

Petiole Anatomy of 21 Representatives of Tribe *Alysseae* (Brassicaceae) from Turkey

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ABSTRACT

This paper presents in detail petiole anatomy of 21 representatives of tribe *Alysseae*, 5 of which are endemic from Turkey. In the examined taxa, differences have found in the petiole shape, arrangement and number of vascular bundles, and the presence of collenchyma. Petiole shapes are in sulcate, circular, or flat types. The most common type is sulcate with blunt or acute margins. The epidermises are in 1, 2 or more layer. The number of vascular bundles in the examined taxa varies between 1 (*Berteroa mutabilis*) and 9 (*Alyssum strictum* and *A. strigosum* subsp. *strigosum*) in total. In addition, vascular bundles in the middle are broadly or narrowly arc-shaped with 1-5 lobed. These results display that the compared petiole anatomical characteristics among the examined taxa are somewhat suitable to their delimitation in traditional rank in the Flora of Turkey.

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Türkiye'den *Alysseae* Tribusunun (Brassicaceae) 21 Temsilcisinin Petiyol Anatomisi

ÖZET

Bu çalışma, Türkiye'den *Alysseae* tribusunun 5'i endemik 21 temsilcisinin petiyol anatomisini ayrıntılı olarak sunmaktadır. İncelenen taksonlarda, petiyol şekli, iletim demetlerinin sayı ve düzenlenmesi ve kollenkima varlığında farklılıklar bulunmuştur. Petiyol şekilleri sulkat, dairesel veya yassı tiplerdedir. En yaygın tip küt veya sivri kenarlı sulkattır. Epidermis 1, 2 veya daha fazla tabakalıdır. İncelenen taksondaki iletim demeti sayısı toplamda 1 (*Berteroa mutabilis*) ve 9 (*Alyssum strictum* ve *A. strigosum* subsp. *strigosum*) arasında değişmektedir. Ek olarak, ortadaki iletim demetleri 1-5 loblu geniş veya dar yay şeklindedir. Bu sonuçlar, incelenen taksonlar arasında karşılaştırılan petiyol anatomik özelliklerinin, Türkiye Florasındaki geleneksel sıralamadaki dağılımları ile kısmen uyumlu olduğunu göstermektedir.

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INTRODUCTION

Brassicaceae is a significant plant family because of including economic plant species and model organisms like *Arabidopsis* Heynh. and *Thlaspi* L. Brassicaceae includes about 338 genera and 3709 species worldwide, mainly in temperate regions of the Northern Hemisphere (Al-Shehbaz et al., 2006; Karaismailoğlu, 2016). In Turkey, this family has 571 species with 65 subspecies, 24 varieties, and 660 taxa belonging to 91 genera (Al-Shehbaz et al., 2007). One of the biggest tribes within family Brassicaceae is tribe *Alysseae*, which is of circa 7% of the family's species variety (Al-Shehbaz, 2012; Rešetnik et al., 2013). Until now, the exhaustive morphological studies on tribe have been performed by Hayek (1911), Schulz (1936), Janchen (1942) and Al-Shehbaz et al. (2006). Generic

delimitation and relations within tribe *Alysseae* are still inadequately known (Al-Shehbaz, 2012), because of the convergent properties that are common in characters.

The practice of anatomical characters in taxonomic applications cannot be overemphasized. But they are more constant than the others, and the systematic researchers trust these characters because of slightly influenced by environmental conditions (Barthlott, 1981); comparatively plant epidermal observations have been also found to be consistent in systematics applications (Metcalf and Chalk, 1950; Stace, 1969; Ogunkunle and Oladele, 2000; Akinnubi et al., 2013).

The petiole is a leaf organ, which links the lamina with the stem, and its anatomy has substantial taxonomic importance. It has certainly a key role in systematics

and has resolved many taxonomic problems in genera in various plant families (Maksymowych et al., 1983; Olowokudejo, 1987; Ozdemir and Senel, 1999, 2001; Ergen Akcin et al., 2011; El Rabiai, 2015).

In made literature research, it has not been found researches including petiole anatomical structures of tribe *Alysseae* taxa. This work presents the first assessment of the taxonomic significance of the petiole anatomies of the examined 21 *Alysseae* taxa.

MATERIAL and METHODS

The studied taxa are taken from natural populations in various phytogeographical regions in Turkey (Table 1). Specimens are stored in Siirt University Flora and Fauna Center (SUFAF) and M.C. KARAISSMAILOĞLU collection.

Anatomical studies were performed with specimens well-maintained in 70% alcohol. Cross-sections of the petioles were taken with a fully automatic microtome (Thermo Shonda Met Finesse). Later, they were passed from various alcohol and xylene series, and dyed with hematoxylin (Harris-RRSP67-E) in a staining device (ASC 720 Medite), and were enclosed with Entellan for anatomical structures to be observed (Algan, 1981; Karaismailoğlu, 2015a, b).

