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Anatomical characterization of *Achillea alimeana* and *Linum punctatum* subsp. *pycnophyllum* from southwestern Türkiye

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Abstract
Purpose: This study aimed to investigate the root, stem, leaf anatomy, and stomatal features of *Achillea alimeana* Semiz & Uysal and *Linum punctatum* Presl subsp. *pycnophyllum* (Boiss. & Heldr.) Gustavsson, two taxa with limited anatomical information from southwestern Türkiye. The study also aimed to evaluate the recorded anatomical characters as supplementary data for future taxonomic assessments.
Method: Plant materials were collected from natural populations in Çameli district, Denizli Province, Türkiye. Root, stem, and leaf samples were fixed in 70% ethanol, dehydrated through a graded ethanol series, embedded in paraffin, and sectioned using a rotary microtome. Transverse sections were stained with the Safranin–Fast Green double-staining method and examined under a light microscope equipped with a digital camera system. Stomatal features were examined from superficial leaf sections. Quantitative anatomical measurements were based on 20 measurements for each evaluated character.
Findings: *A. alimeana* was characterized by a circular root, octagonal stem, well-developed lamellar collenchyma at the stem corners, equifacial leaf structure, collateral vascular bundles, eglandular trichomes, and amphistomatic leaves with anomocytic and mesomorphic stomata. *L. punctatum* subsp. *pycnophyllum* showed a fragmented root periderm, circular stem, hypodermal layer, fibre cells, hollow pith region, equifacial mesophyll, collateral vascular bundles, and amphistomatic leaves with paracytic and mesomorphic stomata.
Conclusion: The anatomical characters recorded in this study contribute to the structural characterization of both taxa. These findings provide additional anatomical data for *A. alimeana* and *L. punctatum* subsp. *pycnophyllum* and support the use of vegetative and stomatal anatomy as complementary evidence in taxonomic studies.

Keywords: Asteraceae, Linaceae, stomatal features, vegetative anatomy

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Güneybatı Türkiye'den *Achillea alimeana* ve *Linum punctatum* subsp. *pycnophyllum*'un anatomik karakterizasyonu

Özet
Amaç: Bu çalışma, Türkiye'nin güneybatısından sınırlı anatomik bilgiye sahip iki takson olan *Achillea alimeana* Semiz & Uysal ve *Linum punctatum* Presl subsp. *pycnophyllum* (Boiss. & Heldr.) Gustavsson'un kök, gövde, yaprak anatomisi ve stoma özelliklerini incelemeyi amaçlamıştır. Çalışma ayrıca kaydedilen anatomik karakterleri gelecekteki taksonomik değerlendirmeler için tamamlayıcı veri olarak değerlendirmeyi amaçlamıştır.
Metod: Bitki materyalleri Türkiye'nin Denizli ili, Çameli ilçesindeki doğal popülasyonlardan toplanmıştır. Kök, gövde ve yaprak örnekleri %70 etanolde fikse edilmiş, dereceli etanol serisinden geçirilerek dehidre edilmiş, parafine gömülmüş ve rotatif mikrotom kullanılarak kesitlenmiştir. Enine kesitler Safranin–Fast Green çift boyama yöntemi ile boyanmış ve dijital kamera sistemi ile donatılmış ışık mikroskobu altında incelenmiştir. Stoma özellikleri yüzeysel yaprak kesitlerinden incelenmiştir. Kantitatif anatomik ölçümler, değerlendirilen her karakter için 20 ölçüme dayandırılmıştır.

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Bulgular: *A. alimeana* dairesel kök, sekizgen gövde, gövde köşelerinde iyi gelişmiş lamellar kollenkima, ekvifasiyal yaprak yapısı, kollateral iletim demetleri, örtü tüyleri ve anomositik ve mezomorf stomalara sahip amfistomatik yapraklar ile karakterize edilmiştir. *L. punctatum* subsp. *pycnophyllum* parçalanmış kök peridermi, dairesel gövde, hipodermal tabaka, lif hücreleri, boşluklu öz bölgesi, ekvifasiyal mezofil, kollateral iletim demetleri ve parasitik ve mezomorf stomalara sahip amfistomatik yapraklar göstermiştir.
Sonuç: Bu çalışmada kaydedilen anatomik karakterler her iki taksonun yapısal karakterizasyonuna katkı sağlamaktadır. Bu bulgular *A. alimeana* ve *L. punctatum* subsp. *pycnophyllum* için ek anatomik veriler sağlamakta ve vejetatif ve stoma anatomisinin taksonomik çalışmalarda tamamlayıcı kanıt olarak kullanımını desteklemektedir.

