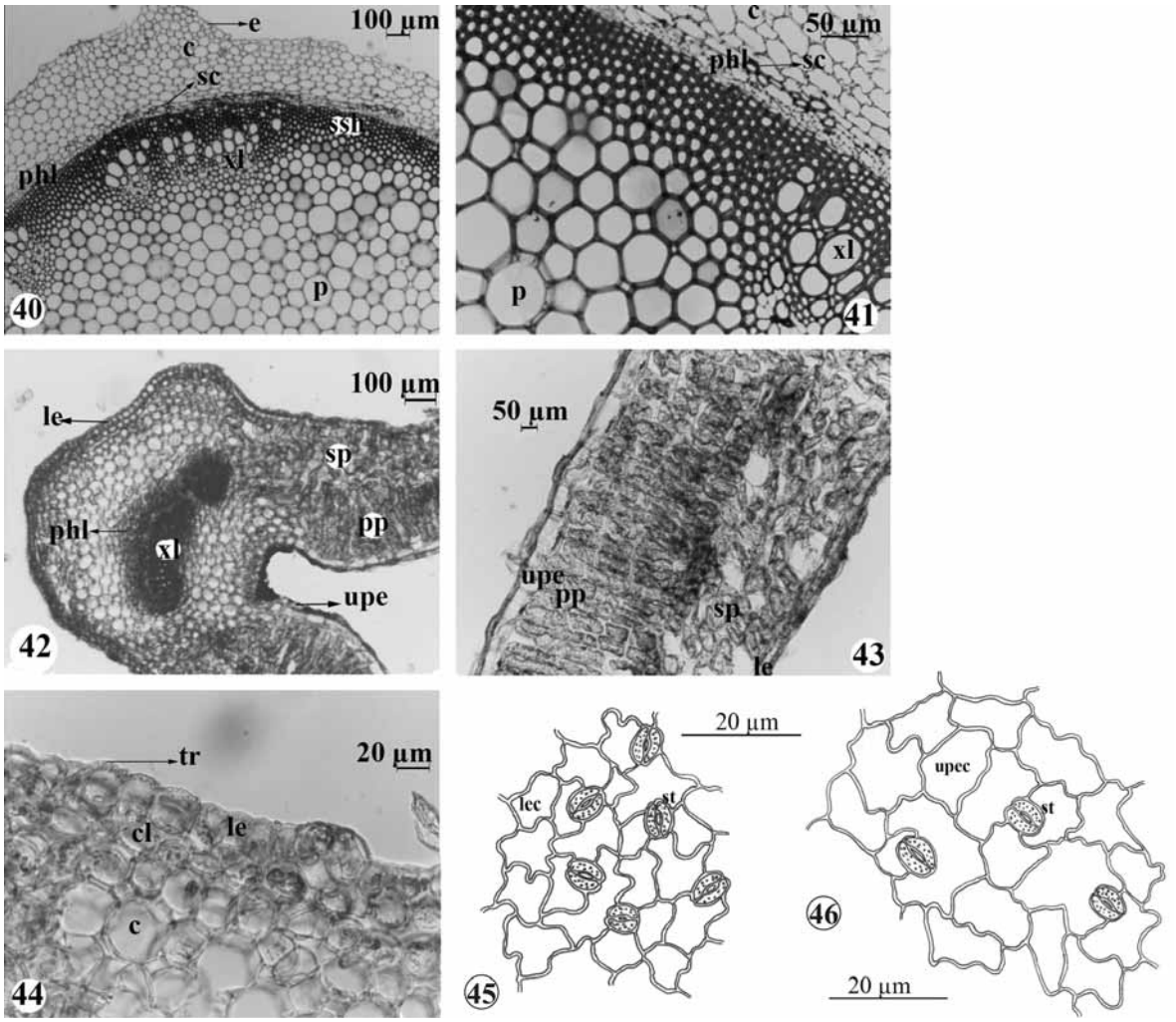
TABLE 3. Percentage of variance accounted for by first three components

	PC-1	PC-2	PC-3
Percentages of variance explained	60.37	27.46	11.86
Cumulative percentages of variance explained	60.37	87.84	99.70

DISCUSSION

The present investigation sought to provide an additional perspective on the relations between the different taxa studied. This is the first anatomical report on the six examined taxa of *Scrophularia*.

