

The leaf anatomy of some *Erica* taxa native to Turkey

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Abstract: There are 5 taxa of *Erica* L. growing in Turkey, 1 of which is endemic. These taxa are *Erica arborea*, *E. manipuliiflora*, *E. bocquetii*, *E. sicula* subsp. *libanotica* and *E. spiculifolia*. In this study, microscopic characteristics of the leaves of 4 taxa native to Turkey are reported. Microscopic views of the transverse and surface sections of the leaves of each species were photographed and are described in detail. The leaves are channelled beneath or strongly revolute. The long, simple, and unicellular eglandular trichomes are located along the channel part of the lower surface of leaves. There are simple, unicellular, and usually short eglandular trichomes on the surface of the upper epidermis.

Key words: *Erica*, leaf, anatomy, Ericaceae

Türkiye'nin bazı doğal *Erica* taksonlarının yaprak anatomisi

Özet: Türkiye'de doğal olarak yetişen biri endemik 5 *Erica* L. taksonu vardır. Bu taksonlar, *Erica arborea*, *E. manipuliiflora*, *E. bocquetii*, *E. sicula* subsp. *libanotica* ve *E. spiculifolia*'dır. Bu çalışmada, Türkiye'de doğal olarak yetişen bu taksonların 4 tanesinin yaprak anatomik özellikleri incelenmiştir. Her bir türün yapraklarından alınan enine ve yüzeyel kesitlerin mikroskopik özellikleri ayrıntılı olarak tanımlanmış ve fotoğraflanmıştır. Yapraklar alt yüzde kanallı ve kuvvetli bir şekilde kıvrıktır. Basit, uzun ve tek hücreli örtü tüyleri, yaprakların alt yüzünde bu kanallar boyunca yer almaktadır. Üst epidermada bir hücreli basit ve genellikle kısa örtü tüyleri vardır.

Anahtar sözcükler: *Erica*, yaprak, anatomi, Ericaceae

Introduction

The genus *Erica* L. (Ericaceae) is represented by more than 700 species throughout the world and can mainly be found in South Africa, the Mediterranean region, and West Europe. In Turkey, this genus is represented by only 5 taxa, 1 of which is endemic to Turkey. *Erica arborea* L. and *E. manipuliiflora* Salisb. are very common in the coastal areas of Turkey, *E. bocquetii* (Peşmen) P.F.Stevens is an endemic species, and *E. sicula* Guss. subsp. *libanotica* (C. & W. Barbey)

P.F.Stevens has rare distribution in south-western Anatolia (Stevens, 1978). *E. spiculifolia* Salisb. (Syn. *Brunckenthalia spiculifolia* (Salisb.) Reichb.) is a new species, which was separated from the *Brunckenthalia* Reichb. (Nelson, 2007). These species are called "funda," "püren," or "süpürge çalısı" in Turkey (Baytop, 1999).

Erica species are evergreen shrubs. Leaves are whorled, almost acicular, channelled beneath or strongly revolute. Inflorescence is terminal or axillary

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umbels, racems, or racem like panicles. Flowers are 4-5 merous, actinomorphic, sepals free. Corolla is campanulate, urceolate, or tubular, persistent. Ovary is 4-5 locular, nectary is prominent. Fruit is a loculicidal capsule enclosed by persistent corolla, seed is ovoid (Stevens, 1978; Kendir & Güvenç, 2008). Synonym is *Pentepera* Klotzsch. (Stevens, 1978). According to the IUCN Red Data Book, *E. bocquetii* and *E. sicula* are vulnerable in Turkey (Ekim et al., 2000).

Herbal teas prepared from the aerial parts of *E. arborea* and *E. manipuliiflora* have been used as a diuretic or astringent and as a treatment for urinary infections in Turkey (Baytop, 1999; Tuzlacı & Eryaşar Aymaz, 2001). Additionally, a 5% infusion of *E. arborea* is taken after meals for slimming (Başer et al., 1986). One of the species of *E. arborea* is exported for collections as a species native to Turkey (Özhatay et al., 1997). These species have been reported to possess antioxidant (Ay et al., 2007), antiinflammatory (Akkol et al., 2008), and antimicrobial (Güvenç et al., 2008) activities.

