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ANALYSIS OF ANATOMICAL AND MORPHOLOGICAL CHARACTERS OF THE *SILENE CAPPADOCICA* BOISS. & HELDR. AND *SILENE SPERGULIFOLIA* BIEB. (CARYOPHYLLACEAE) SPECIES

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Abstract

In this study, analysis of anatomical and morphological characters of the Silene cappadocica Boiss&Heldr and Silene spergulifolia Bieb. specie which belong to family of Caryophyllaceae were determined. In morphological studies of these species, parts of stem, leaves, flower and fruit were measured and given as tables. In anatomical investigations of these two species were taken section from root, stem, and leaves by microtom and hand. These sections were painted and were made constant slide. After that, it was taken photograph of these slides with assist of microscope camera. Stomatal characteristics were examined by section taken superficial from these plants leaves and stomatal index was calculated.

Key words: *Anatomy, Caryophyllaceae, Morphology, Silene, Endemic.*

INTRODUCTION

Silene is one of the largest genera of flowering plants in the world consisting of about 750 species with the generality of them distributed in Mediterranean region (Greuter, 1995). In Turkey, the genus is represented by 148 species (Coode and Cullen 1967; Davis et al. 1988, Greuter 1995; Tan and Vural 2000; Özhatay and Kültür, 2006; Özhatayet al. 2009; Bağcı et al. 2007; Aksoy et al., 2008; Bağcı 2008; Tugay and Ertuğrul 2008; Kandemiret al. 2009; Yıldız and Dadandı 2009; Hamzaoğlu et al. 2010; Yıldız and Erik 2010; Yıldız et al. 2010; Hamzaoğlu et al. 2011, Hamzaoğlu, 2012).

Little work appears to have been done on the anatomy of vegetative organs of *Silene* species especially halophytic ones. Anatomical fluctuations about the plants structure are related with the habitats of plants. Millner (2006) reported that the anatomical structures of two *Silene* species is correlated with a wide range of environmental conditions. The high salinity of soils and the soil's moisture has a major impact on halophytes' anatomical structures and has formative effects. Their cumulated action has accompanied the halophytes evolution through time, as an active and dynamic component of the evolutionary "adventure" (Grigore and Toma, 2007). From this point of view, the present study the anatomical and ecological properties of two local endemic species of *Silene* (glikophytic and halophytic ones) have been investigated.

Silene genus is named various names as locally. Usually it is named "nakil çiçeği" in Turkish. The other names are used as *"salkım çiçeği, gıvışgan otu, gıcı gıcı, acı gıcı, gıcime, cıvrıncık, çığıstak, gıvırsık, ecibücü, ibiş gıbış, kıvırşık, kıvışgan, kıvışık, kıvışkan, kıvrışık, kıvşıyık, tavuk yastığı"* for *Silene* genus in Turkish *(Baytop, 1997)*.

MATERIALS AND METHODS

Materials

The investigated species have been collected from their natural habitats when they are mature. The localities of species are below:

Silene cappadocica: C4: Konya; Cihanbeyli; Tuz Gölü, Gölyazı, 2 June 2012, 38° 45.672 K, 33°06.801 D, 925 m °28.546 K, 32°43.904 D, 1750-1770 m, Bağcı 4145.

Silene spergulifolia: C4: Konya; Hadim-Taşkent between, 2 June 2012, 38° 45.672 K, 33°06.801 D, 1300 m, Bağcı 4156.

Methods

Morphological method

The species have been diagnosed by Davis (1967) and our observations have been stored in KNYA herbarium. Morphological researches for plant samples were done according to Flora of Turkey and the related articles. The diagnostic parts of *Silene* species such as plant length, basal and cauline leaves, petal, sepal, capsule (fruit) dimensions were calculated on 20 plant samples.

Anatomical method

For anatomical studies, roots, stems and leaves were used in paraffin method. And also some parts of plants were taken by hand with the aid of a razor blade. Paraffin sections were stained with safranin-fast green and hand sections were investigated directly. Canon EOS 450D cameras which attached to Leica DM 1000 light microscope were used for photograph and were calculated the cells dimensions with Cameram 21 programme.

