



Anatomical features of some *Jordania* Boiss. taxa in the *Caryophyllaceae* (Caryophyllaceae) family

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Caryophyllaceae (Caryophyllaceae) familyasındaki bazı *Jordania* Boiss. taksonlarının anatomik özellikleri

Abstract: This study aims to provide a detailed anatomical investigation of root, stem, and leaf structures in taxa belonging to the genus *Jordania*. Cross-sections of different species were analyzed to compare their anatomical characteristics. The findings reveal that the root tissues exhibit well-developed vascular structures with open collateral vascular bundles. The stem sections are characterized by dense trichomes, with the cuticle of covering trichomes showing silicification. The endodermis layer consists of a single row of cells containing abundant druse crystals. A wide pith region with large, transparent pith cells is observed at the center of the stem. The leaves are amphistomatic with an equifacial mesophyll structure. The vascular bundles in the leaves are collateral, and numerous druse crystals are found above the sclerenchyma cluster. These anatomical features support the differentiation of *Jordania* taxa and contribute to their taxonomic classification.

Key words: *Jordania*, anatomy, *Caryophyllaceae*, Türkiye

Özet: Bu çalışma, *Jordania* cinsine ait taksonların kök, gövde ve yaprak anatomik özelliklerini detaylı bir şekilde incelemeyi amaçlamaktadır. Çalışma kapsamında, türlerin enine kesitleri analiz edilerek anatomik karakterleri karşılaştırılmıştır. Bulgular, köklerde iyi gelişmiş bir iletim dokusunun bulunduğunu ve açık kollateral iletim demetleri sergilediğini ortaya koymuştur. Gövde kesitleri yoğun tüylenme ile karakterize olup, örtü tüylerinin kütikülalarının silisleşmiş olduğu belirlenmiştir. Endodermis tabakası tek sıralı hücrelerden oluşmakta ve yoğun miktarda druz kristali içermektedir. Gövde merkezinde geniş bir öz bölgesi ve büyük, şeffaf öz hücreleri gözlemlenmiştir. Yapraklar amfistomatik olup ekvifasiyal mezofil yapısına sahiptir. Yaprak iletim demetleri kollateral tiptedir ve sklerankima kümesi üzerinde yoğun druz kristalleri bulunmaktadır. Bu anatomik bulgular, *Jordania* cinsine ait türlerin belirlenmesini desteklemekte ve taksonomik sınıflandırmaya katkı sağlamaktadır.

Anahtar Kelimeler: *Jordania*, anatomi, *Caryophyllaceae*, Türkiye

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1. Introduction

Caryophyllaceae Juss. family includes approximately 100 genus and 3000 species (Hernandez-Ledesma et al., 2015), primarily comprising annual and perennial herbs and subshrubs. Although the *Caryophyllaceae* family has a mainly Holarctic distribution, it is also widely distributed in the temperate regions of the northern hemisphere, with a center in the Mediterranean and Irano-Turanian regions (Bittrich 1993, Heywood 1998).

Jordania is an earlier name for the Turkish representatives of *Bolanthus*. In their 2024 publication, Madhani et al. reported that the genus *Jordania* comprises 14 species, including 11 *Bolanthus* species accepted by Koç et al. (2019), one species transferred to *Bolanthus* by Madhani et al. (2018), and two *Phrynella* species. Except for one species (*J. confertifolia*) and one variety (*J. frankenioides* var. *libanotica* (Boiss.) Rabeler & Madhani), all species are endemic to Turkey. To accommodate the taxa recognized by *Plants of the World Online* (powo.science.kew.org), two resurrected names and 14 new combinations were provided in *Jordania* Boiss. (Madhani et al., 2024).

In this study, the anatomical characters (some of them) of *J. confertifolia*, *J. minuartioides*, *J. thymoides*, *J. aziz-sancarii*, *J. turcica* and *J. cherlerioides* were revealed for the first time and contributed to the classification at the subspecies level.

2. Materials and Method

2.1. Anatomical studies

Jordania species were collected from different localities, and the plant specimens were deposited in the Herbarium of Ankara Yıldırım Beyazıt University (AYBÜ). The plants belonging to the genus *Jordania* were collected during fieldwork and fixed in 70% ethanol.

In the anatomical studies, at least three individuals were selected from each species, and three main organs—root, stem, and leaf—were examined for each individual. All sections were taken transversely (cross-sections) and from the middle region of each organ.

The collected organ samples were cut into small pieces using a scalpel and then subjected to the paraffin embedding method (Johansen, 1940). The tissues

embedded in paraffin blocks were sectioned at a thickness of 8–10 µm using a Leica RM2245 rotary microtome.

The sections were stained with Safranin–Fast Green and mounted with Entellan to prepare permanent slides. The best-quality sections were selected and examined under a Leica DM1000 binocular light microscope at 10x, 20x, and 40x magnifications, and photographed using a Leica DFC280 camera. Measurements were carried out on more than 30 anatomical structures per species, and the cell widths and lengths were determined using the AutoCAD program.

2.2. Statistical Analyses

Statistical evaluations were performed using the SPSS software (Statistics Program for Social and Science; v27.0; IL, USA). In the study, 30 measurements were taken for each anatomical character, and the results were presented as Min- (mean ± SD) – Max values. A significance level of $p < 0.05$ was considered statistically significant. For the analyses, normality tests (Kolmogorov-Smirnov), the Kruskal-Wallis test, and hierarchical clustering (Hierarchical Cluster) with dendrogram tests were used.

3. Results

3.1. Anatomical Analysis

3.1.1. Root anatomy

— *J. confertifolia*: In transverse root sections, *J. confertifolia* exhibits a well-defined circular structure. The periderm layer, located at the outermost part of the root, appears compressed, fragmented, or detached in certain areas. The peridermis consists of 4–5 layers of rectangularly arranged phellem cells. The cortex, extending inward from the periderm, is composed of 6–8 layers of regularly arranged oval or rectangular parenchymatic cells. The vascular tissue is well-developed and exhibits an open collateral vascular bundle system. The phloem, consisting of 5–7 layers of small rectangular or square-shaped cells, occupies a relatively narrow region, whereas the xylem is more extensive and comprises larger, rounded cells. In transverse root sections, the xylem elements completely

occupy the pith region, making it indistinguishable (Fig. 1, Table 2).

— *J. turcica*: In transverse root sections, *J. turcica* exhibits a well-defined circular structure and distinct features indicative of secondary growth. The periderm layer, located on the outermost part of the root, appears compressed, fragmented, or detached in certain areas. The peridermis consists of 6–8 layers of rectangularly arranged phellem cells. The cortex, extending from the periderm towards the center, is composed of 8–10 layers of regularly arranged oval or rectangular parenchymatic cells. The vascular tissue is well-developed and exhibits an open collateral vascular bundle system. The phloem, consisting of 6–7 layers of small rectangular or square-shaped cells, occupies a relatively narrow region, whereas the xylem is more extensive and comprises larger, rounded cells. At the center of the root, translucent, rounded pith cells are present, forming a distinct structural component (Fig. 1, Table 2).

— *J. minuartioides*: In transverse root sections, *J. minuartioides* exhibits a well-defined circular structure. The periderm layer, located on the outermost part of the root, appears compressed, fragmented, or detached in certain areas. The peridermis consists of 6–7 layers of rectangularly arranged phellem cells. The cortex, extending inward from the periderm, is composed of 6–8 layers of regularly arranged oval or rectangular parenchymatic cells. The vascular tissue is well-developed and exhibits an open collateral vascular bundle system. The phloem, consisting of 5–6 layers of small rectangular or square-shaped cells, occupies a relatively narrow region, whereas the xylem is more extensive and comprises larger, rounded cells. In transverse root sections, the xylem elements completely occupy the pith region, making it indistinguishable (Fig. 1, Table 2).

— *J. cherlerioides*: In transverse root sections, *J. cherlerioides* exhibits a well-defined circular structure. The periderm layer, located on the outermost part of the root, appears fragmented, compressed, or detached in certain areas. The peridermis consists of 4–8 layers of

Table 1. Localities of the studied taxa

Species of <i>Jordania</i>	Localities	Herbarium number	Collection Date
<i>Jordania aziz-sancarii</i> (Koç & Hamzaoglu) Rabeler & Madhani	Afyonkarahisar: Between Bayat and Işçehisar, 1500 m, volcanic tuff	Koç 3590	02.07.2022
<i>Jordania cherlerioides</i> (Bornm.) Rabeler & Madhani	Isparta: Around the summit of Davraz Mountain, 2010 m	Koç 3625	30.06.2022
<i>Jordania confertifolia</i> (Hub.-Mor.) Rabeler & Madhani	Burdur: Yeşilova, around Salda lake, serpentine, stony places, 1180 m	Koç 3623	29.06.2022
<i>Jordania turcica</i> (Koç & Hamzaoglu) Rabeler & Madhani	Aksaray: Above Karkın Village, south of Hasan Mountain, around Karbeyaz Hotel, subalpine steppe, 2760 m	Koç 3714	07.08.2023
<i>Jordania minuartioides</i> (Jaub. & Spach) Boiss. & Heldr.	Denizli Babadağ, stony places and forest clearings 1190 m	Koç 3609	28.06.2022
<i>Jordania thymoides</i> (Hub.-Mor.) Rabeler & Madhani	Burdur: Yeşilova, around Salda lake, serpentine, stony places, 1180 m	Koç 3621	29.06.2022