There are botanical reports specifically on new *Erica* species (Oliver & Oliver, 1991, 1998, 2004), as well as a study on the pollen morphology of *E. bocquetii* (Pinar & Oybak, 1995), and stamen development was studied in *Erica carnea* L. cultivated in Morris arboretum (Hermann & Palser, 2000). Several quantitative and qualitative seed characters of the 7 European species of *Erica* were studied by Fagundez and Izco (2009). The seed morphology of *E. bocquetii* and *E. sicula* (4 taxa) has been studied by means of scanning electron microscope techniques (Fagundez & Izco, 2011). However, reports on the anatomical structure of *Erica* species are rare. The wood anatomy of Ericaceae was examined in the subfamily Vaccinioideae (Lens et al., 2004), and root

starch storage and allocation patterns in seeder and resprouter seedlings were investigated in *E. coccinea* L. and *E. calycina* L. (Verdaguer & Ojeda, 2002). The leaf morphology and anatomy, water relations, leaf life-span, and gas exchange of cooccurring *E. arborea* and *E. multiflora* were also analysed in the Mediterranean maquis developing along the coast near Rome. In that study, the characteristics of leaf morphology and anatomy were given as statistical values (Gratani & Varone, 2004). The aim of our study was to provide an improved description of the anatomical properties of the leaves of 4 *Erica* taxa, which is located in the *Flora of Turkey* in volume 6, based on anatomical observations. These anatomical studies include photographs of the cross and surface sections of the leaves.

Material and methods

Plant materials were collected in the flowering season from various locations in Turkey. During the collection of materials, the aerial parts were gathered for all species. Voucher specimens were deposited in the Ankara University Faculty of Pharmacy Herbarium (AEF) in Turkey. The locations of the investigated plant samples are given in Table 1. For the distribution of the species in Turkey, we used Davis's grid system (Davis, 1965).

For anatomical studies, the aerial parts of *Erica* taxa were preserved in 70% ethanol. Cross sections of the leaves were obtained by hand from preserved material in chloral hydrate solution R and Sartur reagent. Sartur reagent contains KI-I, aniline, Sudan III, lactic acid, alcohol, and water (Çelebioğlu & Baytop, 1949). Photographs from the preparations were taken with a camera adapted to an Olympus BX50 microscope.

Table 1. Locations of studied *Erica* taxa.

Taxa	Locations
<i>Erica arborea</i>	A3 Bolu: Akçakoca, 14.08.2003, G.Kendir (AEF 23010)
<i>E. manipuliiflora</i>	C6 Hatay: 07.09.2003, G.Kendir (AEF 23013)
<i>E. sicula</i> subsp. <i>libanotica</i>	C3 Antalya: 10.05.2003, R.S.Göktürk, G.Kendir (AEF 23009)
<i>E. bocquetii</i>	C2 Antalya: Elmalı, 19.07.2003, A. & U.Güvenç, R.S.Göktürk (AEF 23016)

Results

The following anatomical structures and features were observed in cross and surface sections (Figures 1-13) of the leaves of 4 *Erica* taxa.

1 - *Erica arborea* L.

Cross section of leaf blade: The leaf is narrowly revolute (Figure 1). Upper epidermal cells are usually square-shaped, single-layered with thin walls. Cuticle is thin and penetrates towards the border between the cells. Fixed to the upper epidermis, occasionally there are unicellular and short covering trichomes. The palisade parenchyma consists of 1(-2) layers of thin-walled, long, and compactly arranged cylindrical cells. These cells contain starch granules. The spongy parenchyma, consisting of isodiametric cells, is located underneath the palisade. There are collateral vascular bundles in the spongy parenchyma. Lower epidermis cells are compressed in the sides; however, these cells are similar to upper epidermis cells in the centre. The simple eglandular trichomes are located along the channel part of the abaxial surface of

leaves. These trichomes are longer and thinner than the upper surface. Eglandular trichomes are not seen except in the channel of the lower surface (Figure 2).

Surface of upper epidermis: The upper epidermis is composed of cells with 4-6 angled and usually rectangular, irregular form, and covered with a strongly striated cuticle. There are unicellular covering trichomes on epidermis. These trichomes are small, rigid, and triangular. Under each cell of the upper epidermis there are 5-6 cylindrical palisade cells. This epidermis has no stoma cells (Figure 3).

