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Morphological and Anatomical study of *Phlomis kurdica* (Lamiaceae) in Kurdistan Region of Iraq

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ABSTRACT

Phlomis is a significant genus in the Lamiaceae family. However, a comprehensive biosystematics evaluation of *Phlomis kurdica* has never been conducted. Therefore, the objectives of this study are to analyze the morphological, anatomical, trichome, and crystal characteristics of *P. kurdica*. The morphological characteristics were compared with the flora of Turkey and Iran. The anatomical findings were compared with the results of previous research on other *Phlomis* and Lamiaceae members. To study anatomy, cross sections of the plant's root, stem, and leaf parts were examined. *P. kurdica* is a perennial plant with ascending growth. Morphologically leaves are simple and vary in shape from oblong to oblong-ovate. The inflorescence resembles a verticillate cyme. The corolla is bilabiate and yellow, while the calyx is tubular with five subequal lobes. There are three main types of glandular trichomes: petalate, capitate, and dendroid, which coexist with glandular and non-glandular branches. Three kinds of non-glandular trichomes were also identified: dendroid with non-glandular branches stellate, and simple. Anatomically, root have 1-3 rows of pith rays. The stem is quadrangular, with four collenchyma patches at the corners. The leaf was amphistomatic. The stomata were of the diacytic kind. The petiole had a circular form with vascular bundles of the crescent-shaped collateral kind in its center. Prismatic and styloid crystals were observed in cross-sectioned organs. Certain morphological and anatomical features provide significant information for taxonomy.

1. Introduction

The Lamiaceae is a member of the Lamiales order. There are roughly 7886 species in the family and 245 genera (Mohammadi *et al.*, 2023). The family is dispersed around the world. The complex mixtures of bioactive secondary metabolites found in many of this family's highly aromatic species generate aromatic volatile oils, which add to the family's importance as a global supply of materials for the pharmaceutical, culinary, and cosmetic industries (Rattray and Van Wyk, 2021).

Li *et al.* (2016) provide new insight into relationships based on molecular phylogenetic analysis by using the nuclear ribosomal DNA of chloroplast sequences in the Lamiaceae family. In their summary of the Lamiaceae subfamily classification, they identified twelve subfamilies- Lamioideae, Ajugoideae, Prostantheroideae, Callicarpoideae, Nepetoideae, Scutellarioideae, Symphorematoideae, Peronematoideae, Viticoideae s. str., and Tectonoudae, Premnoideae and Cymarioideae (Harley RM, 2004). With over 100 known species spread over Asia, southern Europe, and northern Africa, the genus *Phlomis* constitutes one of the most widely distributed genera in the Lamioideae (Lamiaceae subfamily (Mathiesen *et al.*, 2011).

To differentiate between intently associated *Phlomis* species and other individuals of the Lamiaceae family, several morphological and anatomical researches have been conducted (Saeidnia *et al.*, 2015; Firdous *et al.*, 2015; Çalı, 2016; Sarıkaya and Fakir, 2016). Sarıkaya and Fakir (2016) identified the morphological traits of the taxa *Phlomis armeniaca*, *P. leucophracta*, *P. bourgaei*, *P. grandiflora* var. *grandiflora*, *P. nissolii*, *P. lycia*, *P. pungens* var. *pungens*, and *P. samia*, which are disbursed in the Lakes District. The morphological and anatomical characteristics of *P. aurea* from the Sinai Peninsula, Egypt, were studied by El-Banhawy and Al-Juhani (2019). Oran (2015) distinguished six species of *Phlomis* in Jordan based on pollen grain morphology. *P. russeliana* is an endemic plant in Turkey. Çalı (2016) examined anatomical features of *Phlomis*, while Kılıç and Kılıç (2022) studied *Salvia* species. These studies provide important taxonomic information. Compared to

other Lamiaceae genera, there have been relatively few scientific investigations into the morphology and anatomy of *Phlomis* species.

This study represents the first comprehensive morphological and anatomical research on *P. kurdica*. Therefore, this research aims to identify the morphological and anatomical, trichome, and crystal characteristics of various components of the *P. kurdica* plant, which belongs to the Lamiaceae family.

2. Materials and Methods

The *P. kurdica* specimens for the study were collected between May and June 2024 from various locations in the Sulaymaniyah governorate of Iraqi Kurdistan: Garmian province (Sartak Road-Horen Road at 34.94740 N, 45.70715 E, 545 meters above sea level; and Darbandikhan-Bamo Road at 34.99105 N, 45.70632 E, 682 meters above sea level). Sample collection details, including elevation, latitude, and longitude, were recorded using a Garmin 72 GPS device. The identification of the collected plants was based on descriptions from Iranica (Rechinger *et al.*, 1982) and Turkey Flora (Huber-Morath, 1982) A map indicating the collection sites of *P. kurdica* is shown in Figure 1.

