

REVIEW

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An integrated review of taxonomy, ethnobotany, phytochemistry, value chains and conservation strategies of *Phanera vahlii*

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Abstract

Phanera vahlii (Wight & Arn.) Benth. (syn. *Bauhinia vahlii*) is a large woody liana widely distributed across tropical and subtropical regions of South Asia and recognized for its ecological, ethnobotanical, and economic importance. This review synthesizes available literature up to December 2025 to provide an integrated assessment of its taxonomy, morphology, distribution, utilization, phytochemistry, propagation, and conservation status. Molecular and morphological evidence support its classification within *Phanera* as a distinct lineage of woody climbers. The species is characterized by robust lianescent growth, bilobed leaves, and elongated woody pods, and contributes significantly to forest structure and biodiversity. *P. vahlii* is an important non-timber forest product (NTFP), supporting rural livelihoods through leaf-based biodegradable products, fibre extraction, and seasonal food use. Phytochemical investigations reveal the presence of flavonoids, phenolics, and galactomannan-rich polysaccharides with reported antioxidant, antimicrobial, and antidiabetic activities; however, evidence remains largely preclinical, with limited data on toxicity and clinical validation. Natural regeneration is constrained by seed dormancy, irregular fruiting, and anthropogenic pressures, including overharvesting and habitat degradation. Despite its wide distribution, the species remains unassessed by the IUCN and shows localized population declines. Key research gaps include the need for quantitative ecological data, standardized propagation protocols, and value-chain optimization. This review highlights the potential of *P. vahlii* as a bioresource for sustainable livelihoods and emphasizes the importance of integrated conservation and management strategies.

Keywords Woody liana, Ethnobotany, Phytochemistry, Non-timber forest products, Propagation, Conservation, Value chain, Bioeconomy

1 Introduction

Lianas, or woody climbers that depend on other plants for structural support, are key components of tropical and subtropical forest ecosystems. They influence forest dynamics by modifying canopy structure, altering light availability, and competing with trees for resources. Despite their ecological importance, lianas remain comparatively



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understudied relative to trees and understory vegetation, particularly in relation to their economic and ethnobotanical significance.

Among these, *Phanera vahlii* (Wight & Arn.) Benth. (syn. *Bauhinia vahlii*), commonly known as Malu or Siali, is one of the largest and most ecologically and economically important lianas of the Indian subcontinent. The species is widely distributed across India, Nepal, and Bangladesh, occurring predominantly in moist and dry deciduous forests [62, 77]. It exhibits a broad ecological amplitude, thriving in well-drained soils under both full sunlight and partial shade. Its massive woody stems, paired tendrils, and large bilobed leaves enable efficient climbing and canopy colonization, often influencing forest structure and contributing to habitat heterogeneity [11, 16].

Taxonomically, the species has undergone significant revision. Previously placed under *Bauhinia*, it is now recognized under *Phanera* based on combined morphological and molecular evidence distinguishing climbing taxa from tree-form bauhinias [12, 43, 62, 75]. This reclassification reflects advances in phylogenetic systematics within the subfamily Cercidoideae. While morphological descriptions of the species are well documented in classical floras, repetition across studies highlights the need for a more synthesized and critical presentation of taxonomic and structural traits.

Beyond its ecological importance, *P. vahlii* plays a central role in the livelihoods of forest-dependent communities. Its leaves are widely used to produce biodegradable plates (“patravali”), while seeds are consumed as a seasonal food resource and bark provides strong fibres for rope-making and household applications [6, 16, 56, 67]. These uses make it a valuable non-timber forest product (NTFP), contributing to subsistence and income generation [74, 82]. Increasing global demand for sustainable and biodegradable materials has further enhanced its economic relevance.

Phytochemical and pharmacological studies have identified a range of bioactive compounds, including flavonoids and phenolics, with reported antioxidant, antimicrobial, and antidiabetic properties [5, 39, 41, 59, 84]. However, most studies remain limited to laboratory-scale investigations, with insufficient evidence on toxicity, standardization, and clinical efficacy. Similarly, industrial applications such as fibre-based composites show promise but lack comprehensive lifecycle and scalability assessments.

Despite its wide distribution and multipurpose utility, *P. vahlii* faces several ecological and management challenges. Natural regeneration is constrained by hard-seed dormancy, irregular fruiting, and seed predation, while anthropogenic pressures such as overharvesting and habitat degradation contribute to localized population declines [16, 54]. Additionally, quantitative data on population structure, regeneration dynamics, and value-chain economics remain limited, restricting effective conservation and management planning.

Although substantial information exists on various aspects of the species, it is dispersed across disciplines and often lacks integration and critical evaluation. Therefore, a comprehensive synthesis is required to consolidate existing knowledge and identify research gaps.

This review aims to critically integrate available information on the taxonomy, morphology, ecology, ethnobotany, phytochemistry, propagation biology, and conservation of *Phanera vahlii*. By doing so, it seeks to provide a scientific basis for sustainable utilization, value-chain development, and conservation strategies in the context of emerging bioeconomy and climate-resilient livelihoods.

2 Materials and methods

This review was conducted using a systematic and multi-source literature synthesis approach following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency, rigor, and reproducibility. Scientific databases including Web of Science, Scopus, PubMed, Google Scholar, CAB Abstracts, AGRICOLA, JSTOR, and ProQuest were systematically searched. These were complemented by specialized repositories such as the India Biodiversity Portal, Plants of the World Online (POWO), eFlora of India, and the International Plant Names Index (IPNI). The search covered literature published up to December 2025.