RESULTS AND DISCUSSIONS

S. cappadocica

Morphological characteristics

Perennial. Stems ascending to erect, retroversely puberulent, 10-50 cm. Leaves elliptic to oblanceolate, usually without sterile shoots in their axils, puberulent, less than 5 mm broad. Inflorescence a rather loose though strict panicle. Calyx 3-5 mm in functionally female flowers, 5-11 mm in hermephrodite flowers, puberulent, often glandular. Petals white to grennish yellow, deeply bifid into ± linear lobes. Anthophore (in hermaphrodite flowers) 3-4 mm. Capsule ovoid, trigonous or 3-sulcate, long acuminate, included in the calyx. *Fl.* 5-7. *Steppe*, *slopes, etc. 800-2300 m* (Davis 1967), (Figure 1).

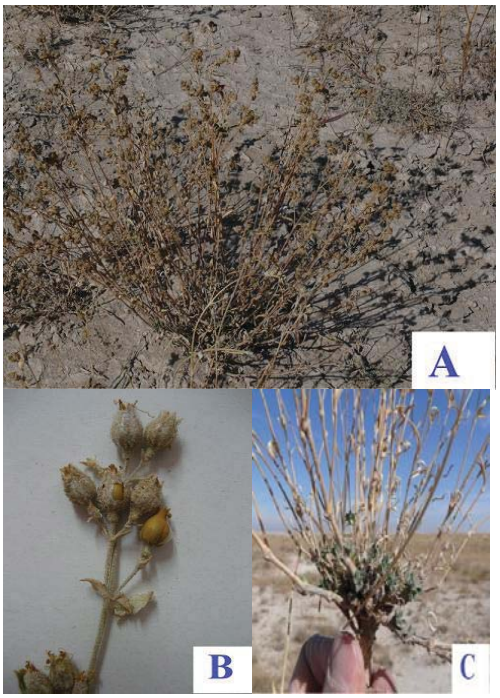

Figure 1. *S.cappadocica*, (A): general view (B): Fruit, (C): Basal leaves

Table 1. Morphological data of *S. cappadocica*

Plant Parts	wide		length	
	MİN	MAX	MİN	MAX
Basal leaf	0.2 cm	0.3 cm	1.2 cm	2.2 cm
Stem leaf	0.3 cm	0.2 cm	1.7 cm	2.3 cm
Calyx	0.3 cm	0.5 cm	0.6 cm	0.8 cm
Corolla	0.1 cm	0.15 cm	0.6 cm	1.2 cm
Fruit	0.2 cm	0.4 cm	0.6 cm	0.8 cm
Calyx teeth length	-	-	0.1 cm	0.1 cm
Bracts	-	-	0.1 cm	0.3 cm
Anthophore length	-	-	0.3 cm	0.5 cm
Plant length	-	-	30 cm	44 cm
Stem diameter	-	-	0.15 cm	0.4 cm

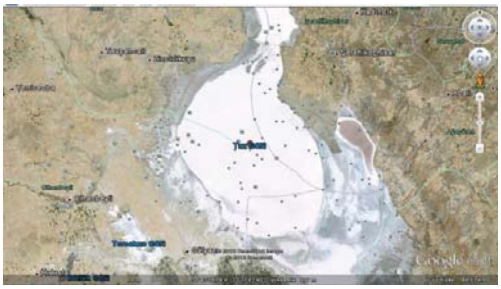

Figure 2. Location of *S.cappadocica* species

Figure 3. Location of *S. spergulifolia* species

Anatomical results

ROOT ANATOMY

Root usuaally comprises of four parts as anatomical; peridermis, cortex, vascular bunds and pith (1, 2 A, B). Peridermis encloses the outermost surface of *S. cappadocica* root cross sections. Below the peridermis, there is 8-10 layered cortex. Vascular system is well developed; there is 2-3 rowed cambium between phloem and xylem. Trachea diameter is 50-100 µm. Pith region is covered with xylem and the pith rays are 1-2 rowed.