RESULTS

In this study, the petiole anatomy of 21 *Alysseae* taxa was first studied in detail (Figures 1-2 and Table 2). The petiole anatomical descriptions in the examined taxa are listed below:

1. *Alyssoides utriculata* var. *utriculata*: Petiole is flat with long and acute or obtuse tips. In cross-section, the adaxial and abaxial epidermises of the petiole occur with rectangular and oval in shaped cells. Epidermis cells are $5.16 \pm 0.21 \mu\text{m}$ (length) x $4.05 \pm 0.44 \mu\text{m}$ (width). Both epidermises are covered with an undulated cuticle. Under both epidermises, it founds 2-3 layers collenchyma in the middle of the petiole, 7-8 layers collenchyma at the margins. Vascular bundles take place in the parenchyma tissue, and this structure covers large parts of the petiole. Petiole includes 3 vascular bundles in total, with a big bundle in the middle and 1 small bundles in each side. The middle bundle is arc-shaped and surrounded by parenchyma cells. There is sclerenchymatic tissue in the vascular bundles. The inner part of the petiole is filled with thin-walled flat parenchyma cells. No trichome present (Figure 1a-b and Table 2).

2. *Alyssum caricum*: Petiole is sulcate with acute tips. The adaxial surface is smooth or slightly concave, however, the abaxial surface is slightly convex. Both epidermis cells are 2 layers, oval and rectangular in shapes. Epidermis cells are $4.87 \pm 0.08 \mu\text{m}$ x $3.91 \pm 0.04 \mu\text{m}$ in dimensions and covered with an undulated cuticle. It founds collenchyma between 3 and 7 layered

under the epidermis. Petiole includes 7 vascular bundles in total, with a big bundle in the middle and 3 small bundles in each side. The middle bundle is broadly arc-shaped and covered with parenchyma cells. There is sclerenchymatic tissue in the vascular bundles. The inner part of the petiole is filled with thin-walled flat parenchyma (Figure 1c-d and Table 2).

3. *A. dasycarpum* var. *dasycarpum*: Petiole is sulcate with obtuse tips. The adaxial surface is smooth, however, the abaxial surface is slightly convex. Both epidermises cells are 2 layers in oval and cubic shapes. Epidermis cells are $5.63 \pm 0.16 \mu\text{m}$ x $4.21 \pm 0.08 \mu\text{m}$ in dimensions and covered with a smooth cuticle. It founds 2 or 3 collenchyma layers under the epidermis layers. Petiole has 7 vascular bundles in total, with a big bundle in the middle and 3 small bundles in each side. The middle bundle is broadly arc-shaped with 2-lobed and covered with bundle sheaths. There is sclerenchymatic tissue in the vascular bundles. The inner part of the petiole is filled with thin-walled flat parenchyma (Figure 1e-f and Table 2).

4. *A. davisianum*: Petiole is a flat type with blunt tips. The adaxial and abaxial surfaces are slightly convex. Both epidermis cells are 2 layered, consisting of the small or large flat and rectangular cells. Epidermis cells are $3.86 \pm 0.24 \mu\text{m}$ x $2.79 \pm 0.04 \mu\text{m}$ in sizes and covered with an undulated cuticle. Collenchyma varies between 2 and 4 layers under the epidermis. Petiole includes 3 vascular bundles in total, with a big bundle in the middle and 1 small bundle in each side. The middle bundle is broadly arc-shaped with 4-lobed and covered with parenchyma cells. The inner part of the petiole is filled with thin or thick-walled crushed or polygonal parenchyma cells (Figure 1g-h and Table 2).

5. *A. desertorum*: Petiole is a flat type with acute tips. The adaxial and abaxial surfaces are smooth. Both epidermis cells are single layer, consisting of coarsely polygonal or flat cells. Epidermis cells are $8.79 \pm 0.26 \mu\text{m}$ x $6.54 \pm 0.35 \mu\text{m}$ in dimensions and covered with an undulated cuticle. Collenchyma has 1 or 2 layers under the epidermis layers. Petiole includes 3 vascular bundles in total, with a big bundle in the middle and 1 small bundle in each side. The middle bundle is broadly arc-shaped with 2-lobed and surrounded by parenchyma cells. The inner part of the petiole is filled with thin-walled crushed parenchyma cells (Figure 1i-j and Table 2).

6. *A. filiforme*: Petiole is a flat type with obtuse or acute tips. The adaxial and abaxial surfaces are smooth. Both epidermis cells are 2 layered, small or large flat cells. Epidermis cells are $8.24 \pm 0.39 \mu\text{m}$ x $6.61 \pm 0.44 \mu\text{m}$ in dimensions and covered with an undulated cuticle. Collenchyma has single layer under the epidermis. Petiole includes 5 vascular bundles in total, with a big bundle in the middle and 2 small bundles in each side. The middle bundle is broadly arc-shaped with 2-lobed