Search queries included combinations of keywords such as “*Phanera vahlii*”, “*Bauhinia vahlii*”, “Mahul”, and “Siali”, along with terms related to taxonomy, ecology, ethnobotany, phytochemistry, pharmacology, propagation, non-timber forest products (NTFPs), and market value.

A total of 312 records were initially identified. After removing duplicates, 250 records were retained for title and abstract screening. Of these, 198 articles were subjected to full-text assessment. Following eligibility evaluation, 79 studies were included in the final synthesis and cited in the manuscript (Fig. 1).

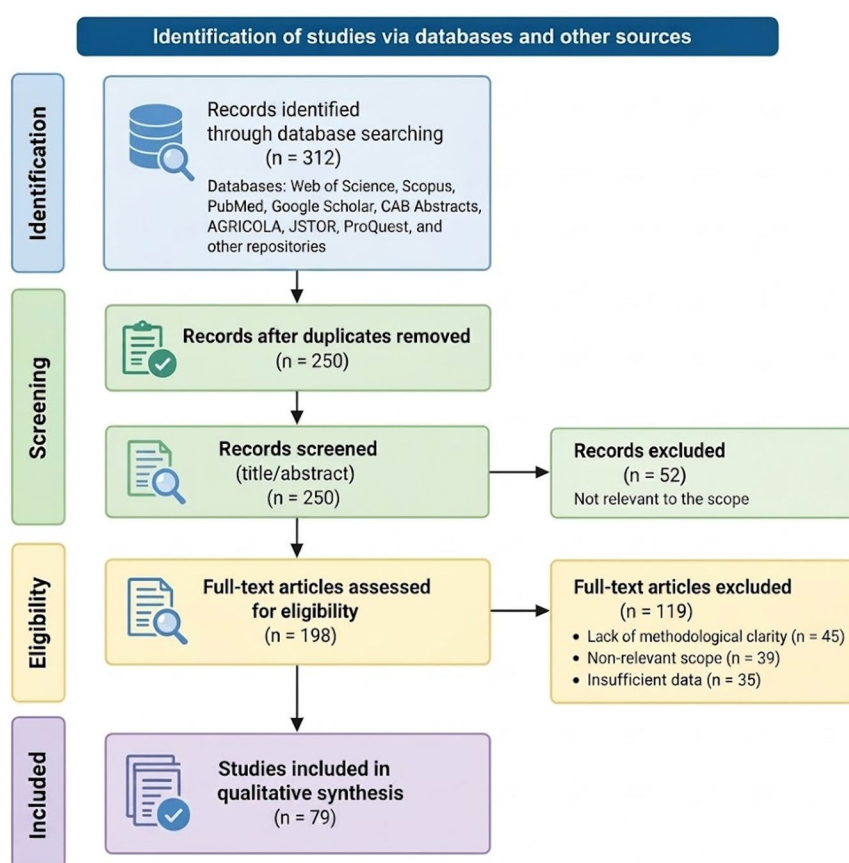


Fig. 1 PRISMA flow diagram illustrating the literature selection process for the review of *Phanera vahlii*. A total of 312 records were identified through database and repository searches. After removal of duplicates, screening, and eligibility assessment, 79 studies were included in the final synthesis and cited in this review

2.1 Inclusion criteria

- Peer-reviewed research articles, books, monographs, and authoritative reports.
- Studies addressing taxonomy, morphology, ecology, ethnobotany, phytochemistry, pharmacology, propagation, or economic aspects of *Phanera vahlii*.
- Publications from credible institutional and scientific sources.

2.2 Exclusion criteria

- Non-scientific or anecdotal sources.
- Studies lacking methodological clarity or verifiable data.
- Duplicate, redundant, or inaccessible publications.

Data from selected studies were extracted into a structured database, including bibliographic metadata, morphological traits, phytochemical composition, pharmacological activities, propagation parameters, fibre properties, distributional records, and market-related information. Taxonomic names and synonyms were verified using POWO, IPNI, and the Catalogue of Life to ensure nomenclatural accuracy and consistency.

Phytochemical and pharmacological data were standardized where possible, and qualitative comparisons were conducted across extraction methods, solvents, dosages, and reported bioactivities. Ethnobotanical information was compiled from field-based studies, ethnographic records, and monographs, and categorized into functional use groups with cross-regional validation. Propagation techniques—including seed treatments, vegetative methods, and micropropagation protocols—were evaluated based on reported success rates and methodological rigor.

Market and livelihood data were synthesized from value-chain analyses, government reports, NGO documentation, and available trade records. Study quality, sampling design, and methodological limitations were critically assessed throughout the review process to ensure the robustness and reliability of interpretations.

2.3 Occurrence data collection

Georeferenced occurrence records of *Phanera vahlii* were retrieved from the Global Biodiversity Information Facility (GBIF; <https://www.gbif.org>). A total of 358 records were downloaded on 9 April 2026 using the GBIF data portal. These records included validated latitude and longitude coordinates and served as the primary dataset for spatial distribution analysis [35].

2.4 Data cleaning and validation

The downloaded dataset was curated to ensure accuracy and reliability. Records lacking geographic coordinates, containing duplicate entries, exhibiting spatial inaccuracies (e.g., zero coordinates or obvious georeferencing errors), or falling outside the natural distribution range were excluded. The cleaned data were standardized using Microsoft Excel and processed in QGIS (version 4.0.0). All spatial analyses were conducted using the World Geodetic System 1984 (WGS 84; EPSG:4326).

