



Structural Anatomy of Papilionaceae (Fabaceae) and Its Importance in Plant Taxonomy: A Review

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Manuscript details:

Received: 11.03.2026

Accepted: 27.03.2026

Published: 30.03.2026

Cite this article as:

Geeta Patil, Sarala Tadavi, Pallavi Rane (2026) Structural Anatomy of Papilionaceae (Fabaceae) and Its Importance in Plant Taxonomy: A Review, *Int. J. of Life Sciences*, 14 (1): 41-46.

Available online on <http://www.ijlsci.in>

ISSN: 2320-964X (Online)

ISSN: 2320-7817 (Print)



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ABSTRACT

Papilionaceae (subfamily Papilionoideae) represents the largest and most diverse lineage within the family Fabaceae, comprising numerous economically and ecologically important species. Anatomical investigations of vegetative organs provide valuable diagnostic characters that contribute to plant taxonomy and phylogenetic interpretation. The present review synthesizes published literature on leaf and stem anatomical characteristics of Papilionaceae species with emphasis on their systematic significance. Leaves generally exhibit dorsiventral anatomy characterized by a well-developed palisade layer, loosely arranged spongy mesophyll, and collateral vascular bundles surrounded by bundle sheath cells. Epidermal features such as stomatal type, trichome morphology, and cuticular patterns show considerable interspecific variation. Stem anatomy typically displays a dicotyledonous organization with epidermis, cortex, vascular bundles arranged in a ring, and central pith, with secondary growth observed in woody taxa. Comparative analysis of 40 representative species reveals that anatomical characters such as stomatal type, trichome distribution, vascular bundle arrangement, and crystal deposition serve as reliable taxonomic markers. Integration of anatomical data with molecular phylogenetic studies enhances our understanding of evolutionary relationships within Papilionoideae. The review highlights the continuing importance of classical plant anatomy in systematic botany and emphasizes its complementary role in modern phylogenomic studies.

Keywords: Papilionaceae, Fabaceae, plant anatomy, leaf structure, stem anatomy, taxonomy

INTRODUCTION

Fabaceae is one of the largest families of flowering plants, consisting of approximately 770 genera and more than 19,000 species distributed worldwide. The family is traditionally divided into three major subfamilies: Caesalpinioideae, Mimosoideae, and Papilionoideae. Among these, the subfamily Papilionoideae represents the most diverse lineage and includes several agriculturally and economically important plants (Lewis et al., 2005; Ahmed et al., 2020; Choi et al., 2022). Recent phylogenetic and molecular studies have enhanced our understanding of

evolutionary relationships within the subfamily Papilionoideae (Qin et al., 2025; Choi et al., 2022).

Plant anatomical characters have long been recognized as valuable tools in systematic botany because they provide stable features that are less influenced by environmental conditions than morphological characters (Kumar & Singh, 2021; Kumar & Patel, 2024). Vegetative anatomical traits, including stomatal structure, trichome morphology, mesophyll organization, and vascular bundle arrangement, have been widely used for species identification and classification.

Recent phylogenetic and molecular studies have significantly improved the understanding of evolutionary relationships within Papilionoideae (Choi et al., 2022; Qin et al., 2025). Anatomical studies of vegetative organs such as leaves and stems provide additional taxonomic characters that complement molecular data (Kumar & Singh, 2021; Kumar & Patel, 2024). Therefore, a comprehensive review of vegetative anatomical characteristics in Papilionaceae is important for understanding their taxonomic significance and evolutionary patterns. Plant anatomy plays an important role in taxonomy because anatomical characters are relatively stable and less influenced by environmental variations (Yadav & Tripathi, 2022).

Taxonomic Position

Kingdom: Plantae
Division: Angiosperms
Class: Eudicots
Order: Fabales
Family: Fabaceae
Subfamily: Papilionoideae

Leaf Anatomy

Leaf Anatomy of Papilionaceae

Leaf anatomical features such as epidermal structure, mesophyll organization, and vascular bundle arrangement are widely used for species identification in legumes (Sharma & Gupta, 2022; Singh et al., 2024). Leaf anatomy in Papilionaceae typically shows a dorsiventral arrangement that facilitates efficient photosynthesis. The upper epidermis consists of a single layer of compact cells covered with a protective cuticle. In many species, epidermal cells bear trichomes that provide protection against herbivory and excessive transpiration.