Table 1. The studied taxa and their collected localities

Çizelge 1. Çalışılan taksonlar ve toplanan lokaliteler

No	Taxa <i>Taksonlar</i>	Localities <i>Lokaliteler</i>
1	<i>Alyssoides utriculata</i> (L.) Med. var. <i>utriculata</i>	A2 Bursa: Uludağ, Aras valley, roadside stony areas, 1600-1650 m, 1.7.2016, Karaismailoğlu 293
2	* <i>Alyssum caricum</i> Dudley et Hub.-Mor.	C1 Muğla: Marmaris, calcareous serpentine rocks, 40 m, 13.8.2016, Karaismailoğlu 331
3	<i>Alyssum dasycarpum</i> Stephen ex Willd. var. <i>dasycarpum</i>	B4 Ankara: Haymana, open areas around Mogan lake, 980 m, 10.8.2016, Karaismailoğlu 330
4	* <i>Alyssum davisianum</i> Dudley	B2 Kütahya: Gediz, Murat mountain, Kesiksöğüt, 1800 m, 16.6.2016, Karaismailoğlu 279
5	<i>Alyssum desertorum</i> Stapf.	B4 Ankara: Keçiören, roadside, open areas, 900 m, 17.08.2016, Karaismailoğlu 337
6	* <i>Alyssum filiforme</i> Nyar.	B7 Gümüşhane: Kürtün, Karagöl, roadsides, inclined slopes, 1600 m, 13.7.2014, Karaismailoğlu 85b
7	* <i>Alyssum haussknechtii</i> Boiss.	A3 Bolu: Abant, hills south of the lake, 1680 m, 21.5.2016, Karaismailoğlu 247
8	<i>Alyssum linifolium</i> Steph. ex Willd. var. <i>linifolium</i>	B4 Konya: Cihanbeyli-Yavsan, salt lake edge, 960 m, 11.7.2016, Karaismailoğlu 316
9	<i>Alyssum minutum</i> Schlecht. ex DC.	A2 Bursa: Uludağ, Yigitali, roadsides, inclined slopes, 1500 m, 1.7.2016, Karaismailoğlu 295
10	<i>Alyssum murale</i> Waldst. et Kit. var. <i>murale</i>	B7 Gümüşhane: Kürtün, Karagöl mountain road, 675 m, 13.7.2014, Karaismailoğlu 74b
11	<i>Alyssum parviflorum</i> Fisch. ex M. Bieb.	A2 İstanbul: Büyükçekmece, roadsides, 4 m, 8.7.2016, Karaismailoğlu 312
12	<i>Alyssum sibiricum</i> Willd.	B2 Kütahya: Gediz, Cukuroren, 1350 m, 24.6.2016, Karaismailoğlu 290
13	<i>Alyssum strictum</i> Willd.	C3 Niğde: Çamardı, Yelatan village hills, 2083 m, 12.6.2016, Karaismailoğlu 271
14	<i>Alyssum strigosum</i> Banks et Sol. subsp. <i>strigosum</i>	A2 Bursa: Uludağ, past the hotels, open inclined slopes, 1800 m, 1.7.2016, Karaismailoğlu 296
15	<i>Alyssum szowitsianum</i> Fisch. et Mey.	B7 Gümüşhane: Zigana-Kurtun, roadsides, stone areas, 850 m, 27.3.2015, Karaismailoğlu 115b
16	<i>Alyssum hirsutum</i> Bieb. var. <i>hirsutum</i> Vent.	C4 Mersin: Mut, Kucukegre mountain, inclined stone slopes, 900 m, 27.7.2012, Karaismailoğlu 8
17	* <i>Bornmuellera kiyakii</i> Z.Aytaç et A.Aksoy	C3 Konya: Derebucak Camlık, Kızıldağ, 1500 m, 11.7.2016, Karaismailoğlu 321
18	<i>Berteroa mutabilis</i> (Vent.) DC.	A1 Kırklareli: Dereköy, roadsides, 650 m, 7.6.2014, Karaismailoğlu 46
19	<i>Clypeola jonthlaspi</i> L.	C4 Mersin: Mut Kucukegre mountain, inclined stone slopes, 900 m, 27.7.2012, Karaismailoğlu 11
20	<i>Fibigia clypeata</i> (L.) Medik.	B7 Erzincan: Munzur mountain, stony slopes, 2650 m, 25.8.2016, Karaismailoğlu 341
21	<i>Fibigia macrocarpa</i> (Boiss.) Boiss.	B4 Aksaray: Ihlara valley, stony slopes, 1250 m, 14.8.2016, Karaismailoğlu 334

*=endemic taxon

Table 2. Petiole anatomical structures of the studied taxa
Çizelge 2. Çalışılan taksonların petiyol anatomik yapıları