Surface of lower epidermis: This epidermis is composed of cells with 4-6 angled and irregular form. Covering trichomes are not seen in this epidermis. Under each cell of the upper epidermis there are 6-12 cylindrical palisade cells. There are more palisade cells in this surface than in the upper epidermis. This epidermis has no stoma cells (Figure 4).

2 - *Erica manipuliflora* Salisb.

Cross section of leaf blade: The leaf is broadly revolute in cross section and the channel is larger

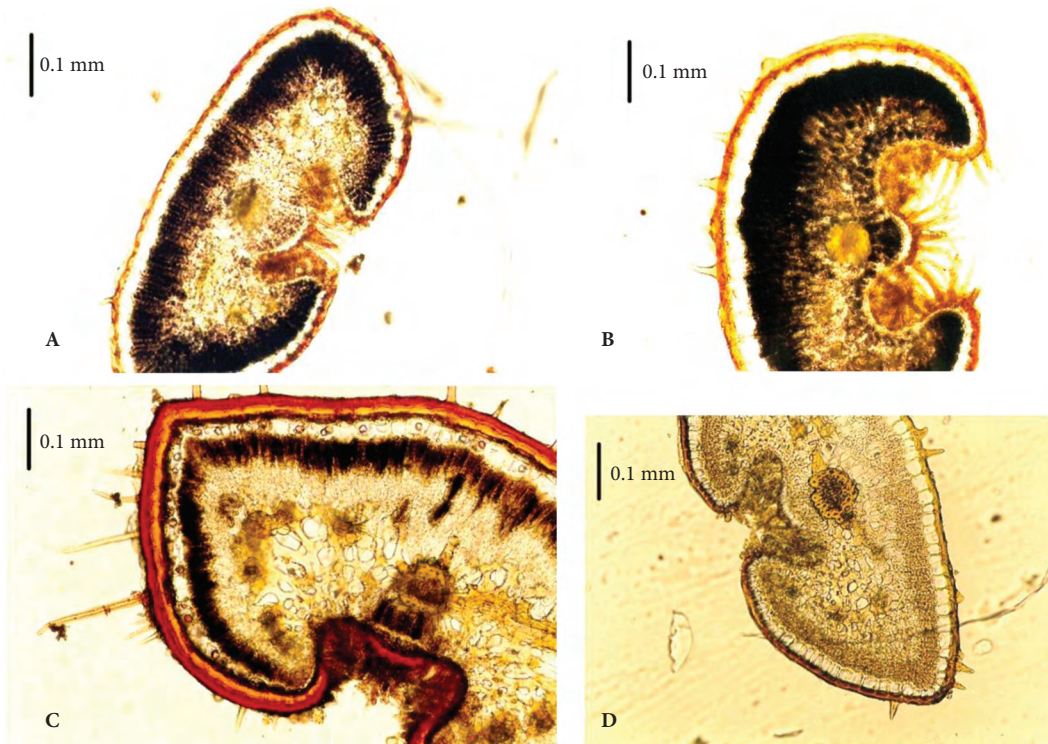


Figure 1. Transverse sections of the leaves of *Erica* species native to Turkey: A- *Erica arborea*, B- *E. manipuliflora*, C- *E. sicula* subsp. *libanotica*, D- *E. bocquetii*.

