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Comparative Anatomy of Some *Verbascum* Taxa (Scrophulariaceae) in Southeastern Anatolia and Distinguishing Characteristics of These Taxa

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Abstract

The *Verbascum* L. genus (Scrophulariaceae) is global in distribution. Türkiye is the genus's hub of genetic diversity, and it contains the greatest number of species within it worldwide. The genus *Verbascum* has significant morphological diversity, making species classification difficult. The anatomy of the roots, stems and leaves of seven *Verbascum* taxa (*Verbascum agrimoniifolium* subsp. *agrimoniifolium*, *V. orientale* subsp. *orientale* (group A), *V. laetum* (group C), *V. geminiflorum* (group I), *V. andrusii*, *V. kotschyi* (group K), *V. lasianthum* (group L)) found in the Southeastern Anatolia Region (Diyarbakır, Mardin, and Şanlıurfa Province) of Türkiye formed the basis of this study. Cross-section of root, stem and leaf samples from seven different *Verbascum* taxa were cut by hand and then examined under a light microscope. The xylem components play an important role in taxonomic root parts. The distribution and size of xylem elements vary according to taxa. The pith region is a large region in stem sections, and the upper part of the epidermis cells is surrounded by a separate indented cuticle layer. The main vein of the leaves is represented by lateral bundles. The presence of idioblasts (*V. laetum* and *V. geminiflorum*) has observed in the leaf. In this study, the importance of various characteristics in *Verbascum* taxa limitation was investigated. In order to support morphological features in taxonomic classification and assist in genus systematics, some characters typically associated with anatomical patterns (such as the presence of idioblasts in the leaf) can be applied.

Keywords: anatomy, light microscopy, Southeastern Anatolia, taxonomy, Türkiye, *Verbascum*

1. Introduction

The genus *Verbascum* L., belonging to the family Scrophulariaceae includes approximately 360 species in the world and a total of 257 species in Türkiye under 13 groups, 132 of which are hybrids. The number of endemic species is approximately 202 and the endemism rate is 80%. The breed is the gene and endemism center for our country and is generally distributed in Eastern, Southern and Central Anatolia. Iran-Turan phytogeographic region is the general distribution area of the species [1-3]. *Verbascum* genus has a wide distribution area and a large number of species. Therefore, there are taxonomic difficulties with the genus *Verbascum*, and its infrageneric classification is a little haphazard and informal. Moreover, taxonomic identification may be difficult due of the difficulties in creating a useful key. To this end, the morphology and systematics of *Verbascum* taxa are being studied by a large number of scientists in Türkiye and around the globe [4]. 13 different artificial groups have been composed for the *Verbascum* genus. Studies on the *Verbascum* genus, which is widespread in Türkiye, were carried out by Huber-Morath [5] and Karavelioğulları [6], and more than 10 species and six hybrid species were described.

Being one of the largest genera in terms of total species, *Verbascum* is known to present challenges in taxonomy and diagnosis due to its high level of general hybridization. Studies on the genus's anatomical traits are few [7]. There are not many anatomical studies on the genus [8-19], there are still lacks and unstudied taxa in Türkiye.

It has been recorded that the genus, which has had medicinal use since ancient times, has been used by the

Egyptians and Romans throughout history and is effective against cough, toothache, cramps, bronchitis, diarrhea and hoarseness. Today, it is known that it is grown for the production of tea, tincture and natural medicine. It has been recorded that it is used externally as a tissue softener and mild analgesic, to relieve menstrual pain, rheumatism, ear aches and hemorrhoids, lung, diabetes, arteriosclerosis and to heal animal wounds, and internally as an expectorant and chest softener [20]. Furthermore, it has antiviral, anti-inflammatory, anticancer, antispasmodic, antiseptic, antimalarial, antiulcerogenic, cytotoxic, sedative, and bactericidal properties in its flowers, leaves, and roots [21-22].

Determining the anatomical links between seven *Verbascum* taxa (*V. agrimoniifolium* subsp. *agrimoniifolium*, *V. orientale* subsp. *orientale* (group A), *V. laetum* (group C), *V. geminiflorum* (group I), *V. andrusii*, *V. kotschyi* (group K), *V. lasianthum* (group L)) that are distributed throughout the Southeastern Anatolia Region is the goal of this study. The relationships between the *Verbascum* taxa were also investigated in order to provide pertinent comparative data, support the morphological features, and provide anatomical information that will aid in their classification. The data gathered ought to be employed for the purpose of classifying or offering solid backing for the assessment of the group and genus in later studies.

2. Materials and Methods

Samples of seven taxa belonging to the genus *Verbascum*, collected for use in anatomy, were collected from different localities of Diyarbakır, Mardin and Şanlıurfa (Figure 1). The voucher samples were stored in the Department of Plants and Animal Production's herbarium at Mardin Artuklu University, Türkiye's Kızıltepe Vocational School (MARIUM). The places of collection, the collector's number, and the habitat of the samples that were analyzed for micromorphological traits are listed in Table 1. The taxonomic description of the plant was determined using the guidelines provided by Davis et al. [1] and Karavelioğulları [2].

Collected specimens were kept in falcon tubes with 70% ethyl alcohol for use in anatomical study. Sections of the plant were taken from the root, stem, and leaf sections using a razor. After staining them with safranin-fast green, they were examined under a light microscope (LM) and photographed [23]. Terms used in the anatomy align with those used by Metcalfe and Chalk [24].

Table 1. *Verbascum* taxa used for anatomy studies and collected localities.

Taxa	Collection areas and habitat	Collector number
V. agrimoniifolium subsp. *agrimoniifolium*	Mardin, Artuklu, Hamzabey Neighborhood, road side, damp wet places, 37°22'22"N 40°42'11"E, 971 m.	M.Kılıç 272 M.Kılıç 364
	Şanlıurfa, Karaköprü, Akbayır Neighborhood, road side, damp wet places, 37°11'22"N 38°48'49"E, 554 m.	M.Kılıç 288 M.Kılıç 383
	Diyarbakır, Siverek-Diyarbakır road, road side, rocky slope, 1014 m.	M.Kılıç 359
V. orientale subsp. *orientale*	Mardin, Artuklu, 13 Mart Neighborhood, rocky slope, 37°20'44"N 40°43'44"E, 835 m.	M.Kılıç 269 M.Kılıç 365 M.Kılıç 412
V. laetum	Mardin, Artuklu, Cevizpınar Neighborhood, road side, stone area, 37°20'12"N 40°46'26"E, 848 m.	M.Kılıç 247 M.Kılıç 258
	Mardin, Artuklu, Sultanköy Neighborhood, road side, stone area, fallow fields, 37°22'49"N 40°39'14"E, 1147 m.	M.Kılıç 273
	Mardin, Mazıdağı, Ömürlü Neighborhood, road side, 37°30'14"N 40°31'19"E, 939 m.	M.Kılıç 281
	Mardin, Mazıdağı, Kebapçı Neighborhood, road side, rocky slope, 37°32'19"N 40°31'51"E, 917 m.	M.Kılıç 282
	Şanlıurfa, Viranşehir-Urfa road, road side, rocky slope.	M.Kılıç 282
	Mardin, Midyat, road side, rocky slope, 37°27'54"N 41°04'59"E, 1030 m.	M.Kılıç 312
	Mardin, Midyat, road side, rocky slope, 37°26'15"N 41°18'07"E, 928 m.	M.Kılıç 314-4
	Mardin, Midyat-Dargeçit road, road side, rocky	M.Kılıç 315-4