Taxa Taksonlar	Petiole Shape Petiyol Şekli	Cuticle Structure Kutikula Yapısı	Number of collenchyma layer Kollenkima tabakasının sayısı			Chlorenchyma Presence Klorenkima varlığı	Number of Vascular Bundle (vb) İletim demeti sayısı			Vb shape Vb şekli	Sclerenchyma presence in the vb Vb de sklerankima varlığı
			Adaxial Adaksiyal	Abaxial Abaksiyal	Corner Köşe		Middle Orta	Side (pair) Yan (çift)			
<i>Alyssoides utriculata</i> var. <i>utriculata</i>	Flat	Undulated	2-3	2-3	7-8	+	1	1	Arc-shaped	+	
* <i>Alyssum caricum</i>	Sulcate	Undulated	3	4	5-6	-	1	3	Broadly arc-shaped	+	
<i>A. dasycarpum</i> var. <i>dasycarpum</i>	Sulcate	Smooth	3	2	3	+	1	3	Broadly arc-shaped with 2-lobed	+	
* <i>A. davisianum</i>	Flat	Undulated	3	2	4	-	1	1	Broadly arc-shaped with 4-lobed	-	
<i>A. desertorum</i>	Flat	Undulated	1	1	2	+	1	1	Broadly arc-shaped with 2-lobed	-	
* <i>A. filiforme</i>	Flat	Undulated	1	1	1	+	1	2	Broadly arc-shaped with 2-lobed	-	
* <i>A. haussknechtii</i>	Flat	Smooth	1	2	2	+	1	2	Arc-shaped	-	
<i>A. linifolium</i> var. <i>linifolium</i>	Flat	Smooth	1	2	3	+	1	1	Broadly arc-shaped	+	
<i>A. minutum</i>	Sulcate	Smooth	-	1	2	+	1	1	Broadly arc-shaped with 3-4-lobed	+	
<i>A. murale</i> var. <i>murale</i>	Sulcate	Undulated	2	2	2	+	1	2	Broadly arc-shaped	-	
<i>A. parviflorum</i>	Sulcate	Undulated	3	3	1	-	1	2	Broadly arc-shaped with 4-5-lobed	+	
<i>A. sibiricum</i>	Sulcate	Undulated	2	-	3	+	1	2	Broadly arc-shaped with 3-lobed	+	
<i>A. strictum</i>	Sulcate	Undulated	2	2	3	+	1	3-4	Broadly arc-shaped	+	
<i>A. strigosum</i> subsp. <i>strigosum</i>	Sulcate	Undulated	4	3	3	+	1	3-4	Broadly arc-shaped with 2-lobed	+	
<i>A. szowitsianum</i>	Sulcate	Smooth	-	2	2	-	1	2	Broadly arc-shaped with 2-3-lobed	+	
<i>A. hirsutum</i> var. <i>hirsutum</i>	Sulcate	Smooth	1	1	2	+	1	2	Broadly arc-shaped with 4-lobed	+	
* <i>Bornmuellera kiyakii</i>	Flat	Undulated	3	3	3	+	1	2-3	Broadly arc-shaped	+	
<i>Berteroa mutabilis</i>	Sulcate	Smooth	2	4	3	+	1	-	Broadly arc-shaped	-	
<i>Clypeola jonthlaspi</i>	Circular	Undulated	2	2	-	-	1	2	Broadly arc-shaped	+	
<i>Fibigia clypeata</i>	Flat	Undulated	3	2	2	-	1	1	Broadly arc-shaped with 4-5-lobed	-	
<i>F. macrocarpa</i>	Sulcate	Undulated	1	1	1	+	1	1	Broadly arc-shaped with 2-lobed	-	

The terminology used in anatomical characters was compatible with Ergen Akcin et al. (2011) and El Rabiai (2015), *=endemic taxon.