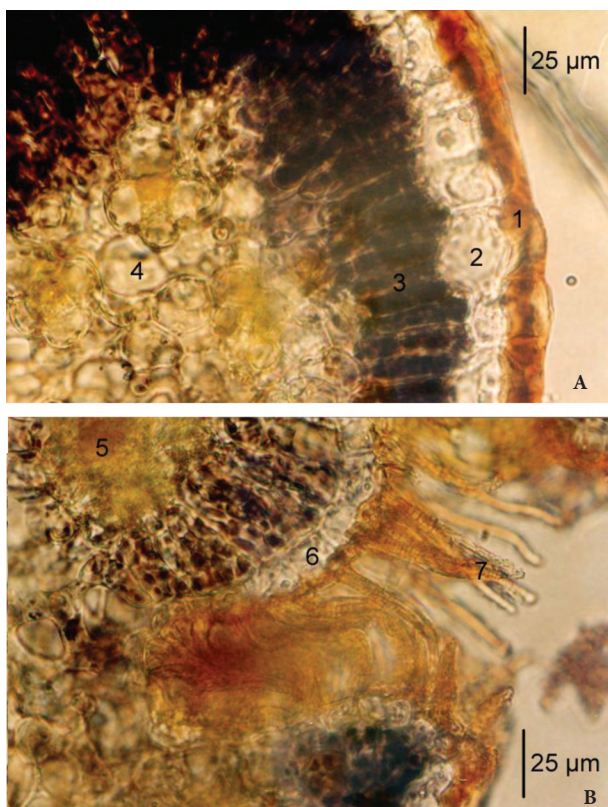


Figure 2. Cross section of *Erica arborea* leaf blade (A and B): 1- cuticle, 2- upper epidermis, 3- palisade parenchyma, 4- spongy parenchyma, 5- vascular bundle, 6- lower epidermis, 7- eglandular trichomes in the revolute margin.

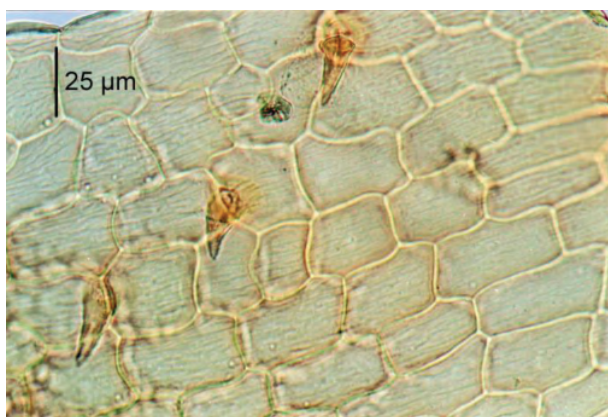


Figure 3. *E. arborea*: surface of the upper epidermis including epidermal cells and eglandular trichomes.

than in the other taxa in this species (Figure 1). Upper epidermal cells are usually rectangular, single-layered with thin walls. Cuticle is rather thicker than in *E. arborea* and smooth. Fixed to the upper epidermis there are unicellular covering trichomes. The palisade



Figure 4. *E. arborea*: surface of the lower epidermis.

parenchyma consists of one layer of thin-walled, long, and compactly arranged cylindrical cells. These cells contain dense starch granules. The spongy parenchyma, consisting of isodiametric loose cells, is located underneath the palisade. There are collateral vascular bundles in the spongy parenchyma. Primary vascular bundle is surrounded by sclerenchymatic cells. Lower epidermis cells are smaller than the upper epidermis cells, especially in the channel part. Covering trichomes are not seen except in grooves. The simple eglandular trichomes fill the grooves in the lower surface of leaves. These trichomes are longer than the epidermal trichomes and they are more abundant in this location. Stomata cells are not present in either the upper or lower epidermis (Figure 5).

Surface of upper epidermis: The upper epidermis is composed of cells with 5-6 angled, irregular form; striated cuticle is not seen. There are unicellular covering trichomes on the epidermis. Under each cell of the upper epidermis there are 6-10 cylindrical palisade cells (Figure 6).

Surface of lower epidermis: The lower epidermal cells are similar to those in the upper epidermis, but they are slightly sinuous. Covering trichomes are not seen in this epidermis. Under each cell of the lower epidermis there are 8-12 cylindrical palisade cells. There are more palisade cells in this surface than in the upper epidermis (Figure 7).

3 - *Erica sicula* Guss. subsp. *libanotica* (C. & W. Barbey) P.F.Stevens

Cross section of leaf blade: Leaf of this species is the biggest among *Erica* taxa in this study, and its leaf is