Anahtar kelimeler: Asteraceae, Linaceae, stoma özellikleri, vejetatif anatomi

1. Introduction

Plant anatomy provides a valuable source of evidence for taxonomic studies because many structural characters are less directly visible in external morphology but may remain informative at different systematic levels [1-3]. Vegetative organs may reflect diagnostic variation through the arrangement of epidermal, ground, and vascular tissues, as well as through characters such as mesophyll type, stomatal organization, sclerenchyma development, trichome structure, and secretory elements [3-5]. Such anatomical evidence has been considered useful in groups where species boundaries are difficult to interpret only by macromorphological characters, and it is often evaluated together with palynological, micromorphological, molecular, and ecological data [6, 7]. Therefore, anatomical investigations of rare or endemic taxa can provide additional descriptive and taxonomic information, especially when the available data on the species are still limited [7, 8].

Asteraceae is one of the largest families of flowering plants, and *Achillea* L. is a member of the tribe *Anthemideae* Cass., a taxonomically important group within the family [9-12]. The genus is represented by about 115 taxa worldwide, while Türkiye is one of its important diversity centres, with 60 taxa in six sections and an endemism rate of approximately 55% [12-14]. *Achillea alimeana* Semiz & Uysal was recently described from Akdağ Mountain in Çameli district of Denizli Province, southwestern Türkiye, and placed in sect. *Santolinoidea* DC. In the original description, the species was evaluated using morphological, palynological, and molecular evidence, and it was considered related to *A. aleppica* DC. subsp. *aleppica* and *A. tenuifolia* L. [12]. Although several anatomical and micromorphological studies have been carried out on Turkish endemic *Achillea* taxa, anatomical data are still limited when compared with the taxonomic diversity of the genus [7, 8, 15]. Therefore, anatomical observations on *A. alimeana* may provide additional descriptive information for a recently described and narrowly distributed endemic species [8, 12, 15].

Linum L. is the largest genus of *Linaceae* and includes more than 180 species distributed mainly in temperate and subtropical regions, especially around the Mediterranean area, the Balkans, Anatolia, Eurasia, North Africa, and North America [16-19]. Türkiye has an important position for the genus, and taxonomic studies have reported 55 taxa, 26 of which are endemic [20]. The high number of taxa, subspecies, varieties, and endemic representatives indicates that Anatolia is one of the important diversity centres for Linum [19]. *Linum* punctatum Presl subsp. pycnophyllum (Boiss. & Heldr.) Gustavsson is a rare taxon previously known from western Greece and eastern Anatolia, and a new distribution area from southwestern Anatolia was later reported for this subspecies [21]. In *Linum*, morphological, palynological, seed micromorphological, molecular, and anatomical characters have been used in taxonomic studies, but the infrageneric classification of the genus has remained partly problematic [22, 23]. Previous studies have also shown that stem and leaf anatomical features, including mesophyll organization, stomatal characters, sclerenchyma distribution, and vascular tissue arrangement, may be informative for distinguishing taxa within the genus [3, 4, 19].

Achillea alimeana and *Linum punctatum* subsp. *pycnophyllum* were selected because of their restricted or rare occurrence in southwestern Türkiye and the limited anatomical information available for these taxa. Anatomical characterization can complement the existing morphological, palynological, and molecular evidence for *A. alimeana* [12] and the morphological and distributional information available for *L. punctatum* subsp. *pycnophyllum* [21]. Accordingly, the present study provides detailed descriptions and quantitative measurements of root, stem, and leaf anatomy, together with qualitative observations of stomatal and epidermal features. The findings are discussed within the respective taxonomic context of each genus to provide baseline anatomical data for future comparative studies involving related taxa and additional populations.

2. Materials and methods

2.1. Plant sampling

Plant materials were collected by Batıkan Günal and Gürkan Semiz in June 2022 from natural populations in Çameli district, Denizli Province, southwestern Türkiye: *Achillea alimeana* from its type locality on limestone at Kargın Plateau, Akdağ Mountain, at 1700–1900 m elevation, and *Linum punctatum* subsp. *pycnophyllum* from alpine steppes at

Karkın Plateau, at 2014 m elevation. General views of the studied taxa are shown in Figure 1. The taxa were identified by Batıkan Günal and Gürkan Semiz according to the original description and related taxonomic literature [12, 21]. Voucher specimens were deposited in the Herbarium of the Chemical Ecology Laboratory, Department of Biology, Faculty of Science, Pamukkale University, which is not registered in Index Herbariorum and has no registered herbarium acronym. The voucher numbers are GSE 2449 for *A. alimeana* and GSE 2448 for *L. punctatum* subsp. *pycnophyllum*.