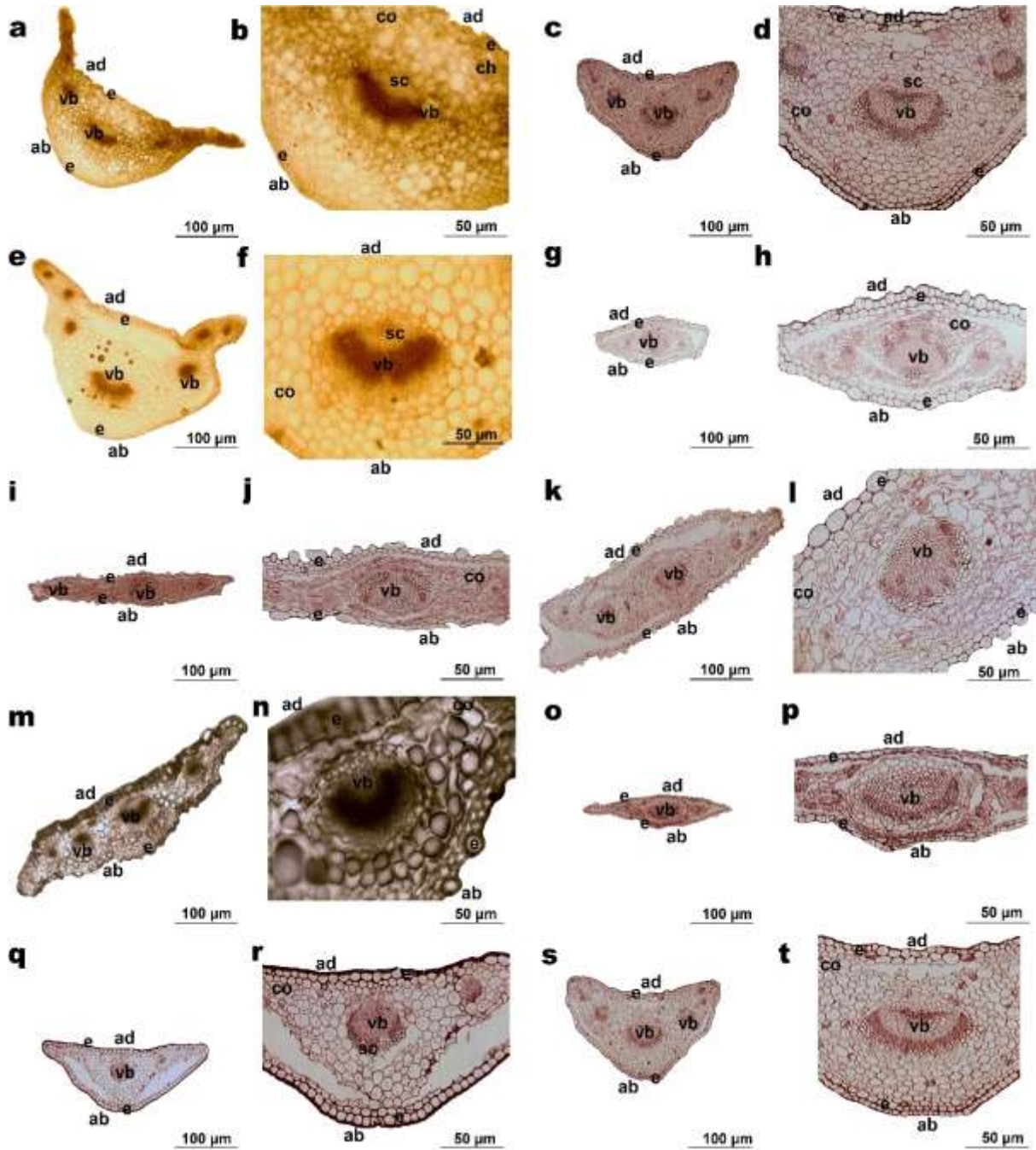


Figure 1. Transverse sections of petioles of the examined taxa: *Alyssoides utriculata* var. *utriculata*: a-b, *Alyssum caricum*: c-d, *A. dasycarpum* var. *dasycarpum*: e-f, *A. davisianum*: g-h, *A. desertorum*: i-j, *A. filiforme*: k-l, *A. haussknechtii*: m-n, *A. linifolium* var. *linifolium*: o-p, *A. minutum*: q-r, *A. murale* var. *murale*: s-t (e: epidermis, vb: vascular bundle, co: collenchyma, sc: sclerenchyma, ch: chlorenchyma, ad: adaxial, ab: abaxial)

Şekil 1. İncelenen taksonların petiyol enine kesitleri

The inner part of the petiole is filled with thick-walled crushed or polygonal parenchyma cells (Figure 1k-l and Table 2).

7. *A. haussknechtii*: Petiole is a flat type with acute tips. The adaxial surface is smooth, however, the abaxial surface is convex. Both epidermis cells are single layer, with rectangular or flat cells. Epidermis

cells are $8.51 \pm 0.04 \mu\text{m} \times 14.12 \pm 0.56 \mu\text{m}$ in sizes and covered with a smooth cuticle. Collenchyma consists of 2 or 3 layers under the epidermis layers. Petiole includes 5 vascular bundles in total, with a big bundle in the middle and 2 small bundles in each side. The middle bundle is arc-shaped. The inner part of the petiole is filled with thick-walled flat parenchyma cells (Figure 1m-n and Table 2).