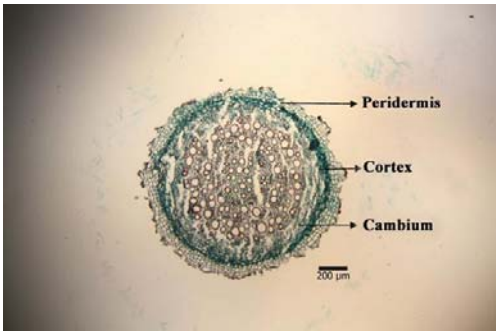

Figure 4. The cross sections of *S.cappadocica* root

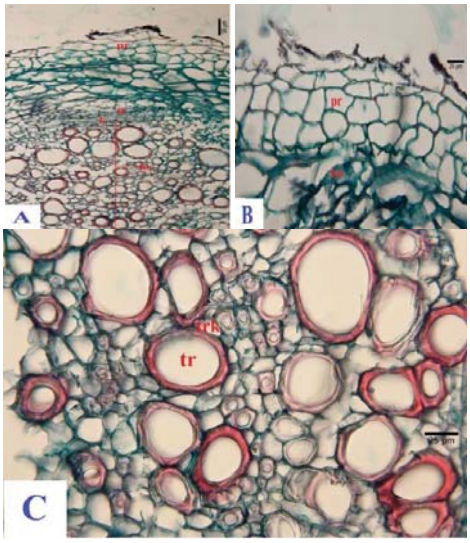

Figure 5. The cross sections of *S.cappadocica* root (A): **pr:** peridermis; ph:phloem; ca:cambium; xy: xylem; (B): pr: peridermis; (C): **tr:** trachea; trk: traceid

STEM ANATOMY

The cross sections of herbaceous stems of *S. cappadocica* have rectangular-oval shaped epidermis on the outermost surface. Under epidermis the 3-5 rowed cortex with chloroplast is located and they have druses in some cells. Endodermis which pentagon shaped and single line lies below the cortex. Sclerenchyma occupies large area (10-12 rowed) under the endodermis as uninterrupted parallel to peripheral. Vascular bundles type is open collateral definitely. Cambium splits up the phloem and xylem. The pith region is composed of parenchymatic cells and contains druses or usually it is empty Figure 3, 4 A-D).

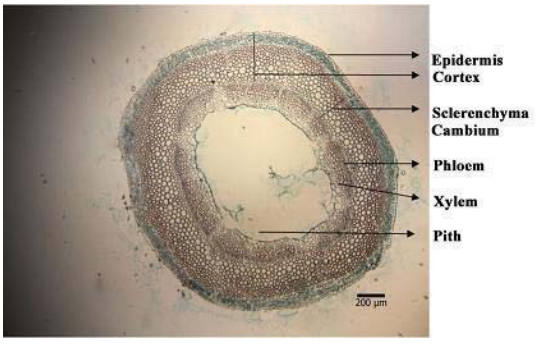

Figure 6. General view of the cross sections of stem parts of *S.cappadocica*

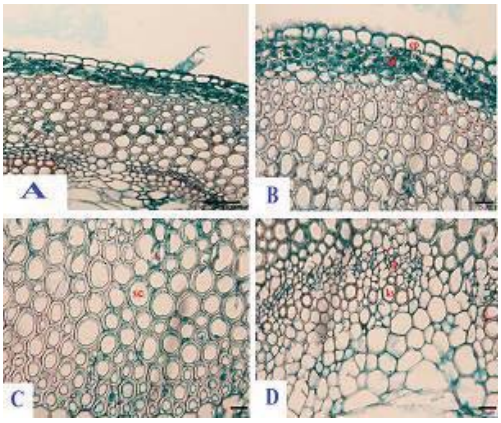

Figure 7. The cross sections of stem parts of *S.cappadocica*, (A): General view of whole parts; (B): **ep:** epidermis, **kl:** klorenkima, (C): **sc:** sclerenchyma rings; (D): **xy:** xylem, ph**:** phloem

LEAF ANATOMY

In cross sections of stem leaves, on the outer surface, there is single row rectangular-oval shaped epidermis. Epidermis is covered by cuticle. Mesophyll is composed of palisade and spongy parenchyma cells (equifacial type). Mesophyll has rarely druses in its large space. Vascular bundles are collateral type and single row bundle-sheath cells are around them. Stem leaves are amphistomatic and stomata of species are diasitic type. The secretory trichomes are abundant in superficial sections of stem leaves (Figure 8, 9, 10).