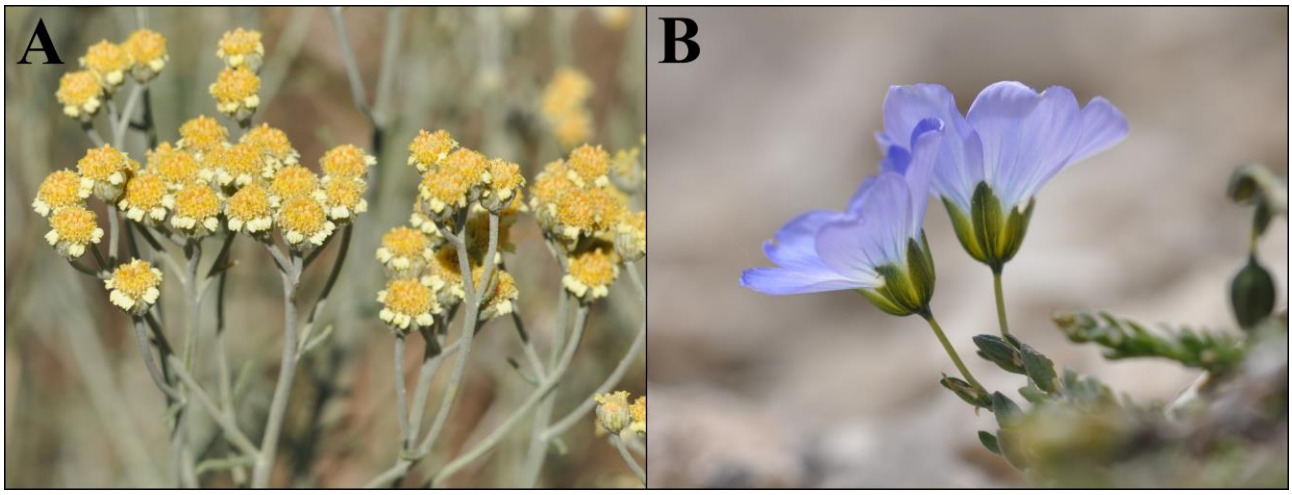

Figure 1. General views of the studied taxa. **A:** *Achillea alimeana*; **B:** *Linum punctatum* subsp. *pycnophyllum*

2.2. Anatomical preparation and microscopy

Both taxa were sampled during the flowering stage. Root sections were taken approximately 1 cm above the root tip. Stem sections and leaf samples were obtained from the middle region of the stem, and leaf transverse sections were taken near the middle of the blade. Fresh materials for transverse sectioning were placed directly in 70% ethanol without any prior fixation procedure and stored until laboratory processing. The samples were dehydrated through a graded ethanol series and embedded in paraffin. Transverse sections approximately 15–20 µm thick were obtained using a rotary microtome. The Safranin–Fast Green double-staining method [24] was applied as follows. Sections were deparaffinized in two successive xylene baths for 30 and 5 min, respectively, and rehydrated through a descending ethanol series (99%, 90%, 70%, and 50%; 5 min each). They were stained with Safranin for 3 h, rinsed three times in distilled water, and transferred to 70% ethanol for 1 min, followed by three brief rinses each in 90% and 99% ethanol. Sections were then counterstained with Fast Green for 1 min, followed by eight rinses in acetic acid, six in distilled water, and eight in 99% ethanol. Finally, sections were cleared in two successive xylene baths for 10 s each and permanently mounted in Entellan.

Anatomical observations and measurements were performed using an Olympus CX23 light microscope equipped with an Olympus EP50 imaging system and EPview software. Anatomical structures were identified and described following the terminology of Metcalfe and Chalk [1] and Dickison [5]. Measurements included tissue thicknesses and cell dimensions in the epidermal, cortical, supporting, vascular, and pith regions, as well as leaf mesophyll cells (Tables 1 and 2). Five individuals of each taxon were examined, with four transverse sections examined per individual. A total of 20 measurements were obtained for each character, using a single field of view in each section. All measurements were recorded in µm, and means and standard deviations were calculated using Minitab Statistical Software version 21.4.2. The analysis was purely descriptive, and no statistical comparisons were performed between the two taxa. Epidermal peels were prepared from both the adaxial and abaxial surfaces of fresh leaves to qualitatively examine stomatal type, stomatal distribution, and the structure and arrangement of epidermal cells. Stomatal density and other quantitative stomatal parameters were not measured.

3. Results

The anatomical examination of *A. alimeana* and *L. punctatum* subsp. *pycnophyllum* revealed distinct vegetative and stomatal features in both taxa. In both species, root, stem, leaf, and stomatal characters were examined in detail using transverse sections of vegetative organs and superficial leaf sections for stomatal observations. The results showed that each taxon has a recognizable anatomical organization in terms of root structure, stem outline, arrangement of supporting and vascular tissues, mesophyll organization, trichome presence, and stomatal features.

3.1. Anatomical features of *Achillea alimeana*

Root: The root of *A. alimeana* was generally circular in transverse section. The outermost region consisted of a relatively thin but firm periderm layer, followed by a cortex composed of 8–9 rows of irregular parenchymatous cells. A distinct single-layered endodermis was observed beneath the cortex, and sclerenchyma cells with thickened walls were present below the endodermis. The vascular region included phloem, a 2–3-layered cambium, and xylem elements, while the central pith region included large parenchymatous cells surrounding a central cavity (Figure 2A-2B, Table 1).