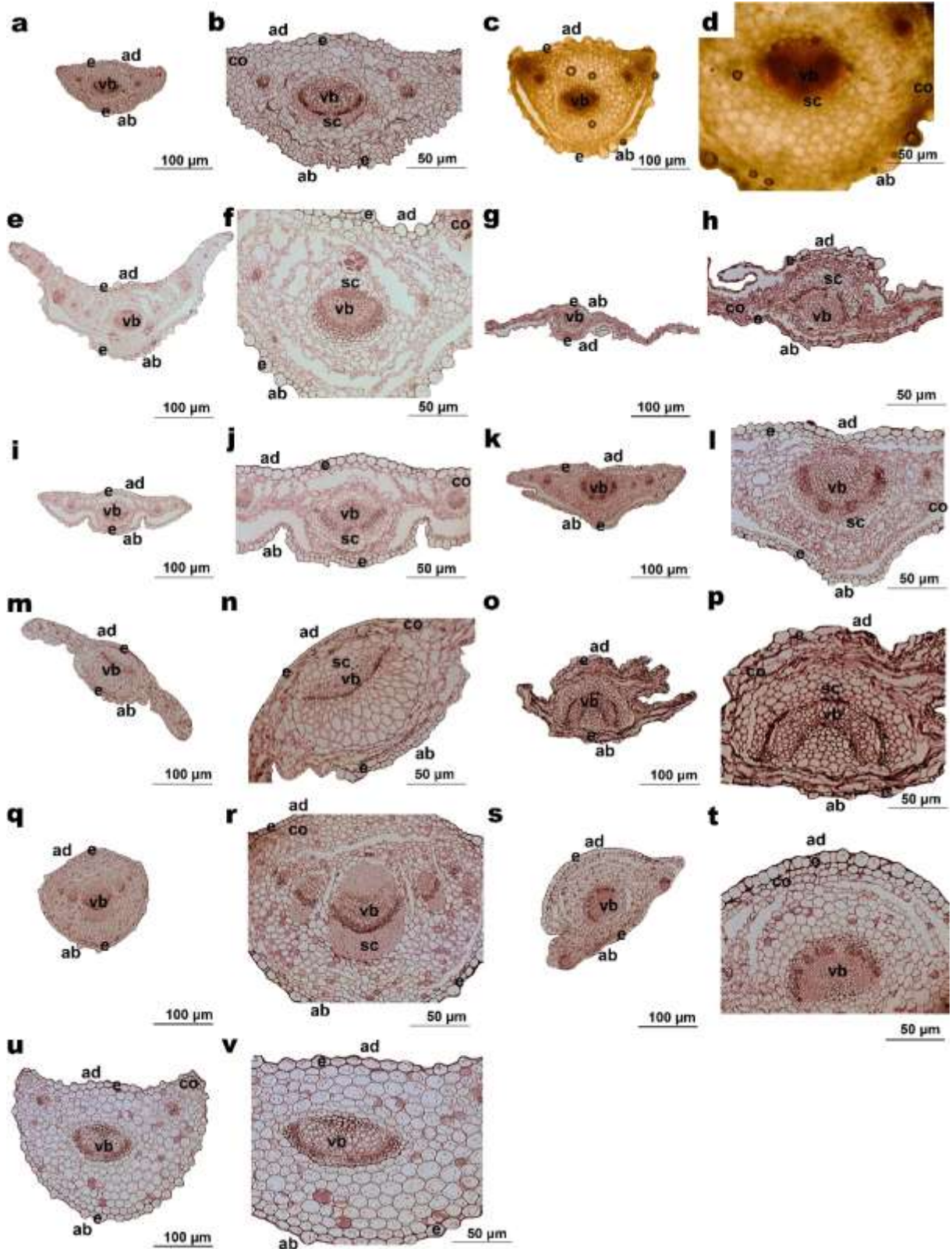


Figure 2. Transverse sections of petioles of the examined taxa: *A. parviflorum*: a-b, *A. sibiricum*: c-d, *A. strictum*: e-f, *A. strigosum* subsp. *strigosum*: g-h, *A. szowitsianum*: i-j, *A. hirsutum* var. *hirsutum*: k-l, *Bornmuellera kiyakii*: m-n, *Berteroa mutabilis*: o-p, *Clypeola jonthlaspî*: q-r, *Fibigia clypeata*: s-t, *F. macrocarpa*: u-v (e: epidermis, vb: vascular bundle, co: collenchyma, sc: sclerenchyma, ch: chlorenchyma, ad: adaxial, ab: abaxial).

Şekil 2. İncelenen taksonların petiyol enine kesitleri

8. *A. linifolium* var. *linifolium*: Petiole is a flat type with acute tips. The adaxial surface is slightly convex, however, the abaxial surface is concave. Both epidermis cells are single layer, with rectangular or flat cells. Epidermis cells are $3.29 \pm 0.06 \mu\text{m} \times 2.76 \pm 0.24 \mu\text{m}$ in dimensions and covered with a smooth cuticle. Collenchyma consists of 1 or 3 layers under epidermis layers. Petiole includes 3 vascular bundles in total, with a big bundle in the middle and 1 small bundle in each side. The middle bundle is broadly arc-shaped. There is sclerenchymatic tissue in the vascular bundles. The inner part of the petiole is filled with thin-walled crushed or polygonal parenchyma cells (Figure 1o-p and Table 2).

9. *A. minutum*: Petiole is sulcate with blunt tips. The adaxial surface is smooth or slightly concave, however, the abaxial surface is slightly convex. Both epidermis cells occur from two layers, with flat or rectangular cells. Epidermis cells are $4.96 \pm 0.04 \mu\text{m} \times 3.01 \pm 0.08 \mu\text{m}$ in sizes and covered with a thick and smooth cuticle. Collenchyma consists of 1 or 2 layers under epidermis layers. Petiole includes 3 vascular bundles in total, with a big bundle in the middle and 1 small bundle in each side. The middle bundle is broadly arc-shaped with 3-4 lobed. There is sclerenchymatic tissue in the vascular bundles. The inner part of the petiole is filled with thin-walled polygonal or flat parenchyma cells (Figure 1q-r and Table 2).

10. *A. murale* var. *murale*: Petiole is sulcate with obtuse tips. The adaxial surface is concave, however, the abaxial surface is slightly convex or smooth. Both epidermis cells are in 2 or 3 layered, with flat or polygonal cells. Epidermis cells are $4.70 \pm 0.06 \mu\text{m} \times 3.29 \pm 0.28 \mu\text{m}$ in dimensions and covered with a thin and undulated cuticle. Collenchyma is in 2 layers under epidermis layers. Petiole includes 5 vascular bundles in total, with a big bundle in the middle and 2 small bundles in each side. The middle bundle is broadly arc-shaped. The inner part of the petiole is filled with thin-walled polygonal or flat parenchyma cells (Figure 1s-t and Table 2).

11. *A. parviflorum*: Petiole is sulcate with obtuse tips. The adaxial and abaxial surfaces are slightly convex. Both epidermis cells are in a single layer, with flat cells. Epidermis cells are $6.19 \pm 0.04 \mu\text{m} \times 4.16 \pm 0.14 \mu\text{m}$ in sizes and covered with a thick and undulated cuticle. Collenchyma is in 1-3 layers under the epidermis layers. Petiole includes 5 vascular bundles in total, with a big bundle in the middle and 2 small bundles in each side, which are surrounded by bundle sheath cells. The middle bundle is broadly arc-shaped with 4-5 lobed. There is sclerenchymatic tissue in the vascular bundles. The inner part of the petiole is filled with thin-walled polygonal parenchyma cells. There are a few simple trichomes in the abaxial surface (Figure 2a-b and Table 2).

12. *A. sibiricum*: Petiole is sulcate with blunt tips. The adaxial surface is slightly convex, however, the abaxial surface is convex. Both epidermis cells are in 2 or 3 layered, with flat or polygonal cells. Epidermis cells are $6.51 \pm 0.46 \mu\text{m} \times 4.11 \pm 0.96 \mu\text{m}$ in sizes and covered with a thick and undulated cuticle. Collenchyma is in 2 or 3 layers under epidermis layers. Petiole includes 5 vascular bundles in total, with a big bundle in the middle and 2 small bundles in each side. The middle bundle is broadly arc-shaped with 3-lobed. There is sclerenchymatic tissue in the vascular bundles. The inner part of the petiole is filled with thick-walled flat parenchyma cells (Figure 2c-d and Table 2).

