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Elucidating the Morpho-taxonomy and Anatomy of *Celastrus paniculatus* Willd., and their correlation with adaptations

Swati Shukla and Shakti Nath Tripathi*

Department of Botany

Nehru Gram Bharati (Deemed to Be University), Prayagraj 221505, India

*Correspondence: tripathishaktinath@gmail.com

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Abstract

The liana Celastrus paniculatus is one of the members of the family Celastraceae and is used extensively in ayurvedic formulations owing to its remarkable neuroprotective qualities. The present investigation assesses the ecological and adaptive importance of C. paniculatus's morpho-taxonomic and anatomical characteristics. The species is a tall, woody, deciduous climber with a corky, twining stem, alternating, elliptic to ovate leaves with finely serrated margins, and small, polygamous, yellowish-green flowers grouped in terminal or axillary panicles, based on morphological observations. Small, globose capsules that dehisce to reveal red arillate seeds are the fruits' distinctive feature, which facilitates bird-mediated spread. Diffuse-porous wood, simple perforation plates, alternating bordered intervessel pits, libriform fibres, and heterogeneous rays (1–3 cells wide) were all examined anatomically in the stem and wood. Calcium oxalate crystals, corky bark, and paratracheal and apotracheal parenchyma all show physiological and structural adaptations for drought resistance and effective conduction in variable tropical conditions. These characteristics confirm Celastraceae's taxonomic placement within Celastrus and are in line with earlier anatomical descriptions of the family. By combining morpho-taxonomic and anatomical characteristics, C. paniculatus's adaptive strategies as a woody climber in deciduous forests are highlighted, and the importance of these studies in bolstering species identification,

phylogenetic interpretation, and conservation planning for endangered medicinal taxa is further highlighted.

Keywords: *Celastrus paniculatus*, *morpho-taxonomy*, *wood anatomy*, *celastraceae*, *medicinal plant conservation*, *ecological adaptation*.

1. Introduction

Identifying and classifying plants according to their outward morphological characteristics is still a fundamental aspect of botanical study. It offers the most user-friendly and useful framework for species differentiation in both natural and artificial environments (Judd et al., 2016). In the past, morphological characteristics have been the main and most common classification criteria (Cronquist, 1981). Despite the development of molecular technologies, these observable characteristics are still essential for field identification and taxonomic initial recognition. Conversely, the plant's body's anatomical structure displays ecological adaptations (Tripathi et al., 2025). For ecological interpretation and taxonomy placement, it offers supplementary evidence (Metcalf & Chalk, 1972). Documenting and comparing these anatomical characteristics among closely related taxa improves diagnostic understanding from a taxonomic perspective.

Celastrus paniculatus Willd. is a member of the spike thorn family, Celastraceae. Within the order Celastrales, the Celastraceae is a reasonably large family that includes over 100 genera and 1,300–1,350 species, most of which are found in tropical and subtropical areas (Simmons, 2004; Christenhusz et al., 2017). Jyotishmati, or the "intellect tree," is another name for *C. paniculatus*, which holds a unique position at the nexus of contemporary botanical science and traditional ethnobotany. It is an endangered medicinal plant that is utilised commercially in many herbal and ayurvedic remedies. The species is prized for its medicinal and seed oil qualities and is also a taxonomically significant member of the Celastraceae family. Comprehending its anatomy and morpho-taxonomy is crucial for precise identification, analysing its ecological adaptations, and creating evidence-based conservation plans.

The general characteristics of the Celastraceae family have been reported by a number of researchers. Bentham and Hooker (1862) recognised genera including *Celastrus*, *Euonymus*, and *Maytenus* and placed Celastraceae under the order Celastrales. The floral structure, inflorescence type, and fruit shape were the main morphological traits that were the focus of early investigations. One of the first comprehensive

monographs on the family was written by Loesener (1942), who described the species diversity and generic limits. The brief taxonomic explanations given by Willis (1966) in *A Dictionary of the Flowering Plants and Ferns* are still cited in field guides and floras. Cronquist (1981) kept the Celastraceae in the order Celastrales under the Rosidae subclass, focusing on the systematic arrangement of floral and fruity traits.