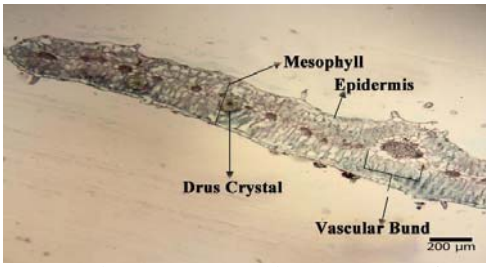

Figure 8. The cross sections of leaves of *S.cappadocica*

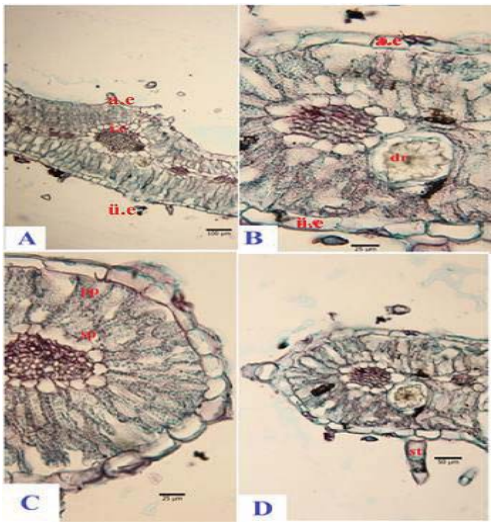

Figure 9. The cross sections of leaves of *S. cappadocica* (A): ie: vascular bund, u.e:upper epidermis, l.e: lower epidermis; (B): u.e: upper eridermis**,** l**.e**: lower epidermis, dr: druses crystal; (C): pp: palisade parenchyma, sp: spongy parenchymas; (D): st: secretory trichomes

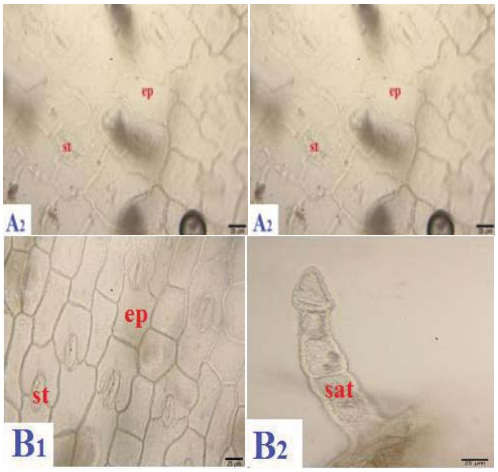

Figure 10. Surface sections of leaves of *S.cappadocica* (A1-A2) lower surface, (A1): Lower surface, sat: secrotery trichome (A2): **ep:** epidermis, **st:** stomata; (B1-B2): upper surface, (B1): upper surface, **ep:** epidermis, **st:** stomata; (B2): sat: secrotery trichome

Table 2. Anatomical data of *S. cappadocica*

Plant part	Item	*Silene cappadocica* Boiss. & Heldr.									
		Wide (µM)			Length Boy (µM)			Diameter / thick (µM)			Number of measurement
		Min	Max	average	Min	Max	average	Min	Max	average	
Root	Peridermis	0.223	0.669	0.37	0.09	0.489	0.24	7413	132.1	1175	110
	Cortex	-	-	-	-	-	-	25.65	75.36	±200	110
	Trachea	-	-	-	-	-	-	50	100	±87.5	110
Stem	Epidermis	9.54	33.07	20.77	9.03	24.58	14.87	-	-	-	110
cortex	cortex	-	-	-	-	-	-	-	-	±225	110
	Sclerenchyma	85.355	256.7	117.9	95.385	260.05	170.15	98.655	353.4	181.25	110
	Trachea	-	-	-	-	-	-	7.96	23.5	21.3±	110
Leaf	Lower Epidermis	12.44	28.53	16.76	14.30	39.73	20.54	-	-	-	50
	Mesophyll	-	-	-	-	-	-	-	-	2.312	50
Upper	Upper Epidermis	14.193	30.105	35.69	13.165	32.22	19.18	-	-	-	50