	slope, stone area, 37°26'15"N 41°18'07"E, 928 m.	
	Mardin, Savur, Savur-Kayatepe road, road side, rocky slope, 37°31'31"N 40°53'37"E, 933 m.	M.Kılıç 340-2
	Mardin, Savur, Savur-Kayatepe road, road side, stone and rocky place, 37°31'18"N 40°54'26"E, 1070 m.	M.Kılıç 341-1
V. geminiflorum	Mardin, Artuklu, Ofis Neighborhood, 37°16'22"N 40°40'49"E, 591 m.	M.Kılıç 284
	Şanlıurfa, Siverek, Siverek-Karacadağ road, road side, cultivated area, 37°43'30"N 39°25'05"E, 867 m.	M.Kılıç 358
V. andrusii	Mardin, Artuklu, Yenişehir Neighborhood, Türkmenler road, road side, serpentine, 37°17'46"N 40°42'47"E, 695 m.	M.Kılıç 252
	Mardin, Artuklu, Çiftlikköy Neighborhood, road side, stony areas, 37°17'09"N 40°43'33"E, 652 m.	M.Kılıç 259
	Mardin, Artuklu, Eskikale Neighborhood, Eskikale road, road side, serpentine, 37°18'09"N 40°46'03"E, 935 m.	M.Kılıç 263
	Mardin, Artuklu, Kötek Neighborhood, Ortaköy-Mardin road, road side, rocky slope, 37°16'34"N 40°46'12"E, 686 m.	M.Kılıç 265
	Mardin, Nusaybin, Akarsu road, streamside, stony area, 37°08'11"N 41°04'44"E, 536 m.	M.Kılıç 300-2
	Mardin, Artuklu, Eskikale Neighborhood, Deyrulzafaran road, road side, 37°17'48"N 40°47'31"E, 876 m.	M.Kılıç 303
	Mardin, Ömerli, Ömerli-Midyat road, road side, rocky slopes.	M.Kılıç 303
	Mardin, Midyat, Düzgeçit Neighborhood, road side, rocky slope, 37°28'15"N 41°07'18"E, 1001 m.	M.Kılıç 313
	Mardin, Midyat, road side, stony area, rocky slope, 37°26'15"N 41°18'07"E, 928 m.	M.Kılıç 314-2
	Mardin, Midyat-Dargeçit road, road side, stony area, rocky slope, 37°26'15"N 41°18'07"E, 928 m.	M.Kılıç 315-3
	Mardin, Dargeçit, road side, 37°33'08"N 41°40'16"E, 933 m.	M.Kılıç 316
	Mardin, Midyat, Yemişli Neighborhood, road side, rocky slope, 37°19'38"N 41°20'57"E, 960 m.	M.Kılıç 318
	Mardin, Kızıltepe, Soğanlı Neighborhood, stony area, rocky slope.	M.Kılıç 322
	Mardin, Kızıltepe, Başdeğirmen road, road side, rocky slope, 37°16'31"N 40°32'41"E, 655 m.	M.Kılıç 323-1
	Mardin, Yeşilli, Bülbül Neighborhood, road side, rocky slope, 37°18'31"N 40°49'54"E, 733 m.	M.Kılıç 328-1
	Mardin, Yeşilli, Bülbül-Uzunköy road, road side, stony and rocky area, 37°17'32"N 40°50'41"E, 698 m.	M.Kılıç 330-1
	Mardin, Savur, Pınardere-Savur road, road side, serpentine, 37°29'33"N 40°49'35"E, 887 m.	M.Kılıç 335
	Mardin, Mardin-Diyarbakır road, road side, calcareous slopes, 1039 m.	M.Kılıç 344-1
	Mardin, Mazıdağı, Mardin-Diyarbakır road, 24 km before Çınar, road side, calcareous slopes, 929 m.	M.Kılıç 345-1
	Diyarbakır, Çınar, 6 km before Çınar, road side, 37°40'47"K 40°27'28"D, 725 m.	M.Kılıç 346-1
	Mardin, Artuklu, Yardere Neighborhood, road side,	

	stony area, 37°13'22"N 40°58'23"E, 701 m.	M.Kılıç 363-2
	Mardin, Artuklu, Sultanköy Neighborhood, Leylak street road, water source location, 37°22'55"N 40°39'07"E, 1132 m.	M.Kılıç 396-2
	Mardin, Artuklu, Nur Neighborhood, location around Çağatay Cemetery, road side, streamside, 37°21'37"N 40°40'26"E, 930 m.	M.Kılıç 400-1
V. kotschyi	Mardin, Artuklu, Eskikale Neighborhood, Bakırkırı-Yeşilli road, road side, stony area, 37°19'38"N 40°47'48"E, 828 m.	M.Kılıç 252
	Mardin, Artuklu, Eryeri Neighborhood, Eryeri-Cezaevi road, road side, vineyards, 37°17'50"N 40°45'11"E, 770 m.	M.Kılıç 262
	Mardin, Artuklu, Kötek Neighborhood, Mardin-Ortaköy road, road side, 37°17'07"N 40°46'32"E, 742 m.	M.Kılıç 264
	Mardin, Artuklu, 13 Mart Neighborhood, 13 Mart-Hamzabey road, road side, stony area, 37°20'44"N 40°43'44"E, 834 m.	M.Kılıç 268
	Şanlıurfa, Karaköprü, Borsa İstanbul Middle School, road side, rocky slope, 37°12'40"N 38°47'22"E, 621 m.	M.Kılıç 298
	Mardin, Nusaybin, Akarsu road, road side, stony area, 37°08'06"N 41°04'41"E, 546 m.	M.Kılıç 299
	Mardin, Ömerli, Ömerli-Midyat road, road side, rocky slopes.	M.Kılıç 308-1
	Mardin, Dargeçit-Midyat road, 29 km before Midyat, road side.	M.Kılıç 317-2
	Mardin, Yeşilli, Şirinevler Neighborhood, road side, stony area, rocky slopes, 37°20'40"N 40°49'53"E, 904 m.	M.Kılıç 327-2
	Mardin, Yeşilli, Bülbül-Uzunköy road, road side, stony area, 37°16'53"N 40°50'46"E, 676 m.	M.Kılıç 331-4
	Mardin, Savur, Dereyanı-Köprülü road, road side, 37°27'12"N 40°51'38"E, 940 m.	M.Kılıç 333-1
	Mardin, Artuklu, Dara-Yardere road, road side, rocky and stony area, 37°12'02"N 40°57'37"E, 619 m.	M.Kılıç 361-1
	Mardin, Artuklu, 13 Mart Neighborhood, 13 Mart-Hamzabey road, road side, stony area, 37°20'44"N 40°43'44"E, 834 m.	M.Kılıç 371-2
V. lasianthum	Şanlıurfa, Karaköprü, Borsa İstanbul Middle School, road side, 37°12'26"N 38°47'30"E, 606 m.	M.Kılıç 293-2
	Şanlıurfa, Karaköprü, Güllübağ Neighborhood, Necip Fazıl Kısakürek School, 37°13'46"N 38°49'06"E, 665 m.	M.Kılıç 294
	Mardin, Yeşilli, Bülbül-Uzunköy road, road side, stony area, 37°16'53"N 40°50'46"E, 676 m.	M.Kılıç 331-3
	Mardin, Savur, 1 km after Pınardere, road side, 37°29'05"N 40°49'40"E, 903 m.	M.Kılıç 334
	Diyarbakır, Çınar, 6 km from Çınar, road side, 37°40'47"N 40°27'28"E, 725 m.	M.Kılıç 346-2
	Diyarbakır, Yenişehir, 28 km from Ergani, road side, cultivated area, 766 m.	M.Kılıç 349
	Diyarbakır, Ergani, 9 km from Ergani, road side, stony and rocky area, 38°11'53"N 39°49'57"E, 809 m.	M.Kılıç 350

Şanlıurfa, Hilvan, road side, 592 m.	M.Kılıç 390
Diyarbakır, Siverek-Diyarbakır road, 48 km from Diyarbakır, road side, stony area, 37°49'55"N 39°40'06"E, 1077 m.	M.Kılıç 393
Mardin, Artuklu, Sultanköy Neighborhood, Leylak Street road, water supply location, 37°22'55"N 40°39'07"E, 1132 m.	M.Kılıç 396-1
Mardin, Ömerli, 6 km after Ömerli, road side.	M.Kılıç 402-2

Figure 1. General appearance of the genus *Verbascum*. **(a)** *V. agrimoniifolium* subsp. *agrimoniifolium,* **(b)** *V. orientale* subsp. *orientale*,**(c)** *V. laetum*,**(d)** *V. geminiflorum*,**(e)** *V. andrusii*,**(f)** *V. kotschyi*, **(g)** *V. lasianthum*.

3. Results and Discussion

3.1. Anatomy

3.1.1. Root Anatomy

V. agrimoniifolium subsp. *agrimoniifolium*: Peridermis, cortex, phloem, and xylem are oriented from outside to inside in root cross-sections. The peridermis typically has 3-5 cell layers. Beneath the periderm is a stratified parenchyma. Beneath the parenchyma are 3-5 layers of phloem cells. There is unclear cambium. The center of the root is filled with xylem, which covers a wider region. Trachea cells are longer than they are wide, and their locations are asymmetrical. The phloem has a smaller area than the xylem. There are 1-2 rows of rectangular and quadrangular cells in its pith rays. The round or polygonal parenchymatous cells make up the pith (Table 2, Figure 2).

V. orientale subsp. *orientale*: Peridermis, cortex, phloem, and xylem are oriented from outside to inside in root cross-sections. The peridermis typically has 5-7 cell layers. Beneath the periderm is a stratified parenchyma. Beneath the parenchyma are 3-5 layers of phloem cells. There is unclear cambium. The center of the root is filled with xylem, which covers a wider region. Trachea cells are longer than they are wide, and their locations are asymmetrical. The phloem has a smaller area than the xylem. There are 1-2 rows of rectangular and quadrangular cells in its pith rays. The

round or polygonal parenchymatous cells make up the pith (Table 2, Figure 2).