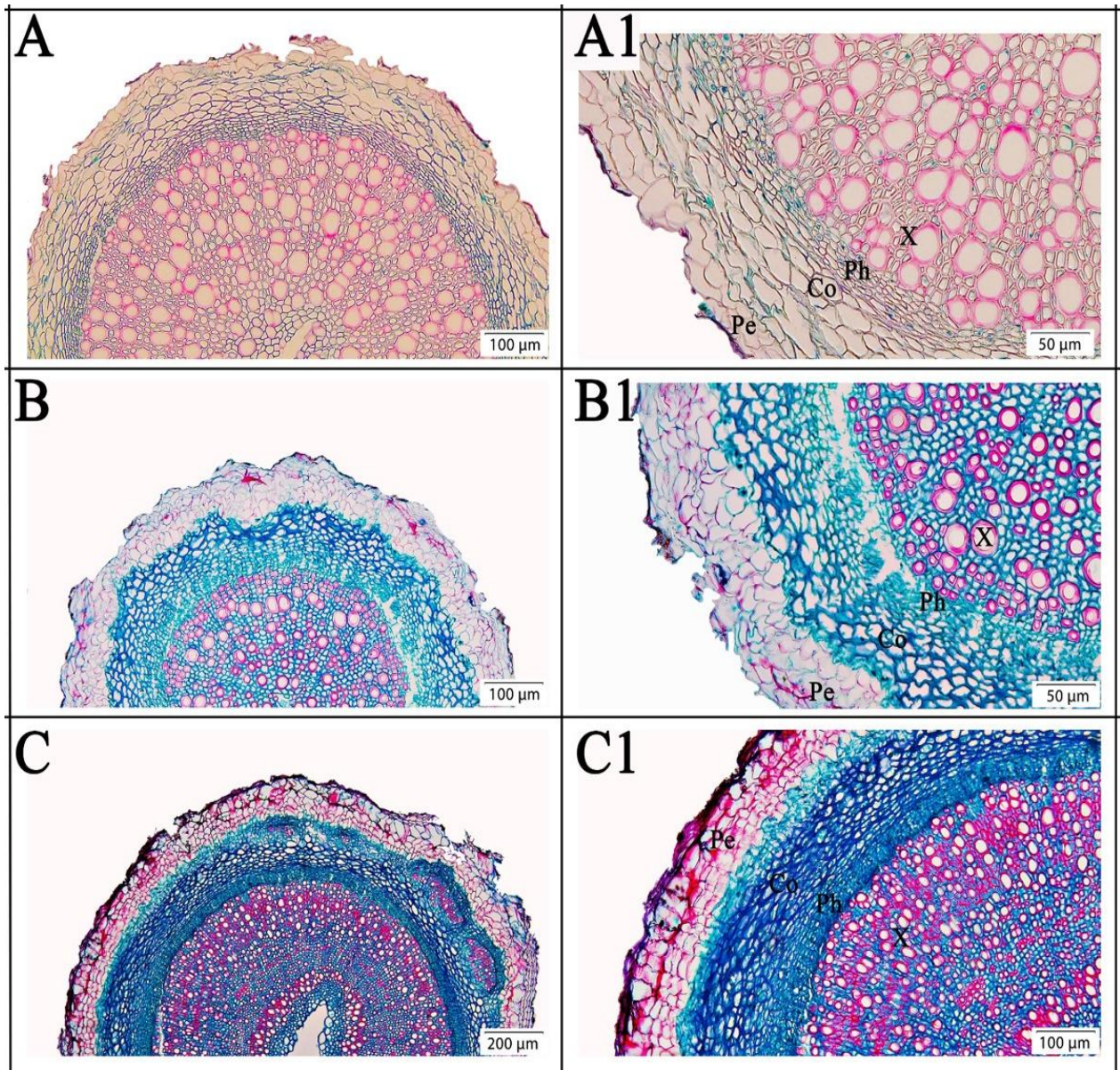


Figure 1. Cross-section of the root. A–A1: General and detailed view of *J. confertifolia*, B–B1: General and detailed view of *J. minuartioides*, C–C1: General and detailed view of *J. turcica*. Pe: Peridermis, Co: Cortex, Ph: Phloem, X: Xylem

rectangularly arranged phellem cells. The cortex, extending inward from the periderm, is composed of 7–8 layers of regularly arranged oval or rectangular parenchymatic cells. The vascular tissue is well-developed and exhibits an open collateral vascular bundle system. The phloem, consisting of 5–6 layers of small rectangular or square-shaped cells, occupies a relatively narrow region, whereas the xylem is more extensive and comprises larger, rounded cells. In transverse root sections, the xylem elements completely occupy the pith region, making it indistinguishable (Fig. 2, Table 2).

— *J. thymoides*: In transverse root sections, *J. thymoides* exhibits a well-defined circular structure and distinct features indicative of secondary growth. The periderm layer, located on the outermost part of the root, appears compressed, fragmented, or detached in certain areas. The peridermis consists of 6–8 layers of rectangularly arranged phellem cells. The cortex, extending inward from the periderm, is composed of 6–8 layers of regularly arranged oval or rectangular parenchymatic cells.

The vascular tissue is well-developed and exhibits an open collateral vascular bundle system. The phloem, consisting of 5–7 layers of small rectangular or square-shaped cells, occupies a relatively narrow region, whereas the xylem is more extensive and comprises larger, rounded cells. In transverse root sections, the xylem elements completely occupy the pith region, making it indistinguishable (Fig. 2, Table 2).

— *J. aziz-sancarii*: In transverse root sections, *J. aziz-sancarii* exhibits a well-defined circular structure. The periderm layer, located on the outermost part of the root, appears compressed, fragmented, or detached in certain areas. The peridermis consists of 3–6 layers of rectangularly arranged phellem cells. The cortex, extending inward from the periderm, is composed of 3–5 layers of regularly arranged oval or rectangular parenchymatic cells. The vascular tissue is well-developed and exhibits an open collateral vascular bundle system. The phloem, consisting of 4–6 layers of small rectangular or square-shaped cells, occupies a relatively narrow region, whereas the xylem is

more extensive and comprises larger, rounded cells. In transverse root sections, the xylem elements completely occupy the pith region, making it indistinguishable (Fig. 2, Table 2).

3.1.2. Stem Anatomy

— *J. confertifolia*: In the transverse sections of the *J. confertifolia* stem, the epidermal cells were observed to be single-layered, regularly arranged, and nearly rectangular to oval in shape. A thin, wavy cuticle layer covered the epidermis. The stem was densely covered with trichomes originating from the epidermis, including numerous covering hairs and a few glandular hairs. The cuticle of the covering hairs was silicified. The stem generally had a round shape, but structural variations were observed in regions with collenchymatic cells. The cortex consisted of 3-4 layers of cylindrically arranged parenchymatic cells. The endodermis, following the cortex, was composed of a single layer of round-rectangular cells and contained abundant druse crystals. The sclerenchyma layer typically

consisted of 4-6 layers of cells, with the outermost cells having thick walls and narrow lumens, while toward the center, the cell walls became thinner and lumens wider. The vascular bundle system comprised phloem (6-7 cell layers) and xylem (3-7 cell layers), with the phloem occupying a narrower area than the xylem. At the center of the transverse sections, a large pith region was observed, containing large, transparent, round pith cells. These pith cells had a parenchymatic structure and included a distinct pith cavity (Fig. 3, Table 3).

— *J. minuartioides*: In the transverse sections of the *J. minuartioides* stem, the epidermal cells were observed to be single-layered, regularly arranged, and nearly rectangular to oval in shape. A thin, wavy cuticle layer covered the epidermis. The stem was densely covered with trichomes originating from the epidermis, consisting of numerous covering hairs and a few glandular hairs. The cuticle of the covering hairs was silicified. The stem generally exhibited a round shape. The cortex consisted of