13. *A. strictum*: Petiole is sulcate with long and acute tips. The adaxial surface is slightly concave, however, the abaxial surface is convex. Both epidermis cells are in 1 or 2 layered, with flat or rectangular cells. Epidermis cells are $5.48 \pm 0.04 \mu\text{m} \times 3.41 \pm 0.38 \mu\text{m}$ in dimensions. Collenchyma is in 2 or 3 layers under the epidermis layers. Petiole includes 7-9 vascular bundles in total, with a big bundle in the middle and 3-4 small bundles in each side. The middle bundle is broadly arc-shaped. There is sclerenchymatic tissue in the vascular bundles. The inner part of the petiole is filled with thin-walled polygonal parenchyma cells (Figure 2e-f and Table 2).

14. *A. strigosum* subsp. *strigosum*: Petiole is sulcate with long and acute tips. The adaxial and abaxial surfaces are convex. Both epidermis cells are in a single layer, with polygonal cells. Epidermis cells are $4.87 \pm 0.16 \mu\text{m} \times 2.74 \pm 0.34 \mu\text{m}$ in dimensions and covered with a thin and undulated cuticle. Collenchyma is in 3-4 layers under epidermis layers. Petiole includes 7-9 vascular bundles in total, with a big bundle in the middle and 3 or 4 small bundles in each side, which are surrounded by bundle sheath cells. The middle bundle is broadly arc-shaped with 2 lobed. There is sclerenchymatic tissue in the vascular bundles. The inner part of the petiole is filled with thick-walled crushed parenchyma cells (Figure 2g-h and Table 2).

15. *A. szowitsianum*: Petiole is sulcate with obtuse tips. The adaxial surface is slightly concave, however, the abaxial surface is convex. Both epidermis cells are in a single layer, with flat cells. Epidermis cells are $9.17 \pm 0.41 \mu\text{m} \times 6.13 \pm 0.24 \mu\text{m}$ in dimensions and covered with a thin and smooth cuticle. Collenchyma is in 3-4 layers under epidermis layers. Petiole includes 5 vascular bundles in total, with a big bundle in the middle and 2 small bundles in each side, which are surrounded by bundle sheath cells. The middle bundle is broadly arc-shaped with 2-3 lobed. There is sclerenchymatic tissue in the vascular bundles. The inner part of the petiole is filled with thin-walled crushed or polygonal parenchyma cells (Figure 2i-j and Table 2).

16. *A. hirsutum* var. *hirsutum*: Petiole is sulcate with blunt tips. The adaxial surface is slightly concave, however, the abaxial surface is smooth or convex. Both epidermis cells are in 2 layered, with flat cells. Epidermis cells are $8.21 \pm 0.16 \mu\text{m} \times 5.42 \pm 0.24 \mu\text{m}$ in sizes and covered with a thin and smooth cuticle. Collenchyma is in 1 or 2 layers under the epidermis layers. Petiole includes 5 vascular bundles in total, with a big bundle in the middle and 2 small bundles in each side, which are surrounded by bundle sheath cells. The middle bundle is broadly arc-shaped with 4 lobed. There is sclerenchymatic tissue in the vascular bundles. The inner part of the petiole is filled with thick-walled polygonal parenchyma cells (Figure 2k-l and Table 2).

17. *Bornmuellera kiyakii*: Petiole is a flat type with blunt tips. The adaxial and abaxial surfaces are convex. Both epidermis cells are in 1 or 2 layered, with rectangular or flat cells. Epidermis cells are $5.32 \pm 0.29 \mu\text{m} \times 2.42 \pm 0.26 \mu\text{m}$ in sizes and covered with a thin and undulated cuticle. Collenchyma is in 3 layers under the epidermis layers. Petiole includes 5-7 vascular bundles in total, with a big bundle in the middle and 2-3 small bundles in each side, which are surrounded by bundle sheath cells. The middle bundle is broadly arc-shaped. There is sclerenchymatic tissue in the vascular bundles. The inner part of the petiole is filled with thick-walled crushed or polygonal parenchyma cells. No trichome present (Figure 2m-n and Table 2).

18. *Berteroa mutabilis*: Petiole is sulcate with acute tips. The adaxial surface is convex, however, the abaxial surface is smooth. Both epidermis cells are in a single layer, with flat cells. Epidermis cells are $7.97 \pm 0.44 \mu\text{m} \times 3.15 \pm 0.37 \mu\text{m}$ in sizes and covered with a thick and undulated cuticle. Collenchyma is in 2-4 layers under the epidermis layers. Petiole includes 1 vascular bundle in total, which is a big bundle in the middle and surrounded by bundle sheath cells. The middle bundle is broadly arc-shaped. There is sclerenchymatic tissue in the vascular bundles. The inner part of the petiole is filled with thick-walled flat parenchyma cells. No trichome present (Figure 2o-p and Table 2).

19. *Clypeola jonthlaspi*: Petiole is a circular type. Epidermis cell occurs from 2 layers with rectangular and flat cells. Epidermis cells are $7.27 \pm 0.32 \mu\text{m} \times 6.58 \pm 0.39 \mu\text{m}$ in sizes and covered with a thick and smooth cuticle. Collenchyma is in 2 layers under the epidermis layers. Petiole includes 5 vascular bundles in total, with a big bundle in the middle and 2 small bundles in each side, which are surrounded by bundle sheath cells. The middle bundle is broadly arc-shaped. The inner part of the petiole is filled with thin-walled flat parenchyma cells. No trichome present (Figure 2q-r and Table 2).