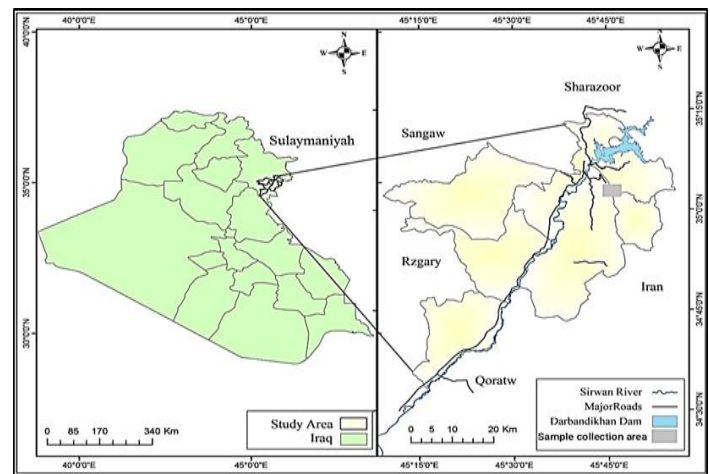


Figure 1: Distribution map of *P. kurdica*

During the study, fresh plant samples were used to determine the morphological characteristics of the flowers, stems, petioles, and leaves. For the purpose of anatomical analysis, the plant specimen was stored in 70% ethanol (ethyl alcohol+distilled water) (Kaya *et al.*, 2007; Yetişen, 2014; Çalı, 2016). The slide preparation

was performed in the University of Garmian Research Centre Plant Laboratory. After manually cutting the plant parts (root, stem, petiole, and leaf) by using a sharp razor blade, the sections were stained with clarified safranin solutions (Bozdağ *et al.*, 2016; Kılıç and Kılıç, 2022). The sections were photographed by using a Canon camera (DS126311, NO. 091025004604), which was connected to a binocular light microscope, the Meiji TECHNO compound microscope (MT4300L, model number 139635), which was made in Japan. And then, to measure the size of each cell of different tissue, five cells of different sizes (five replicates) were measured for each part of the section, and the obtained results were recorded in Microsoft Excel 2021. Measurements were taken under $\times 40$ objective lens to determine the minimum and maximum values of width-length measurements in different tissues. To display the numerical results, minimum, maximum, and average (arithmetic mean) were calculated. Despite the limited number of scientific studies on the genus *Phlomis*' anatomy, the results of the current study were compared with those of earlier investigations on this genus and some Lamiaceae family members.

3. Results

3.1. Morphological characterization

P. kurdica is a type of perennial dicotyledonous herb that grows near the Iranian and Iraqi borders. It blooms from late April to early June. Although it can be found in various habitats, *P. kurdica* is mainly located in moderate biomes. This plant thrives in hilly regions between rocky slopes and steppe vegetation, at an elevation between 545 and 682 meters above sea level. The specimen-collecting areas experience arid and hot summers, as well as freezing winters.

The current results are illustrated in Table 1 and Figure 2. In general, the descriptions of the plant species studied in this research align with those found in the Flora of Iranica and the Flora of Turkey. However, some differences were identified but need to expand and revise the descriptions of this plant.

The study states that the stem is 45–50 cm high, branching, solid, square, and erect. Simple, opposite, decussate, cordate leaves at the base

with crenate edges; lower cauline leaf oblong to oblong-ovate (9-10.7 cm long x 3-5.5 cm wide), having obtuse ends; floral cauline leaves broadly lanceolate. White, or predominantly yellowish, hairs cover the leaves. Petioles are 5–15 mm long on upper leaves and 10–11 cm long on lower leaves, almost matching the length of the leaf blade.



Figure 2: General appearance of *P. kurdica*

Floral leaves are equally lengthy as the verticillasters or longer; bracteoles were petiolated, limited (not more than 2) for each verticil (6.5-8 cm length x 1.6-1.8 cm wide); verticillasters are 5 to 8 clusters with three to nine flowers each; the space between each cluster is 5-6.5 cm. The teeth are soft, measuring 3-5 mm in length, while the calyx is tubular-hard, hairy, and divided into five subequal lobes, measuring 14–16 mm in length and 6-7 mm in width. Corolla: upper lips: 12–15 mm long, densely hairy; lower lips: extending with lateral lobes with 18–20 mm length; corolla bi-labiate, yellowed in color, 32–35 mm long with 20–23 mm wide (that includes the tube, which is 12–14 mm long), primarily hairy; tube approximately as long as the calyx or maybe slightly longer. Four stamens, with the two anterior stamens being longer, and a two-celled, dorsifixed anther. The ovarian lobes' central depression gives rise to a single gynobasic style.

The posterior branch is longer than the anterior branch of a bifid, with subulate and unequal branches. The form of the four pollen grains is ovoid.