Stem: The stem was octagonal in transverse section. The epidermis was single-layered and composed of cubic cells, and the surface was densely covered with eglandular trichomes. Beneath the epidermis, the cortex consisted of collenchyma and parenchyma tissues, while 8–10 rows of lamellar collenchyma were observed at the stem corners. A single-layered endodermis, sclerenchyma, phloem, cambium, xylem elements, and a broad hollow pith region were clearly distinguished in the stem structure (Figure 2C-2D, Table 1).

Leaf: The leaves were pinnatisect and equifacial in anatomical structure. Both adaxial and abaxial epidermal layers were single-layered, composed of cubic cells, and covered by a thin cuticle. Palisade parenchyma was arranged in two layers along both leaf surfaces, while spongy parenchyma was clearly differentiated and contained intercellular spaces. The vascular bundle in the midrib was collateral, with the xylem oriented toward the adaxial epidermis. The leaf surfaces were covered with trichomes (Figure 2E-2F, Table 1).

Table1. Mean measurement values of the anatomical characters of *A. alimeana* (*n* = 20).

		Width/Thickness (µm) $\bar{x} \pm SD$	Length (µm) $\bar{x} \pm SD$	Diameter (µm) $\bar{x} \pm SD$
Root	**Periderm**	13.64 ± 2.42		
	Cortex parenchyma cells	21.76 ± 4.24	26.47 ± 4.06	
	Endodermis	23.62 ± 2.52	10.78 ± 1.55	
	Phloem			5.63 ± 0.72
	Cambium	12.15 ± 1.85	6.20 ± 1.10	
	Tracheary elements			19.97 ± 2.75
	Pith parenchyma cells			37.49 ± 4.06
Stem	**Epidermis**	12.91 ± 1.96	8.34 ± 1.18	
	Cortex parenchyma cells	20.24 ± 1.96	13.32 ± 1.67	
	Collenchyma	10.77 ± 1.61	12.96 ± 1.92	
	Endodermis	22.62 ± 2.46	15.34 ± 2.02	
	Sclerenchyma			7.96 ± 0.99
	Phloem			7.19 ± 0.95
	Tracheary elements			23.36 ± 2.30
	Pith parenchyma cells			48.45 ± 5.68
Leaf	**Adaxial epidermis**	21.32 ± 2.30	16.46 ± 1.80	
	Abaxial epidermis	22.30 ± 2.50	17.06 ± 1.86	
	Palisade parenchyma	10.13 ± 1.17	33.37 ± 2.57	
	Spongy parenchyma			17.51 ± 2.65
	Tracheary elements			7.22 ± 1.46
	Phloem			6.16 ± 0.87