In Celastraceae, wood anatomy has also been widely explored to elucidate ecological adaptations and taxonomic relationships. The family was described in a pioneering study of wood anatomy by Metcalfe and Chalk (1950). In his analysis of morphology, Chattaway (1932) emphasises the diagnostic relevance of morphology in differentiating genera within the family. Carlquist (1988) investigated the Celastraceae wood's functional architecture, relating environment adaptability to vascular structure. In order to facilitate phylogenetic interpretation, Lens et al. (2008) used comparative wood anatomy across Celastraceae and adjacent families to further clarify the anatomical understanding. These studies support our understanding of *C. paniculatus*'s systematic position, ecological adaptation, and conservation value within the framework of applied botany and current plant taxonomy.

2. Materials and Methods:

2.1. Systematic Position of *Celastrus paniculatus* Willd.

Taxonomic Rank	Classification
Kingdom	Plantae
Subkingdom	Tracheobionta
Superdivision	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Rosidae
Order	Celastrales
Family	Celastraceae
Genus	<i>Celastrus</i>
Species	<i>Celastrus paniculatus</i> Willd.

Collection of plants materials: For morpho-taxonomic and wood anatomical analysis Plant and their parts were collected from forest divisions of MP and Botanical Garden of NGBU.

Taxonomic identification: During extensive field tours, detailed information such as habit, habitat, leaves, stem, color, shape, size of flower and fruit, nature of bark, etc. was collected. The identification of

species was carried out with the help of various floras and relevant taxonomic literature (Hooker 1872-1897; Brandis, 1906).

Preparation of Permanent Slides: Three types of sections were prepared: radial longitudinal sections (RLS), tangential longitudinal sections (TLS), and transverse sections (TS). These include sections made by hand and with a microtome. Using a graded sequence of tertiary butyl alcohol (TBA), materials were dried in order to prepare them for microtome. The dehydrated ingredients were immersed in paraffin wax, which has a melting temperature of 58°C, for three days. The slices were repeatedly dehydrated for three minutes each in an ethanol sequence following five minutes of staining with 2.0% safranin in 50% ethanol. They were then rinsed with distilled water. 70%, 95%, 100%, and 50%. Subsequently, the sections were passed through graded xylene–ethanol solutions (25:75, 50:50, and 75:25) and onto pure xylene following two minutes of 1.0% fast green counterstaining in absolute ethanol. Permanent slides were mounted with Canada balsam. Transverse sections were used to measure the diameters of the tangential vascular lumen.

Observations: Anatomical sections and photographs were studied using a binocular compound microscope. Each parameter lowest, mean, and maximum values were noted after measurements were made from 30 replicates. Micrometers (μm) were used to convert ocular micrometer measurements. Measurements, cell counts, and anatomical descriptions adhere to International Association of Wood Anatomists (IAWA) Committee (1989) and other standards. To facilitate uniform comparison of wood anatomical data across species, the IAWA Committee established a classification system for vessel size and fiber length.

Photographs: Digital single-lens reflex camera for morphological study and Binocular compound microscope (magnifications: 4X, 10X, 40X, 100X) with camera (Model: CH2i) for anatomical observation were used to take photographs of Transverse Section (TS), Radial Longitudinal Section (RLS), and Tangential Longitudinal Section (TLS) in order to record qualitative and quantitative anatomical aspects.

3. Results:

3.1. Morphology and Taxonomy:

It is a large deciduous, woody climbing shrub (liana) that can reach a height upto 10–13 meters. The stem is slender, twining, and develops a corky texture as it matures, while the bark is greyish or pale brown, rough, and peels off in thin flakes. The leaves are simple, alternate, and vary from ovate to elliptic in shape, measuring about 5–10.5 cm in length and 2–5.5

cm in width. They have a finely serrulate margin with an acute or acuminate apex, and a thin-coriaceous texture that gives them a shining green appearance on the upper surface; the petiole is short, and ranging from 0.5–1.5 cm long.