Table (1): Morphological characteristics of *P. kurdica* derived from current study and the Flora of Iranica and also the Flora of Turkey

Parameters	Current study	Flora of Iranica	Flora of Turkey
Stem	45-50 cm	50-70 cm	60 cm
Leaf length	9-10.7 cm	12 cm	5-12 cm
Leaf width	3-5.5 cm	6	3-8 cm
Petiole	10-11 cm	Equal to the leaf blade	11 cm
No. of flower in each bracelet	3-9 flowers	8-10 flowers	8-10 flowers
Length between each bracelet	5-6.5 cm	Not determined	Not determined
Verticillasters	5-8 flower	5-7 flowers	3-6 flowers
Bract length	6.5-8 cm	1.5-2 mm	Not determined
Bract width	1.6-1.8 cm	Not determined	Not determined
Calyx length	14-18 mm	15-18 mm	15-18 mm
Calyx width	6-7 mm	Not determined	Not determined
Calyx teeth length	3-5, subequal	3-4 mm, subequal	4-6 mm, subequal
Corolla length (with corolla tube)	32-35 mm	30 mm	30-35 mm
Corolla width	20-23 mm	15 mm	Not determined
Corolla colour	Yellow	Yellow	Yellow
Corolla upper lips length	12-15 mm	15-17 mm	Not determined
Corolla lower lips length	18-20 mm	Longer than upper lips	Not determined
Corolla tube length	12-14 mm	Not determined	Not determined
Filament length	25-26 mm	Not determined	Not determined
Anther length	1.5 mm	Not determined	Not determined
Style length	28-30 mm	Not determined	Not determined
Stigma length	1.5 mm	Not determined	Not determined
Pollen grain length	2-3 mm	Not determined	Not determined
Pollen grain width	1 mm	Not determined	Not determined

The trichomes are present on the outer surface of *P. kurdica* parts and possesses different forms of glandular trichomes and simple and branching (stellate and dendroid) non-glandular trichomes. The glandular trichomes include peltate and capitate glandular trichomes and dendroid trichomes with two to three branches that coexist with non-glandular end cells or support glandular cells at the end. The outer surface of the petiole and stem had a more excellent distribution of capitated glandular trichomes. The capitated glandular trichom was not determined on both surfaces of the leaf. The surfaces of the midrib and petiole did not exhibit peltate glandular or simple non-glandular trichomes, which were only infrequently distributed. In addition to the peltate and capitate glandular trichomes, *P. kurdica* also covered by dendroid glandular trichomes; the petiole and stem exhibit this shape of glandular trichome.

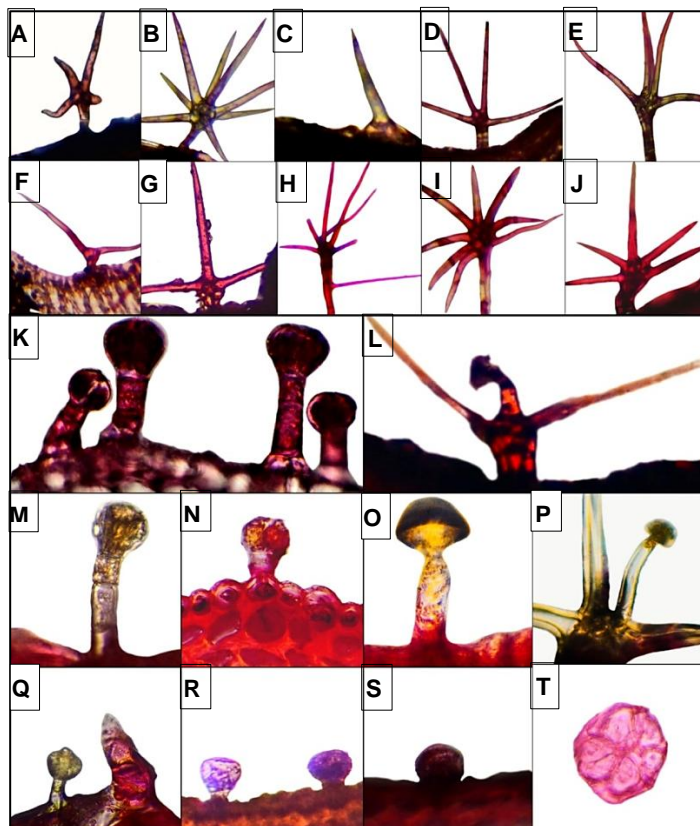


Figure 3: Types of Glandular and Non-glandular trichomes in *P. kurdica*. A-K, and Q (X=10), M-O, and R-T (X=40), A, B, G-J: Dendroid, C: Simple unicellular, D, and E: Stellate with multiseriate, unicellular branch, F: Stellate (Bifurcate), L and P: Dendroid with glandular branch, K and M: Capitated glandular with 2 celled stalk, O: Capitated glandular with 1 celled stalk, Q: Capitated glandular and simple non-glandular, N and R-T: Peltated glandular.

Compared to different *P. kurdica* plant components that were analyzed, stellate non-glandular trichomes have been more extensively distributed at the stem surface. While dendroid trichomes with non-glandular branches nearly equally distributed at the areal plant parts.