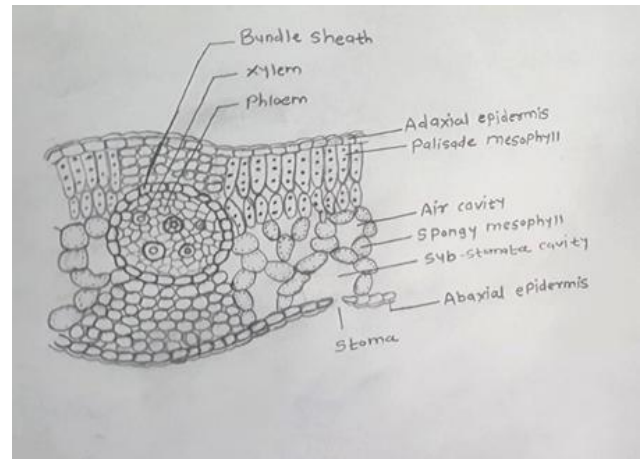


Figure 1. Transverse section of a typical dorsiventral leaf of Papilionaceae showing upper epidermis, palisade mesophyll, spongy mesophyll, vascular bundle, and lower epidermis with stomata.

Epidermal Characteristics

The epidermis usually consists of a single layer of cells covered with a cuticle. In many species, different types of trichomes are present, which may serve protective and ecological functions (Ali et al., 2021; Ninkaew et al., 2023). The epidermis may contain different stomatal types including paracytic, anomocytic, and diacytic stomata. These stomatal configurations vary among genera and are frequently used as diagnostic characters in plant identification. (Yadav & Tripathi, 2022).

Mesophyll Structure

The mesophyll is generally differentiated into palisade and spongy parenchyma layers that facilitate photosynthesis and gas exchange (Singh et al., 2022; Fortunato et al., 2021). In certain amphibious or aquatic legumes, modifications in mesophyll structure have been observed as adaptive features (Leme & Scremin-Dias, 2020).

Palisade mesophyll

Located beneath the upper epidermis and composed of elongated chlorenchyma cells responsible for photosynthesis.

Spongy mesophyll:

Consists of loosely arranged parenchyma cells with large intercellular spaces that facilitate gas exchange.

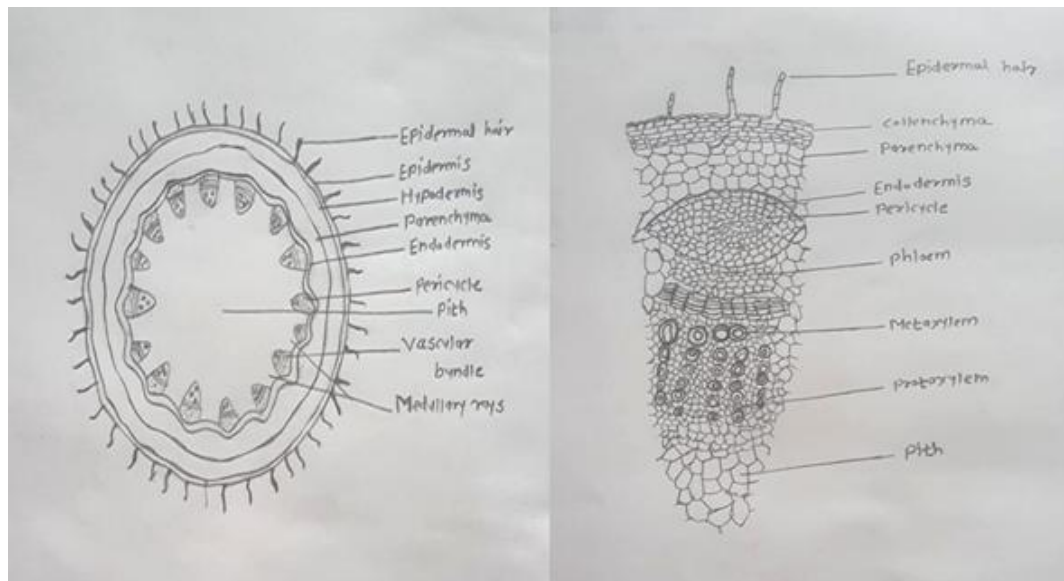


Figure 2. Transverse section of a typical dicot stem of Papilionaceae showing epidermis, cortex, and vascular bundles arranged in a ring, cambium, xylem, phloem, and central pith.