Table 3. Numerical data of *S.cappadocica* leaves

Leaf	Leaf		
	Min	Max	Ort.
Number of stomata of lower surface / mm^2	122	204	162
Number of stomata of upper surface / mm2	82	183	144
Number of lower surface / mm2	367	693	482
Number of upper surface / mm2	408	672	591
Stomata index of lower surface	7.95		
Stomata index of upper surface	7.05		
Stoma index ratio	0.886		

Silene spergulifolia Bieb.

Morfologic Results

Perennial. Stems ascending to erect, retroversely puberulent, 30-44 cm. Leaves lineare to oblange, usually witht sterile shoots in their axils, puberulent, less than 5 mm broad. Basal leaves 8-16 mm×0.5-1.5 mm. Bract 1-1.5 mm, Inflorescence a rather loose though strict panicle. Calyx 10-14 mm in flowers, puberulent, often glandular. Petals whıte to grennish yellow, deeply bifid into ± linear lobes. Anthophore (in hermaphrodite flowers) 4-6 mm. Capsule roundade, trigonous or not 3-sulcate, long acuminate, included in the calyx. *Fl. 5-7. Screes and slopes*, *steppe, 800-3100 m*, (Figure 11).

Table 4. Morphological data of *S.spergulifolia*

Plant parts	Measurement data			
	wide		length	
	MİN	MAX	MİN	MAX
Basal leaf	0.05 cm	0.15 cm	0.8 cm	1.6 cm
Stem leaf	0.1 cm	0.2 cm	1 cm	1.5 cm
Calyx	0.2 cm	0.4 cm	1 cm	1.4 cm
Corolla	0.1 cm	0.1 cm	0.8 cm	1.5 cm
Fruit	0.2 cm	0.4 cm	0.6 cm	0.8 cm
Calix teeth length	-	-	0.1 cm	0.2 mm
Bracts	-	-	0.1 cm	0.15 cm
Anthophor length	-	-	0.4 cm	0.6 cm
Plant length	-	-	30 cm	40 cm
Stem diameter	-	-	0.1 cm	0.3 cm

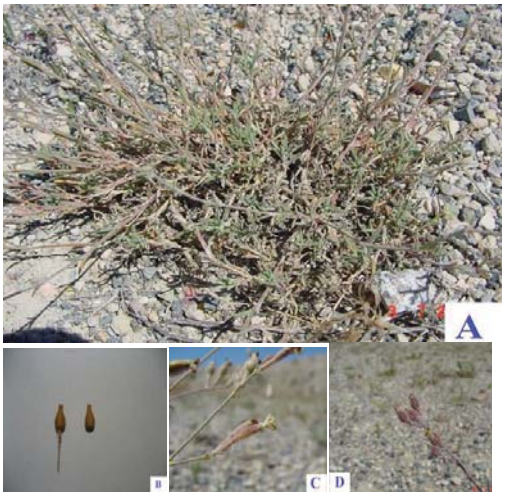

Figure 11. *S.spergulifolia* (A): General view, (B): Mature fruit (C): Young flower; (D) Semi-mature fruit

Anatomical Results

ROOT ANATOMY

Root usually comprises of four parts as anatomical; peridermis, cortex, vascular bunds and pith (Figure 12-15). Peridermis encloses the outermost surface of *S. spergulifolia* root cross sections. Below the peridermis, there is 10-12 layered cortex. Vascular system is well developed; there is 2-3 rowed cambium between phloem and xylem. Trachea diameter is 35-70 µm. Pith region is covered with xylem and the pith rays are 1-2 rowed.