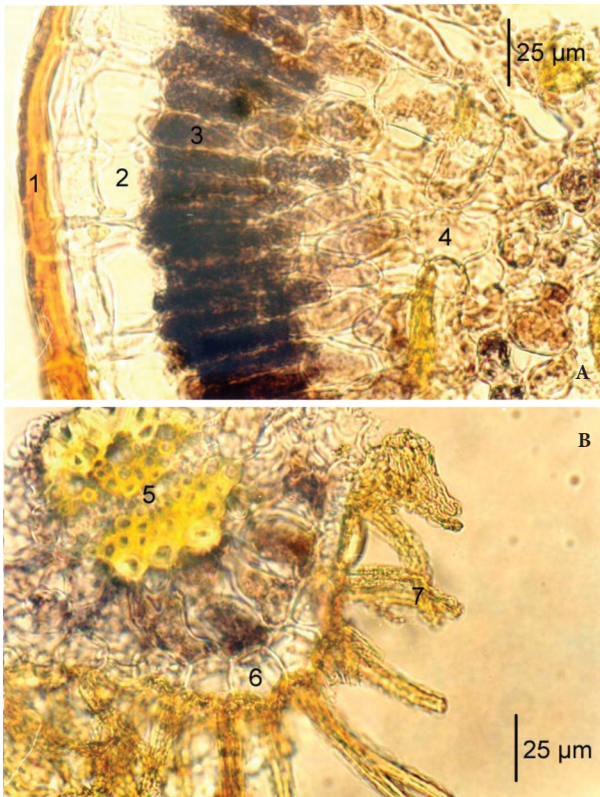


Figure 5. Cross section of *E. manipuliflora* leaf blade (A and B): 1- cuticle, 2- upper epidermis, 3- palisade parenchyma, 4- spongy parenchyma, 5- vascular bundle, 6- lower epidermis, 7- eglandular trichomes in the revolute margin.

channelled (Figure 1). Upper epidermis consists of usually square cells with thickened outer walls. Cuticle is thick in this species. Fixed to the upper epidermis there are unicellular covering trichomes. These eglandular trichomes are larger and longer than in the other *Erica* taxa. The palisade parenchyma consists of one layer of thin-walled, long, and compactly arranged cylindrical cells. These cells contain dense starch granules. The spongy parenchyma, consisting of isodiametric loose cells, is located underneath the palisade. There are collateral vascular bundles in the spongy parenchyma. Primary vascular bundle is surrounded by sclerenchymatic cells. Lower epidermis cells are smaller than the upper epidermis cells. Covering trichomes occasionally are seen on the whole surface of the epidermis. Furthermore, eglandular trichomes densely fill the grooves in the lower surface of leaves. Stomata cells are not present in either the upper or lower epidermis (Figure 8).



Figure 6. *E. manipuliflora*: surface of the upper epidermis including epidermal cells and eglandular trichome.

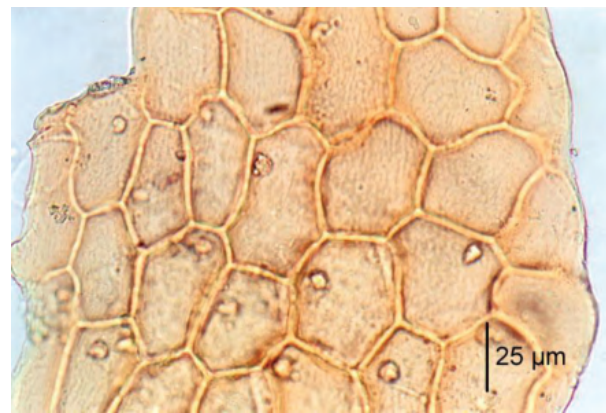


Figure 7. *E. manipuliflora*: surface of the lower epidermis.

Surface of upper epidermis: The upper epidermis is composed of cells with oval-shaped or 5-6 angled, irregular form; striated cuticles are not seen. There are unicellular covering trichomes on epidermis. Under each cell of the upper epidermis there are 6-10 cylindrical palisade cells (Figure 9).

Surface of lower epidermis: The lower epidermal cells are usually 5-6 angled. Covering trichomes are seen in this epidermis. This property of *E. sicula* subsp. *libanotica* is different from the other 3 species. Under each cell of the lower epidermis there are 6-8 cylindrical palisade cells (Figure 10).

4 - *Erica bocquetii* (Peşmen) P.F.Stevens

Cross section of leaf blade: The leaf is narrowly revolute in cross section (Figure 1). Upper epidermal cells are square, single-layered with thin walls. Cuticle is thinner than in *E. sicula* subsp.