Table 2: Density and types of glandular and non-glandular trichomes in *P. kurdica*

Plant organ	Glandular trichome types			Non-glandular trichome types			
	Peltate	Capitate (stalk 1-2 or more cells)		Dendroid (with glandular and non-glandular arms)	Simple (Unicellular and unbranched)	Stellate	Dendroid (with non-glandular arms only)
		1	2 or more				
Stem	+	-	++	+	+	+++	++
Petiole	+	+	++	+	-	++	++
Midrib	-	+	+	-	+	++	++
Leaf (without the midrib)	+	-	-	-	+	++	++

3.2. Anatomical study

3.2.1. Root

The cross section of the *P. kurdica* root revealed multilayers of peridermis, with its cells crushed or breaking on the outside. The periderm cells measured 22.5–35 x 37.5–50 μm. There were several layers of sclerenchymatic cells, and parenchymatic cells that make up the cortex are generally angular to ovoidal in shape. The phloem and secondary xylem are typically ring-shaped. The phloem tissue thickness is at 7.5–10 x 15–17.5 μm. The xylem tissue consisted of tracheid cells and trachea. The trachea cell's dimensions were 12.5-37.5 x 25-50 μm. The pith cells (30-37.5 x 35-50 μm) were

also located in the center. The pith rays are 1-3 layers. The cambium is found in the space between the xylem and phloem and is composed of irregular cells. The phloem layer is situated above the cambium. Styloid crystals were seen as clusters with nearly pointed ends, or may be regarded as raphides, and determined in root.

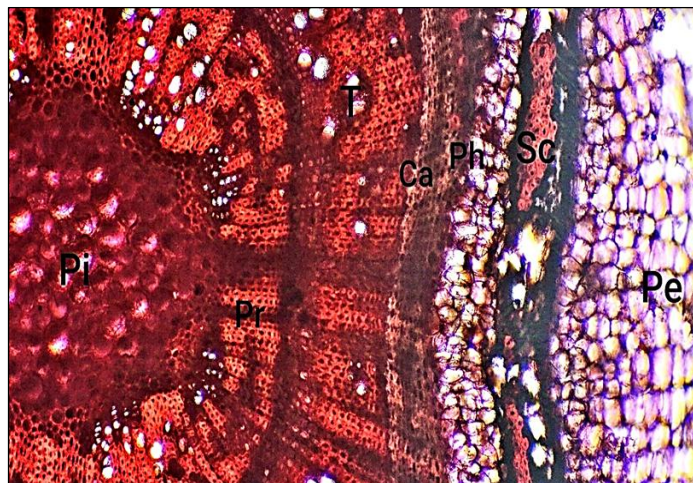


Figure 4: Transverse section of root of *P. kurdica*: A (X=10); Pe: Periderm, Sc: Sclerenchyma, Ph: Phloem, Ca: Cambium, T: Trachea, Pr: Pith ray, Pi: Pith region

3.2.2. Stem

The cross-section of the stem of *P. kurdica* shows that it is square. The epidermis is covered by a thin cuticle ranging from 2.5 to 5 μm thick and contains both glandular and non-glandular hairs, which can be single-celled or multi-cellular. The epidermis is made up of oval or squarish cells measuring 10-12.5 x 10-17.5 μm. The thickness of the cortex tissue in the corners is almost twice that of the thickness in the spaces between the corners, with thicknesses of 170-187.5 μm in the corners and 100-112.5 μm in the spaces between the corners. The structure consists of collenchyma cell layers directly beneath the epidermis, followed by parenchyma cells layers. The collenchyma cells measure 7.5-20 x 12.5-25 μm and have an oval or annular shape, with four collenchyma patches located at the corners. The cortex parenchyma cells measure 12.5–20x 20–37.5 μm having intercellular spaces, and they are oval or nearly rectangular.

The vascular bundles located at the corners are almost or a little larger than those in the middle. They were collateral and situated beneath the

layers of cortex parenchyma. Sclerenchyma cells are found above the phloem tissue. The phloem tissue had a thickness of 20–25 μm . Phloem cells have dimensions of 6.25–10 \times 7.5–12.5 μm . Cambium has not been distinguished. The thickness of the xylem tissue ranged from 225 to 237.5 μm . The trachea cell, with dimensions of 10-20 \times 10-25 μm , is situated in the xylem tissue. The pith area was thick, solid, and wide. It is composed of parenchyma cells that are virtually circular or hexagon-shaped, with intercellular spaces located in the centre of the stem as well as the dimension of its cells range from 22.5-65 \times 27.5-80 μm , and they are significantly crystallized with styloid crystals. The quantity of styloid crystals varied from cell to cell, but they were observed as clusters with almost pointed ends, or they could be thought of as raphides.