Vascular System

Leaf vascular bundles are generally collateral and surrounded by bundle sheath cells. Some species also exhibit sclerenchymatous tissues associated with vascular bundles, providing additional mechanical support.

Crystals and Secretory Structures

Calcium oxalate crystals and secretory cells have been reported in several papilionoid species. These structures may play roles in defense and metabolic storage.

Stem Anatomy

The stem of Papilionaceae species typically exhibits a dicotyledonous pattern with epidermis, cortex, vascular bundles arranged in a ring, and a central pith (Patel & Verma, 2023; Mehta & Shah, 2023).

Figure 2. Transverse section of a typical dicot stem of Papilionaceae showing epidermis, cortex, and vascular bundles arranged in a ring, cambium, xylem, phloem, and central pith.

Epidermis

The outermost layer consists of tightly packed cells covered with a cuticle that minimizes water loss.

Cortex

The cortex is composed of collenchyma and parenchyma tissues. Collenchyma provides mechanical

support, while parenchyma cells function in storage and metabolic activities.

Vascular Bundles

Vascular bundles are arranged in a circular ring and consist of xylem and phloem separated by a vascular cambium. Secondary growth is common in woody members such as *Dalbergia* and *Pterocarpus*.

Pith

The central pith consists of parenchymatous cells involved in storage and transport of nutrients.

Secondary growth is commonly observed in woody species and contributes to structural support and efficient conduction (Das et al., 2023).

Comparative anatomical studies of legume stems have revealed variations in vascular bundle arrangement and sclerenchyma distribution among species (Fernandes et al., 2023; Nwachukwu et al., 2020).

Taxonomic Importance of Anatomical Characters

Anatomical characters play a crucial role in plant taxonomy. In Papilionaceae, features such as stomatal type, trichome morphology, and vascular bundle arrangement and mesophyll organization are valuable tools in plant taxonomy (Kumar & Singh, 2021; Kumar & Patel, 2024). These characters often remain stable across environmental conditions, making them reliable diagnostic markers.