V. laetum: Peridermis, cortex, phloem, and xylem are oriented from outside to inside in root cross-sections. The peridermis typically has 5-7 cell layers. Beneath the periderm is a stratified parenchyma. Beneath the parenchyma are 3-5 layers of phloem cells. There is unclear cambium. The center of the root is filled with xylem, which covers a wider region. Trachea cells are longer than they are wide, and their locations are asymmetrical. The phloem has a smaller area than the xylem. There are 2-4 rows of rectangular and quadrangular cells in its pith rays. The round or polygonal parenchymatous cells make up the pith (Table 2, Figure 2).

V. geminiflorum: In root cross-sections, peridermis, cortex, phloem and xylem are oriented from outside to inside. Peridermis cells are crushed and typically have 5-7 cell layers. There is a multilayered parenchyma under the periderm. There are 3-5 rows of phloem cells under the parenchyma. There is indistinct cambium. The middle of the root is filled with xylem, which covers a larger area. Tracheal cells are longer than wide and their position is asymmetrical. Phloem has a smaller area than xylem. There are 1-3 rows of rectangular and quadrangular cells in its core rays. The round or polygonal parenchymatous cells form the pith (Table 2, Figure 2).

V. andrusii: Peridermis, cortex, phloem, and xylem are oriented from outside to inside in root cross-sections. The peridermis typically has 7-15 cell layers. Beneath the periderm is a stratified parenchyma. Beneath the parenchyma are 5-7 layers of phloem cells. There is unclear cambium. The center of the root is filled with xylem, which covers a wider region. Trachea cells are longer than they are wide, and their locations are asymmetrical. The phloem has a smaller area than the xylem. There are 1-3 rows of rectangular and quadrangular cells in its pith rays. The round or polygonal parenchymatous cells make up the pith (Table 2, Figure 2).

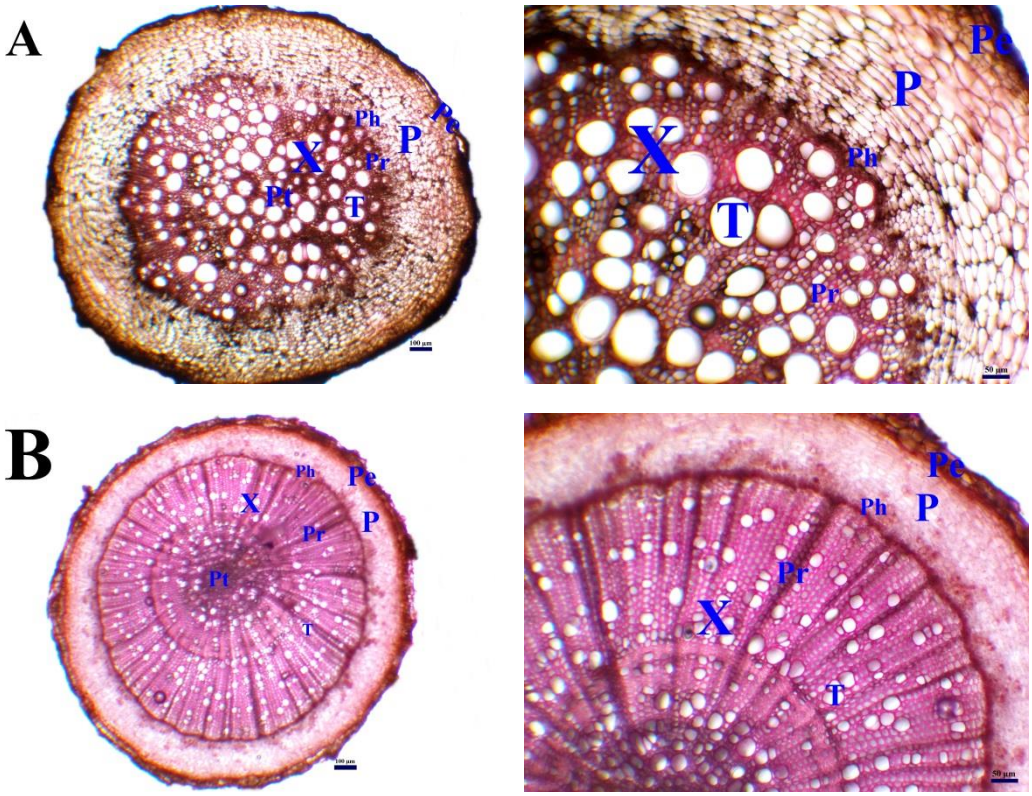
V. kotschyi: Peridermis, cortex, phloem, and xylem are oriented from outside to inside in root cross-sections. The peridermis typically has 7-9 cell layers. Beneath the periderm is a stratified parenchyma. Beneath the parenchyma are 3-5 layers of phloem cells. There is unclear cambium. The center of the root is filled with xylem, which covers a wider region. Trachea cells are longer in width than in length and their positions are asymmetrical. The phloem has a smaller area than the xylem. There are 2-4 rows of rectangular and quadrangular cells in its pith rays. The round or polygonal parenchymatous cells make up the pith (Table 2, Figure 2).

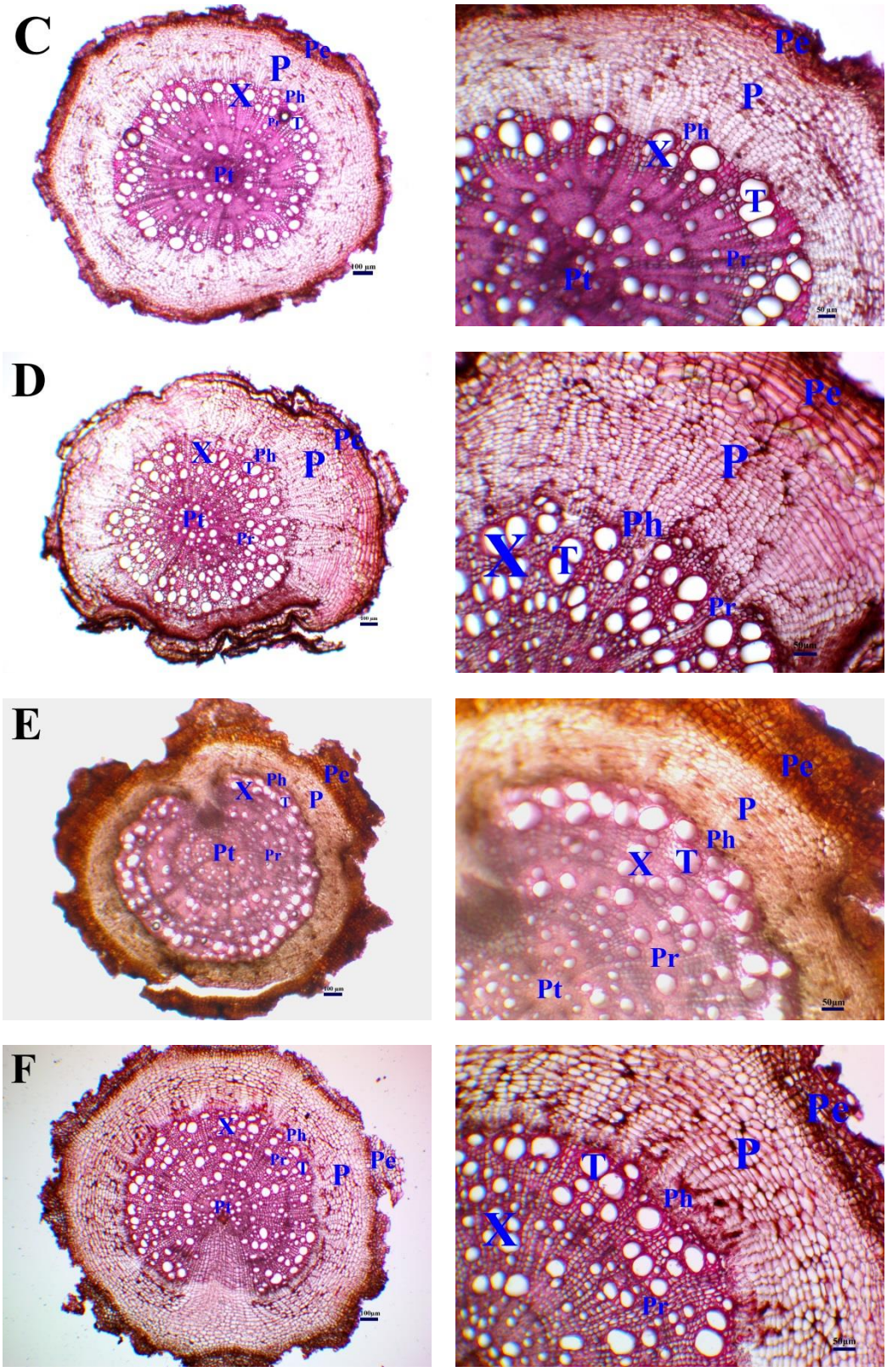
V. lasianthum: Peridermis, cortex, phloem, and xylem are oriented from outside to inside in root cross-sections. The peridermis typically has 7-9 cell layers. Beneath the periderm is a stratified parenchyma. Beneath the parenchyma are 3-5 layers of phloem cells. There is unclear cambium. The center of the root is filled with xylem, which covers a wider region. Trachea cells are longer in width than in length and their positions are asymmetrical. The phloem has a smaller area than the xylem. There are 1-3 rows of rectangular and quadrangular cells in its pith rays. The round or polygonal parenchymatous cells make up the pith (Table 2, Figure 2).