20. *Fibigia clypeata*: Petiole is sulcate. The adaxial surface is convex, however, the abaxial surface is

smooth. Epidermis cells are $8.78 \pm 0.16 \mu\text{m} \times 11.16 \pm 0.24 \mu\text{m}$ in dimensions and covered with a thick and undulated cuticle. Collenchyma is in 2-3 layers under the epidermis layers. Petiole includes 3 vascular bundles in total, with a big bundle in the middle and 2 small bundles in each side, which are surrounded by bundle sheath cells. The middle bundle is broadly arc-shaped with 4-5 lobed. The inner part of the petiole is filled with thin-walled flat or polygonal parenchyma cells. No trichome present (Figure 2s-t and Table 2).

21. *F. macrocarpa*: Petiole is sulcate with obtuse tips. The adaxial surface is concave, however, the abaxial surface is convex. Both epidermis cells are in a single layer, with flat cells. Epidermis cells are $12.26 \pm 0.32 \mu\text{m} \times 8.41 \pm 0.28 \mu\text{m}$ in sizes and covered with a thick and undulated cuticle. Collenchyma is in 1 layer under the epidermis layers. Petiole includes 3 vascular bundles in total, with a big bundle in the middle and 1 small bundle in each side, which are surrounded by bundle sheath cells. The middle bundle is broadly arc-shaped with 2 lobed. The inner part of the petiole is filled with thick-walled flat parenchyma cells. No trichome present (Figure 2u-v and Table 2).

DISCUSSION

In this work, anatomical structures of the petiole of 21 taxa belonging to tribe *Alysseae* were studied and compared. In almost all of the studied taxa were determined differences in terms of the arrangement, number of vascular bundles, sclerenchyma presence or absence in vascular bundles, and shapes of the petioles, and a number of collenchyma layers, and the structure and thickness of the epidermis cells.

Petiole shapes demonstrated variations in the studied taxa, which are mostly sulcate (12 taxa), flat (8 taxa) or rarely circular types (1 taxon). In addition, the petiole margins of the examined taxa showed diversity, which is long or short, acute, blunt, or obtuse tipped. As an exception, there are no petiole margins in *Berteroa mutabilis* (Figure 1 and Table 2). Ergen Akcin et al. (2011) worked the petiole shapes of 7 taxa belonging to Lamiaceae family and informed the variations in the petiole shapes. Similarly, Olowokudejo (1987) reported the differences in the petiole shapes of 46 taxa belonging to the Cruciferae family. The results obtained from this study showed that the anatomical characteristics of the petioles may provide in the taxonomical applications. Moreover, the epidermises in the examined taxa were in 1, 2 or more layer with smooth or undulated, thin or thick cuticle on the surface. All the taxa examined included collenchyma in the petioles. Besides, a number of collenchyma layer and the position were different among taxa.

The number of the vascular number in the examined taxa range from 1 to 9 in total, from 0 to 4 in each corner. The most vascular bundle number is *A.*

strictum and *A. strigosum* subsp. *strigosum* with 8 or 9 vascular bundles, however, the lowest vascular number is *Berteroa mutabilis* with 1. The middle vascular bundle in the examined taxa is located in the center and is one. In addition, it is narrow or broad, arc-shaped and consists of the lobes ranging from 1 to 5 (Table 2).

The outcomes indicated that there were many differences within the examined taxa in terms of the amount and arrangement of vascular bundles, as well as their shapes and lobed number. These results are consistent with the previous studies on vascular bundles in petioles of the various genera (Maksymowych et al., 1983; Ozdemir and Senel, 1999 and 2001).

Many researchers have also studied in various families vascular bundles in the petiole. Ergen Akcin et al. (2011) observed 7 different types of the Lamiaceae family and indicated the significance of hairs and the anatomy of the vascular bundles. Heneidak et al. (2007) studied 15 different types in Fabaceae and had found that there were differs in the shape of the petioles, hairs, and anatomy of vascular bundles. El Rabiai (2015) found 6 different petiole types on 15 Cruciferae taxa. Moreover, another study in Rubiaceae showed that petiole anatomical features such as the structure of the vascular bundles and the hair types were significant in point of the taxonomical application. In this study, it has been found 3 different types as sulcate, circular, and flat types in the figure of petiole, and 5 types (number of lobes 1-5) in the figure of vascular bundle. Vascular bundle and petiole shapes have generally shown variations on the basis of genus in studied taxa. Also, the number of collenchyma layer is different in almost all taxa examined.

CONCLUSION

The practicality of the examined characters in the infrageneric and intergeneric delimitation in Tribe *Alysseae* has been questioned in this work. The compared petiole anatomical characters among the studied *Alysseae* taxa are partly consistent with their delimitation agreed in the flora of Turkey with some important characters such as the arrangement, number of vascular bundles, sclerenchyma presence or absence in vascular bundles, and shapes of the petioles, presence of collenchyma and a number of collenchyma layers, and the structure and thickness of the epidermis cells. Also, the characters studied have showed significant differences between taxa in genera. However, the obtained results displayed that new arrangements may be necessary for the systematic positions of some taxa.

Statement of Conflict of Interest

Author has declared no conflict of interest.

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