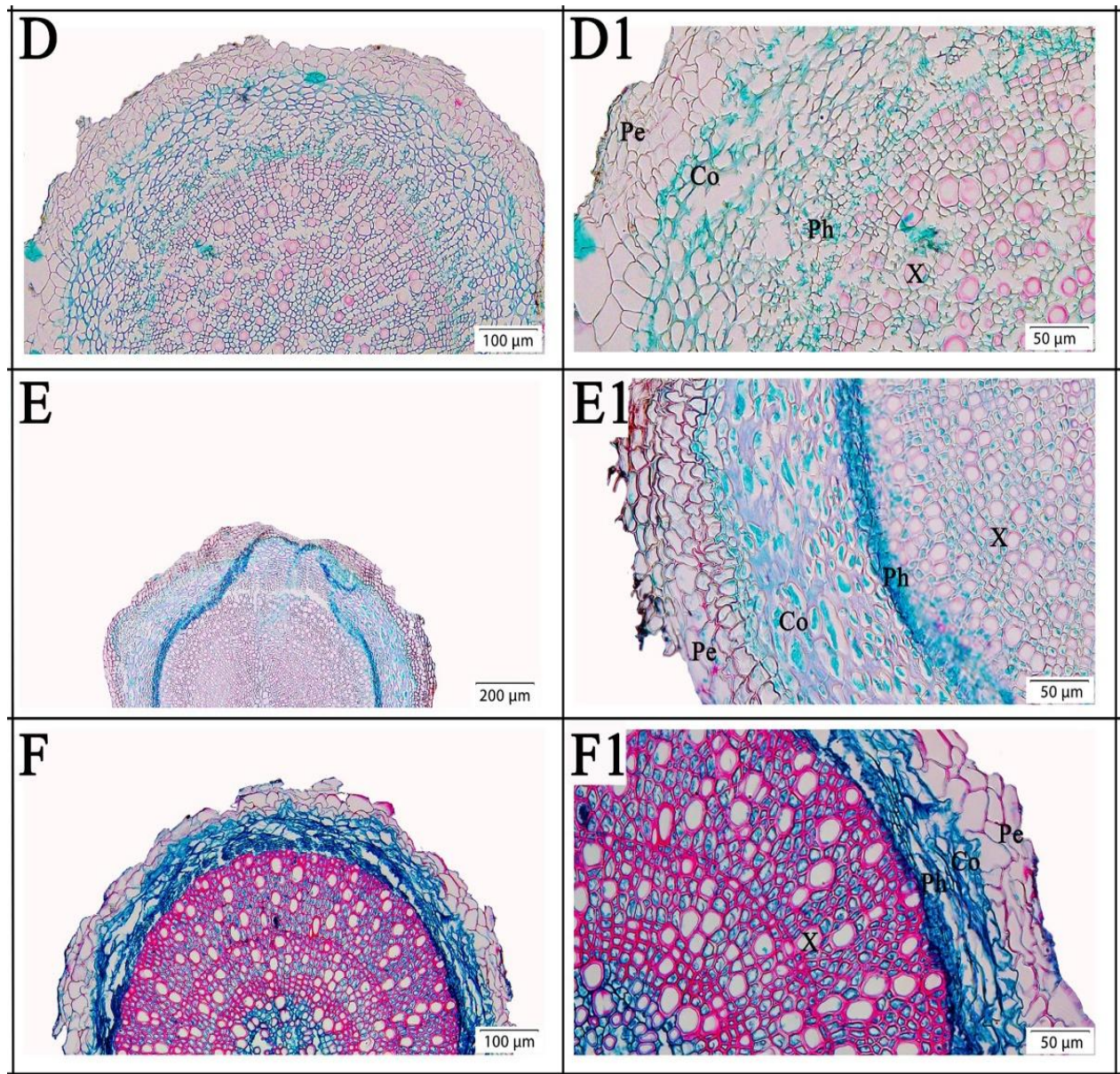


Figure 2. Cross-section of the root. D–D1: General and detailed view of *J. cherlerioides*, E–E1: General and detailed view of *J. thymoides*, F–F1: General and detailed view of *J. aziz-sancarii*. Pe: Peridermis, Co: Cortex, Ph: Phloem, X: Xylem

Table 2. The anatomical root measurements of *Jordania* taxa (μm)

Root Characters	<i>J. aziz-sancarii</i>	<i>J. cherlerioides</i>	<i>J. confertifolia</i>	<i>J. minuartioides</i>	<i>J. thymoides</i>	<i>J. turcica</i>	p değeri
Periderm layer	3-6	4-8	4-5	6-7	6-8	6-8	
Cortex layer	3-5	7-8	6-8	6-8	6-8	8-10	
Phloem layer	4-6	5-6	5-7	5-6	6-7	6-7	
Periderm Length	8,00-(14,16 $\pm$ 3,85)-24,79	6,21-(10,81 $\pm$ 2,34)-14,26	8,58-(15,45 $\pm$ 4,18)-22,50	10,77-(15,25 $\pm$ 2,93)-21,52	5,29-(8,90 $\pm$ 1,80) –11,91	5,17-(12,08 $\pm$ 5,33)-23,58	
Periderm Width	13,37-(25,97 $\pm$ 6,46)-39,05	12,10-(20,06 $\pm$ 3,36)-28,85	14,79-(31,45 $\pm$ 8,16)-48,37	13,20-(21,69 $\pm$ 3,49)-27,80	9,65-(14,72 $\pm$ 2,96)- 22,49	16,49-(26,45 $\pm$ 5,23)-38,29	
Cortex Length	7,49-(14,19 $\pm$ 3,40)-24,03	6,74-(11,42 $\pm$ 2,94)-17,63	5,91-(10,25 $\pm$ 3,21)-17,52	4,27-(9,09 $\pm$ 2,67)-16,18	4,46-(8,66 $\pm$ 2,59) –13,76	6,88-(10,99 $\pm$ 2,60)-16,46	p<0,001
Cortex Width	15,35-(25,45 $\pm$ 5,07)-38,44	11,45-(19,13 $\pm$ 4,88)-30,81	12,13-(23,75 $\pm$ 7,78)-48,10	10,09-(17,13 $\pm$ 3,52)-24,40	8,86-(17,29 $\pm$ 5,74 –30,92	11,09-(19,95 $\pm$ 5,66)-31,49	
Xylem Length	3,70-(9,41 $\pm$ 3,88)-18,99	6,84-(14,28 $\pm$ 4,48)-22,56	5,48-(9,54 $\pm$ 3,42)-19,91	5,68-(13,39 $\pm$ 4,54)-21,84	7,52-(11,77 $\pm$ 2,18 –16,70	7,51-(12,26 $\pm$ 2,60)-17,16	
Xylem Width	6,72-(15,25 $\pm$ 5,12)-26,77	9,50-(17,11 $\pm$ 4,96)-28,58	8,12-(16,30 $\pm$ 4,97)-27,27	10,54-(17,04 $\pm$ 4,59)-26,13	10,98-(15,70 $\pm$ 3,32)-23,57	7,86-(16,09 $\pm$ 3,74)-22,29	
Phloem Length	2,29-(3,76 $\pm$ 1,03)-5,79	3,10-(4,45 $\pm$ 0,85)-6,12	2,77-(4,86 $\pm$ 1,53)-9,37	2,80-(5,23 $\pm$ 1,59)-8,62	3,51-(5,16 $\pm$ 1,37) –9,32	2,33-(4,54 $\pm$ 1,26)-7,54	
Phloem Width	4,16-(6,80 $\pm$ 1,44)-9,43	4,92-(6,81 $\pm$ 1,00)-8,67	5,82-(10,84 $\pm$ 3,80)-19,29	4,39-(10,62 $\pm$ 3,16)-17,72	5,58-(9,42 $\pm$ 1,65) –12,93	5,43-(8,21 $\pm$ 2,09)-12,60	
The data are presented in the format of Min-(M $\pm$ SD)-Max (μm) values.							

Abbreviations: M: Average, SD: Standart deviation, Min: Minimum, Max: Maximum, μm : Micrometer

According to the data obtained from anatomical investigations, statistically significant differences were found between the length and width of periderm, cortex, xylem, and phloem cells in the root ($p<0.001$).