Table 2. The root anatomical measurements of taxa belonging to the genus *Verbascum* (µm).

		Width			Length		
Taxa	**Tissues**	**Min.**	**Max.**	**Mean±S.**	**Min.**	**Max.**	**Mean±S.**
V. agrimoniifolium subsp. *agrimoniifolium*	Peridermis	18.42	61.44	32.09±11.76	10.01	29.59	17.36±5.99
	Parenchyma	19.39	75.70	46.33±14.42	12.07	36.52	22.74±6.04
	Phloem	11.21	23.32	16.17±3.25	6.20	16.74	11.50±2.94
	Trachea	47.02	129.90	89.86±23.55	45.70	113.10	87.38±18.57
V. orientale subsp. *orientale*	Peridermis	11.05	53.92	27.37±11.36	9.01	28.49	17.73±6.97
	Parenchyma	12.37	41.01	24.61±8.74	8.34	16.97	11.98±2.20
	Phloem	5.73	12.73	8.81±1.96	4.76	9.89	6.75±1.23
	Trachea	16.97	39.80	26.88±6.31	19.20	42.26	32.25±6.69
V. laetum	Peridermis	8.58	39.33	21.51±9.22	8.18	24.51	15.45±4.33
	Parenchyma	14.98	49.86	28.71±9.98	9.99	24.97	18.37±4.15

	Phloem	7.49	23.43	13.57±4.68	5.48	11.84	8.44±1.67
	Trachea	28.91	74.87	45.05±12.02	31.28	90.38	54.45±15.91
V. geminiflorum	Peridermis	14.55	60.45	31.87±10.23	7.19	30.53	18.10±6.94
	Parenchyma	17.03	43.58	28.01±6.23	8.24	23.10	14.44±3.64
	Phloem	5.91	27.70	14.83±5.20	4.02	14.98	8.62±2.69
	Trachea	19.78	63.69	39.12±12.48	20.29	76.91	47.28±18.35
V. andrusii	Peridermis	14.38	45.87	25.14±7.97	14.56	39.19	22.73±5.87
	Parenchyma	10.88	43.71	27.53±8.58	8.68	17.04	13.19±2.14
	Phloem	5.63	16.19	10.15±3.15	5.41	16.44	9.01±2.58
	Trachea	32.42	85.67	55.37±15.13	35.36	91.28	60.29±16.19
V. kotschyi	Peridermis	22.79	49.44	35.76±8.16	13.39	33.97	24.24±5.50
	Parenchyma	19.00	65.38	37.27±12.15	10.89	26.12	19.97±4.56
	Phloem	7.54	17.44	11.70±2.54	6.81	13.92	9.88±2.36
	Trachea	29.64	72.92	48.83±13.59	26.79	75.43	48.01±14.04
V. lasianthum	Peridermis	10.00	23.45	16.54±4.14	6.09	21.31	11.54±3.41
	Parenchyma	11.38	38.90	19.52±6.77	10.54	19.77	13.06±2.27
	Phloem	8.17	19.48	12.36±2.71	6.32	15.37	11.05±2.40
	Trachea	35.66	99.45	59.84±21.18	39.50	83.17	55.14±12.94

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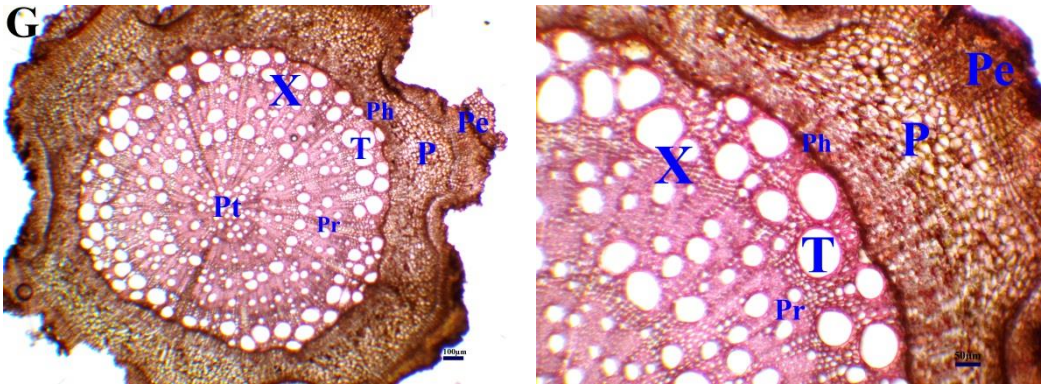


Figure 2. Cross-section of the root of *Verbascum* **(A)** *V. agrimoniifolium* subsp. *agrimoniifolium*, **(B)** *V. orientale* subsp. *orientale*, **(C)** *V. laetum*, **(D)** *V. geminiflorum*, **(E)** *V. andrusii*, **(F)** *V. kotschyi*, **(G)** *V. lasianthum*. Pe: Periderm, P: Parenchyma, Ph: Phloem, X: Xylem, Pr: Pith ray, T: Trachea, Pt: Pith region. Bars: 100 and 50 µm.

3.1.2. Stem Anatomy

V. agrimoniifolium subsp. *agrimoniifolium*: Cross-sections from the plant's stem showed a single-layered epidermis with a wavy cuticle. Cells that are round or rectangular make up the epidermis. Under the epidermis are 2-3 rows of collenchyma cells. Oval and round parenchyma cells are arranged in 4-6 rows to form parenchyma tissue. Underneath the parenchyma lies a layer of sclerenchyma arranged in 2-4 rows. There is no difference in the cambium. The phloem is found in a smaller area than xylem. Six or octagonal circular parenchymatous cells with intercellular gaps make up the pith (Table 3, Figure 3).

V. orientale subsp. *orientale*: Cross-sections from the plant's stem showed a single-layered epidermis with a wavy cuticle. Cells that are round or rectangular make up the epidermis. The epidermis is covered with glandular and eglandular hairs. Under the epidermis are 3-4 rows of collenchyma cells. Oval and round parenchyma cells are arranged in 2-3 rows to form parenchyma tissue. Underneath the parenchyma lies a layer of sclerenchyma arranged in 2-4 rows. There is no difference in the cambium. The phloem is found in a smaller area than xylem. Six or octagonal circular parenchymatous cells with intercellular gaps make up the pith (Table 3, Figure 3).

V. laetum: Cross-sections from the plant's stem showed a single-layered epidermis with a wavy cuticle. Cells that are round or rectangular make up the epidermis. The epidermis is covered with eglandular hairs. Under the epidermis are 3-4 rows of collenchyma cells. Oval and round parenchyma cells are arranged in 5-7 rows to form parenchyma tissue. Underneath the parenchyma lies a layer of sclerenchyma arranged in 3-6 rows. There is no difference in the cambium. The phloem is found in a smaller area than xylem. Polygonal circular parenchymatous cells with intercellular spaces form the pith (Table 3, Figure 3).

V. geminiflorum: Cross-sections from the plant's stem showed a single-layered epidermis with a wavy cuticle. Cells that are round or rectangular make up the epidermis. The epidermis is covered with glandular and compound hairs. Under the epidermis are 2-3 rows of collenchyma cells. Oval and round parenchyma cells are arranged in 7-9 rows to form parenchyma tissue. Underneath the parenchyma lies a layer of sclerenchyma arranged in 2-4 rows. There is no difference in the cambium. The phloem is found in a smaller area than xylem. Polygonal circular parenchymatous cells with intercellular spaces form the pith (Table 3, Figure 3).

V. andrusii: Cross-sections from the plant's stem showed a single-layered epidermis with a wavy cuticle. Cells that are round or rectangular make up the epidermis. The epidermis is covered with glandular, eglandular and compound hairs. Under the epidermis are 2-3 rows of collenchyma cells. Oval and round parenchyma cells are arranged in 5-9 rows to form parenchyma tissue. Underneath the parenchyma lies a layer of sclerenchyma arranged in 2-7 rows. There is no difference in the cambium. The phloem is found in a smaller area than xylem. Polygonal circular parenchymatous cells with intercellular spaces form the pith (Table 3, Figure 3).