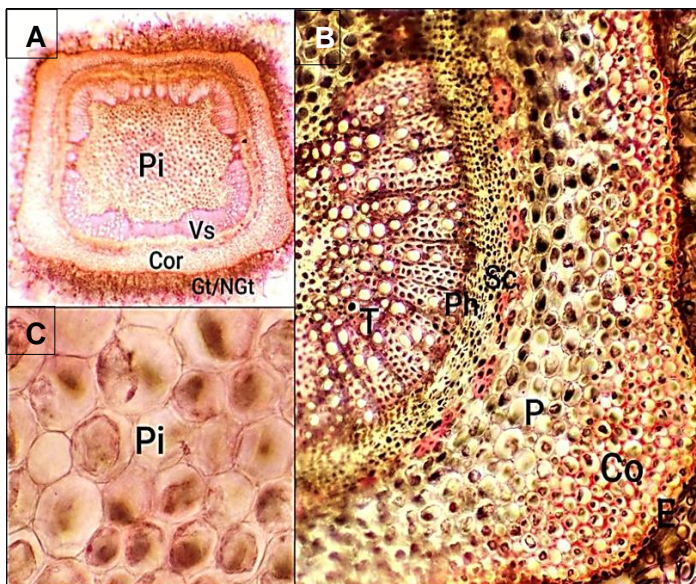


Figure 5: Transverse section of stem of *P. kurdica*: A (X=4), B (X=10), C (X=40); Pi: Pith region, Vs: Vascular bundles, Cor: Cortex tissue, GT/NGt: Glandular/Non-Glandular trichome, E: Epidermis, Co: Collenchyma, P: Parenchyma, Sc: Sclerenchyma, Ph: Phloem, T: Trachea

3.2.3. Petiol

The petiole of *P. kurdica* has two lateral wings and a half-circle shape in the cross section. There are two distinct forms of surfaces: convex abaxial and flat adaxial. The cuticle thickness ranges from 2.5 to 5 μm , undulating in both the adaxial and abaxial epidermis. Oval, square, and nearly rectangular epidermal cells make up both surfaces of the epidermis, which is covered in an abundance of glandular and non-glandular hairs.

Adaxial epidermal cells have dimensions of 10-22.5 \times 15-27.5 μm , which is relatively bigger than abaxial epidermal cells (10-20 \times 12.5-27.5 μm).

The cortex was comprised of collenchyma in the adaxial side, abaxial side, and in the corners. Within the petiole, there were parenchymal cells with dimensions of 40-70 \times 50-105 μm and shapes that were both polygonal and round. It contained styloid and prismatic-type crystals that varied in quantity and size. These cells surrounded the median vascular bundle. Four vascular bundles compose the vascular tissue: two big, equal, crescent-shaped in the centre and one smaller subsidiary in each wing. There were collateral type. The phloem is surrounded by sclerenchyma tissue. The dimensions of the phloem and trachea cells were 5-10 \times 7.5-12.5 μm and 7.5-27.5 \times 12.5-37.5 μm , respectively.

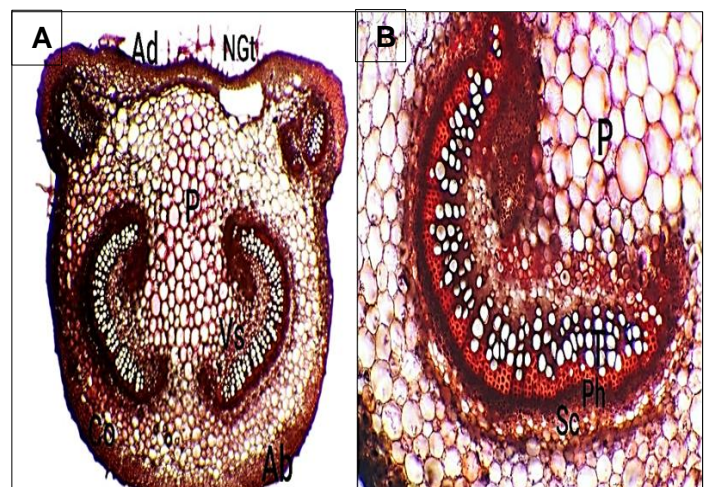


Figure 6: Transverse section of petiole of *P. kurdica*: A (X=4), B (X=10); Ad: Adaxial epidermis, P: Parenchyma, Vs: Vascular bundles, Ab: Abaxial epidermis, Co: Collenchyma, Sc: Sclerenchyma, Ph: Phloem, T: Trachea, NGt: Non-Glandular trichome

3.2.4. Leaf and Midrib

In the cross-section of the leaf of *P. kurdica*, the outermost surface is the thick cuticle layer. The cuticles of the epidermal layers have a thickness ranging from 7.5 to 10 μm . Oval or rectangular cells make up both epidermis. The cells in the upper epidermis are bigger than those in the lower epidermis. The cells in the upper epidermis measured 12-21 \times 12.5-37.5 μm , while the cells in the lower epidermis were 12.5-20 \times 12.5-30 μm . The epidermis contains both glandular and

non-glandular hairs. The mesophyll region is placed under the epidermis and is dorsiventral. It is made of elongate palisade parenchyma cells, which have dimensions of 15-17.5 x 32.5-72.5 μm, and irregular spongy parenchyma, which have dimensions of 18.75-23.75 x 20-27.5 μm, which are placed beneath the palisade. Compared to the palisade parenchyma, the spongy parenchyma occupies a larger area. The leaves are equifacial and possess stomata on both surfaces (amphistomatic type), with a nearly equal number of stomata on the lower than upper epidermis.