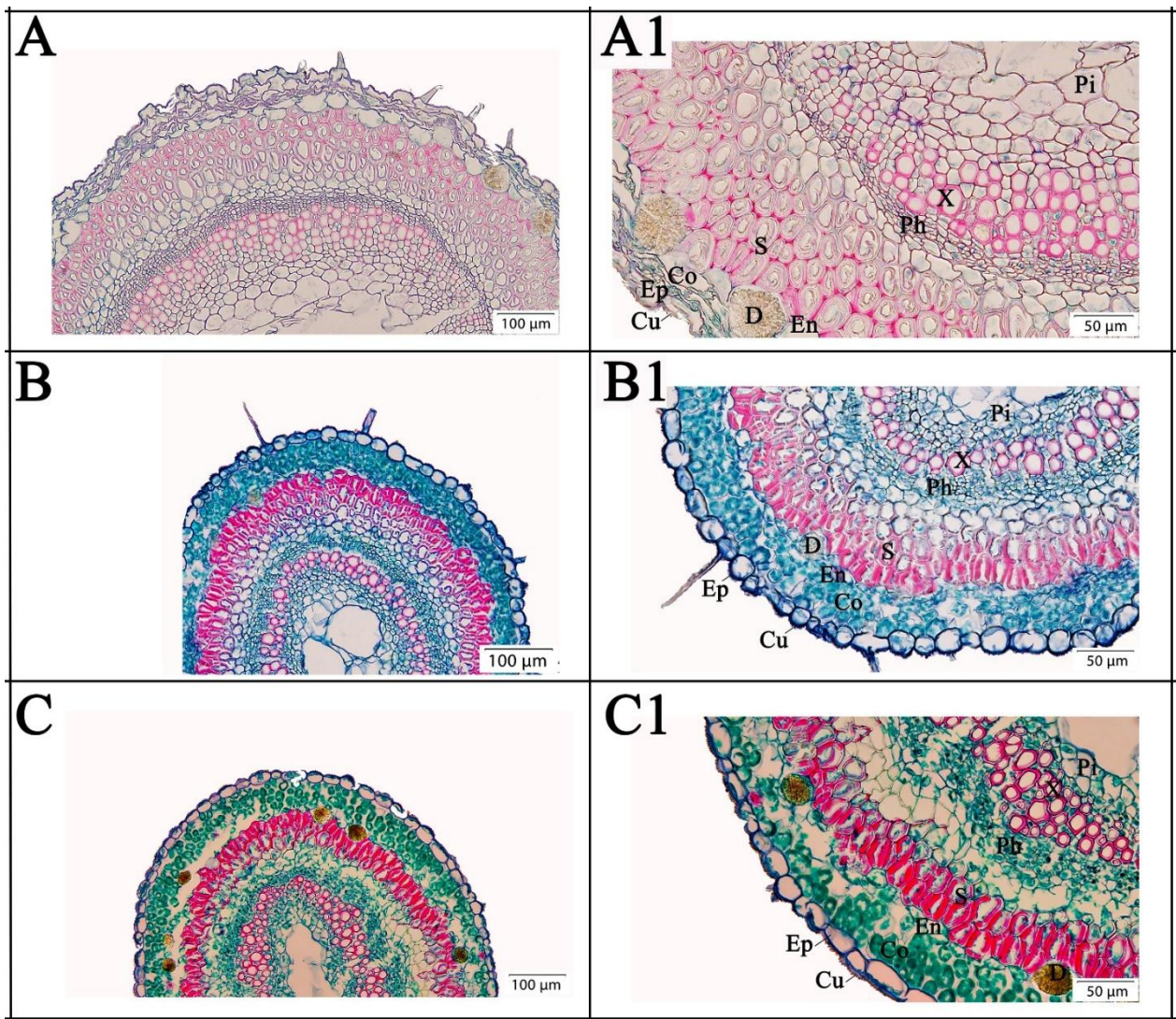


Figure 3. Cross-section of the stem. A–A1: General and detailed view of *J. confertifolia*, B–B1: General and detailed view of *J. minuartioides*, C–C1: General and detailed view of *J. turcica*. Cu: Cuticle, Ep: Epidermis, Co: Cortex, En: Endodermis, S: Sclerenchyma, Ph: Phloem, X: Xylem, Pi: Pith, D: Druse Crystal.

2-3 layers of cylindrically arranged parenchymatic cells. The endodermis, following the cortex, was composed of a single layer of round-rectangular cells and contained druse crystals. The sclerenchyma layer typically consisted of four layers, with the outermost cells having thick walls and narrow lumens, while towards the center, the cell walls became thinner and the lumens widened. The vascular bundle system comprised phloem (6-8 layers) and xylem (3-4 layers), with the phloem occupying a narrower area than the xylem. At the center of the transverse sections, a large pith region was observed, containing large, transparent, round pith cells. These parenchymatic pith cells included a distinct pith cavity (Fig. 3, Table 3).

— *J. turcica*: In the transverse sections of the *J. turcica* stem, the epidermal cells were observed to be single-layered, regularly arranged, and nearly rectangular to oval in shape. A thin, wavy cuticle layer covered the epidermis, which was densely covered with trichomes originating from the epidermis. Among these trichomes, numerous covering hairs and a few glandular hairs were present, with the cuticle of the covering hairs being silicified. The stem generally had a round shape, though structural variations were observed in regions with collenchymatic cells. The

cortex consisted of 3-4 layers of cylindrically arranged parenchymatic cells, followed by a single-layered endodermis with round-rectangular cells containing numerous druse crystals. The sclerenchyma layer, typically 2-4 layers thick, had thick-walled, narrow-lumened cells in the outer region, while towards the center, the cell walls became thinner and lumens wider. The vascular bundle system included phloem (6-7 cell layers) and xylem (2-4 cell layers), with the phloem occupying a narrower area than the xylem. At the center of the transverse sections, a large pith region with transparent, round parenchymatic pith cells containing a distinct pith cavity was observed (Fig. 3, Table 3).

— *J. cherlerioides*: In the transverse sections of the *J. cherlerioides* stem, the epidermal cells were observed to be single-layered, regularly arranged, and rectangular in shape. A thin, wavy cuticle layer covered the epidermis. The stem was densely covered with trichomes originating from the epidermis, consisting of numerous covering hairs and a few glandular hairs. The glandular hairs had a single-celled head and a three-celled stalk. The cuticle of the covering hairs was silicified. The stem generally exhibited a round shape. The cortex consisted of 2-3 layers of cylindrically

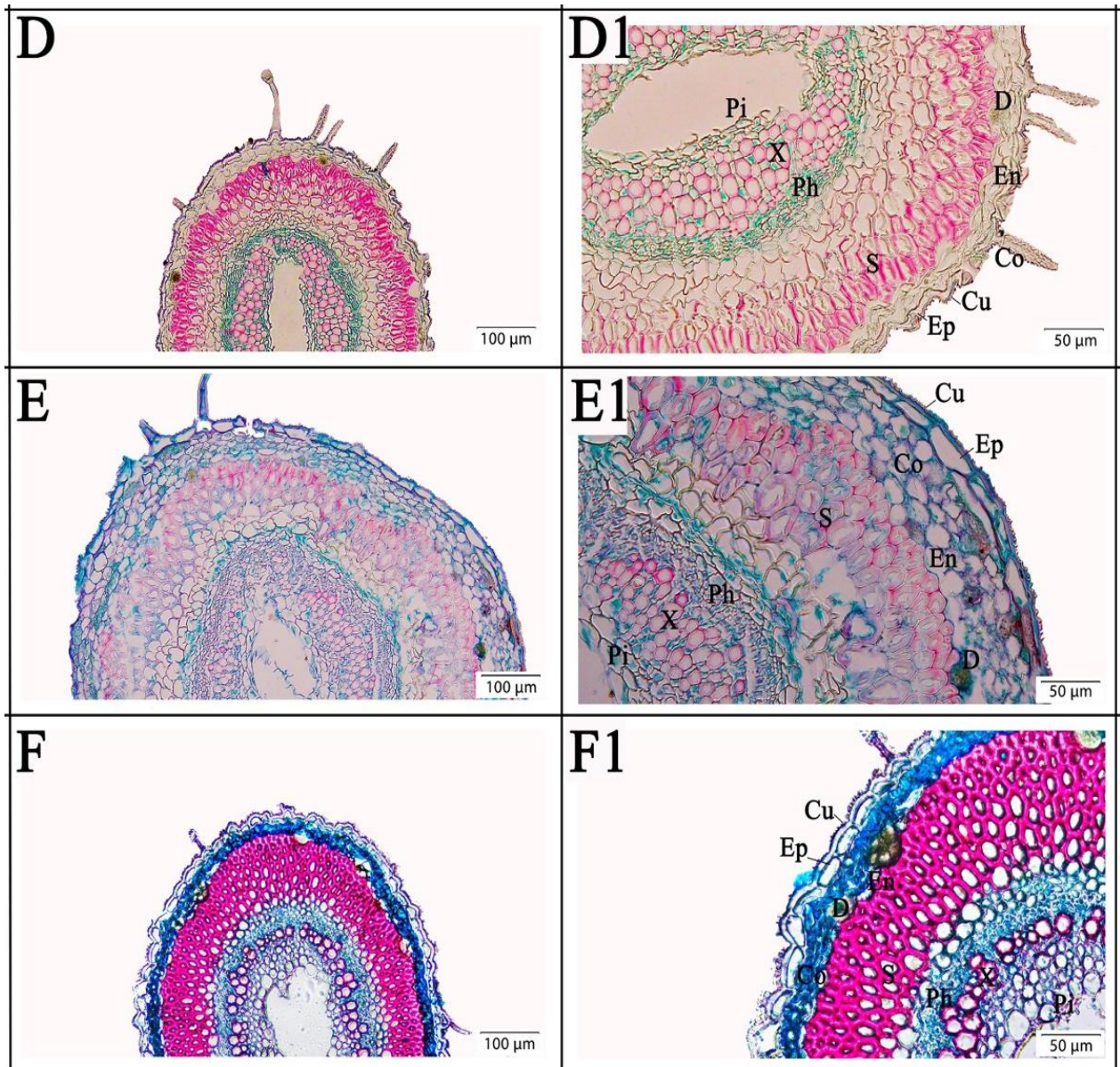


Figure 4. Cross-section of the stem. D–D1: General and detailed view of *J. cherlerioides*, E–E1: General and detailed view of *J. thymoides*, F–F1: General and detailed view of *J. aziz-sancarii*. Cu: Cuticle, Ep: Epidermis, Co: Cortex, En:Endodermis, S: Sclerenchyma, Ph: Phloem, X: Xylem, Pi:Pith, D: Druse Crystal.

arranged parenchymatic cells. The endodermis, following the cortex, was composed of a single layer of round-rectangular cells and contained druse crystals. The sclerenchyma layer typically consisted of four layers, with the outermost cells having thick walls and narrow lumens, while towards the center, the cell walls became thinner and the lumens widened. The vascular bundle system comprised phloem (5-6 layers) and xylem (3-5 layers), with the phloem occupying a narrower area than the xylem. At the center of the transverse sections, a large pith region was observed, containing round, transparent pith cells of varying sizes. These parenchymatic pith cells included a distinct pith cavity (Fig. 4, Table 3).