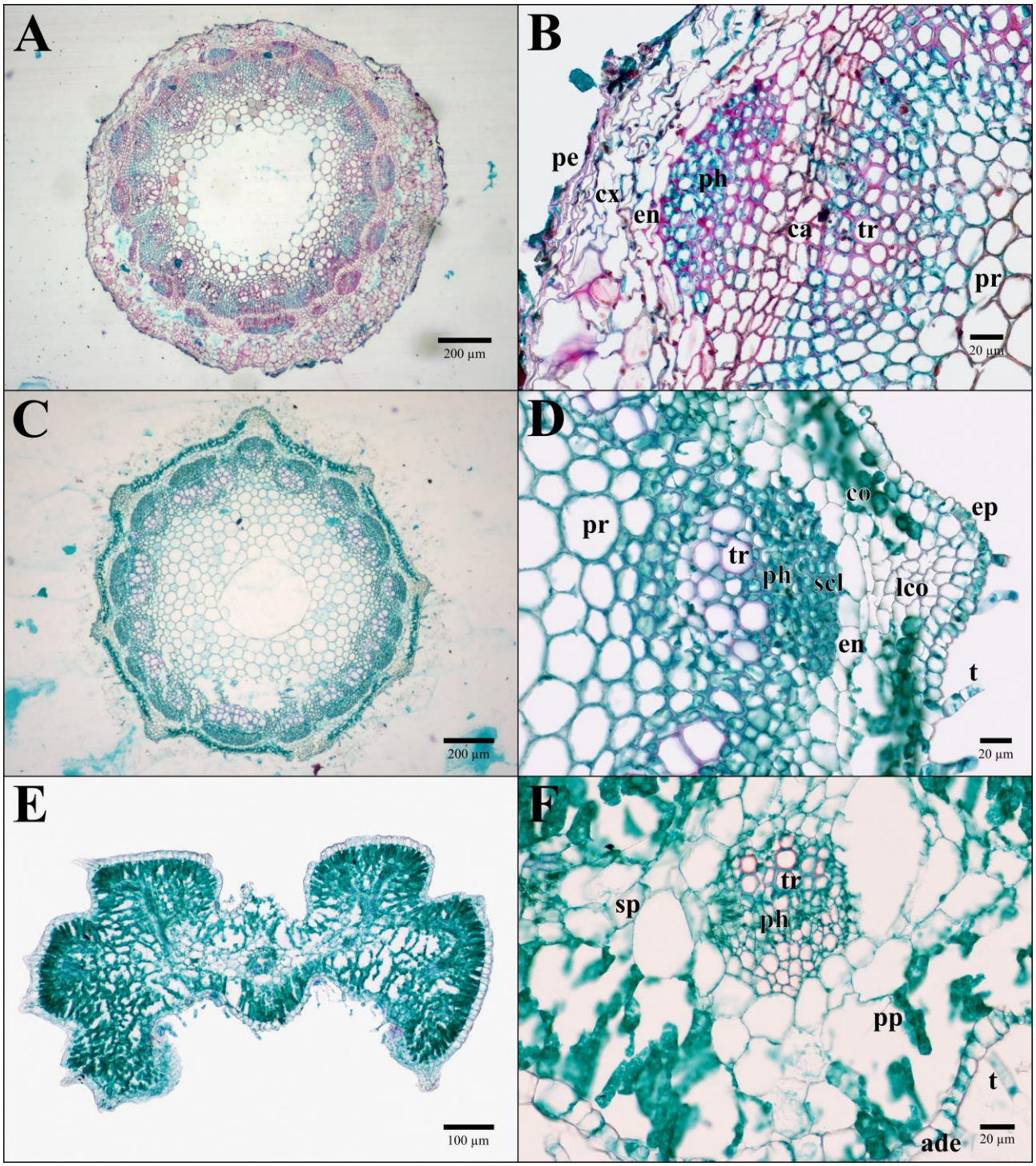

Figure 2. Anatomical sections of *A. alimeana*. **A–B:** root transverse section; **C–D:** stem transverse section; **E–F:** leaf transverse section (**pe:** periderm; **cx:** cortex; **en:** endodermis; **ph:** phloem; **ca:** cambium; **tr:** tracheary elements; **pr:** pith region; **ep:** epidermis; **co:** collenchyma; **scl:** sclerenchyma; **lco:** lamellar collenchyma; **pp:** palisade parenchyma; **sp:** spongy parenchyma; **t:** trichome)

3.2. Anatomical features of *Linum punctatum* subsp. *pycnophyllum*

Root: In transverse section, the root of Linum punctatum subsp. pycnophyllum showed a fragmented periderm layer in the outermost region. Beneath the periderm, a relatively thick cortex was observed, consisting of rectangular to nearly rectangular parenchymatous cells. The vascular region included phloem and densely arranged xylem elements, and pith rays were visible within the vascular tissue. The pith occupied a narrow central region and was composed of rounded parenchymatous cells (Figure 3A-3B, Table 2).

Stem: The stem was circular in transverse section and covered by a cuticle. Stem protrusions were not observed in the transverse sections. The epidermis consisted of a single layer of cubic cells, and a hypodermal layer composed of oval cells was located beneath the epidermis. Below this region, collenchyma tissue and parenchymatous cells containing fibre cells were observed. The vascular region consisted of phloem and xylem elements, and the vascular bundle occupied a distinct area in the stem. The pith region was hollow, with large and rounded pith parenchyma cells (Figure 3C-3D, Table 2).

Leaf: The leaf surface was covered by a cuticle, and both adaxial and abaxial epidermal layers were single-layered and composed of cubic cells. The leaf was equifacial in anatomical structure. Palisade parenchyma was arranged in 1–2 layers and consisted mostly of elongated cylindrical cells, whereas the spongy parenchyma was composed of dense, rounded to oval cells. The vascular bundle in the midrib was collateral, and sclerenchymatic cells were observed above the phloem region (Figure 3E-3F, Table 2).

Table 2. Mean measurement values of the anatomical characters of *L. punctatum* subsp. *pycnophyllum* (*n* = 20)