V. kotschyi: Cross-sections from the plant's stem showed a single-layered epidermis with a wavy cuticle. Cells that are round or rectangular make up the epidermis. The epidermis is covered with glandular and eglandular hairs. Under the epidermis are 2-4 rows of collenchyma cells. Oval and round parenchyma cells are arranged in 9-11 rows to form parenchyma tissue. Underneath the parenchyma lies a layer of sclerenchyma arranged in 4-7 rows. There is no

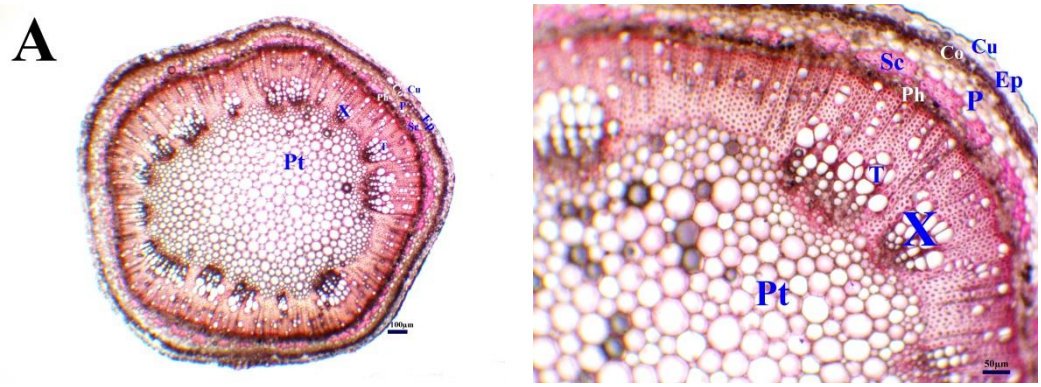
difference in the cambium. The phloem is found in a smaller area than xylem. Polygonal circular parenchymatous cells with intercellular spaces form the pith (Table 3, Figure 3).

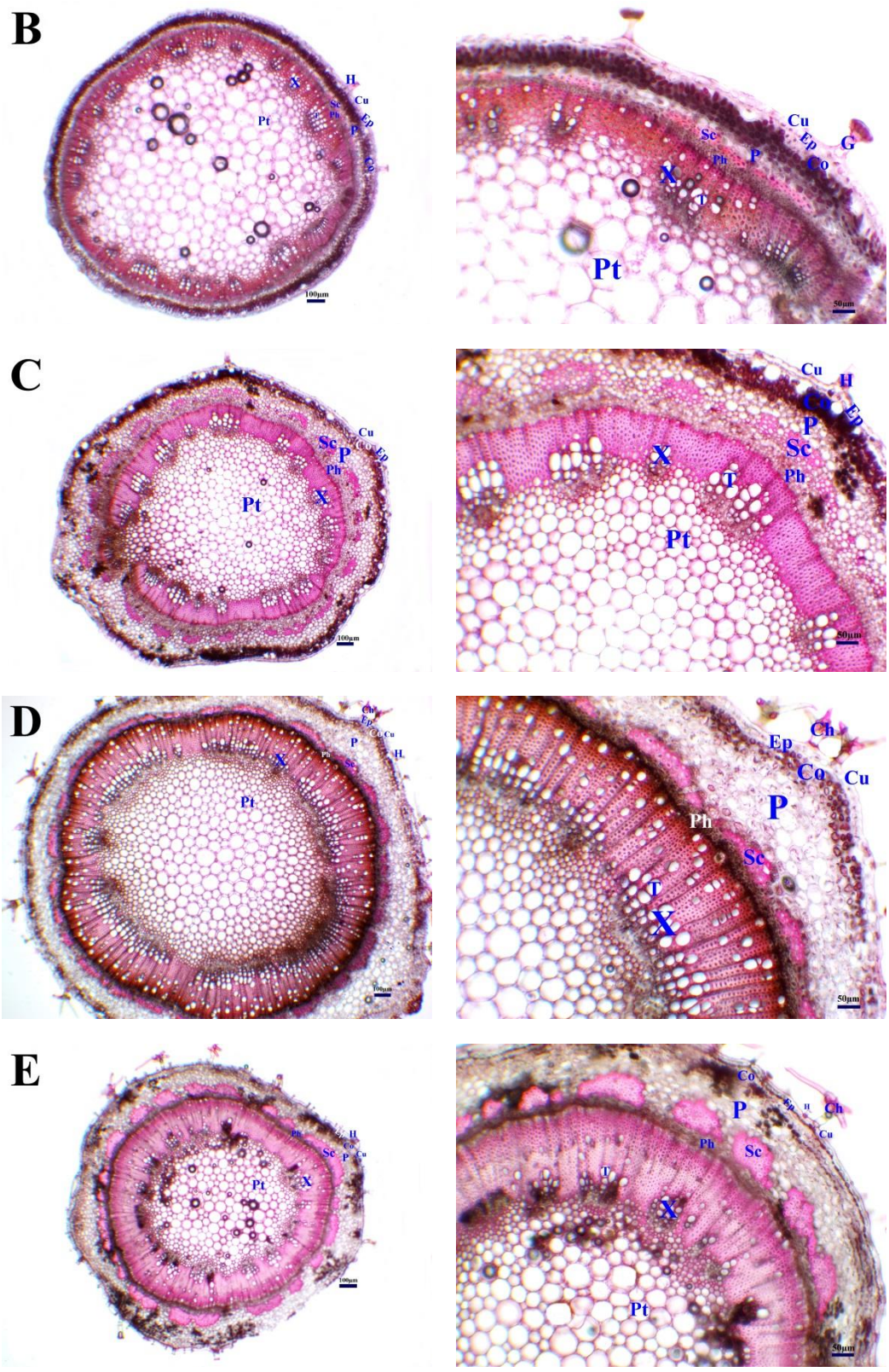
V. lasianthum: Cross-sections from the plant's stem showed a single-layered epidermis with a wavy cuticle. Cells that are round or rectangular make up the epidermis. The epidermis is covered with glandular, eglandular and compound hairs. Under the epidermis are 2-3 rows of collenchyma cells. Oval and round parenchyma cells are arranged in 5-7 rows to form parenchyma tissue. Underneath the parenchyma lies a layer of sclerenchyma arranged in 3-5 rows. There is no difference in the cambium. The phloem is found in a smaller area than xylem. The pith region of the stem consists of large and small parenchymatic polygonal and round-shaped cells (Table 3, Figure 3).

Table 3. The stem anatomical measurements of taxa belonging to the genus *Verbascum* (µm).

		Width			Length		
Taxa	**Tissues**	**Min.**	**Max.**	**Mean±S.**	**Min.**	**Max.**	**Mean±S.**
V. agrimoniifolium subsp. *agrimoniifolium*	Cuticle	-	-	-	6.45	13.09	8.69±1.79
	Epidermis	19.13	44.54	30.28±7.46	10.40	27.48	19.22±4.76
	Collenchyma	6.47	18.48	11.67±3.44	6.12	16.96	9.48±2.87
	Parenchyma	12.24	53.52	27.21±11.51	7.93	31,72	15.75±6.47
	Phloem	6.11	13.46	9.02±2.04	4.90	10.51	7.00±1.45
	Trachea	17.07	36.65	26.50±5.62	16.63	51.84	31.39±9.35
	Pith	27.97	87.96	51.06±14.42	29.08	85.60	50.76±13.50
V. orientale subsp. *orientale*	Cuticle	-	-	-	3.27	7.44	5.85±1.21
	Epidermis	13.09	33.82	23.78±6.00	13.20	22.00	16.77±2.52
	Collenchyma	10.13	20.23	14.79±2.84	12.00	32.76	19.85±4.93
	Parenchyma	16.13	55.76	33.53±12.08	10.77	27.11	17.94±4.67
	Phloem	6.15	14.69	8.78±2.44	4.28	8.82	5.94±1.25
	Trachea	15.09	35.78	21.80±5.12	15.91	32.96	22.61±4.57
	Pith	55.96	185.96	128.01±44.49	57.06	174.81	119.66±42.45
V. laetum	Cuticle	-	-	-	3.79	7.51	6.42±0.90
	Epidermis	13.76	33.61	23.29±5.24	14.80	24.88	19.03±2.41
	Collenchyma	9.01	16.08	13.04±2.00	9.34	15.92	12.75±1.89
	Parenchyma	14.75	38.10	24.34±6.49	16.06	39.14	24.84±5.81
	Phloem	4.14	10.54	8.20±1.70	3.76	11.24	6.85±2.14
	Trachea	12.13	38.90	21.30±6.62	12.16	43.45	24.08±8.14
	Pith	34.01	92.32	57.46±16.49	33.68	94.06	61.78±16.62
V. geminiflorum	Cuticle	-	-	-	5.71	10.85	8.63±1.33
	Epidermis	11.28	37.41	19.45±6.14	11.36	24.33	16.25±3.46
	Collenchyma	9.45	25.15	16.87±3.80	8.57	21.68	15.68±3.49
	Parenchyma	24.90	54.80	39.88±6.91	14.64	42.80	27.02±7.05