— *J. thymoides*: In the transverse sections of the *J. thymoides* stem, the epidermal cells were observed to be single-layered, regularly arranged, and rectangular in shape. A thin, wavy cuticle layer covered the epidermis. The stem was densely covered with trichomes originating from the epidermis, consisting of numerous covering hairs

and a few glandular hairs. The cuticle of the covering hairs was silicified. The stem generally exhibited a round shape. The cortex consisted of three layers of cylindrically arranged parenchymatic cells. The endodermis, following the cortex, was composed of a single layer of round-rectangular cells and contained abundant druse crystals. The sclerenchyma layer typically consisted of 4-5 layers, with the outermost cells having thick walls and narrow lumens, while towards the center, the cell walls became thinner and the lumens widened. The vascular bundle system comprised phloem (5-6 layers) and xylem (2-4 layers), with the phloem occupying a narrower area than the xylem. At the center of the transverse sections, a large pith region was observed, containing round, transparent pith cells of varying sizes. These parenchymatic pith cells included a distinct pith cavity (Fig. 4, Table 3).

— *J. aziz-sancarii*: In the transverse sections of the *J. aziz-sancarii* stem, the epidermal cells were observed to be single-layered, regularly arranged, and rectangular in shape.

Tablo 3. The anatomical stem measurements of *Jordania* taxa(μm)

Stem Characters	<i>J. aziz-sancarii</i>	<i>J. cherlerioides</i>	<i>J. confertifolia</i>	<i>J. minuartioides</i>	<i>J. thymoides</i>	<i>J. turcica</i>	p değeri
Cortex layer	2-4	2-3	3-4	2-3	3	3-4	
Sclerenchyma layer	2-6	4	4-6	4	4-5	2-4	
Phloem layer	4-6	5-6	6-7	6-8	5-6	6-7	
Xylem layer	2-3	3-5	3-7	3-4	2-4	2-4	
Epidermis Length	8,41-(12,62 $\pm$ 3,16) -22,95	7,34-(10,69 $\pm$ 2,64)-16,40	14,62-(19,55 $\pm$ 3,55)-25,37	14,85-(20,72 $\pm$ 2,99)-26,10	10,07-(14,15 $\pm$ 2,23)-17,49	10,51-(18,17 $\pm$ 3,45)-24,42	
Epidermis Width	13,91-(23,46 $\pm$ 5,63)-33,48	14,53-(25,41 $\pm$ 5,22)-34,49	21,40-(39,12 $\pm$ 11,25)-59,26	20,13-(31,28 $\pm$ 4,62)-39,06	15,29-(27,62 $\pm$ 4,65)-37,13	15,00-(24,50 $\pm$ 3,10)-29,84	
Cortex Length	7,35-(10,92 $\pm$ 2,14)-16,12	4,77-(11,01 $\pm$ 2,77)-16,54	14,73-(25,62 $\pm$ 7,25)-42,39	6,96-(14,50 $\pm$ 3,14)-20,80	9,42-(12,95 $\pm$ 2,21)-16,54	5,88-(11,80 $\pm$ 2,50)-16,70	
Cortex Width	10,62-(14,62 $\pm$ 2,65)-23,84	10,07-(19,80 $\pm$ 4,44)-30,85	22,12-(35,68 $\pm$ 8,29)-52,47	13,04-(26,99 $\pm$ 5,36)-38,10	14,71-(21,13 $\pm$ 3,88)-29,22	9,99-(17,24 $\pm$ 3,80)-24,31	p<0,001
Sclerenchyma Length	9,46-(14,17 $\pm$ 2,01)-17,52	5,75-(13,74 $\pm$ 3,02)-19,54	8,91-(16,74 $\pm$ 3,83)-22,14	8,23-(15,07 $\pm$ 3,12)-20,68	12,58-(18,43 $\pm$ 3,06)-25,27	9,38-(14,91 $\pm$ 3,03)-22,92	
Sclerenchyma Width	15,24-(22,38 $\pm$ 3,42)-28,29	11,61-(21,42 $\pm$ 4,52)-30,06	12,43-(22,87 $\pm$ 5,20)-30,85	14,65-(22,76 $\pm$ 3,90)-28,72	18,09-(27,86 $\pm$ 4,73)-41,81	21,24-(25,41 $\pm$ 2,40)-30,39	
Xylem Length	9,13-(14,04 $\pm$ 2,42)-18,95	5,75-(10,78 $\pm$ 2,21)-14,66	6,23-(13,89 $\pm$ 3,30)-19,82	5,97-(11,46 $\pm$ 2,83)-16,73	6,89-(10,25 $\pm$ 1,87)-15,19	6,12-(12,86 $\pm$ 3,55)-19,22	
Xylem Width	10,63-(16,67 $\pm$ 2,42)-21,32	8,28-(12,96 $\pm$ 2,53)-18,16	7,15-(18,86 $\pm$ 4,66)-27,31	7,80-(14,79 $\pm$ 3,97)-21,53	8,63-(13,04 $\pm$ 1,98)-18,07	9,15-(16,74 $\pm$ 4,17)-22,99	
Phloem Length	3,03-(4,71 $\pm$ 0,79)-6,12	2,76-(4,19 $\pm$ 1,10)-6,50	2,07-(4,09 $\pm$ 1,27)-7,56	2,80-(5,23 $\pm$ 1,59)-8,62	2,56-(4,16 $\pm$ 1,06)-6,23	3,21-(5,01 $\pm$ 1,92)-10,79	
Phloem Width	4,86-(6,90 $\pm$ 1,18)-9,44	4,55-(7,71 $\pm$ 1,82)-11,41	4,52-(7,36 $\pm$ 1,71)-12,11	4,39-(10,62 $\pm$ 3,16)-17,72	3,72-(6,89 $\pm$ 1,79)-11,27	4,58-(8,25 $\pm$ 2,91)-14,00	
Pith Cell Length	7,22-(11,65 $\pm$ 2,89)-17,82	5,82-(10,89 $\pm$ 2,85)-18,45	6,68-(12,78 $\pm$ 5,41)-28,62	4,94-(8,62 $\pm$ 2,97)-16,40	5,98-(11,32 $\pm$ 2,52)-17,05	4,28-(8,83 $\pm$ 3,06)-15,50	
Pith Cell Width	7,91-(14,38 $\pm$ 3,65)-22,36	9,28-(15,40 $\pm$ 3,51)-22,44	9,90-(21,47 $\pm$ 7,15)-40,91	6,81-(11,93 $\pm$ 3,22)-8,66	7,83-(16,84 $\pm$ 3,30)-21,99	7,93-(13,69 $\pm$ 4,46)-22,38	
The data are presented in the format of Min-(M $\pm$ SD)-Max (μm) values.							

Abbreviations: M: Average, SD: Standart deviation, Min: Minimum, Max: Maximum, μm : Micrometer

According to the data obtained from anatomical analyses, statistically significant differences were detected in the width and length of epidermis, cortex, xylem, phloem, sclerenchyma, and pith cells in the stem ($p < 0.001$).

A thin, wavy cuticle layer covered the epidermis. The stem was densely covered with trichomes originating from the epidermis, consisting of numerous covering hairs and a few glandular hairs. The cuticle of the covering hairs was silicified. The stem generally exhibited a round shape. The cortex consisted of 2-4 layers of cylindrically or rectangularly arranged parenchymatic cells. The endodermis, following the cortex, was composed of a single layer of round-rectangular cells and contained abundant druse crystals. The sclerenchyma layer typically consisted of 2-6 layers, with the outermost cells having thick walls and narrow lumens, while towards the center, the cell walls became thinner and the lumens widened. The vascular bundle system comprised phloem (4-6 layers) and xylem (2-3 layers), with the phloem occupying a narrower area than the xylem. At the center of the transverse sections, a large pith region was observed, containing large, transparent, round pith cells. These parenchymatic pith cells included a distinct pith cavity (Fig. 4, Table 3).

3.1.3. Leaf Anatomy

— *J. confertifolia*: In the cross-sections of *J. confertifolia* leaves, the upper and lower epidermis consist of a single row of tightly arranged, rectangular to nearly oval-shaped cells. The epidermis is covered by a thin cuticle layer, which is occasionally interrupted by stomata. The leaf is of the amphistomatic type, with cuticle wrinkling observed on both surfaces. The mesophyll tissue is equifacial, comprising 3-4 layers of palisade parenchyma on both sides, with 2-3 layers of spongy parenchyma in between. Numerous covering trichomes and fewer glandular trichomes are observed in the cross-sections of the leaves. Vascular bundles are present along the transverse axis of the mesophyll, with the largest one located in the midrib. The vascular bundles in the midrib and leaf tips are large and contain a prominent sclerenchyma cluster. The vascular bundles are of the collateral type, consisting of xylem, phloem, and sclerenchyma cells. In the midrib, the xylem is followed by the phloem, which is composed of small, thin-walled, and irregularly arranged cells. The phloem is enclosed by a crescent-shaped, extensive phloem sclerenchyma. Druse crystals are arranged on the upper and lower parts of the sclerenchyma cluster, and a high density of druse crystals is observed in the midrib of the leaf (Fig. 5, Table 4).

— *J. minuartioides*: The transverse sections of *J. minuartioides* leaves reveal a uniseriate upper and lower epidermis composed of tightly arranged, rectangular to nearly oval-shaped cells. The epidermis is covered with a thin cuticle layer, which is occasionally interrupted by stomata. The leaf is of the amphistomatic type, with cuticular wrinkles observed on both surfaces. The mesophyll tissue exhibits an equifacial structure, consisting of 1-2 layers of palisade parenchyma on both sides and 1-2 layers of spongy parenchyma in between. Numerous covering trichomes and fewer glandular trichomes are present in the transverse sections of the leaves. Vascular bundles are located in the middle of the mesophyll layer, with the largest one in the midrib. The vascular bundles in the midrib are relatively large and contain an extensive sclerenchyma mass. The vascular bundles are of the collateral type, consisting of xylem, phloem, and sclerenchyma cells. The xylem in the midrib continues with the phloem, which is composed of small, thin-walled, and

irregularly arranged cells. The phloem is surrounded by a crescent-shaped, extensive phloem sclerenchyma. Numerous druse crystals are observed on the sclerenchyma mass (Fig. 5, Table 4).