2.5 Spatial analysis and mapping

The validated occurrence records were used to generate a geographic distribution map and kernel density heatmap in QGIS (version 4.0.0). Kernel Density Estimation (KDE)

was applied to identify spatial clustering patterns using a search radius of approximately 2° (~200 km). The resulting heatmap illustrates spatial variation in occurrence intensity across India.

3 Results and discussion

This review provides a rigorous and cohesive assessment of *P. vahlii*, structured around ten thematic domains: (i) taxonomic placement and evolutionary context; (ii) morphological and reproductive characteristics; (iii) distributional ecology; (iv) economic, ethnobotanical, and livelihood significance; (v) ethnomedicinal importance; (vi) phytochemical and pharmacological attributes; (vii) industrial and biomedical potential; (viii) propagation constraints and technological advancements; (ix) marketing and commercial prospects; and (x) conclusion and future research directions.

3.1 Taxonomic placement and evolutionary context

Phanera vahlii (Wight & Arn.) Benth. (syn. *Bauhinia vahlii*) is a massive climbing legume belonging to the family Fabaceae, subfamily Cercidoideae, and tribe Bauhinieae, a lineage long recognized for its distinctive bilobed leaves and bauhinioid floral traits. Historically, the species was included within the broadly circumscribed genus *Bauhinia*, which comprised trees, shrubs, and climbers, resulting in a morphologically heterogeneous and taxonomically complex group [28, 50].

Advances in molecular systematics have significantly refined this classification. Phylogenetic analyses based on chloroplast markers such as *matK*, *rbcL*, and *ndhF* demonstrate that lianescent taxa form a distinct and monophyletic lineage, justifying the segregation of *Phanera* as an independent genus [12, 75]. Accordingly, *P. vahlii* is now recognized as an accepted species in authoritative databases including Plants of the World Online [62] and the International Plant Names Index [43]. The species represents an important member of early-diverging bauhinioid climbers within Cercidoideae.

3.1.1 Taxonomic history and nomenclatural transition

The taxonomic transition between *Bauhinia* and *Phanera* reflects the broader shift from morphology-based to phylogeny-based classification. *Bauhinia* was originally established by Linnaeus (1753) as a large pantropical genus; however, subsequent studies revealed its polyphyletic nature [33]. *Phanera*, described by Loureiro (1790), was historically treated as a subgenus (*Bauhinia* subg. *Phanera*) before being reinstated as a distinct genus based on molecular evidence [2, 3, 38].

As part of this revision, several climbing species were transferred to *Phanera*, including *Bauhinia vahlii*, now accepted as *Phanera vahlii* [4]. Despite this, the synonym *Bauhinia vahlii* remains widely used in ethnobotanical, ecological, and pharmacological literature, necessitating careful standardization in scientific communication.

3.1.2 Molecular and morphological basis for recognizing *Phanera*

The distinction between *Phanera* and *Bauhinia* sensu stricto is supported by both molecular and morphological evidence. Multilocus phylogenetic analyses consistently resolve *Phanera* as a monophyletic lineage distinct from related genera such as *Lasiobema* and *Piliostigma* [12, 75].

Morphologically, *Phanera* species are characterized by:

- Lianescent growth habit
- Presence of paired axillary tendrils
- Deeply bilobed leaves
- Reduced number of fertile stamens (typically 2–3)
- Distinct calyx and hypanthium morphology

These features are consistently expressed in *P. vahlii*, distinguishing it from tree-form bauhinias such as *B. variegata* and *B. racemosa*, which lack climbing adaptations [3].

3.1.3 Evolutionary relationships within Cercidoideae

Within Cercidoideae, *Phanera* represents an early-diverging bauhinioid lineage characterized by bilobed leaves and diverse growth forms. Molecular clock analyses suggest that major bauhinioid lineages diverged during the Paleogene (~62.7 Ma), with Asian clades—including *Phanera*—representing early evolutionary splits [75].

The evolution of climbing mechanisms such as tendrils and flexible stems is interpreted as an adaptive response to competition for light in dense tropical forests [12]. *P. vahlii* exemplifies this specialization, combining ancestral leaf morphology with derived structural adaptations that enable canopy dominance.

3.1.4 Synonymy and nomenclatural context

The nomenclatural history of *P. vahlii* reflects successive revisions in bauhinioid taxonomy. Initially described as *Bauhinia vahlii* Wight & Arn., it was later transferred to *Phanera* by Bentham [8], a classification now supported by molecular evidence [43, 62].

The species has accumulated several synonyms, including *Bauhinia scandens* Roxb. and *B. tomentosa* Wall. ex Benth., reflecting historical taxonomic interpretations [28]. Vernacular names such as Malu, Siali, and Mahul further indicate its widespread cultural and ethnobotanical relevance [16].

3.1.5 Diagnostic characters for field identification

P. vahlii is readily identifiable by its massive woody liana habit, paired axillary tendrils, and exceptionally large bilobed leaves with a pronounced central sinus. Leaves are broadly ovate with radiating venation, while flowers are white turning buff with age, typically bearing three fertile stamens and several staminodes [34, 45].

The species produces elongated, flattened woody pods (20–30 cm) covered with fine hairs, containing 8–12 flat seeds [16]. These traits distinguish it from related taxa such as *B. variegata*, *B. racemosa*, and *Piliostigma* spp.

3.1.6 Taxonomic uncertainties and future directions

Despite substantial advances, taxonomic uncertainties persist due to limited population-level molecular sampling and observed morphological variability across regions [16]. This variability may reflect ecological adaptation, phenotypic plasticity, or genetic differentiation.