The inflorescences are axillary, 5–15 cm long, bearing numerous small, yellowish-green flowers that are either unisexual or polygamous. Each flower possesses five small, persistent sepals, and five yellowish-green, spreading petals. There are five stamens positioned opposite the petals, while the ovary is three-celled with a short style and a three-lobed stigma. The flowers are actinomorphic. The fruit is a small, globose capsule about 1 cm in diameter, which turns yellow to orange upon ripening. When mature, it dehisces into three valves, revealing 1–3 scarlet seeds enclosed in a bright red aril. The seeds are ovoid, brown in color (Figure 1 A-G).

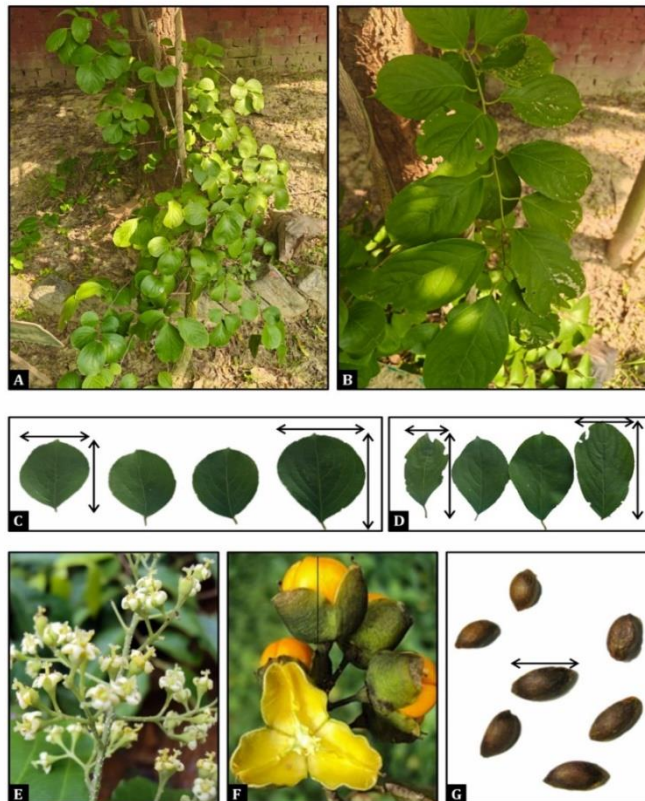


Figure 1; (A) Plant of the the *Celastrus paniculatus*, (B) Arrangement of the leaves, (C) Ovate shape leaves, (D) Elliptic shape leaves, (E) Figure showing the inflorescence, (F) Fruits in dispersed condition, (G) Seeds; (measurement of images in centimeter)

3.2. Anatomical observations (Stem)

The stem's transverse section reveals an outer, thick cuticle followed by a single-layered epidermis with lenticels. Below the epidermis chlorenchymatous tissue present and vascular bundles are arranged in a ring. The center contains parenchymatous pith with crystals.

The stem wood is diffuse-porous, solitary and in short radial multiples (2–3 vessels) mostly, oval in cross-section, and sparse medium to large in diameter (105-190 μm). Perforation Plates simple, intervessel pitting alternate, bordered. Frequently present, especially in older xylem. Fibres libriform, Axial Parenchyma paratracheal, confluent, and apotracheal diffuse, calcium oxalate crystals present. Rays, Uniseriate to multiseriate (1–3 cells wide), low to medium, composed of procumbent and square cells, heterogeneous both procumbent and upright cells present (Figure 2 H-K).