— *J. turcica*: In the transverse sections of *J. turcica* leaves, the upper and lower epidermis consist of a single row of tightly arranged, rectangular to oval-shaped cells. The epidermis is covered with a thin cuticle layer, which is occasionally interrupted by stomata. The leaf is of the amphistomatic type, with cuticle wrinkles observed on both surfaces. The mesophyll tissue is equifacial, consisting of 2-3 layers of palisade parenchyma on both sides and 2-3 layers of spongy parenchyma in between. Numerous covering trichomes and fewer glandular trichomes are observed in the transverse sections of the leaves. Vascular bundles are located in the middle part of the mesophyll, with the largest one in the midrib. The vascular bundles in the midrib and leaf tips are large and associated with a prominent sclerenchyma cluster. The vascular bundles are of the collateral type, composed of xylem, phloem, and sclerenchyma cells. In the midrib, the xylem is followed by the phloem, which consists of small, thin-walled, and irregularly arranged cells. The phloem is surrounded by a crescent-shaped, extensive phloem sclerenchyma. Additionally, druse crystals are abundantly present above the sclerenchyma cluster and in the midrib region (Fig. 5, Table 4).

— *J. cherlerioides*: In the transverse sections of *J. cherlerioides* leaves, the upper and lower epidermis consist of a single row of tightly arranged, rectangular, and nearly oval-shaped cells. The epidermis is covered with a thick cuticle layer, which is occasionally interrupted by stomata. The leaf is of the amphistomatic type, and cuticle wrinkles are observed on both surfaces. The mesophyll tissue has an equifacial structure, comprising two layers of palisade parenchyma on both sides, with a single layer of spongy parenchyma in between. Numerous covering trichomes and fewer glandular trichomes are observed in the transverse sections of the leaves. Vascular bundles are present in the middle part of the mesophyll layer, with the largest one located in the midrib. The vascular bundles in the midrib are quite large and contain a prominent sclerenchymatous mass. The vascular bundles are of the collateral type and consist of xylem, phloem, and sclerenchyma cells. The xylem in the midrib is followed by phloem, composed of small, thin-walled, and irregularly arranged cells. The phloem is surrounded by a crescent-shaped, extensive phloem sclerenchyma. Numerous druse crystals are observed above the sclerenchyma mass (Fig. 6, Table 4).

— *J. thymoides*: In transverse sections of *J. thymoides* leaves, the upper and lower epidermis consist of a single row of tightly arranged, rectangular, and nearly oval-shaped cells. The epidermis is covered with a thick cuticle layer, which is occasionally interrupted by stomata. The leaf is of the amphistomatic type, and cuticle wrinkles are observed on both surfaces. The mesophyll tissue has an equifacial structure, consisting of two layers of palisade parenchyma on both sides, with 1-2 layers of spongy parenchyma in between. Numerous covering trichomes and fewer glandular trichomes are observed in transverse sections of the leaf. Vascular bundles are present in the middle part of the mesophyll tissue, the largest one being in

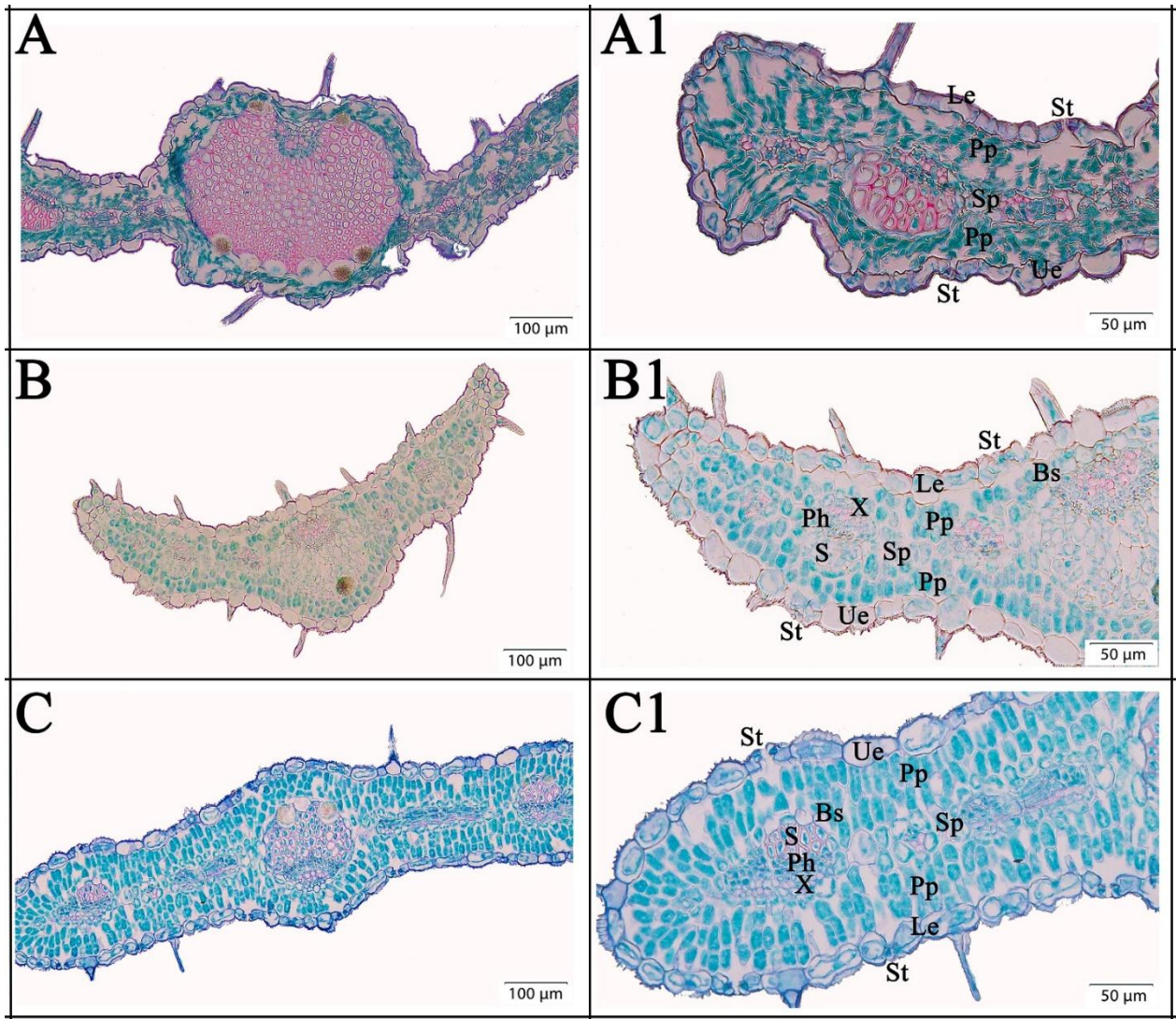


Figure 5. Cross-section of the leaf. A–A1: General and detailed view of *J. confertifolia*, B–B1: General and detailed view of *J. minuartioides*, C–C1: General and detailed view of *J. turcica*. Cu: Cuticle, Ue: Upper epidermis, Le: Lower epidermis, Pp: Palisade parenchyma, Sp: Spongy parenchyma, X: Xylem, Ph: Phloem, S: Sclerenchyma, St: Stoma, D: Druse crystal, Bs: Bundle sheath.

the midrib. The vascular bundles in the midrib are quite large and contain an extensive sclerenchyma cluster. The vascular bundles are collateral in structure and consist of xylem, phloem, and sclerenchyma cells. The xylem in the midrib is followed by the phloem, which is composed of small, thin-walled, and irregularly arranged cells. The phloem is surrounded by a crescent-shaped, extensive phloem sclerenchyma. Numerous druse crystals are observed above the sclerenchyma cluster (Fig. 6, Table 4).

— *J. aziz-sancarii*: The transverse sections of *J. aziz-sancarii* leaves show a single-layered upper and lower epidermis composed of tightly packed, rectangular to oval-shaped cells. The epidermis is covered by a thin cuticle layer, which is occasionally interrupted by stomata. The leaf is amphistomatic, with cuticle wrinkles observed on both surfaces. The mesophyll tissue has an equifacial structure, consisting of 2-3 layers of palisade parenchyma on both sides, with 2-3 layers of spongy parenchyma in between. Numerous covering trichomes and fewer glandular trichomes are present in the transverse sections of the leaf. Vascular bundles are located in the middle of the mesophyll layer, with the largest one positioned in the midrib. The vascular bundles in the midrib are considerably

large and contain a prominent sclerenchyma cluster. The vascular bundle are of the collateral type, consisting of xylem, phloem, and sclerenchyma cells. The xylem in the midrib is followed by small, thin-walled, irregularly arranged phloem cells. The phloem is surrounded by a crescent-shaped, extensive phloem sclerenchyma. Numerous druse crystals are observed on the sclerenchyma cluster (Fig. 6, Table 4).