Future research should integrate genomics, morphometric analyses, and ecological niche modelling to clarify intraspecific variation, evolutionary relationships, and taxonomic boundaries of *P. vahlii*, particularly across central and northeastern India where diversity appears highest.

3.2 Morphological and reproductive traits

Phanera vahlii (syn. *Bauhinia vahlii*) is one of the largest and most structurally specialized lianas of the Indian subcontinent, exhibiting morphological and reproductive adaptations that enable it to dominate forest canopies across tropical moist and dry deciduous habitats. Its morphology has been extensively documented in classical floras, field surveys, and taxonomic databases [16, 19, 34, 43, 45, 62].

The species is characterized by a massive woody climbing habit, paired tendrils, and large bilobed leaves, which together facilitate efficient canopy colonization and persistence (Fig. 2).

3.2.1 Vegetative morphology

The vegetative morphology of *P. vahlii* reflects extreme lianescent specialization. Mature stems may exceed 30–40 m in length and reach diameters of 15–20 cm, enabling the plant to span multiple canopy layers [16]. Young shoots are densely covered with rusty or silvery trichomes, which protect against desiccation and herbivory, while older stems become glabrous, lignified, and rope-like.

Leaves are large, coriaceous, and deeply bilobed, typically measuring 10–30 cm across, with a prominent central sinus and radiating venation [34, 45]. The lower surface is densely pubescent, whereas the upper surface is comparatively glabrous, reflecting adaptations for water balance and light interception.

A key diagnostic feature of *Phanera* is the presence of axillary tendrils, derived from modified rachial tissues, which enable strong attachment and climbing efficiency [12, 75]. These features distinguish *P. vahlii* from non-climbing bauhinias such as *B. variegata* and *B. racemosa*.

3.2.2 Anatomical characteristics

Anatomical adaptations in *P. vahlii* support its mechanical and ecological requirements as a canopy liana. Leaves possess a thick cuticle and dorsiventral mesophyll organization, enhancing tolerance to high radiation and environmental stress [20]. Calcium oxalate crystals and mucilage canals are present, contributing to defense and water regulation [34].

Stems exhibit well-developed vascular bundles and sclerenchymatous tissues that provide high tensile strength and flexibility. Secondary xylem is heavily lignified in mature stems, enabling resistance to mechanical stress in canopy environments.

3.2.3 Floral biology

The floral biology of *P. vahlii* is characterized by axillary sub-corymbose racemes bearing numerous white flowers that turn buff upon maturation [45]. Flowers typically consist of five petals and ten stamens, of which three to five are fertile and the remainder are reduced to staminodes, a key feature supporting its classification within *Phanera* [12].

Anthesis generally occurs in the early morning, coinciding with peak pollinator activity. Pollination is primarily entomophilous, involving bees, hoverflies, and other insects, reflecting a generalized pollination system [15, 28, 30, 72].



Fig. 2 Morphological characteristics of *Phanera vahlii* (Wight & Arn.) Benth.: **a** massive woody liana climbing over forest canopy; **b** characteristic bilobed leaf with a deep central sinus; **c** inflorescence bearing white flowers; **d** elongated, flattened woody pod; **e** discoid seeds with hard testa (2900.00 μm). Images compiled from field observations

3.2.4 Fruit and seed traits

Fruits are elongated, flattened woody pods measuring 15–25 cm (occasionally up to 30 cm), covered with rusty-brown pubescence [16, 81]. Each pod typically contains 5–12 flat, discoid seeds measuring 1.5–2.5 cm in diameter.

Seeds possess a hard testa that restricts water imbibition, contributing to dormancy and delayed germination. While this trait enhances survival under variable conditions, it also limits natural regeneration. Germination rates vary widely (approximately 40–80%) depending on environmental conditions and pretreatment methods.

3.2.5 Reproductive phenology

P. vahlII exhibits a seasonal phenological cycle with regional variation. Flowering typically occurs between February and April, while fruit development and maturation extend from May to July [19, 34].

Flowering intensity and synchrony vary annually and are influenced by climatic factors such as rainfall and temperature. Irregular or semi-mast flowering patterns have been observed, leading to fluctuations in seed production and regeneration success [61].

3.2.6 Reproductive constraints

Despite its widespread distribution, *P. vahlII* faces several reproductive limitations. Seed predation by insects and rodents reduces viable seed availability [45]. Competition from invasive species such as *Mikania micrantha* suppresses seedling establishment [16].

Additionally, anthropogenic pressures including leaf harvesting, bark extraction, and habitat degradation reduce plant vigor and reproductive output. The dependence on large host trees further constrains regeneration in disturbed forests.

3.2.7 Comparative morphology

Comparative analysis highlights the distinctiveness of *P. vahlII*. Unlike *Bauhinia tomentosa*, which is a shrub or small tree lacking climbing structures, *P. vahlII* exhibits a lianescent habit with tendrils and significantly larger leaves [12, 75].

In contrast to *B. variegata*, a tree species with upright growth and smaller leaves, *P. vahlII* shows pronounced climbing adaptations and larger lamina size. Similarly, *Ptilostigma malabaricum* differs in lacking tendrils and having distinct fruit morphology.

These differences support the taxonomic separation of *Phanera* from *Bauhinia* sensu stricto and reinforce field-level diagnostic identification.

3.3 Distributional ecology of *Phanera vahlII*

Phanera vahlII (syn. *Bauhinia vahlII*) is a widely distributed lianescent species across the Indian subcontinent, predominantly occurring in tropical and subtropical forest ecosystems. It thrives in moist and dry deciduous forests, forest edges, riverbanks, and open thickets, where well-drained, slightly acidic to neutral soils rich in organic matter are available [17, 68].