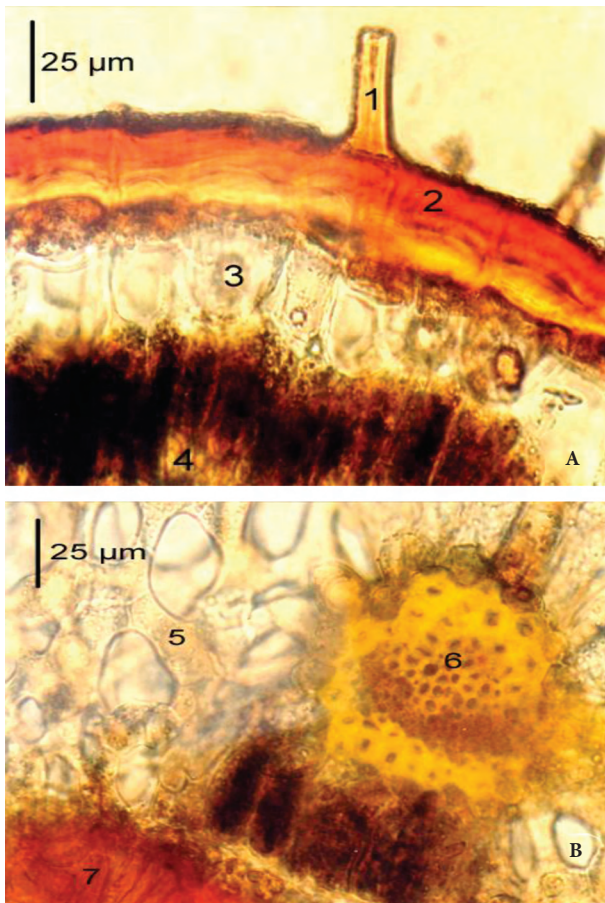


Figure 8. Cross section of *E. sicala* subsp. *libanotica* leaf blade (A and B): 1- eglandular trichomes in the surface of epidermis, 2- cuticle, 3- upper epidermis, 4- palisade parenchyma, 5- spongy parenchyma, 6- vascular bundle, 7- eglandular trichomes in the revolute margin.

libanotica and this layer is striate. Fixed to the upper epidermis there are unicellular covering trichomes. The palisade parenchyma consists of 2 layers of cylindrical cells with thin walls; the upper layer is long and compactly arranged and the lower layer is short and usually loose. These cells do not contain starch granules. The spongy parenchyma, consisting of isodiametric loose cells, is located underneath the palisade. There are collateral vascular bundles in the spongy parenchyma. The primary vascular bundle is surrounded by sclerenchymatic cells. Lower epidermis cells are smaller than the upper epidermis cells. The simple eglandular trichomes fill the grooves in the lower surface of leaves. However, covering trichomes are not seen except in grooves.

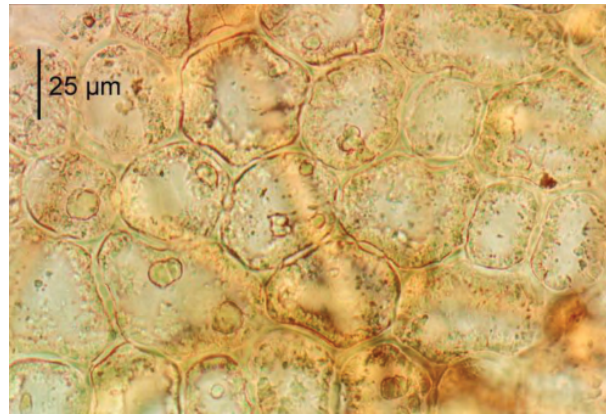


Figure 9. *E. sicala* subsp. *libanotica*: surface of the upper epidermis.



Figure 10. *E. sicala* subsp. *libanotica*: surface of the lower epidermis including epidermal cells and eglandular trichomes.

Stomata cells are not present in either the upper or lower epidermis (Figure 11).

Surface of upper epidermis: The upper epidermis is composed of cells with 5-6 angled, irregular form; striated cuticle is not clear. There are unicellular covering trichomes on epidermis; these trichomes are rigid and triangular. Under each cell of the upper epidermis, there are 6-10 cylindrical palisade cells (Figure 12).

Surface of lower epidermis: The lower epidermal cells are similar to those in the upper epidermis. However, striated cuticle is seen on this surface. Covering trichomes are not seen in this epidermis. Under each cell of the lower epidermis there are 6-10 cylindrical palisade cells (Figure 13).