3.2. Statistical Analyses

Anatomical data were obtained through examinations conducted among the species. To analyze these data statistically, the Kolmogorov-Smirnov test was used to assess normality. However, since the variables did not follow a normal distribution and the number of groups exceeded two, the Kruskal-Wallis test and dendrogram analyses were preferred. In these analyses, anatomical examinations were performed on transverse sections taken from the root, stem, and leaf parts of the species, and the results were evaluated comparatively. A significance level of 5% ($p < 0.05$) was considered statistically significant.

According to the anatomical data, statistically significant differences were detected ($p < 0.001$) in the following

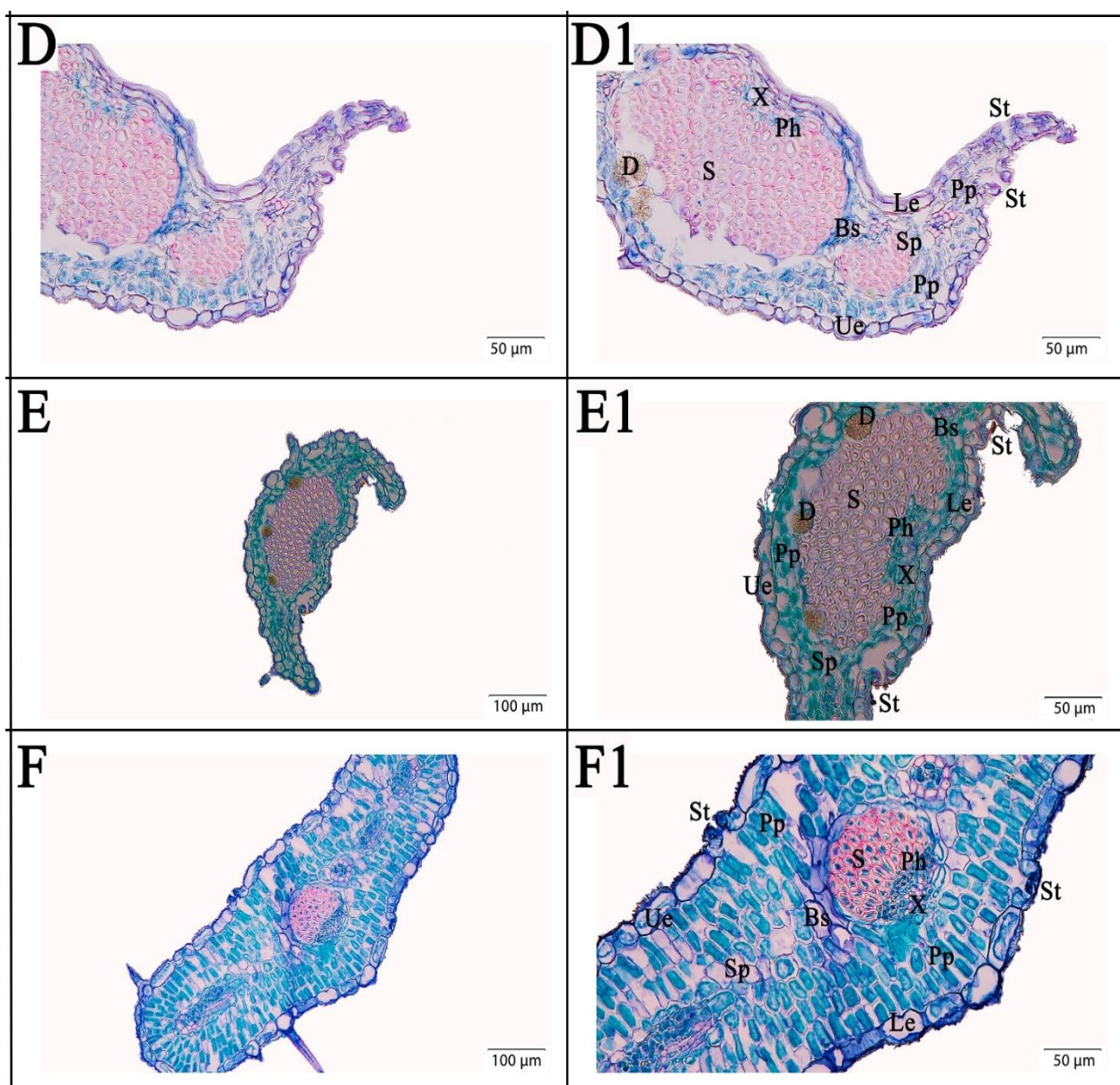


Figure 6. Cross-section of the leaf. D–D1: General and detailed view of *J. cherlerioides*, E–E1: General and detailed view of *J. thymoides*, F–F1: General and detailed view of *J. aziz-sancarii*. Cu: Cuticle, Ue: Upper epidermis, Le: Lower epidermis, Pp: Palisade parenchyma, Sp: Spongy parenchyma, X: Xylem, Ph: Phloem, S: Sclerenchyma, St: Stoma, D: Druse crystal, Bs: Bundle sheath.

parameters: root (peridermis, cortex, xylem, and phloem width and length); stem (epidermis, cortex, xylem, phloem, sclerenchyma, and pith cell width and length); and leaf (upper epidermis, lower epidermis, palisade parenchyma, spongy parenchyma, midrib xylem, midrib phloem, and midrib sclerenchyma cell width and length).

3.2.1. Normality Tests

The Kolmogorov-Smirnov normality test was used to determine whether the data of anatomical characters followed a normal distribution. The results of the tests indicated that the p-values obtained for all characters were statistically significant ($p < 0.05$). Due to the non-normal distribution of the data, the Kruskal-Wallis test was applied, revealing that all taxa possessed statistically distinctive characteristics. This analysis was chosen as an appropriate non-parametric statistical method for data that do not follow a normal distribution.

3.2.2. Dendrogram Analyses

A dendrogram is a visualization tool that represents the similarity or dissimilarity relationships among different groups within a dataset in a hierarchical structure, forming a tree-like diagram. The Between-Group Average Linkage method was used in the clustering analysis to illustrate the similarity relationships among taxa based on their average distances. This dendrogram was employed to identify taxonomic similarities and differences, grouping taxa based on the examined characteristics in the study. The constructed tree system allows for a clearer understanding of the classification and relationships of the taxa.

According to the dendrogram analysis, taxa 1 (*J. turcica*) and 6 (*J. aziz-sancarii*) exhibit strong similarities, forming a cluster at a 1-unit distance. Similarly, 4 (*J. thymoides*) and 5 (*J. cherlerioides*) are closely related taxa, clustering together at a 2-unit distance.

Tablo 4. The anatomical leaf measurements of *Jordania* taxa(µm)

Leaf Characters	<i>J. aziz-sancarii</i>	<i>J. cherlerioides</i>	<i>J. confertifolia</i>	<i>J. minuartioides</i>	<i>J. thymoides</i>	<i>J. turcica</i>	p değeri
Palisade Parenchyma layer	2-3	2	3-4	1-2	2	2-3	
Spongy Parenchyma layer	2-3	1	2-3	1-2	1-2	2-3	
Upper Epidermis Length	12,26-(19,65±6,57)-46,13	7,22-(9,73±1,40)-13,48	10,32-(15,51±3,16)-21,25	13,55-(19,87±4,22)-29,09	7,91-(11,32±1,77)-14,14	11,29-(19,01±4,35)-28,71	
Upper Epidermis Width	15,63-(33,77±8,42)-42,93	10,26-(15,15±4,02)-23,86	16,75-(26,39±5,29)-35,92	16,51-(30,14±5,78)-43,48	9,56-(18,59±6,94)-36,01	14,17-(33,49±11,85)-50,76	
Lower Epidermis Length	10,41-(18,04 ±3,77)-25,19	4,90-(9,46 ±3,33)-16,81	9,91-(15,31 ±3,24)-21,88	10,71-(17,76 ±3,44)-24,69	9,19-(12,28±2,84)-18,93	10,23-(18,61±4,89)-30,12	
Lower Epidermis Width	13,33-(30,38±9,11)-44,33	9,04-(18,16±6,64)-36,04	11,01-(24,36±7,17)-35,96	15,04-(24,97±5,18)-34,62	10,18-(19,43±6,52)-36,37	15,01-(30,88±10,86)-50,31	
Palisade Parenchyma Length	8,36-(12,98±2,13)-17,65	8,12-(12,06±2,39)-16,96	7,58-(11,09±2,21)-14,85	8,57-(10,41±1,16)-13,19	6,77-(9,96±1,93)-15,18	6,51-(9,61±1,15)-12,09	
Palisade Parenchyma Width	20,04-(29,31±5,32)-39,55	13,14-(21,72±5,40)-35,82	10,28-(20,65±5,39)-27,19	13,86-(19,39±3,07)-29,84	11,29-(18,73±3,78)-25,01	11,88-(25,80±7,13)-39,08	
Spongy Parenchyma Length	11,67-(16,55±4,44)-28,97	4,38-(8,72±2,83)-15,09	6,03-(12,66±3,39)-18,70	8,98-(14,97±3,44)-20,12	3,94-(5,56±1,45)-10,94	9,79-(13,48±2,16)-18,25	p<0,001
Spongy Parenchyma Width	12,93-(21,00±4,72)-31,74	5,58-(12,52±4,58)-25,29	8,21-(18,92±5,53)-30,33	12,73-(19,43±4,67)-28,90	4,30-(7,31±2,32)-13,48	14,84-(21,46±4,61)-31,04	
Midrib Sclerenchyma Cell Length	8,27-(12,80±2,20)-18,75	5,47-(9,85±2,33)-15,43	4,92-(12,01±2,48)-17,78	6,19-(9,83±2,10)-13,52	6,36-(11,27±2,19)-14,89	4,46-(9,05±2,72)-16,65	
Midrib Sclerenchyma Cell Width	11,33-(16,04±2,02)-19,94	7,94-(13,03±3,09)-18,72	8,29-(16,03±2,92)-20,18	10,02-(16,46±3,14)-22,84	7,42-(14,70±2,92)-18,47	6,66-(14,50±4,11)-20,50	
Midrib Xylem Cell Length	2,47-(5,00±1,38)-8,20	3,47-(5,13±1,38)-8,79	5,26-(8,34±1,55)-10,57	3,73-(5,99±1,26)-8,41	3,47-(6,01±1,10)-7,50	3,91-(6,23±1,35)-9,46	
Midrib Xylem Cell Width	3,59-(6,73 ± 1,77) -10,85	4,78-(6,75 ± 1,47) -10,56	7,86-(11,38 ± 1,97) -15,34	3,76-(7,27 ± 1,48) -9,88	4,22-(7,37 ± 1,44) -11,20	5,24-(7,77 ± 1,64) -10,67	
Midrib Phloem Cell Length	1,98-(3,42 ± 0,70)-4,74	1,97-(3,07 ± 0,80)-4,89	2,06-(3,67 ± 0,77)-5,59	2,06-(3,34 ± 0,73)-4,91	2,12-(4,69 ± 1,23)-7,38	2,05-(3,52± 0,84)-4,92	
Midrib Phloem Cell Width	2,92-(4,95± 1,23)-7,34	2,63-(4,92± 1,30)-6,74	3,10-(4,77± 0,75)-6,32	2,87-(4,59± 0,85)-5,98	3,94-(6,98± 1,64)-11,07	3,06-(5,13± 1,03)-6,98	
The data are presented in the format of Min-(M ± SD)-Max (µm) values.							