Table 1: Papilionaceae Plants with comparative Anatomical Characters

Sr. no.	Plant Species	Leaf Anatomy	Stomata	Special Anatomical Feature
1	<i>Crotalaria juncea</i>	Dorsiventral	Paracytic	Dense trichomes
2	<i>Crotalaria retusa</i>	Dorsiventral	Paracytic	Thick cuticle
3	<i>Indigofera tinctoria</i>	Dorsiventral	Paracytic	Calcium oxalate crystals
4	<i>Indigofera cassioides</i>	Dorsiventral	Paracytic	Hairy epidermis
5	<i>Sesbania grandiflora</i>	Dorsiventral	Paracytic	Large vascular bundles
6	<i>Sesbania sesban</i>	Dorsiventral	Paracytic	Collenchyma in midrib
7	<i>Dalbergia sissoo</i>	Thick cuticle	Paracytic	Abundant fibres
8	<i>Dalbergia latifolia</i>	Dorsiventral	Paracytic	Sclerenchyma bundles
9	<i>Arachis hypogaea</i>	Dorsiventral	Paracytic	Oil cells
10	<i>Arachis pintoi</i>	Dorsiventral	Paracytic	Trichomes
11	<i>Trifolium pratense</i>	Dorsiventral	Anomocytic	Thin cuticle
12	<i>Trifolium repens</i>	Dorsiventral	Paracytic	Spongy mesophyll
13	<i>Clitoria ternatea</i>	Dorsiventral	Paracytic	Crystal deposits
14	<i>Tephrosia purpurea</i>	Dorsiventral	Paracytic	Hairy epidermis
15	<i>Tephrosia villosa</i>	Dorsiventral	Paracytic	Thick mesophyll
16	<i>Pongamia pinnata</i>	Dorsiventral	Paracytic	Oil glands
17	<i>Pterocarpus marsupium</i>	Dorsiventral	Paracytic	Thick sclerenchyma
18	<i>Aeschynomene indica</i>	Dorsiventral	Paracytic	Air spaces
19	<i>Aeschynomene americana</i>	Dorsiventral	Paracytic	Large vascular bundles
20	<i>Desmodium gangeticum</i>	Dorsiventral	Paracytic	Glandular trichomes
21	<i>Desmodium triflorum</i>	Dorsiventral	Paracytic	Thin epidermis
22	<i>Stylosanthes hamata</i>	Dorsiventral	Paracytic	Hairy surface
23	<i>Stylosanthes capitata</i>	Dorsiventral	Paracytic	Secretory cells
24	<i>Glycyrrhiza glabra</i>	Dorsiventral	Paracytic	Crystals
25	<i>Medicago sativa</i>	Dorsiventral	Paracytic	Well-developed palisade
26	<i>Medicago truncatula</i>	Dorsiventral	Paracytic	Trichomes
27	<i>Astragalus membranaceus</i>	Dorsiventral	Paracytic	Thick cortex
28	<i>Astragalus sinicus</i>	Dorsiventral	Paracytic	Fibres
29	<i>Lotus corniculatus</i>	Dorsiventral	Paracytic	Large midrib
30	<i>Vicia faba</i>	Dorsiventral	Anomocytic	Spongy mesophyll
31	<i>Vicia sativa</i>	Dorsiventral	Paracytic	Thin cuticle
32	<i>Lathyrus sativus</i>	Dorsiventral	Paracytic	Sclerenchyma
33	<i>Phaseolus vulgaris</i>	Dorsiventral	Paracytic	Large vascular bundle
34	<i>Phaseolus mungo</i>	Dorsiventral	Paracytic	Hairy epidermis
35	<i>Glycine max</i>	Dorsiventral	Paracytic	Trichomes
36	<i>Canavalia ensiformis</i>	Dorsiventral	Paracytic	Thick mesophyll
37	<i>Abrus precatorius</i>	Dorsiventral	Paracytic	Crystal deposits
38	<i>Sophora japonica</i>	Dorsiventral	Paracytic	Sclerenchyma fibres
39	<i>Robinia pseudoacacia</i>	Dorsiventral	Paracytic	Thick cortex
40	<i>Butea monosperma</i>	Dorsiventral	Paracytic	Fibrous vascular bundles

For example, Comparative anatomical studies of genera such as *Crotalaria*, *Dalbergia*, and *Stylosanthes* have demonstrated significant structural diversity that aids species identification (Joshi & Deshmukh, 2024; Khan & Ali, 2021; Silva et al., 2023). Furthermore, anatomical investigations of medicinal legumes provide useful information for pharmacognostic identification and quality control (Ahmed et al., 2020; Rao & Patil, 2022). Such anatomical evidence complements morphological data and enhances taxonomic accuracy.

Integration with Molecular Phylogeny

Recent advances in molecular systematics have greatly improved our understanding of legume evolution. Plastid genome sequencing and phylogenomic analyses have revealed complex relationships among papilionoid legumes. When combined with anatomical data, molecular studies provide a more comprehensive view of plant diversity and evolutionary history.

Ecological and Applied Significance

Anatomical adaptations in legumes are often associated with ecological factors such as drought tolerance, nutrient acquisition, and environmental stress resistance (Kaur & Singh, 2021; Das et al., 2023). Recent research has highlighted the importance of structural modifications in legume leaves and stems that contribute to ecological fitness and evolutionary success (Gupta & Sharma, 2024; Silva et al., 2023).

DISCUSSION

Comparative anatomical studies demonstrate both uniformity and diversity among Papilionaceae species. While the basic structural organization remains consistent across the subfamily, several microscopic features vary among genera. These variations reflect evolutionary adaptations to different ecological conditions. Environmental factors such as light intensity, water availability, and temperature influence anatomical modifications. For instance, species inhabiting dry environments often develop thicker cuticles and multiple palisade layers to minimize water loss.

CONCLUSION

Vegetative anatomical characters play an essential role in understanding diversity within Papilionaceae. Variations in epidermal structure, mesophyll

organization, and vascular bundle arrangement contribute significantly to species identification and classification within the subfamily (Kaur & Singh, 2021; Gupta & Sharma, 2024). Integrating anatomical observations with modern molecular approaches will further improve systematic studies within the subfamily.

Conflict of interest

The authors declare no competing interests.

Data Availability Statement: Not applicable.

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