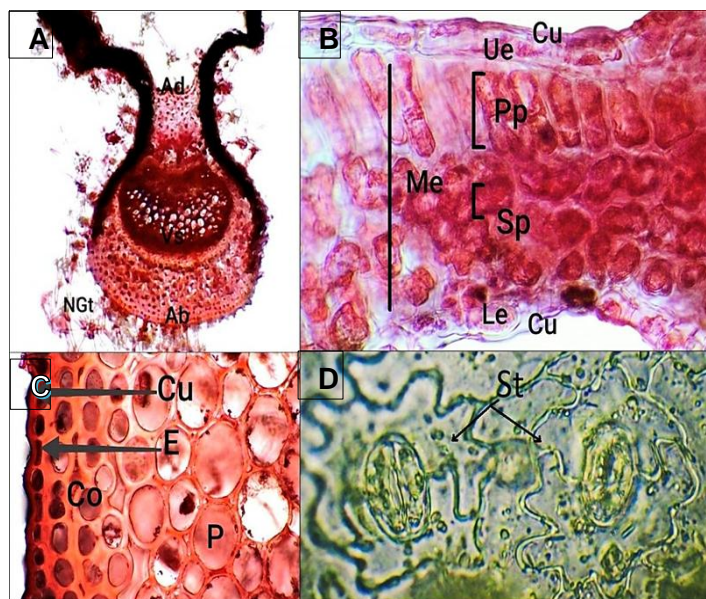


Figure 7: The transverse section of leaf and midrib of *P. kurdica*. A (X=4), B, C, and D (X=40), Ad: Adaxial epidermis, Vs: Vascular bundles, Ab: Abaxial epidermis, NGt: Non-Glandular trichome, Cu: Cuticle, Ue: Upper epidermis, Me: Mesophyll region, Pp: Palisade parenchyma, Sp: Spongy parenchyma, Le: Lower epidermis, E: Epidermis, Co: Collenchyma, P: Parenchyma, St: Stomata

The Midrib region forms a project part. Its adaxial surface was flat, while its abaxial surface was convex, making it a semicircle. The adaxial and abaxial epidermis are both oval, or nearly rectangular, and have a cuticle that is 2.5–6.25 μm thick. The abaxial cell surface measures 7.5-12.5 x 9.75-10 μm, whereas the adaxial cell surface measures 12.5-22.5 x 17.5-32.5 μm. The epidermis contains both glandular and non-glandular hairs. The support structure beneath both epidermis consists of oval-shaped collenchymatous cells. The parenchyma cells

measured 22.5–55 x 32.5–62.5 μm and were nearly oval with a notable intracellular space. Styloid crystals were seen in paranchymatic cells as clusters with nearly pointed ends, as well as the prismatic type, which was detected in the midrib of the leaf. In the middle, there is a single, large, crescent-shaped vascular bundle that is enclosed by sclerenchymatic tissue and has two smaller subsidiary vascular bundles. The vascular bundles are collateral kind. Phloem cells, found beneath sclerenchyma cells, have dimensions of 5-10 x 7.5-15 μm. The xylem tissue is broad and covers a significant portion of the midrib. The trachea cell size is 12.5-32.5 x 15-37.5 μm.

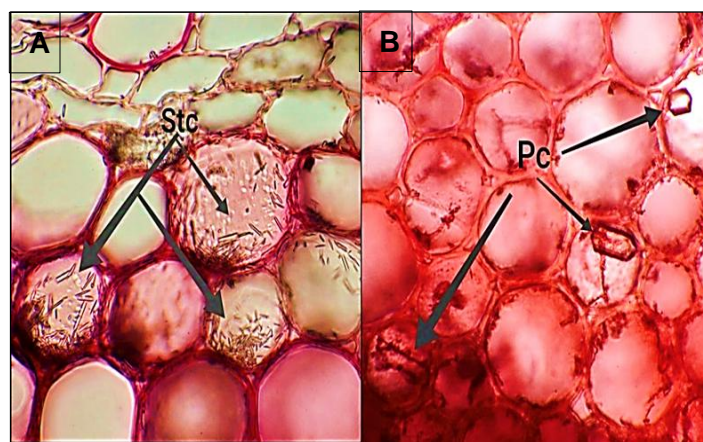


Figure 8: Different types of crystals in of *P. kurdica*. A, and B (X=40), Stc: Styloid crystal, Pc: Prismatic crystal

Table 3: The thickness of some different tissues of *P. kurdica*.