		Width/Thickness (µm) $\bar{x} \pm SD$	Length (µm) $\bar{x} \pm SD$	Diameter (µm) $\bar{x} \pm SD$
Root	**Periderm**	52.71 ± 8.97		
	Cortex parenchyma cells	25.05 ± 2.30	14.94 ± 1.96	
	Tracheary elements			11.16 ± 0.94
	Phloem			6.64 ± 0.91
	Pith parenchyma cells			17.13 ± 2.34
	Cortex thickness	139.11 ± 12.37		
Stem	**Cuticle**	2.47 ± 0.38		
	Epidermis	22.39 ± 2.58	17.35 ± 1.64	
	Hypodermis	27.55 ± 2.56		
	Collenchyma	16.07 ± 2.34	15.49 ± 2.16	
	Fibre cells			14.06 ± 2.01
	Tracheary elements			9.65 ± 1.29
	Phloem			6.94 ± 0.93
	Vascular bundle	62.94 ± 5.95		
	Pith parenchyma cells			17.23 ± 1.24
Leaf	**Adaxial epidermis**	28.99 ± 5.57	21.42 ± 4.03	
	Abaxial epidermis	31.59 ± 4.14	26.17 ± 2.82	
	Palisade parenchyma	10.33 ± 1.87	31.06 ± 3.65	
	Spongy parenchyma			14.70 ± 1.47
	Phloem			6.79 ± 1.06
	Tracheary elements			6.46 ± 0.70
	Mesophyll	166.42 ± 8.93		

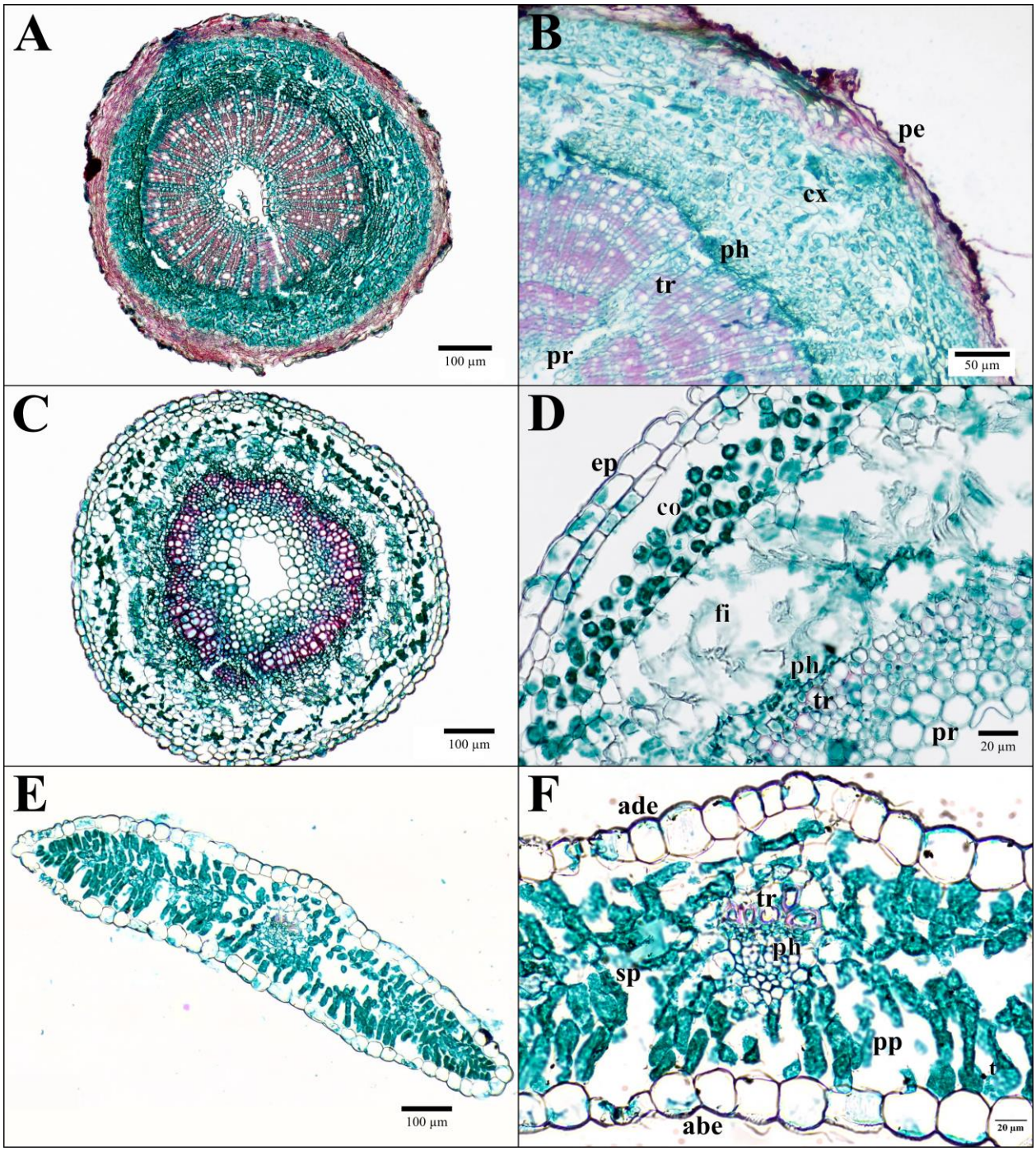

Figure 3. Anatomical sections of *L. punctatum* subsp. *pycnophyllum*. **A–B:** root transverse section; **C–D:** stem transverse section; **E–F:** leaf transverse section (**abe:** abaxial epidermis; **ade:** adaxial epidermis; **co:** collenchyma; **cx:** cortex; **ep:** epidermis; **fi:** fibre cells; **pe:** periderm; **ph:** phloem; **pp:** palisade parenchyma; **pr:** pith region; **sp:** spongy parenchyma; **tr:** tracheary elements.)