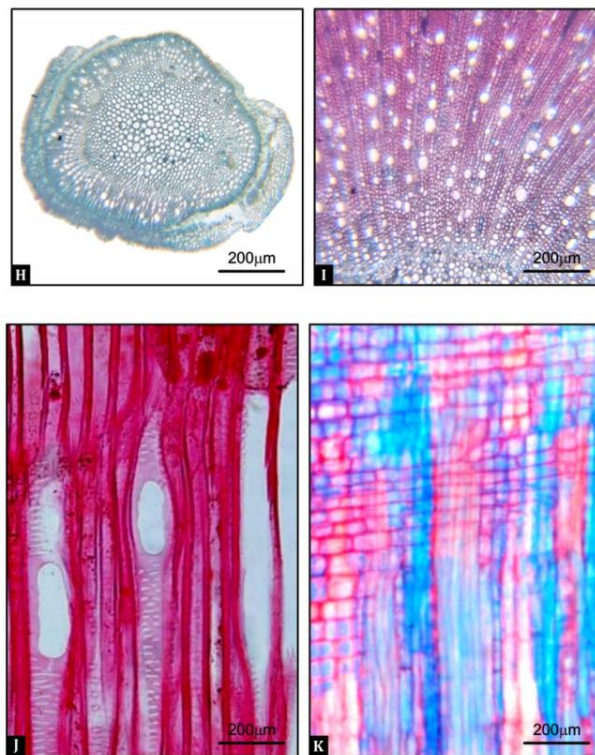


Figure 2: H) T.S. of the young stem (I) TS of the stem wood showing diffuse porous arrangement of vessels, (J) TLS showing the perforation plates with pits and other xylem elements, (K) RLS showing the parenchyma cells.

4. Discussion

The present study provides an integrative understanding of the morpho-taxonomic and anatomical attributes of *C. paniculatus*, an important medicinal liana of the family Celastraceae. The observed characteristics align well with previous descriptions, validating the species' distinct systematic position within the genus *Celastrus* and supporting its adaptation to deciduous forest environments. The species exhibits the typical habit of a large woody climber, attaining heights up to 10–13 meters (Simmons, 2004). The twining, corky stem and exfoliating bark are characteristic features that help in climbing and protection against desiccation, reflecting ecological adaptations for survival in open forest canopies (Carlquist, 1988). Such stem morphology is often observed in woody climbers that rely on secondary thickening for mechanical support and flexibility (Ewers et al., 2015). The leaves of *C. paniculatus* are simple, alternate, and ovate to elliptic in shape, a trait typical of the genus *Celastrus* (Loesener, 1942). Their shining green, thin-coriaceous texture indicates adaptation to moderate light intensity and water availability, aiding in photosynthetic efficiency. A morphological adaptation frequently observed in tropical and subtropical taxa, the acuminate apices and coarsely serrulate edges enable effective transpiration and water runoff (Gentry, 1991). Sharma and Balakrishnan (1993) have confirmed the taxonomic significance of additional Indian *Celastrus* species by describing similar leaf features.

The inflorescence type, axillary, is a diagnostic feature of *C. paniculatus*, distinguishing it from *C. monospermus* and *Celastrus hindsii*, which typically bear fewer flowers (Hooker, 1875; Willis, 1966). Furthermore supporting the findings of Bhattacharyya and Johri (1998), who highlighted the importance of floral dimorphism in species identification, are the tiny, yellowish-green, bisexual or polygamous blooms. According to Cronquist (1981) and Simmons (2004), the Celastraceae family's floral plan is followed by the presence of five sepals and petals, as well as stamens on either side of the petals.

One of the main identifying factors is the fruit, which is a tiny, globose, three-valved capsule. When the capsule is fully grown, it cracks open to reveal scarlet arillate seeds, a visually arresting method of dissemination that draws frugivorous birds (Pandey & Tripathi, 2015). In forest habitats, this adaptation improves the efficacy of seed dispersal, guaranteeing population persistence and broad genetic dissemination.

The ecological amplitude of *C. paniculatus* may possibly be

connected to the morphological plasticity that has been seen in this species. In India and South-east Asia, the species is found in semi-evergreen and dry deciduous woods (Naik & Nimbalkar, 2012). The ability to adapt has been ascribed to structural characteristics like corky stems and coriaceous leaves, which control water balance during periods of seasonal drought. *C. paniculatus* is a representative of xeric liana forms in the Celastraceae based on its morphological characteristics.

Diffuse-porous hardwoods are characterised anatomically by *C. paniculatus*'s uniformly dispersed vessels throughout the growth ring. Favourable adaptation in tropical regions with alternating dry and wet periods, this vascular design represents consistent water conduction across the seasons (Carlquist, 2001; Lens et al., 2008). There is an ecological trade-off between conduction and safety because the medium to large vessel diameter (105–190 µm) increases hydraulic efficiency but may make the plant susceptible to embolism during extreme drought (Hacke & Sperry, 2001).