Parameters		Thickness (μm)					
		Min	Interval		Max	Mean	
Root							
Cortex tissue thickness		200	212.5	217.5	230	250	222
Stem							
Cortex tissue thickness	At corners	170	175	180	185	187.5	179.5
	At sides	100	102.5	107.5	110	112.5	106.5
Xylem tissue thickness		225	230	230	232.5	237.5	231
Phloem tissue thickness		20	20	22.5	23.75	25	22.25
Leaf							
Mesophyll region thickness		75	80	87.5	97.5	100	88

Table 4: The diameter of different cells of *P. kurdica* [The anatomical features, including the minimum, maximum, and average of at least six replicates for each section part].

Parameters	Width (µm)					Length (µm)						
	Min	Interval			Max	Mean	Min	Interval			Max	Mean
Root												
Periderm cells	22.5	25	30	32.5	35	29	37.5	40	45	47.5	50	44
Trachea cells	12.5	15	20	32.5	37.5	23.5	25	32.5	35	47.5	50	38
Phloem cells	7.5	7.5	8.75	8.75	10	8.5	15	15	15	16.25	17.5	15.75
Pith parenchyma	30	31.25	32.5	35	37.5	33.25	35	37.5	40	45	50	41.5
Stem												
Cuticle layer thickness	2.5	2.5	3.75	5	5	3.75	-	-	-	-	-	-
Epidermis cells	10	10	10	10	12.5	10.5	10	12.5	15	16.25	17.5	14.25
Parenchyma cells	12.5	15	15	17.5	20	16	20	25	30	32.5	37.5	29
Collenchyma cells	7.5	10	15	17.5	20	14	12.5	17.5	20	22.5	25	19.5
Trachea cells	10	12.5	17.5	17.5	20	15.5	10	12.5	17.5	21.25	25	17.25
Phloem cells	6.25	7.5	7.5	10	10	8.25	7.5	8.75	10	10	12.5	9.75
Pith cells	22.5	32.5	40	60	65	44	27.5	35	57.5	72.5	80	54.5
Petiole												
Cuticle layer thickness	2.5	2.5	3	3.75	5	3.35	-	-	-	-	-	-
Adaxial epidermis cells	10	15	16.25	20	22.5	16.75	15	17.5	20	25	27.5	21
Parenchyma cells	40	55	62.5	65	70	58.5	50	57.5	77.5	95	105	77
Trachea cells	7.5	12.5	20	25	27.5	18.5	12.5	17.5	30	32.5	37.5	26
Phloem cells	5	7.5	8.75	10	10	8.25	7.5	7.5	10	10	12.5	9.5
Abaxial epidermis cells	10	15	15	17.5	20	15.5	12.5	14	15	25	27.5	18.8
Leaf												
Cuticle layer thickness	7.5	8.75	8.75	10	10	9	-	-	-	-	-	-
Upper epidermis cells	12	14	17	20	21	16.8	12.5	17.5	20	32.5	37.5	24
Palisade cells	15	16.25	16.25	17.5	17.5	16.5	32.5	37.5	47.5	65	72.5	51
Spongy cells	18.75	20	20	21.25	23.75	20.75	20	22.5	23.75	25	27.5	23.75
Lower epidermis cells	12.5	15	17.5	18.75	20	16.75	12.5	15	22.5	27.5	30	21.5
Midrib												
Cuticle layer thickness	2.5	3.75	5	5	6.25	4.5	-	-	-	-	-	-
Adaxial epidermis cells	12.5	17.5	20	20	22.5	18.5	17.5	22.5	25	30	32.5	25.5
Parenchyma cells	22.5	30	42.5	50	55	40	32.5	35	47.5	55	62.5	46.5
Trachea cells	12.5	15	22.5	30	32.5	22.5	15	20	32.5	35	37.5	28
Phloem cells	5	7.5	8.75	10	10	8.25	7.5	10	11.25	15	15	11.75
Abaxial epidermis cells	7.5	8.75	10	10	12.5	9.75	10	12.5	15	20	22.5	16

Discussion

This study of *P. kurdica* found its morphology and anatomy consistent with the general Lamiaceae structure, with some variances compared to descriptions in Turkish Flora (Huber-Morath, 1982) and the Flora of Iranica (Rechinger et al., 1982). In contrast to these sources, *P. kurdica* has higher values in specific morphological features, like bract and calyx dimensions, noted here for the first time. Trichomes in Lamiaceae, including glandular and non-glandular forms, hold significant taxonomic value as well (Werker, 2000). Peltate and capitate trichomes, which produce essential oils, are especially notable in Lamiaceae for their

morphological diversity (Baran et al., 2010; Haratym and Weryszko-Chmielewska, 2017). Trichomes also contribute to defensive functions. For instance, peltate trichomes are present on the leaves and other plant parts of *Phlomis* species, while capitate trichomes vary across species, aiding pollination and deterring herbivores. In addition to the peltate and capitate glandular trichomes, *P. kurdica* also covered by dendroid glandular trichomes, which have two to three branches and resemble non-glandular trichomes in general shape. Having dendroid glandular trichomes, an uncommon type of glandular trichomes, sets the genus *Phlomis* distinct from the other genera within the

Lamiaceae (Navarro and El Oualidi, 2000; Gangaram *et al.*, 2020; Giuliani, 2024; Gostin and Blidar, 2024). Non-glandular trichomes offer physical defence against environmental stresses (Santos Tozin *et al.*, 2016), enhancing plant survival across different habitats. Stellate trichome is one of the kinds of non-glandular trichomes found in *P. kurdica* plant components that were analysed. Numerous *Phlomis* species have been shown to have this form of non-glandular trichomes (Saeidnia *et al.*, 2015).