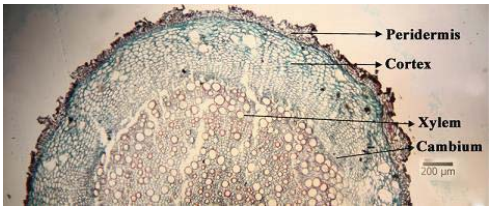

Figure 12. General view; The cross sections of *S.spergulifolia* root

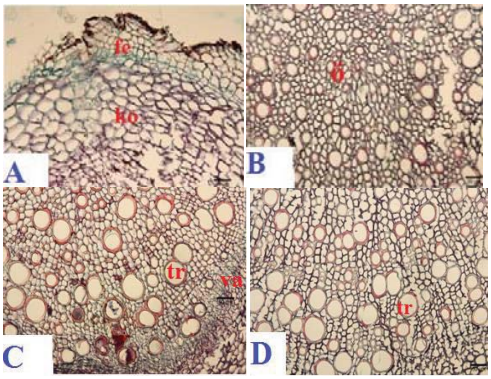

Figure 13. The cross sections of *S. spergulifolia* root, (A): **ko:** cortex, **pe:** peridermis**;** (B): p:pith region parenchyma (C): **tr:** trachea, **va:** vasculer region (D): **tr:** trachea

STEM ANATOMY

The cross sections of herbaceous stems of *S. spergulifolia* have rectangular-oval shaped epidermis on the outermost surface. Under epidermis the 3-5 rowed cortex with chloroplast is located and they have druses in some cells. Endodermis which pentagon shaped and single line lies below the cortex. Sclerenchyma occupies large area (9-10 rowed) under the endodermis as uninterrupted parallel to peripheral. Vascular bundles type is open collateral definitely. Cambium splits up the phloem and xylem. The pith region is composed of parenchymatic cells and contains druses or usually it is empity. Probably pith regioan may be decomposed while it is mature (Figure 14-15).

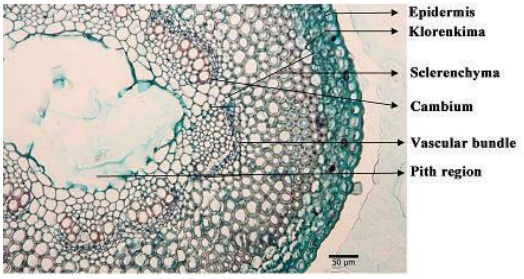

Figure 14. The cross sections of *S.spergulifolia* stem

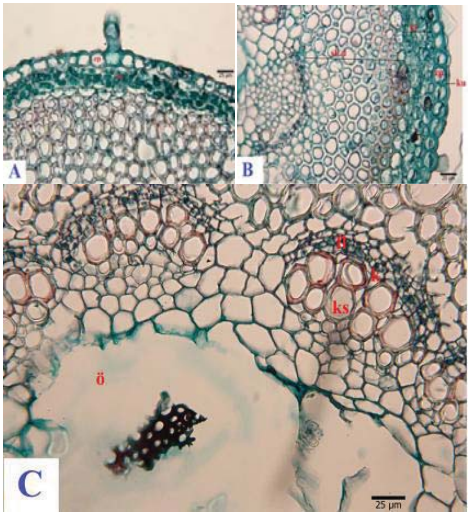

Figure 15. The cross sections of *S.spergulifolia*i stem, (A): **ep:** epidermis, **kl:** klorenkima; (B): cr**:** cycleranchima ring; **kl:** klorenkima; **ep:** epiderma; **ku:** cuticle (C): xy**:** xylem**, ph.**: phloem**,** p: pith region, **k:** cambium

LEAF ANATOMY

In cross sections of stem leaves, on the outer surface, there is single row rectangular shaped epidermis. Epidermis is covered by cuticle. Mesophyll is composed of palisade and spongy parenchyma cells (equifacial type). Mesophyll has druses in its large space. Vascular bundles are collateral type and single row bundle-sheath cells are around them. Stem leaves are *amphistomatic* and stomata of species are *diasitic* type. The secretory trichomes are abundant in superficial sections of stem leaves (Figure 16-18).