	Phloem	5.57	14.49	9.26±2.45	4.83	9.26	7.06±1.71
	Trachea	15.78	41.58	26.51±6.76	20.75	51.20	35.35±9.70
	Pith	33.69	108.44	66.89±21.40	31.20	101.45	72.51±21.36
V. andrusii	Cuticle	-	-	-	3.67	7.93	5.73±1.14
	Epidermis	2.92	16.87	11.09±4.42	6.70	16.69	10.80±2.58
	Collenchyma	6.11	23.66	14.14±4.37	7.65	20.12	13.78±3.69
	Parenchyma	33.99	68.23	47.26±9.66	15.12	33.46	25.60±4.49
	Phloem	3.91	15.26	9.82±3.22	3.01	14.06	6.81±2.35
	Trachea	23.30	53.47	38.13±8.10	24.75	69.99	48.76±13.09
	Pith	11.36	28.40	19.57±5.28	11.40	31.50	20.21±5.93
V. kotschyi	Cuticle	-	-	-	5.73	11.38	9.06±1.38
	Epidermis	13.46	23.38	17.48±2.80	16.96	24.10	20.25±1.94
	Collenchyma	11.49	26.99	16.39±4.60	11.26	27.32	16.72±4.31
	Parenchyma	21.11	67.50	45.21±15.47	15.90	37.21	27.14±7.15
	Phloem	4.66	15.11	9.11±2.71	5.14	12.78	7.78±2.13
	Trachea	16.45	40.98	28.34±7.08	18.06	50.18	32.22±7.93
	Pith	25.05	81.45	51.79±17.71	25.85	88.67	55.33±20.53
V. lasianthum	Cuticle	-	-	-	3.91	11.44	8.84±1.69
	Epidermis	7.00	18.48	11.44±3.52	7.81	18.02	12.28±2.92
	Collenchyma	10.32	22.54	16.77±2.98	10.38	20.30	14.59±2.71
	Parenchyma	19.43	43.63	32.50±7.39	20.60	44.82	33.69±7.41
	Phloem	4.98	14.03	10.35±2.62	7.54	12.58	9.51±1.44
	Trachea	10.26	25.95	18.37±4.52	15.01	40.07	24.99±5.70
	Pith	19.09	63.31	43.72±11.64	14.72	41.94	28.72±7.59

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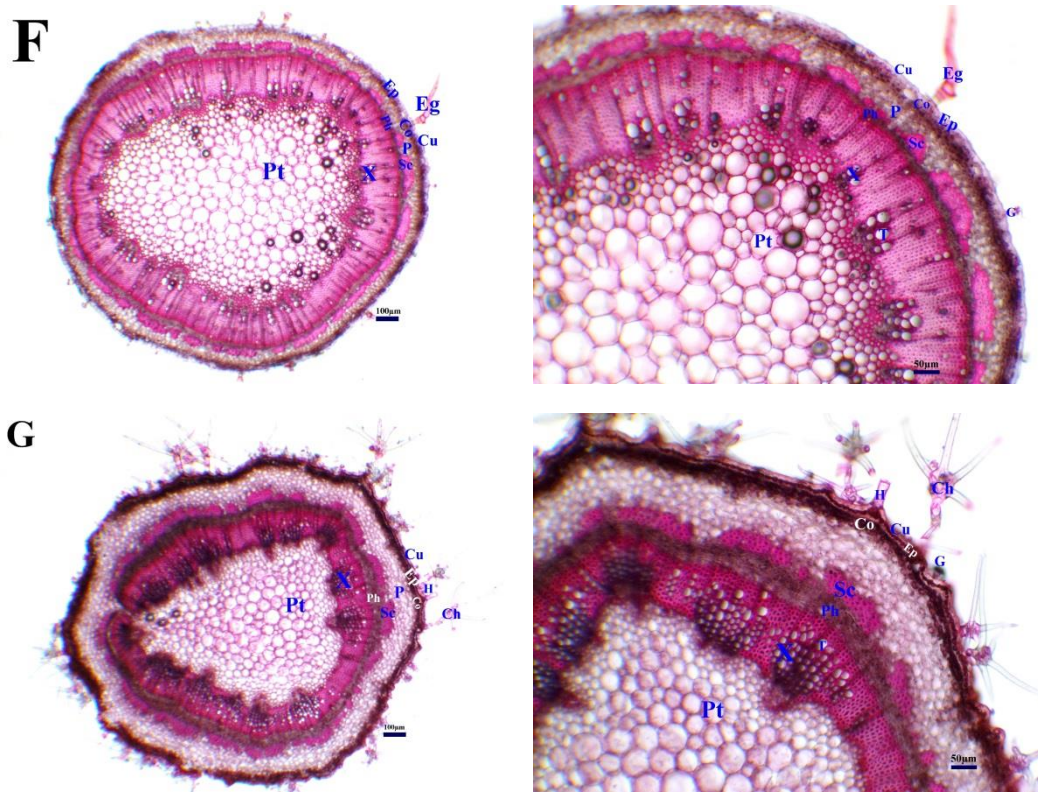


Figure 3. Cross-section of the stem of *Verbascum* **(A)** *V. agrimoniifolium* subsp. *agrimoniifolium*,**(B)** *V. orientale* subsp. *orientale*,**(C)** *V. laetum*, **(D)** *V. geminiflorum*, **(E)** *V. andrusii*, **(F)** *V. kotschyi*, **(G)** *V. lasianthum*. Eg: Eglandular, G: Glandular hair, Ch: Compound hair, H: Hair, Cu: Cuticle, Ep: Epidermis, Co: Collenchyma, P: Parenchyma, Sc: Sclerenchyma, Ph: Phloem, X: Xylem, T: Trachea, Pt: Pith region.

3.1.3. Leaf Anatomy

V. agrimoniifolium subsp. *agrimoniifolium*: The epidermis consists of a single row of round, rectangular or oval cells. The epidermis is covered with a thin layer (5.43-12.23 µm) of cuticle. Covering and glandular hairs were observed in both epidermis. Mesophyll tissue is divided into palisade and sponge parenchyma. While there are 2-3 layers of palisade parenchyma under the upper epidermis and 1-2 layers of palisade parenchyma above the lower epidermis, there are 2-3 layers of sponge parenchyma in between (Table 4, Figure 4).

V. orientale subsp. *orientale*: The epidermis consists of a single row of round, rectangular or oval cells. The epidermis is covered with a thin layer (4.72-10.79 µm) of cuticle. Glandular hairs were observed in both epidermis. Mesophyll tissue is divided into palisade and sponge parenchyma. While there are 2-3 rows of palisade parenchyma under the upper epidermis, 1-2 rows of palisade parenchyma above the lower epidermis, there are 2-3 rows of sponge parenchyma in between (Table 4, Figure 4).

V. laetum: The epidermis consists of a single row of round, rectangular or oval cells. The epidermis is covered with a thin layer (7.63-16.66 µm) of cuticle. The glandular, eglandular and compound hairs were observed in both epidermis. Mesophyll tissue is divided into palisade and sponge parenchyma. While there are 3-4 rows of palisade parenchyma under the upper epidermis, 2-3 rows of palisade parenchyma above the lower epidermis, there are 3-4 rows of sponge parenchyma in between. The idioblasts have also been found in the mesophyll tissue of leaves (Table 4, Figure 4).

V. geminiflorum: The epidermis consists of a single row of round, rectangular or oval cells. The epidermis is covered with a thin layer (5.53-13.42 µm) of cuticle. The glandular and compound hairs were observed in both epidermis. Mesophyll tissue is divided into palisade and sponge parenchyma. While there are 3-4 rows of palisade parenchyma under the upper epidermis, 2-3 rows of palisade parenchyma above the lower epidermis, there are 3-4 rows of sponge parenchyma in between. The idioblasts have been found in the mesophyll tissue of leaves. Intercellular spaces are noticeable in the mesophyll. Additionally, there is an amaryllis type stoma in the mesophyll (Table 4, Figure 4).

V. andrusii: The epidermis consists of a single row of round, rectangular or oval cells. The epidermis is covered with a thin layer (5.42-9.45µm) of cuticle. The

glandular, eglandular and compound hairs were observed in both epidermis. Mesophyll tissue is divided into palisade and sponge parenchyma. While there are 2-3 rows of palisade parenchyma under the upper epidermis, 1-2 rows of palisade parenchyma above the lower epidermis, there are 3-5 rows of sponge parenchyma in between. Intercellular spaces are noticeable in the mesophyll. Additionally, there is an amaryllis type stoma in the mesophyll (Table 4, Figure 4).

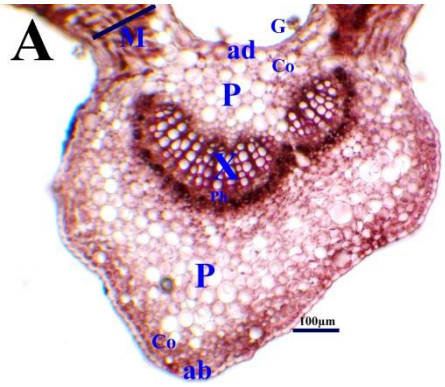
V. kotschyi: The epidermis consists of a single row of round, rectangular or oval cells. The epidermis is covered with a thick layer (10.48-14.83 µm) of cuticle. The glandular, eglandular and compound hairs were observed in both epidermis. Mesophyll tissue is divided into palisade and sponge parenchyma. While there are 1-2 rows of palisade parenchyma under the upper epidermis, 1-2 rows of palisade parenchyma above the lower epidermis, there are 2-3 rows of sponge parenchyma in between. Additionally, there is an amaryllis type stoma in the mesophyll (Table 4, Figure 4).