Detailed anatomical analysis also revealed unique traits in *P. kurdica* that align with Lamiaceae descriptions by Yetişen (2014), Çalı (2016), El-Banhawy, and Al-Juhani (2019), confirming aspects noted by Metcalfe and Chalk (1972) and others. For example, *P. kurdica* exhibited pith rays in the root similar to other Lamiaceae members, with cell layers comparable to findings by Çalı (2016) and Psaras and Sofroniou (2004), yet distinct from those in other genera like *Scutellaria albida* and *Lamium lycium* (Minareci *et al.*, 2019; Baran and Özdemir, 2009). The stem features align with observations by Metcalfe and Chalk (1983), showing quadrate shapes and distinct collenchyma, similar to traits in other species (Çalı, 2016; Ya'ni *et al.*, 2018; Kılıç and Kılıç, 2022). Cortex thickness in *P. kurdica* was larger than in most related species but less than in *Scutellaria albida* subspecies (Minareci *et al.*, 2019).

The study noted lower phloem and xylem tissue thickness in *P. kurdica* than in certain species such as *Salvia limbata* (Kahraman and Dogan, 2010) but higher than others like *S. indica* (Kahraman *et al.*, 2009). Additionally, the presence of solid pith, typical in *Phlomis* and similar Lamiaceae members, was consistent with findings by Yetişen (2014) and Çalı (2016), with some Lamiaceae exceptions like hollow-pithed species in the genus *Thymus* (Ya'ni *et al.*, 2018).

Overall, the number of collenchyma layers was identified as significant for taxonomy; *P. kurdica* shared this feature with other members, showing variability in the layering among different species, similar to findings by Kılıç and Kılıç (2022) and El-Banhawy and Al-Juhani (2019). This detailed investigation advances the anatomical understanding of *P. kurdica* and its positioning

within Lamiaceae.

The vascular bundle shape of the petiole in Lamiaceae species serves as a diagnostic feature, allowing for species and genera differentiation (Metcalfe and Chalk, 1972; Kahraman *et al.*, 2010a, b; Ya'ni *et al.*, 2018). Lamiaceae vascular bundles are typically surrounded by a parenchymatous sheath, with significant variation across species (Metcalfe and Chalk, 1979). For example, *P. russeliana* has two smaller vascular bundles in the petiolar wings and two large central ones, with collenchyma layers below its surfaces (Çalı, 2016), while *P. aurea* shows a unique round petiole shape (El-Banhawy and Al-Juhani, 2019). Various other Lamiaceae, such as *Marrubium vulgare* and *Nepeta deflersiana*, exhibit distinct vascular bundle patterns.

Leaves of Lamiaceae, often isobilateral or dorsiventral (Metcalfe and Chalk, 1979), also show taxonomically useful traits in mesophyll structure and stomatal types. *Stachys* species, for example, show differences in palisade and spongy parenchyma layers influenced by light and water availability (Salmaki *et al.*, 2011). Certain species, such as *S. limbata*, exhibit equifacial leaves, while others like *P. kurdica* are amphistomatic with diacytic stomata (Kahraman and Dogan, 2010; Çalı, 2016). Hypostomatic with dia-anisocytic stomata were determined in *Stachys yemenensis* (Ya'ni *et al.*, 2018).

Crystal morphology within Lamiaceae also aids in taxonomy, with calcium oxalate crystals present in various forms across taxa (Metcalfe and Chalk, 1983; Tyagi *et al.*, 2021). These crystals appear in shapes like druses or prismatic forms in specific Lamiaceae species (Ryding, 2010) and offer diagnostic details, especially in subfamily distinctions.

Conclusion

P. kurdica shares the majority of its morphological and anatomical characteristics with other Lamiaceae family members. Based on the findings, certain anatomical features, including the total number of pith rays in the root, palisade and spongy parenchyma layers in the leaf, the types of stomata and leaves, the structure of the petiole, the presence of

trichomes and the types of crystals, provide significant for plant taxonomy.

Recommendation

Given the scarcity of studies on the morphology and anatomy of the genus *Phlomis*, especially *P. kurdica*, we recommend conducting further scientific research to determine the internal, external, and genetic characteristics of this plant.

Authors contribution

All authors of this research participated equally to all stages of the assessment, writing, review, and submission of this study.

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