According to Metcalfe and Chalk (1950) and Rajput and Rao (1998), the wood anatomy documented for other Celastraceae members is congruent with the simple perforation plates and alternating bordered intervessel pits. These characteristics, which preserve structural integrity while facilitating effective water movement, are thought to be evolutionarily advanced. Particularly important for a climbing liana, the presence of libriform fibres suggests the function of fibres in mechanical support (Chattaway, 1932; Carlquist, 1988). One crucial diagnostic feature of *C. paniculatus* is the paratracheal and apotracheal parenchyma. Alkaloids and fixed oils, which are known to accumulate in this species, are among the secondary metabolites and nutrients that are stored and transported radially by the parenchyma cells, which are frequently confluent (Khare, 2007). Presence of calcium oxalate crystals within parenchyma further supports its taxonomic placement within Celastraceae, as crystal morphology and distribution have been used as family-level markers (Fahn, 1990). Deciduous forest lianas rely on their large arteries and well-developed parenchyma to store water during dry spells and recover quickly from embolisms (Zhang et al., 2021).

From an ecological point of view, the existence of lenticels and corky bark suggests active gas exchange and desiccation resistance. Thus, the anatomical traits support morphological adaptations, demonstrating how *C. paniculatus* preserves physiological equilibrium in arid tropical environments. These findings support Carlquist's (1988) "ecological wood anatomy" theory, which holds that the fibre composition and vessel

properties reflect the ecosystem. A thorough grasp of *C. paniculatus* is provided by the combination of morphological and anatomical data, which connects traditional taxonomy with contemporary ecological and conservation viewpoints. Understanding the morphological and ecological adaptations of different plant taxa has been greatly aided by recent anatomical studies. The stem and root morphology of *P. paniculata* Roxb. (Convolvulaceae) was thoroughly studied by Sahney & Tripathi (2020), who focused on the connection between wood structure and ecological adaptation. In a different investigation, Sahney & Tripathi (2020) looked at the wood anatomy of *Berberis lycium* Royle (Berberidaceae), emphasising how anatomical characteristics show ways of adapting to particular environmental circumstances. Tripathi et al. (2023) continued this line of enquiry by describing the anatomical characteristics and adaptive relevance of *Kopsia fruticosa* Roxb. (Apocynaceae), revealing a strong relationship between wood anatomy, ecological behaviour, and physiological strength. When taken as a whole, these investigations highlight how crucial anatomical analysis is for deciphering ecological adaptations and evolutionary patterns in a variety of angiosperm families. Morphological plasticity, anatomical specialisation, and functional adaptability all work together to determine evolutionary success in tropical woody climbers, as this species demonstrates.

5. Conclusion

The present study provides a comprehensive evaluation of the morpho-taxonomic and anatomical features of *C. paniculatus*, linking classical taxonomy with modern ecological and adaptive insights. The species displays a well-defined set of diagnostic characters including its twining woody habit, coriaceous leaves, and arillate fruits that distinctly align it within the genus *Celastrus* and the family Celastraceae. The wood anatomy, characterized by diffuse-porous vessels, libriform fibers, heterogeneous rays, and paratracheal apotracheal parenchyma, reflects both taxonomic consistency and adaptive functionality. These anatomical adaptations support efficient hydraulic conductivity, mechanical flexibility, and resilience under seasonal drought stress, all of which are essential for the survival of lianas in dry deciduous forests. The study reinforces the importance of integrative morpho-anatomical analyses in plant systematics, especially for climbers exhibiting significant ecological plasticity. Moreover, the structural traits identified herein such as corky bark, wide vessels, and well-developed parenchyma demonstrates evolutionary adaptations that facilitate survival in variable moisture regimes. Given the endangered status and high pharmacological value of

C. paniculatus, its detailed morpho-anatomical characterization is crucial not only for accurate identification and authentication in medicinal plant trade but also for the formulation of in situ and ex situ conservation strategies. Future work integrating molecular phylogenetics, ecological modeling, and tissue-specific metabolomics could further clarify its evolutionary relationships and adaptive mechanisms. Thus the study exemplifies how traditional morphological taxonomy, when combined with anatomical and ecological insights, contributes to a holistic understanding of plant diversity and conservation biology within Celastraceae.

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