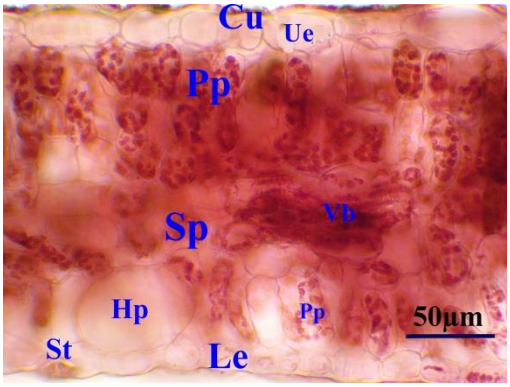
V. lasianthum: The epidermis consists of a single row of round, rectangular or oval cells. The epidermis is covered with a thin layer (6.21-10.99 µm) of cuticle. The glandular, eglandular and compound hairs were observed in both epidermis. Mesophyll tissue is divided into palisade and sponge parenchyma. While there are 2-3 rows of palisade parenchyma under the upper epidermis, 1-2 rows of palisade parenchyma above the lower epidermis, there are 3-5 rows of sponge parenchyma in between. Additionally, there is an amaryllis type stoma in the mesophyll (Table 4, Figure 4).

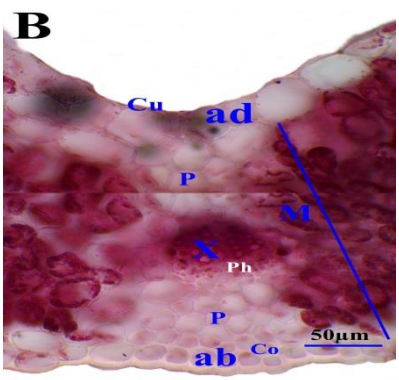
Table 4. The leaf anatomical measurements of taxa belonging to the genus *Verbascum* (µm).

		Width			Length		
Taxa	**Tissues**	**Min.**	**Max.**	**Mean±S.**	**Min.**	**Max.**	**Mean±S.**
V. agrimoniifolium subsp. *agrimoniifolium*	Cuticle	-	-	-	5.43	12.23	8.15±2.30
	Upper epidermis	13.32	41.70	25.26±6.39	17.79	30.90	25.92±3.35
	Palisade parenchyma	10.23	18.61	15.42±2.27	27.60	44.85	35.37±3.81
	Spongy parenchyma	14.00	31.02	20.87±4.66	15.00	27.79	20.52±3.64
	Mesophyll layer	-	-	-	222.55	277.65	251.59±15.89
	Lower epidermis	5.44	21.27	14.59±3.90	6.09	20.96	13.08±3.56
V. orientale subsp. *orientale*	Cuticle	-	-	-	4.72	10.79	7.38±1.70
	Upper epidermis	12.36	37.81	21.60±6.87	12.69	30.28	20.69±5.45
	Palisade parenchyma	14.01	29.19	22.41±3.51	30.58	52.67	38.34±5.77
	Spongy parenchyma	13.38	31.82	22.00±4.44	15.67	32.06	22.29±4.30
	Mesophyll layer	-	-	-	189.05	267.44	234.43±20.03
	Lower epidermis	20.48	57.42	32.55±11.05	22.08	44.05	31.50±6.73
V. laetum	Cuticle	-	-	-	7.63	16.66	11.10±2.53
	Upper epidermis	12.41	46.71	24.71±8.41	12.04	26.27	20.57±3.93
	Palisade parenchyma	7.37	21.46	15.70±3.26	23.96	65.33	44.45±9.96
	Spongy parenchyma	13.91	25.26	20.13±2.73	14.99	33.48	22.93±5.45
	Mesophyll layer	-	-	-	265.96	372.48	314.04±29.23
	Lower epidermis	13.52	29.27	20.66±4.37	12.70	25.83	18.88±3.51
V. geminiflorum	Cuticle	-	-	-	5.53	13.42	9.23±1.80
	Upper epidermis	26.62	62.16	39.84±8.75	27.76	51.75	36.22±6.57

	Palisade parenchyma	15.28	32.07	22.90±4.67	30.76	62.91	49.62±9.46
	Spongy parenchyma	14.22	26.86	21.16±3.18	12.97	33.19	22.19±5.00
	Mesophyll layer	-	-	-	383.00	196.26	297.50±50.65
	Lower epidermis	9.32	23.11	17.99±3.67	9.23	24.32	16.74±3.68
V. andrusii	Cuticle	-	-	-	5.42	9.45	6.73±0.96
	Upper epidermis	11.85	23.06	16.28±3.22	11.06	18.35	14.50±2.23
	Palisade parenchyma	12.18	24.28	17.35±2.94	19.21	36.90	26.72±4.72
	Spongy parenchyma	12.29	19.97	16.04±2.23	9.74	18.08	13.38±2.25
	Mesophyll layer	-	-	-	190.12	256.82	182.41±38.09
	Lower epidermis	9.17	20.03	14.93±3.59	8.05	16.03	11.93±2.22
V. kotschyi	Cuticle	-	-	-	10.48	14.83	12.05±1.11
	Upper epidermis	15.82	40.32	26.91±6.83	9.92	19.90	13.78±2.47
	Palisade parenchyma	8.56	17.72	12.12±2.43	21.55	38.41	28.71±4.61
	Spongy parenchyma	11.76	20.59	16.02±2.51	13.81	25.43	19.47±3.75
	Mesophyll layer	-	-	-	167.48	325.89	212.52±46.54
	Lower epidermis	10.50	24.03	17.93±4.62	9.83	21.35	13.48±2.92
V. lasianthum	Cuticle	-	-	-	6.21	10.99	8.04±1.19
	Upper epidermis	9.18	23.41	15.40±3.76	7.30	17.77	12.72±2.96
	Palisade parenchyma	4.69	9.18	6.61±0.93	7.59	15.94	12.71±1.98
	Spongy parenchyma	6.44	11.80	8.94±1.56	7.12	13.03	10.57±1.79
	Mesophyll layer	-	-	-	88.97	191.27	128.24±26.39
	Lower epidermis	11.15	22.12	15.57±3.78	7.97	13.52	11.13±2.65