Among the morphological traits, leaf characters are the most important for separation of taxa (Davis, 1978). In out study we found that the lamina shape is pinnatifid in *S. libanotica* var. *pontica*, *S. lucida* and *S. cinerascens*, and entire in the others. All taxa except for *S. capillaris* have glands on the capsule or the pedicel. The presence/absence and shapes of



Figs. 40–46. *Scrophularia cinerascens*. **Figs. 40, 41.** Transverse section of stem. **Figs. 42–44.** Transverse section of leaf. **Figs. 45, 46.** Surface section of leaf. e – epidermis; c – cortex; sc – sclerenchyma; phl – phloem; xl – xylem; ssh – sclerenchymatic sheath; p – pith; le – lower epidermis; upe – upper epidermis; sp – spongy parenchyma; pp – palisade parenchyma; tr – trichome; upec – upper epidermis cell; lec – lower epidermis cell; cl – collenchyma; st – stoma.

staminodes are important in distinguishing related taxa. The staminode is linear to ovate in *S. libanotica* var. *pontica*, and reniform, cordate to emarginate, cordate to reniform or oblong to ovate in the others. The alar pedicel is up to 15 mm long in *S. capillaris*, and from 1.5 to 3.5 mm long in the others. The leaves are alternate and stamens are exerted in *S. ilwensis* and *S. libanotica* var. *pontica*; leaves are opposite and the stamens are included in the rest of the taxa. All our morphological observations are similar to those reported by Davis (1978).

A foliar endodermis with a casparian strip is rarely present in angiosperms (Dickson and Weitzman, 1996). It is known from Plantaginaceae, however (Metcalfe and Chalk, 1950), a family possibly related to Scrophulariaceae (Hufford, 1992). A foliar endodermis and crystals were previously described by Metcalfe and Chalk (1950) in Scrophulariaceae, but we did not observe such features in this study.

The distribution of sclerenchymatic tissue in the cortex and phloem has considerable taxonomic value (Hilliker and Kampny, 1990). It occurred as solitary or bundled fibers in all examined taxa. Fibers consist of 15–20 cells in *S. libanotica* var. *pontica*, 10–15 cells in *S. cinerascens*, 5–10 in *S. nodosa* and 8–10 in *S. lucida*, but they are solitary in *S. ilwensis* and *S. capillaris*. Pennel (1929) did not report any fibers on stem ridges of *Agalinis* a member of Scrophulariaceae. Our results did show the presence of fibers, especially in stem ridges. The fibers are solitary in *S. capillaris*, unlike in the others. The pres-

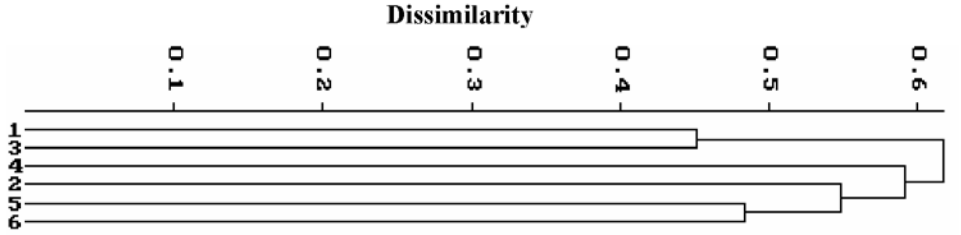


Fig. 47. Cluster analysis – UPGMA. Taxa numbers given in Table 1.

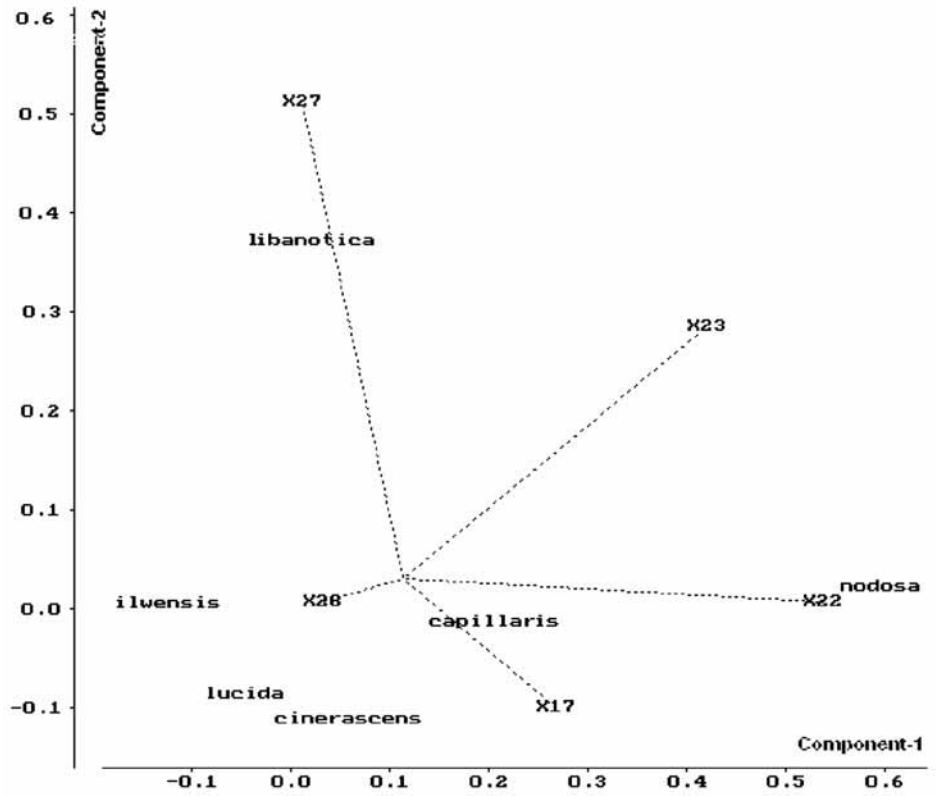


Fig. 48. Principal component analysis of 6 taxa and 5 variables projected onto the first two axes. Variable numbers explained in Table 2.

ence/absence and distribution of fibers also serve as features for separating the examined taxa. Intravascular sclerenchymatic tissue is ~300 μm thick in *S. ilwensis*, but ranges from 65 μm to 125 μm thick in the other examined taxa.