3.3. Stomatal features

The leaves of *A. alimeana* were amphistomatic, with stomata present on both adaxial and abaxial surfaces. The stomata were anomocytic according to the arrangement of the surrounding epidermal cells. In transverse section, they were positioned at the same level as the epidermal cells, indicating a mesomorphic stomatal condition (Figure 4A).

The leaves of *L. punctatum* subsp. *pycnophyllum* were also amphistomatic. The stomata were observed on both adaxial and abaxial surfaces and were positioned at the same level as the surrounding epidermal cells, indicating a mesomorphic stomatal condition. According to the arrangement of neighbouring cells, the stomata were paracytic (Figure 4B).

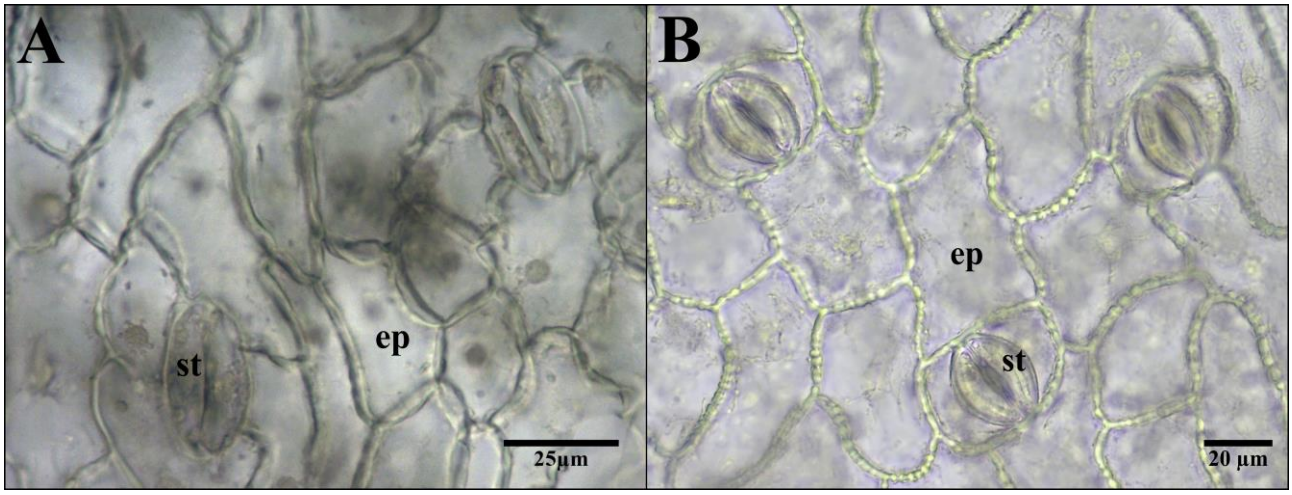

Figure 4. Superficial view of stomata and epidermal cells in the studied taxa. **A:** *A. alimeana* showing anomocytic stomata; **B:** *L. punctatum* subsp. *pycnophyllum* showing paracytic stomata (**ep:** epidermal cells; **st:** stomata)

4. Discussion

The present study provides anatomical data on the root, stem, leaf, and stomatal features of *Achillea alimeana* and *Linum punctatum* subsp. *pycnophyllum*. The results show that both taxa have clearly recognizable vegetative anatomical characters, including differences in root organization, stem outline, supporting tissue arrangement, mesophyll structure, vascular bundle organization, and stomatal type. In *A. alimeana*, characters such as the octagonal stem outline, lamellar collenchyma, equifacial leaf structure, and anomocytic stomata are notable, whereas *L. punctatum* subsp. *pycnophyllum* is characterized by a circular stem, hypodermal layer, fibre cells, equifacial mesophyll, and paracytic stomata. These findings indicate that vegetative and stomatal anatomical characters may provide useful supplementary information for the anatomical characterization of these taxa when evaluated together with previous morphological, palynological, micromorphological, molecular, and distributional data [3,8,12,15,21,22].