The species is adapted to warm climatic conditions, with optimal growth occurring at temperatures of 22–30 °C, moderate to high humidity, and annual rainfall ranging from 900–1500 mm [34, 68]. It shows moderate drought tolerance but performs best under consistent soil moisture regimes.

3.3.1 Geographic distribution

P. vahlII is native to South Asia and occurs across India, Nepal, Bangladesh, Bhutan, and parts of Myanmar and Sri Lanka [19, 44, 62]. Within India, it is widely distributed across the sub-Himalayan belt and peninsular regions, including Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, Odisha, Chhattisgarh, Madhya Pradesh, Maharashtra, and the Eastern and Western Ghats [16, 17] (Fig. 3).

Core populations are particularly abundant in central and eastern India, where the species supports forest-based livelihoods and non-timber forest product (NTFP) economies [5].

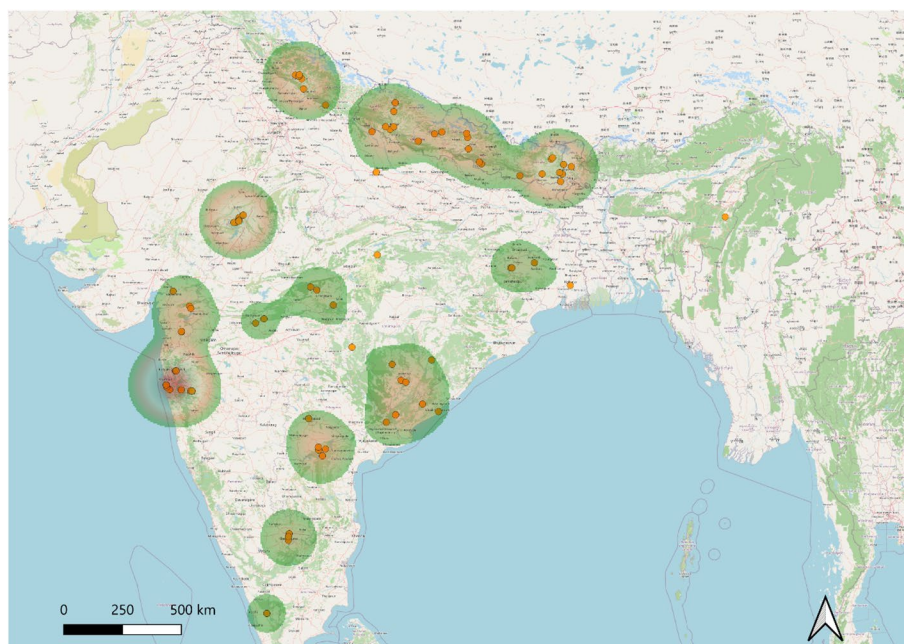


Fig. 3 Geographic distribution and kernel density estimation of *Phanera vahlII* across India based on georeferenced occurrence records ($n=358$) obtained from the Global Biodiversity Information Facility (GBIF). Point locations represent individual occurrence records, while the kernel density heatmap illustrates spatial variation in occurrence intensity. Warmer colors (yellow–red) indicate areas of higher density (hotspots), whereas cooler colors (green) represent lower density. Kernel density analysis was performed using a search radius of approximately 2° (~ 200 km) to highlight regional clustering patterns

3.3.2 Altitudinal range and habitat preferences

The species is generally distributed from lowland regions up to 1200–1500 m, particularly in moist deciduous forests. Reports of occurrence at higher elevations (up to ~ 2000 m) exist in Himalayan regions; however, such records are limited and require further verification [22, 68].

P. vahlII occupies a wide range of habitats including moist deciduous forests, mixed dry deciduous forests, riparian zones, lateritic uplands, and rocky hill slopes. It shows strong association with *Shorea robusta* (sal) forests, where it frequently forms dense canopy networks [76]. Its ability to tolerate varied soil types—from acidic sandy soils to alkaline rocky substrates—contributes to its broad ecological amplitude [22].

3.3.3 Ecological role

Ecologically, *P. vahlII* plays a significant role in forest structure and function. As a large liana often exceeding 30–40 m in length, it enhances canopy connectivity and provides habitat for arboreal fauna, including birds and primates [16]. Flowers serve as nectar sources for pollinators, while leaves and fruits are consumed by herbivores, including large mammals.

The species also contributes to soil stabilization on slopes and nutrient cycling through substantial leaf litter input. However, its aggressive climbing habit can impose competitive pressure on host trees, sometimes suppressing regeneration and causing structural damage, particularly in dense infestations [22].

3.3.4 Climatic and environmental requirements

The species is adapted to tropical monsoonal climates characterized by seasonal rainfall (900–1800 mm) and temperature ranges of 22–35 °C [34]. Vegetative flushing typically occurs before the monsoon, while flowering is synchronized with seasonal climatic patterns, generally between February and April [19, 34].

In Himalayan regions, phenological events may be delayed due to lower temperatures. The species performs best in well-drained soils with moderate moisture and partial sunlight conditions.

3.3.5 Threats and conservation concerns

Despite its wide distribution, *P. vahlii* faces increasing threats due to habitat fragmentation, overharvesting, and ecological disturbances. Intensive harvesting of leaves for the leaf-plate industry reduces photosynthetic capacity and reproductive output, while bark extraction for fibre weakens plant structure [13, 16].

Loss of host trees due to logging and land-use change further restricts its growth, as the species depends on mature trees for support. Invasive species such as *Mikania micrantha* compete with seedlings and reduce regeneration success.