Abbreviations: M: Average, SD: Standart deviation, Min: Minimum, Max: Maximum, µm: Micrometer

According to the data obtained from anatomical analyses, statistically significant differences were detected in the width and length of upper epidermis, lower epidermis, palisade parenchyma, spongy parenchyma, midrib xylem, midrib phloem, and midrib sclerenchyma cells (p < 0.001).

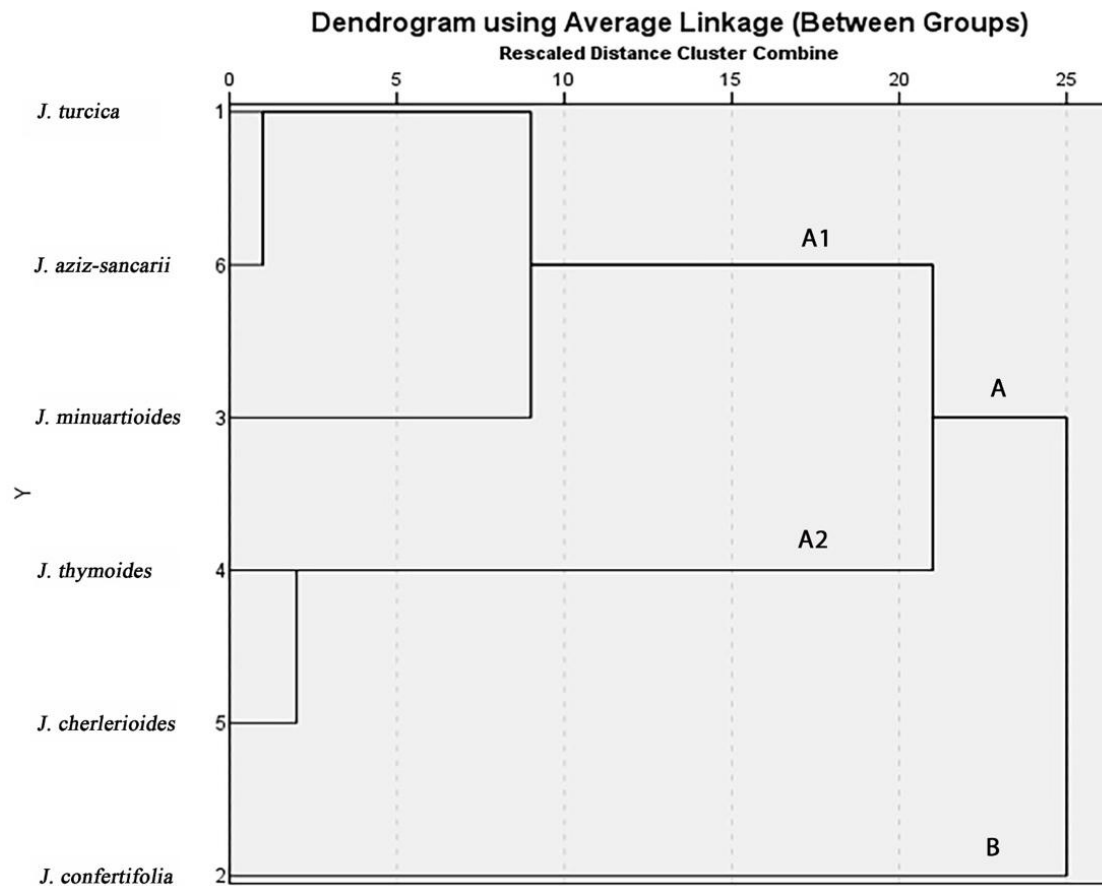


Figure 7. Dendrogram analysis of taxa based on hierarchical clustering of anatomical character similarities. 1 (*J. turcica*), 2 (*J. confertifolia*), 3 (*J. minuartioides*), 4 (*J. thymoides*), 5 (*J. cherlerioides*), 6 (*J. aziz-sancarii*).

3 (*J. minuartioides*) is included in the group containing 1 (*J. turcica*) and 6 (*J. aziz-sancarii*) at a 9-unit distance, forming Cluster 1.

4 (*J. thymoides*), with a 21-unit distance, shows lower similarity but still joins Cluster 1.

In contrast, 2 (*J. confertifolia*), with a 25-unit distance, exhibits the least similarity and forms Cluster 2 (Fig. 7).

4. Discussions

This study provides the first detailed anatomical investigation of six taxa belonging to the genus *Jordania*, offering significant insights into its systematic position. The genus *Jordania* has previously been classified within *Bolanthus*, which was itself transferred from *Gypsophila* (Madhani et al., 2024). In this context, the anatomical data obtained in the present study highlight both similarities and differences between *Jordania* and these related genera, thereby contributing to its taxonomic classification.

The root anatomy of *Jordania* exhibits certain similarities with some *Gypsophila* species. For instance, *Gypsophila lepidioides* (Özdemir et al., 2010) and *Gypsophila osmangaziensis* (Ataşlar & Ocak, 2017) have roots characterized by secondary growth, a periderm layer, and druse crystals in the cortex. However, a distinguishing feature of *Jordania* taxa is the absence of druse crystals in the roots. This difference suggests a potential anatomical distinction between *Jordania* and the genera *Gypsophila* and *Bolanthus*.

Regarding stem anatomy, the epidermis of *Jordania* taxa

consists of a single layer of cells covered by a thin cuticle, a characteristic also reported in *Gypsophila davisii* (Armağan & Özgökçe, 2018) and *Gypsophila olympica* (Aktürk & Yılmaz, 2021). However, *Jordania* is distinguished by its high trichome density, including both covering and glandular trichomes, which is not a prevalent feature in most *Gypsophila* species.

Leaf anatomical analysis revealed that *Jordania* taxa exhibit amphistomatic leaves with an equifacial mesophyll arrangement. This structure is also observed in *Gypsophila osmangaziensis* (Armağan & Özgökçe, 2018). Nevertheless, the presence of extensive sclerenchymatic structures and a high density of druse crystals in the central vascular bundle of *Jordania* leaves differentiates it from *Gypsophila* and *Bolanthus*.

The findings of this study indicate that while *Jordania* shares certain anatomical traits with *Gypsophila* and *Bolanthus*, it also possesses distinct structural characteristics that warrant its recognition as a separate taxon. The absence of druse crystals in the roots, the presence of extensive sclerenchymatic tissues in the leaves, and the high density of trichomes in the stems suggest that *Jordania* exhibits unique anatomical adaptations.

In conclusion, this study provides valuable new data on the anatomy of *Jordania* taxa, contributing to a better understanding of their systematic placement. The results support the recognition of *Jordania* as a distinct genus closely related to *Gypsophila* and *Bolanthus*. Future studies incorporating molecular and morphological data will be

essential for further clarifying the systematic position of *Jordania* within the Caryophyllaceae family.

Conflict of Interest

Authors have declared no conflict of interest.

Authors' Contributions

D.A.: Literature review and data analysis, design and implementation of the study, execution of experimental processes, data recording and measurements, writing and editing of the manuscript. **M.K.:** Provision of plant material, establishment of the necessary physical and

technical conditions for the research, development and guidance of the research idea.

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