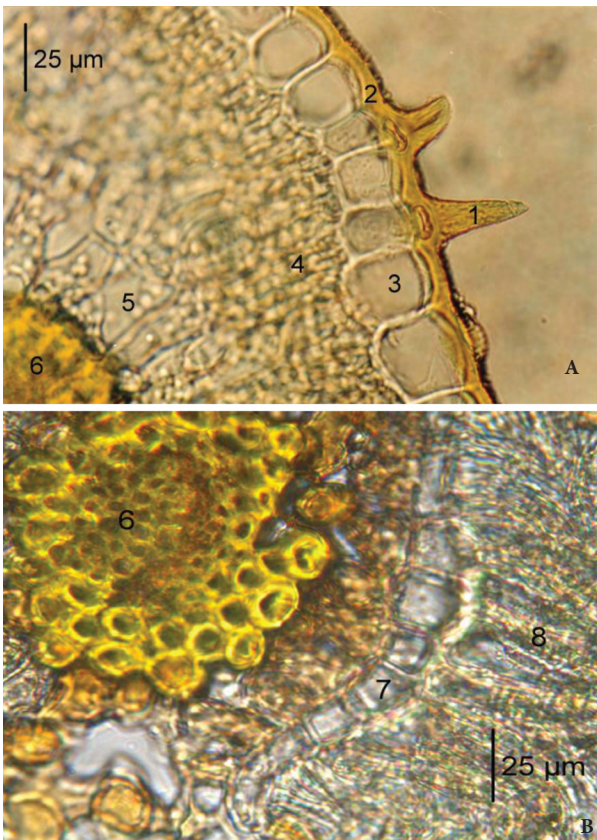


Figure 11. Cross section of *E. bocquetii* leaf blade (A and B): 1- eglandular trichomes in the surface of epidermis, 2- cuticle, 3- upper epidermis, 4- palisade parenchyma, 5- spongy parenchyma, 6- vascular bundle, 7- lower epidermis, 8- eglandular trichomes in the revolute margin.

Discussion

In this study, we investigated the anatomical structure of leaves of the 4 *Erica* taxa native to Turkey. The anatomical characteristics of leaves of these species were studied and their structures were determined for the first time.

It has been observed that, generally, the anatomical structures of the leaves of these 4 *Erica* taxa are similar to one another. Furthermore, these leaves are ericoid. Phylogenetic studies are based on morphological and anatomical characteristics. Anatomical characters are not always as useful as morphological characters for plant identifications; however, it is possible to use anatomical characters to differentiate between closely related species. Anatomic structures are also very important for the identification of medicinal

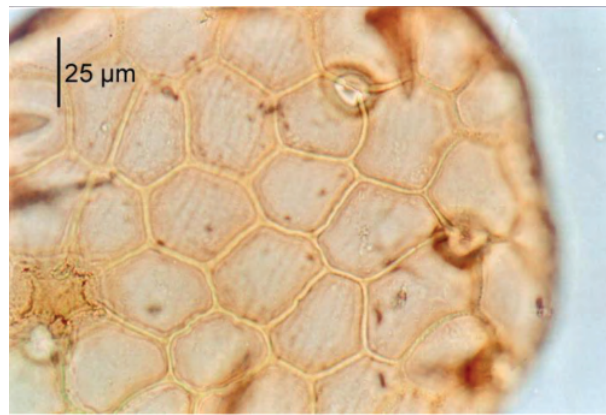


Figure 12. *E. bocquetii*: surface of the upper epidermis including epidermal cells and eglandular trichome.

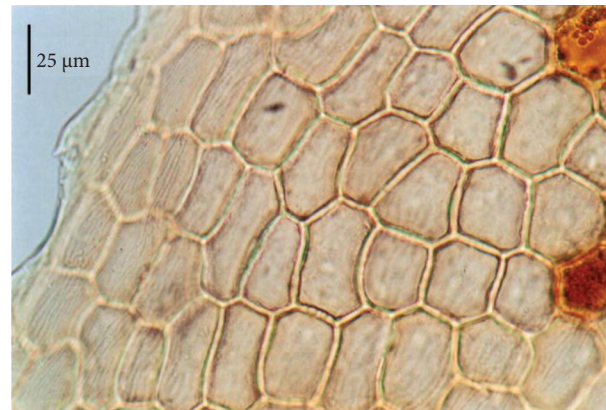


Figure 13. *E. bocquetii*: surface of the lower epidermis.

plant parts (Güvenç & Duman, 2010; Güvenç et al., 2011) and economic plants (Şen et al., 2011).