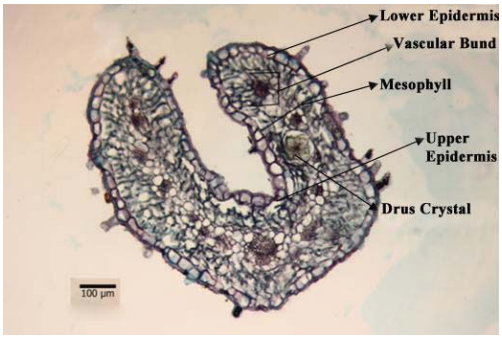

Figure 16. The cross sections of leaf of *S.spergulifolia*

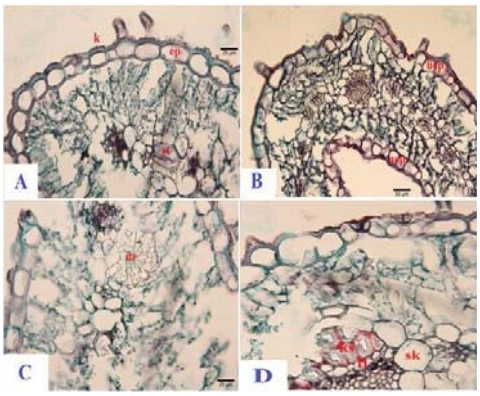

Figure 17. The cross sections of leaf of *S.spergulifolia*, **(A):** ep: epidermis, k: cuticle, **st:** stomata; **(B):** uep: upper epidermis, lep; lower epidermis; **(C):** dr: druse crystal; **(D):** sk: sclerenchyma, xy: xylem, ph: pholem

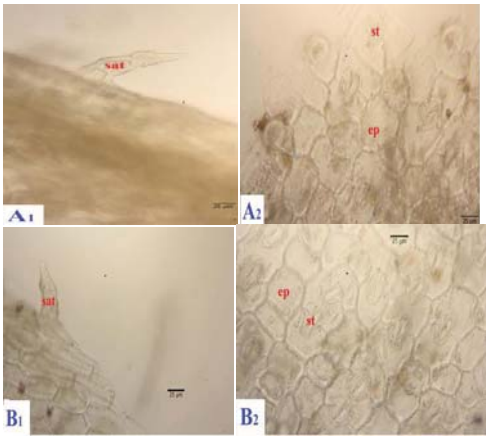

Figure 18. Surface sections of leaves of *S.spergulifolia*, (A1-A2) Lower surface, (A1): Lower surface, **sat:** secrotery trichome (A2): **ep:** epidermis, **st:** stomata; (B1-B2): upper surface, (B1): upper surface, **ep:** epidermis, **st:** stomata; (B2): **sat:** secrotery trichome

Table 5. Anatomical measure data of *S.spergulifolia*

Plant part	Item	*Silene spergulifolia* Bieb.									
		Wide (µM)			Lenght (µM)			Diameter/ Thick (µM)			Number of measurement
		Min	Max	Average	Min	Max	Average	Min	Max	Average	
ROOT	Peridermis	8.612	53.871	22.891	8.824	32.261	16.182	27.848	95.07	175±	110
	cortex	-	-	-	-	-	-	-	-	50±	110
	Trachea	-	-	-	-	-	-	35	70	50	110
STEM	Epidermis	6.07	7.024	22.55	23.87	36.51	20.04	-	-	-	110
	cortex	-	-	-	-	-	-	27.59	50.44	37.45	110
	Sclerenchyma	7.858	28.307	13.53	10.19	29.055	16.845	-	-	-	50
	Trachea	-	-	-	-	-	-	-	-	14.67	110
	Pith	-	-	-	-	-	-	-	-	-	-
LEAF	Lower epidermis	13.54	42.90	21.45	10.53	29.02	20.44	-	-	-	50
	Mesophyll	-	-	-	-	-	-	36.249	202.3	135.81	110
	Upper epidermis	14.56	40.943	24.38	11.92	27.11	19.67	-	-	-	50