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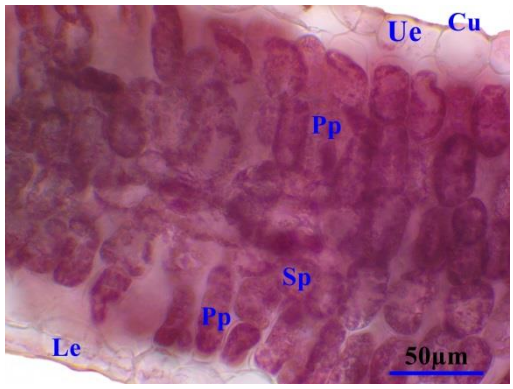
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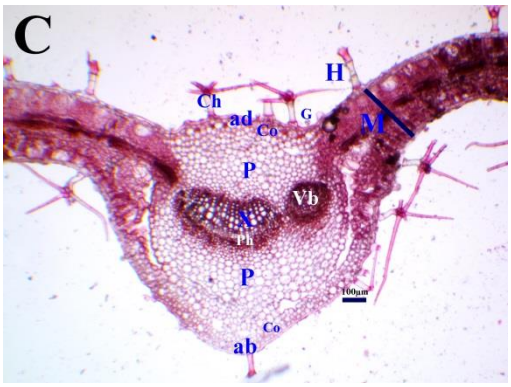
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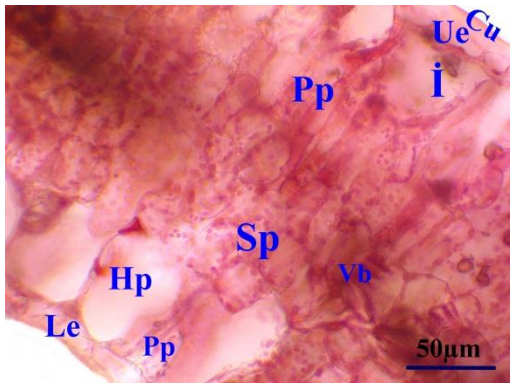
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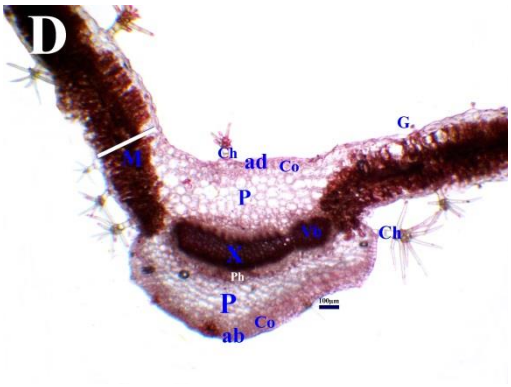
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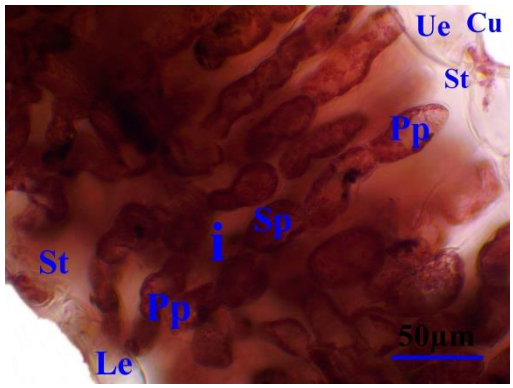
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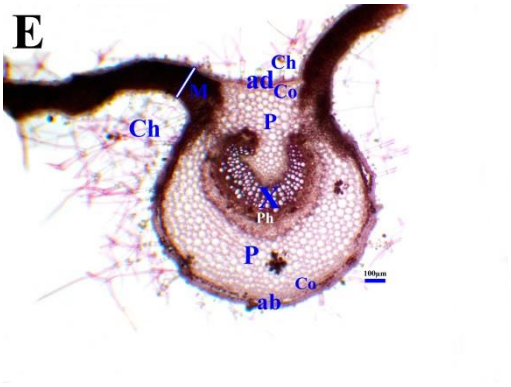
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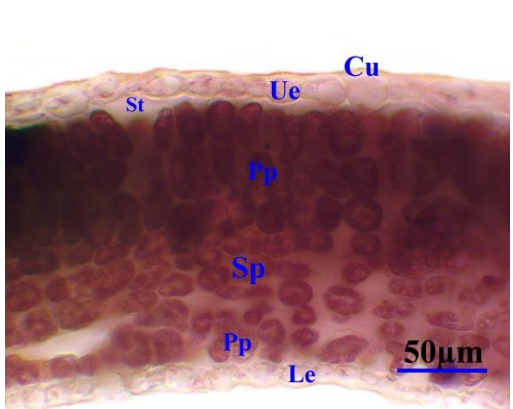
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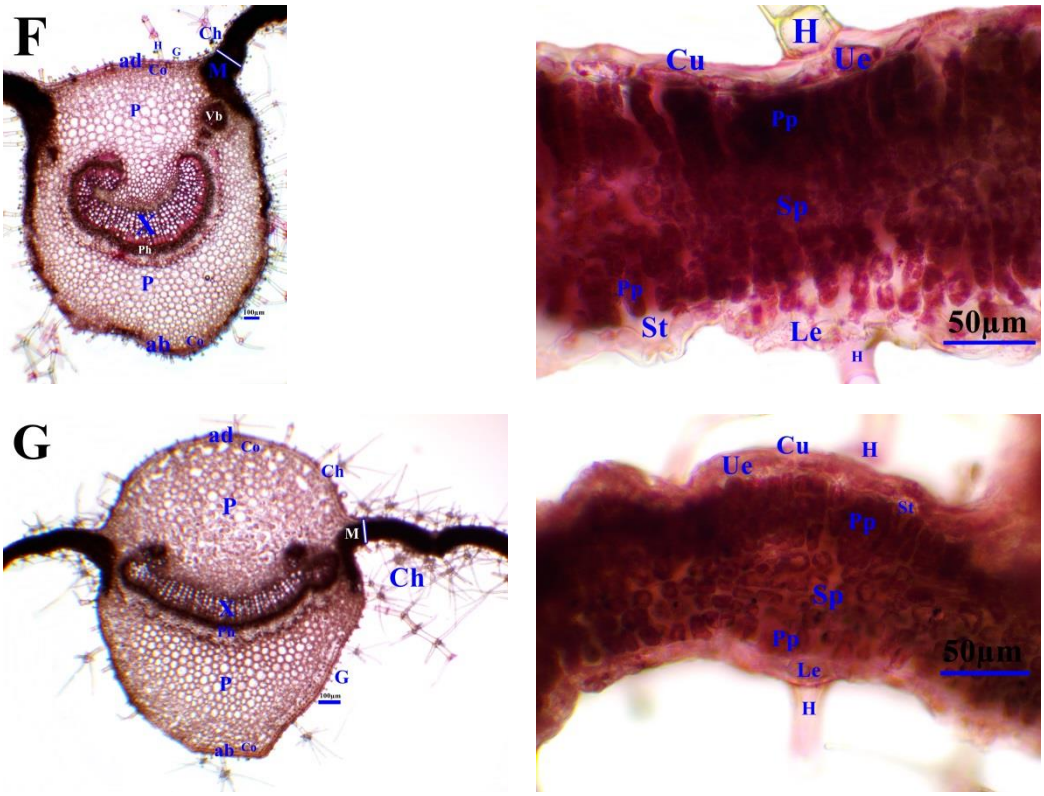

Figure 4. Cross-section of the stem of *Verbascum* **(A)** *V. agrimoniifolium* subsp. *agrimoniifolium*, **(B)** *V. orientale* subsp. *orientale*, **(C)** *V. laetum*, **(D)** *V. geminiflorum*, **(E)** *V. andrusii*, **(F)** *V. kotschyi*, **(G)** *V. lasianthum.* G: Glandular hair, Ch: Compound hair, M: Mesophyll layer, ad: Adaxial surface, Co: Collenchyma, P: Parenchyma, X: Xylem, Ph: Phloem, ab: Abaxial surface, Ue: Upper epidermis, Le: Lower epidermis, Pp: Palisade parenchyma, Sp: Spongy parenchyma, Hp: Hypodermis, i: idioblast, Vb: Vascular bundle.

4. Conclusion

In this study, the anatomical analyzes of seven taxa belonging to the *Verbascum* genus, distributed in the Southeastern Anatolia Region, were examined to ensure comparability with other *Verbascum* members examined.

The tracheae located in the root of the taxa show differences in size and magnitude. V. agrimoniifolium subsp. agrimoniifolium has the largest tracheae, while V. orientale subsp. orientale has the smallest. In V. laetum, V. geminiflorum, V. andrusii and V. lasianthum species, the tracheae are arranged close to the phloem, while in other taxa the tracheae are distributed throughout the vascular bundle. However, all taxa show differences in size and magnitude. A substantial xylem region was seen in the root of every taxon, and the stem had a thick coating of cuticle. Additionally, comparable traits were discovered in earlier research [8,13-19]. Various studies have reported that the cambium in the vascular bundle of the root is unclear [15, 18-19, 25], and this study has shown that the roots of taxa show similar characteristics. With the exception of *V. orientale* subsp. *orientale*, cross-sectional studies of the leaf's epidermal cells revealed densely glandular, non-glandular, and compound multicellular hairs. Similar outcomes have been reported for other *Verbascum* species under investigation [15]. Identification within the *Verbascum* genus may be aided by the presence of idioblasts in the leaf's mesophyll tissue [26]. This work and others have reported the presence of idosblasts (*V. laetum* and *V. geminiflorum*) in the leaf mesophyll [13]. Leaf epidermal characteristics of the common taxa (*V. agrimoniifolium* subsp. *agrimoniifolium*, *V. andrusii*, *V. geminiflorum*, *V. laetum*) used in this study with the study by El-Haadety et al. [27] are similar.

Because the stem of vascular plants is less susceptible to external factors, it is the primary subject of anatomical studies [28]. The distinct physical makeup of this taxa lends credence to this information.

In this study, the importance of several features in the classification of *Verbascum* taxa was investigated (presence of idioblasts in the leaves, stem shape-structure and measurements, etc.). The anatomical investigations revealed that while the taxa's root, stem, and leaf structures were similar, their shapes and sizes, and tissue layer counts varied. Anatomical characteristics such the existence or lack of cambium in the root, the number of collenchyma layers in the stem, the mesophyll forms in the leaves, the presence of idioblasts, and the shape of the midrib provide crucial

taxonomic information as a result of all the data that have been mentioned. In Addition to this, systematic distinction or interpretation of taxa of the genus may benefit from the use of specific features typically associated with their anatomical patterns.

As a result the availability of anatomical data indicates that species distinction can be established with greater accuracy in addition to morphological characteristics. Furthermore, it is obvious that carrying out and supporting such research will contribute both the taxonomic classification of species and genera and modern plant science.

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Author's Contributions

Murat KILIÇ: He did field work. Prepared and wrote the manuscript, performed the anatomical experiments and result analysis.

Fatma MUNGAN KILIÇ: Assisted in analytical analysis on the structure, supervised the experiment's progress, result interpretation and helped in manuscript preparation.

Ethics

There are no ethical issues after the publication of this manuscript.

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