Cross sections of leaf blades of *Erica* taxa were characterised with revolute margins protected by eglandular trichomes. Two different types of eglandular trichomes are observed in the leaf surface and in revolute margins. Both types of eglandular trichomes are unicellular, small, and rigid in the surface. In the revolute margins, however, trichomes are longer and softer than in the surface. Palisade parenchyma consists of usually 1 or occasionally 2 layers while spongy parenchyma is loose in *E. sicula* subsp. *libanotica* and *E. bocquetii*, 2 taxa that have intercellular spaces. The vascular bundle is surrounded by sclerenchyma cells, except in *E. arborea*. Special anatomical characteristics of these species showed wide differences. A comparison of

Table 2. A comparison of leaf cross sections in 4 *Erica* taxa native to Turkey.

Taxa	Upper epidermis	Covering trichomes (in the surface)	Eglandular trichomes (in the channel)	Palisade parenchyma	Spongy parenchyma	Vascular bundle
<i>Erica arborea</i>	Irregular form and covered with a strongly striated cuticle, thin	Only upper epidermis; rigid and triangular; unicellular	Simple, unicellular and longer than the surface trichomes; rare	One layer; starch (+)	Isodiametric	Sclerenchyma (-)
<i>E. manipuliflora</i>	Irregular form; striated cuticle is not seen, thin	Only upper epidermis; rigid and triangular; unicellular	Simple, unicellular and longer than the surface trichomes; abundant	One layer; starch (+)	Isodiametric	Sclerenchyma (+)
<i>E. sicula</i> subsp. <i>libanotica</i>	Irregular form; striated cuticle is not seen, thick	Whole surface; bigger than the other species; unicellular	Simple, unicellular and longer than the surface trichomes; dense	One layer; starch (+)	Isodiametric, loose	Sclerenchyma (+)
<i>E. bocquetii</i>	Irregular form; striated cuticle is not clear in the upper surface, but is seen in the lower surface	Covering trichomes abundant in upper epidermis, rare in lower epidermis; rigid and triangular; unicellular	Simple, unicellular and longer than the surface trichomes; dense	Two layers; starch (-)	Isodiametric, loose	Sclerenchyma (+)

the anatomic structure of leaves of the species under study is given in Table 2.

Ericaceae leaves often have stomatal grooves that extend the entire length of the lower surface (Metcalf & Chalk, 1965; Dickison, 2000). In this investigation, we did not observe stomata on either epidermis. Calcium oxalate crystals were also not observed in these 4 species. In the present work, the anatomical characters found for leaves of *Erica* taxa were in accordance with those given in previous reports (Metcalf & Chalk, 1965; Dickison, 2000; Gratani & Varone, 2004). Metcalfe and Chalk (1965) pointed out that the epidermal cells contain papillae in *Erica* taxa; however, we did not observe papillae in either the upper or lower epidermis of the leaves of these 4 taxa from Turkey.

Erica taxa growing in Turkey include 4 or 5 corolla lobes and sepals and 8 or 10 stamens. Flowers of *Erica arborea* and *E. manipuliiflora* have 4 parts and 8 stamens, while *E. sicula* subsp. *libanotica* and *E. bocquetii* have 5 parts and 10 stamens (Stevens,

1978; Kendir & Güvenç, 2008). These diagnostic characters are the main morphological findings of the 4 taxa in Turkey. In the present study, it was observed in the cross sections that the leaves of *E. arborea* and *E. manipuliiflora* are round in the margin, whereas leaves of *E. sicula* subsp. *libanotica* and *E. bocquetii* are angled in the margin. Furthermore, there are covering trichomes on the whole surface of the epidermis of *E. sicula* subsp. *libanotica* and *E. bocquetii*; however, covering trichomes only appear on the upper surface in the other 2 taxa (Figure 1). With the exception of these findings, there were no observed differences in the anatomical characters of *Erica* leaves.

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