Field observations indicate declining population densities and regeneration bottlenecks in central and eastern India, particularly outside protected areas [48].

3.3.6 Research gaps and future directions

Despite its ecological and economic importance, detailed spatial and ecological data on *P. vahlii* remain limited. There is a need for:

- Population density and regeneration studies
- Host-tree association analysis
- Long-term ecological monitoring
- Climate change vulnerability assessment

Spatial modelling integrating climate and land-use data would help identify conservation hotspots and restoration priority areas. Such efforts are essential for sustainable NTFP management and conservation planning [16, 22, 48].

3.4 Economic, ethnobotanical, and livelihood significance

Phanera vahlii (syn. *Bauhinia vahlii*) is a highly important non-timber forest product (NTFP) species that plays a central role in the subsistence economy, traditional knowledge systems, and livelihood security of forest-dependent communities across South Asia. The species is widely harvested across the sub-Himalayan belt, Assam, central India, Bihar, and the Eastern and Western Ghats, where it contributes significantly to household consumption as well as income generation [10, 48, 74, 82, 83].

Nearly all plant parts—including leaves, stems, bark, seeds, and pods—are utilized, reflecting its multipurpose nature and high socio-economic value (Table 1). Field-based studies indicate that *P. vahlii* is harvested throughout the year in several tribal regions, particularly in the Eastern Ghats, underscoring its importance as a continuous livelihood resource [48].

Table 1 Summary of economic and ethnobotanical uses of *Phanera vahlii*, highlighting its multipurpose utility and role in rural livelihood systems

Plant Part	Key Uses / Functions	Supporting Details	References
Stems & Bark	Rope-making, basketry, fibre craft	Durable bast fibres used in ropes, mats, and household utilities; key livelihood activity	Kumar and Raju [49],Gantait et al. [31]
Leaves	Plates, cups, wrappers, ritual use	Biodegradable, antimicrobial; widely used in festivals and commercial markets	Kumar and Raju [49],Chouhan and Saklani [14], Sahu and Padhy [71], Somayaji and Hegde [80],Aruna Jyothi [1],Devi et al. [16]
Seeds	Food, nutrition, medicinal use	High protein and mineral content; consumed by tribal communities	Rajaram and Janardhanan [67],Vadivel and Janardhanan [42],Singh et al. [60, 61]
Pods	Fuelwood, organic manure	Supports zero-waste utilization	Kumar and Raju [49]
Tendrils	Climbing support	Enables canopy access and biomass availability	Kumar and Raju [49]
Whole plant	NTFP, livelihood support	Year-round resource for subsistence and income	Tewari [83], Burman [10]; Singh et al. [60, 61], Kumar and Raju [49]

3.4.1 Multipurpose utility and economic contributions

The economic significance of *P. vahlii* is primarily derived from its diverse applications in rural and forest-based economies. Leaves represent the most commercially valuable component, being widely used for preparing biodegradable plates, cups, and food wrappers. These products are integral to traditional food systems, religious ceremonies, and local markets, and have gained increased relevance due to the growing demand for eco-friendly alternatives to plastic disposables [7, 14, 16, 55, 64].

The stems and bark provide strong bast fibres that are processed into ropes, mats, and basketry products, forming an important artisanal and livelihood activity in tribal regions [23, 33]. Seeds serve as a valuable nutritional resource and are consumed in various forms (raw, roasted, or cooked), contributing to food security and dietary diversity [51, 60, 61, 73]. Pods are further utilized as fuelwood or organic manure, reflecting efficient resource use and minimal waste [49].

A consolidated overview of plant-part utilization and associated functions is presented in Table 1.

3.4.2 Cultural and ethnobotanical relevance

In addition to its economic value, *P. vahlii* holds deep cultural and ethnobotanical significance. Leaves are extensively used in community feasts, weddings, and religious rituals, while bark fibres are traditionally used in ceremonial practices such as sacred thread preparation and ritual binding [16].

In several indigenous belief systems, the species is associated with fertility, forest protection, and ancestral traditions, reflecting its integration into cultural identity and traditional ecological knowledge.

3.4.3 Nutritional and subsistence value

The seeds of *P. vahlii* constitute an important dietary component among tribal communities, containing 18–22% crude protein, 4–7% lipids, and significant amounts of calcium (100–150 mg/100 g) and iron (4–6 mg/100 g) [67]. The presence of albumins and

globulins as major protein fractions and relatively low levels of antinutritional factors enhances digestibility and nutritional value.

The consumption of seeds and flowers, particularly in regions such as Araku Valley and central India, highlights the species’ role in supporting food security and traditional diets [33, 60, 61].

3.4.4 Livelihood systems and value chain

The commercialization of *P. vahlii*-based products follows a predominantly informal but structured value chain involving collectors, local traders, processors, and market intermediaries. Leaf plate production represents the most significant economic activity, often carried out by tribal households and self-help groups, contributing to rural employment and income diversification.

The generalized value chain is summarized in Table 2, illustrating the flow from forest collection to final consumption.

3.4.5 Sustainability and harvesting concerns

Despite its socio-economic importance, *P. vahlii* faces increasing pressure due to unsustainable harvesting practices. Intensive leaf collection reduces photosynthetic capacity and reproductive potential, while indiscriminate bark extraction weakens plant structure and affects long-term survival [16].

Additionally, the lack of regulated harvesting systems and organized market frameworks results in uneven benefit distribution and resource overexploitation. Sustainable management approaches—including controlled harvesting, community-based resource governance, and value-chain strengthening—are essential to ensure long-term ecological sustainability and livelihood security.