Although taxa including idioblasts are present in all sections and subsections of the genus, the state, distribution and shapes of idioblasts are particularly significant characters in *Scrophularia* (Stiefelhagen, 1910; Murbeck, 1933). The presence of idioblasts in *S. capillaris*, *S. ilwensis* and *S. libanotica* var. *pontica* is an additional taxonomic trait for identifying these taxa. While the idioblasts are distinctly oval, abundant and large in *S. libanotica* var. *pontica*, they are spherical, sparse and small in *S. capillaris* and *S. ilwensis*. Lersten and Curtis (2001) stated that strictly subepidermal idioblasts with primary cell walls are empty at cell maturity, although their development has not been studied. No substances were observed in any of the idioblasts in the present study. The other anatomical features of leaves determined in this study are also important characters. These findings supplement the information about the genus and the family given by Metcalfe and Chalk (1950), and should be useful in future studies on this genus.

Endomorphic characters can be used in conjunction with morphological characters. The concor-

dance between the UPGMA results and those of traditional taxonomic treatments (Davis, 1978) bear out this idea, and show that morphological and anatomical traits can be easily used to identify the examined taxa. PCA analysis also shows that some anatomical characters such as average number of stomata, epidermal cell characteristics, and the dimensions of vascular bundles and intervascular sclerenchyma seem to be more important than morphological ones, and explain most of the total variation among the examined taxa.

REFERENCES

CANNE-HILLIKER JM, and KAMPNY CM. 1990. Taxonomic significance of leaf and stem anatomy of *Agalinis* (Scrophulariaceae) from the USA and Canada. *Canadian Journal of Botany* 69: 1935–1950.

DAVIS PH. 1978. *Flora of Turkey and the East Aegean Island*, vol. 6. Edinburgh University Press, Edinburgh.

DICKSON WC, and WEITZMAN L. 1996. Comparative anatomy of the young stem, node and leaf of Bonnetiaceae, including observations on a foliar endodermis. *American Journal of Botany* 83: 405–418.

HEATHER M, and HENDERSON MRH. 1994. The physicians of Myddfai, The Welsh herbal tradition. *Scotland Journal of Botany* 46: 623–627.

HUFFORD L. 1992. Leaf structure of *Besseya* and *Synthris* (Scrophulariaceae). *Canadian Journal of Botany* 70: 921–932.

LERSTEN NR, and CURTIS JD. 1997. Anatomy and distribution of foliar idioblasts in *Scrophularia* and *Verbascum (Scrophulariaceae). American Journal of Botany* 84: 1638–1645.

LERSTEN NR, and CURTIS JD. 2001. Idioblasts and other unusual internal foliar secretary structures in *Scrophulariaceae. Plant Systematic and Evolution* 227: 63–73.

METCALFE CR, and CHALK L. 1950. A*natomy of Dicotyledons*, 1st edition, vol. 2. Clarendon Press, Oxford.

MURBECK S. 1933. *Monographie der Gattung Verbascum*. Lunds Universitets Arsskrift, Vol. 29, Hakan Ohlsson, Lund.

PENNEL FW. 1929. *Agalinis* and allies in North America. II. *Proceedins of Academy of Natural Sciences Philadelphia* 81: 111–249.

PENNEL FW. 1935. The *Scrophulariaceae* of Eastern Temperate North America (41 Gerardia). *Academy of Natural Sciences Philadelphia* Monogr. 1: 419–476.

PODANI J. 1994. Multivariate data analysis in ecology and systematic: A methodological guide to Syn-Tax 5.0 Package, SPB Academic Publishing, Netherlands.

SNEATH PHA, and SOKAL RR. 1973. *Numerical taxonomy: The principles and practice of numerical classification*. W.H. Freeman and Company, San Francisco.

STIEFELHAGEN H. 1910. Systematische und pflanzengeographicsche Studien zur Kenhtnis der Gattung *Scrophularia. Botanische Fahrbücher* 44: 406–496.

VARDAR Y. 1987. *Botanikte Preperasyon Teknigi*. Ege Universitesi Fen Fakültesi Yayinlari, Izmir.

VOLKENS G. 1887. *Die Flora der Aegyptisch-arabischen Wüste auf Grundlage anatomisch-physiologischer Forschungen dargesttellt*. Gebrüder Borntraeger, Berlin.