Table 6. Numerical datas of leaves of *S.spergulifolia*

Leaf	Leaf		
	Min	Max	Ort.
Number of stomata of lower surface / mm^2	122	306	204
Number of stomata of upper surface / mm2	122	428	329
Number of lower surface / mm2	346	611	491
Number of upper surface / mm2	387	713	532
Stomata index of lower surface	10		
Stomata index of upper surface	15.35		
Stoma index ratio	1.535		

Table 7. The morphological differences between investigated species

Characters	*Silene cappadocica*		*Silene spergulifolia*	
	According to Results of our	According to Flora of Turkey (Davis, 1967)	According to Results of our	According to Flora of Turkey (Davis, 1967)
plant length	30-44 cm	10-50 cm	30-40 cm	30 - 50 cm
basal leaves	12-22×2-3mm eliptice – oblanceolate	Less than 5 mm eliptice – oblanceolate	8-16×0.5-1.5 mm Eliptic-oblanceolate	eliptic–oblanceolate
stem leaves	17-23x2-3 mm eliptic–oblanceolate	30-60x1-3 mm eliptic–oblanceolate	10-15 x 1-2 mm Linear -oblong	Linear - oblong
calyx	6-8×3-5 mm	3-5mm	10-14×2-4 mm	-
anthophore	3-5 mm	3-4mm	4-6 mm	-
stem diameter	1.5-4 mm	-	1-3 mm	-
flowering period	June-July	June-July	June-July	June-July
location	Konya/Tuzgölü	Konya/Hadim	Konya/Hadim	
bract	1-3 mm	-	1-1.5 mm	-

The root, stem and leaf anatomical differences between investigated species are given below in Table 8-10.

Table 8. The root anatomical differences between investigated species

Species tissue	*Silene cappadocica*	*Silene spergulifolia*
peridermis	Average ± 117.5 µm	average ± 175 µm
cortex	150-200 µm / 8–10 layer	400-600 µm/ 10-12 layer
trachea	average : 87.5 µm	average : 50 µm

Table 9. The stem anatomical differences between investigated species

Tissue-species	*S. cappadocica*	*S.spergulifolia*
epidermis	9.03-24.58 x 9.54-33.07	6.07-23.87 x 7.024x 36.51
cortex	±225 µm	27.59-50.44 µm
trachea	average 21.3 ± µm	average 14.7 ± µm

Table 10. The leaf anatomical differences between investigated species

Species tissue		*S. cappadocica*	*S. spergulifolia*
Present of stomata on leaf surface		Amfistomatik	Amfistomatik
According to epidermis position of stomata		Kseromorf	Kseromorf
Type of stomata		Diasitik	Diasitik
Place in druse		Mesophyle layer	Mesophyle layer
Stomata index rate	Upper surface	7.05	15.35
	Lower surface	7.95	10
	Stomata index ratio	0.886	1.535

CONCLUSIONS

Although *S.cappadocica* and *S.spergulifolia* are related species, there are anatomical and morphological different between the two species.

From morphological point of view, *Silene spergulifolia* has leaf narrow than *Silene cappadocica*. *Silene spergulifolia* has different fruit shapes according to fruit of *Silene cappadocica.*

S. cappadocica has 30-44 cm length while *S.spergulifolia* has 30-40 cm length. *S. cappadocica* is taller than *S. spergulifolia*. Calyx is 6-8 mm length in *S.cappadocica* but calyx of *S.spergulifolia* is 10-14 mm length. Anthofor length is 3-5 mm at *S. cappadocica* but calyx length of *S. Spergulifolia* is 4-6 mm

Fruits of *S.cappadocica* are smaller than *S. spergulifolia*. Also, S. *cappadocica* has a split on fruit (capsule) and this feature is a distinct character for this two species.

In anatomical terms, while stomata index rate of *S.cappadocica* is 0.886, iken stomata index rate is 1.535 at *S. spergulifolia.* Leaf of *S. cappadocica* has thinner cuticle layer than leaf of *S. sperguliolia.* While *S.cappadocica* has 4-5 layer peridermis, *S. spergulifolia* has 8-9 layer peridermis.

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