3.5 Phytochemical and pharmacological profiles

Phanera vahlii exhibits a diverse and structurally complex phytochemical profile distributed across its leaves, bark, stems, roots, flowers, and seeds. Evidence from ethnobotanical documentation, biochemical assays, and chromatographic analyses (including GC–MS) consistently indicates the presence of flavonoids, phenolic acids, tannins, saponins, sterols, triterpenoids, fatty acids, and galactomannan-rich polysaccharides [16]. These phytoconstituents form the biochemical basis for a range of pharmacological activities reported in experimental studies (Table 3).

It is important to emphasize that most available evidence is derived from in vitro assays and animal models, and therefore represents preclinical findings that require further validation through clinical research.

Table 2 Generalized value chain of *Phanera vahlii* products, illustrating stages from forest collection to final consumption

Stage	Stakeholders	Activities	Value Addition
Collection	Tribal communities	Harvesting plant materials	Raw resource
Processing	Households/SHGs	Leaf stitching, fibre extraction	Semi-processed goods
Aggregation	Local traders	Bulk collection and transport	Market linkage
Secondary processing	Small enterprises	Plate making, packaging	Product enhancement
Distribution	Wholesalers/retailers	Market supply	Commercial expansion
Consumption	Consumers	End-use	Final value

Table 3 Major phytochemical classes identified in *Phanera vahlii* and their general functional relevance based on biochemical and chromatographic studies

Phytochemical class	Representative compounds	Plant Part(s)	Reported significance	References
Flavonoids & phenolics	Quercetin, quercitrin, kaempferol, luteolin, avicularin, gallic acid	Leaves, bark	Antioxidant and anti-inflammatory potential (preclinical)	Elbanna et al. [21], Devi et al. [16]
Tannins	Condensed tannins (15–17%)	Bark	Astringent and antimicrobial properties	Devi et al. [16]
Saponins	Various saponins	Roots, leaves	Immunomodulatory and antimicrobial activity	Devi et al. [16]
Polysaccharides (galactomannan)	Mannose-rich galactomannan (~ 30%)	Seeds	Thickening and stabilizing properties	Rajaram and Janardhanan [67]
Fatty acids	Palmitic, oleic, linoleic acids	Leaves, seeds	Nutritional and metabolic relevance	Devi et al. [16]
Sterols & triterpenoids	β -sitosterol, stigmasterol, α -amyrin, lupeol	Multiple parts	Anti-inflammatory and membrane-stabilizing roles	Devi et al. [16]

3.5.1 Phytochemical composition

The phytochemical composition of *P. vahlii* is dominated by phenolic and flavonoid compounds, including quercetin, quercitrin, kaempferol derivatives, luteolin, and avicularin, which are widely associated with antioxidant and anti-inflammatory potential [16, 21]. Tannins (notably 15–17% in bark) and saponins are also prevalent and contribute to antimicrobial and astringent properties [16].

Seeds represent an important biochemical component, containing approximately 30% galactomannan with a favorable mannose:galactose ratio (~ 4.2:1), supporting their functional applications as thickening and stabilizing agents in food and pharmaceutical systems [67].

In addition, fatty acids (e.g., palmitic, oleic, linoleic acids), phytosterols (β -sitosterol, stigmasterol), and triterpenoids (α -amyrin, lupeol) contribute to membrane stabilization and metabolic regulation [16].

A consolidated overview of major phytochemical classes, representative compounds, and functional relevance is provided in Table 3.

3.5.2 Pharmacological activities

A broad spectrum of pharmacological activities has been reported for *P. vahlii* extracts, primarily based on preclinical studies (Table 4). Antioxidant activity is strongly correlated with phenolic and flavonoid content, as demonstrated by free radical scavenging assays [35, 37, 65].

Antimicrobial activity has been observed against a range of bacterial and fungal pathogens, including *Escherichia coli*, *Staphylococcus aureus*, and *Candida albicans*, supporting traditional applications in treating infections and wounds [16, 18, 41, 58, 60, 61].

Antidiabetic effects have been reported in streptozotocin-induced experimental models, where plant extracts were associated with reduced blood glucose levels and oxidative stress markers [21, 35, 36]. Anti-inflammatory, analgesic, and antipyretic activities have also been demonstrated in animal models, largely attributed to phenolic and triterpenoid constituents [80, 81].

Table 4 Summary of pharmacological activities reported for *Phanera vahlii* based on in vitro and in vivo studies; evidence is primarily preclinical

Activity	Key Observation	Plant Part / Extract	Experimental Model	References
Antioxidant	Free radical scavenging activity	Leaves, flowers	In vitro assays	Mannangatti et al. [53], Lohani and Sharma [51]
Antimicrobial	Activity against bacteria and fungi	Roots, leaves, stems	Microbial cultures	Dugasani et al. [18], Shukla and Gahlot [77], Devi et al. [16]
Antidiabetic	Reduction in blood glucose	Whole plant extracts	STZ models	Elbanna et al. [21], Mahrous and Nooh [52]
Anti-inflammatory	Reduced inflammation and pain	Roots, stems	Animal models	Tiwari and Singh [80, 81]
Hepatoprotective	Improved liver function markers	Various extracts	Experimental models	Elbanna et al. [21]
Nephroprotective	Protection against renal toxicity	Leaves	Animal models	Kannan et al. [46]
Immunomodulatory	Enhanced immune response	Leaves	In vivo assays	Panda et al. [57]