In *A. alimeana*, the root, stem, and leaf anatomy generally agree with the main structural patterns reported for other Turkish endemic *Achillea* taxa, but some characters provide useful descriptive information for the species. The presence of a distinct endodermis in the root and stem is consistent with previous observations in *A. phrygia*, *A. gypsicola*, and *A. sivasica*, where the endodermal layer was also recorded as a prominent anatomical feature [8,15]. The octagonal stem outline, well-developed lamellar collenchyma at the stem corners, sclerenchymatous tissue above the vascular region, and broad pith region characterize the stem anatomy of *A. alimeana*. Similar supporting tissue organization has been reported in endemic *Achillea* species, although stem outline may vary among taxa and may therefore be useful as a descriptive anatomical character [8,15]. In the leaf, the equifacial mesophyll structure of *A. alimeana* is comparable to that reported for *A. sivasica*, whereas *A. phrygia* and *A. gypsicola* were described as having bifacial mesophyll [8,15]. Unlike *A. sivasica*, in which secretory ducts were reported in root, stem, and leaf tissues, such structures were not observed in the examined sections of *A. alimeana* [15]. Therefore, the combination of stem outline, supporting tissue arrangement, equifacial mesophyll, and absence of observed secretory ducts contributes to the anatomical characterization of this recently described endemic species.

In *L. punctatum* subsp. *pycnophyllum*, the anatomical structure of the root, stem, and leaf shows several characters that can be evaluated within the general anatomical framework reported for *Linum*. The root was characterized by a fragmented periderm, a relatively thick cortex, densely arranged xylem elements, pith rays, and a narrow pith region. In the stem, the circular outline, cuticularized epidermis, hypodermal layer, collenchyma, fibre cells, vascular tissues, and hollow pith region represent the main structural features of the taxon. Previous anatomical studies on *Linum* have shown that stem structure, especially the presence or absence of stem protrusions, fibre tissue, sclerenchyma distribution, and vascular tissue arrangement, may vary among taxa and may have taxonomic value [23]. In this respect, the absence of stem protrusions in *L. punctatum* subsp. *pycnophyllum* is noteworthy, since such protrusions have been reported in some other *Linum* taxa and suggested to be useful in sectional or taxonomic evaluations [23]. The leaf anatomy of the taxon, including its equifacial mesophyll, collateral vascular bundle, and sclerenchymatic cells above the phloem region, is also consistent with the range of anatomical variation previously reported in the genus [19]. Therefore, the root, stem, and leaf characters recorded here provide additional anatomical information for *L. punctatum* subsp. *pycnophyllum* and may contribute to future comparative studies within *Linum*.

Stomatal characters also provide useful supplementary information for both taxa. In *A. alimeana*, the leaves were amphistomatic, and the stomata were anomocytic and mesomorphic. Anomocytic stomata have also been reported in several *Achillea* taxa, including *A. phrygia*, *A. gypsicola*, *A. sivasica*, *A. distans*, *A. stricta*, and *A. carpatica*,

suggesting that this stomatal type is common within the genus [8, 15, 25]. In *L. punctatum* subsp. *pycnophyllum*, the leaves were also amphistomatic and mesomorphic, but the stomata were paracytic. Previous studies on *Linum* have shown that stomatal distribution, stomatal type, and mesophyll organization may vary among taxa and may contribute to anatomical characterization when evaluated together with other vegetative traits [3,4,19,23]. Therefore, stomatal features should be considered as complementary characters contributing to the anatomical profile of each taxon within its respective taxonomic context.

The anatomical features documented here provide a basis for future comparisons with closely related taxa, particularly regarding stem outline, supporting tissue arrangement, mesophyll organization, and stomatal type. However, closely related taxa were not directly examined, and the diagnostic value of these characters for distinguishing the studied taxa from their nearest relatives remains to be tested. Comparisons with published anatomical descriptions should therefore be interpreted as contextual evidence rather than proof of species- or subspecies-level discrimination.

5. Conclusions

This study provides anatomical data on the root, stem, leaf, and stomatal features of *Achillea alimeana* and *Linum punctatum* subsp. *pycnophyllum*. The results contribute to the anatomical characterization of *A. alimeana*, a recently described endemic species, and provide supplementary anatomical information for *L. punctatum* subsp. *pycnophyllum*, a rare taxon recorded from southwestern Anatolia. The observed characters, including stem outline, supporting tissue arrangement, mesophyll structure, vascular bundle organization, trichome occurrence, and stomatal type, may be useful in future comparative studies involving related taxa. However, these anatomical characters should be regarded as complementary rather than primary diagnostic evidence and should be evaluated together with morphological, palynological, micromorphological, molecular, and distributional data. Further studies based on broader population sampling and closely related taxa would help clarify the taxonomic value of these anatomical features.

Artificial Intelligence Statement

( ) This article did not use artificial intelligence.

(X) This article does use artificial intelligence. During the preparation of this manuscript, the authors used ChatGPT to improve English phrasing and grammar. The authors reviewed and edited the content as needed and take full responsibility for the framework and validity of the final paper

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Ethical statement: "This study does not require ethical approval")

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( ) Option D (No Data): "No new data were created or analyzed in this study. Data sharing is not applicable to this article."

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