Table 5 Industrial and biomedical applications of *Phanera vahlii* based on its phytochemical composition and functional properties

Domain	Application	Plant Part	Relevance	References
Fibre applications	Rope, composites	Stems, bark	Moderate tensile strength (~187 MPa)	Bar and Chaudhary [5], Pratap and Patel [64], Raja et al. [66]
Hydrocolloid	Thickener, stabilizer	Seeds	High galactomannan content	Rajaram and Jannardhanan [67]
Nutraceutical	Functional foods	Leaves, seeds	Rich in bioactive compounds	Patil and More [60]
Herbal therapeutics	Anti-inflammatory, antimicrobial	Whole plant	Supported by experimental studies	Dugasani et al. [18], Patil and More [60]
Cosmetic	Skin care formulations	Leaves, seeds	Bioactive-rich extracts	Devi et al. [16]

Additional activities, including hepatoprotective, nephroprotective, immunomodulatory, and antifungal effects, further indicate the pharmacological potential of the species [18, 41, 83].

A summary of experimentally reported pharmacological activities is presented in Table 4.

3.5.3 Industrial and functional relevance of phytochemicals

The phytochemical richness of *P. vahlii* also underpins its emerging industrial and functional applications. The presence of galactomannan polysaccharides in seeds supports their use as natural hydrocolloids in food, pharmaceutical, and cosmetic formulations [67].

Similarly, flavonoids, tannins, and triterpenoids contribute to the development of nutraceuticals, antioxidant formulations, and plant-based therapeutic products, although such applications remain largely at the exploratory or preclinical stage [18, 44].

Bast fibres derived from stems and bark exhibit moderate tensile strength (~187 MPa) and durability, making them suitable for rope-making and potential reinforcement in eco-friendly biocomposites [5, 48, 50].

A summary of industrial and biomedical relevance is provided in Table 5.

3.5.4 Limitations and research gaps

Despite extensive traditional use and growing experimental evidence, several limitations constrain the scientific validation and practical application of *P. vahlii*:

- Lack of clinical trials to confirm efficacy and safety in humans
- Limited toxicity and pharmacokinetic data, particularly for long-term use
- Absence of standardized extraction methods and dosage protocols
- Insufficient investigation of synergistic interactions among phytochemicals
- Underrepresentation in formal pharmacopeial systems (e.g., AYUSH)

In addition, phytochemical composition may vary with environmental factors such as altitude, soil type, season, and climate, yet such variability remains poorly characterized.

Future research should prioritize integrative approaches combining phytochemistry, pharmacology, and clinical validation to support evidence-based utilization of this species.

3.6 Propagation challenges and technological advances

Phanera vahlii (syn. *Bauhinia vahlii*) is a large woody liana of significant ecological and socio-economic importance; however, its natural regeneration is often inconsistent due to seed dormancy, habitat disturbance, and anthropogenic pressures. Effective propagation strategies are therefore essential for conservation, restoration, and sustainable utilization of the species.

Given its biological characteristics and climbing growth habit, propagation of *P. vahlii* requires an integrated approach combining sexual (seed-based), vegetative, and in vitro techniques, each with distinct advantages and limitations (Plants of the World Online, 2025).

3.6.1 Sexual propagation (Seed-based)

Seed propagation remains the most widely used method for raising *P. vahlii* seedlings. Seeds are typically sown during the pre-monsoon to early monsoon period (March–August), when environmental conditions favor germination and establishment [22].

However, the species exhibits hard-seededness, leading to dormancy and delayed germination. Pre-sowing treatments such as hot-water soaking (60–70 °C for 12–24 h) or mechanical scarification are required to break dormancy and enhance germination. Under nursery conditions, these treatments can improve germination rates to approximately 70–85%, with emergence occurring within 3–4 weeks [32].

Natural regeneration occurs through both seeds and vegetative means (e.g., root suckers and layering), but is highly dependent on soil moisture, partial shade, and minimal disturbance [7].

3.6.2 Vegetative propagation

Vegetative propagation provides an effective alternative for clonal multiplication and rapid establishment. Semi-hardwood and softwood cuttings treated with rooting hormones such as indole-3-butyric acid (IBA) or naphthalene acetic acid (NAA) have shown promising results.

Experimental studies report rooting success of up to ~80% using IBA (1000 ppm) under controlled nursery or mist chamber conditions [55]. In addition, natural layering

is commonly observed in wild populations, and artificial methods such as air layering and ground layering have been successfully applied in agroforestry and community forestry systems [23].

Vegetative propagation is particularly advantageous for maintaining desirable genotypes and establishing plantations in areas where seed-based regeneration is limited however, reports on field survival are still lacking.

3.6.3 *In vitro* propagation (Micropropagation)

Micropropagation represents an advanced approach for rapid multiplication and conservation of *P. vahlii*. Protocols developed using nodal and cotyledonary explants cultured on Murashige and Skoog (MS) medium supplemented with growth regulators (e.g., ~1.0 µM TDZ) have demonstrated efficient shoot proliferation [32].

Despite its potential, several technical constraints limit large-scale application, including:

- Phenolic browning of explants
- Microbial contamination
- Poor rooting response
- High mortality during acclimatization

Nevertheless, micropropagation remains a valuable tool for germplasm conservation and ex situ multiplication of elite genotypes.

3.6.4 Propagation constraints and restoration challenges

The propagation and restoration of *P. vahlii* are constrained by multiple biological and ecological factors. Seed dormancy and irregular germination reduce the reliability of nursery production [22]. Overharvesting of leaves, bark, and fibres, combined with habitat fragmentation and grazing pressure, has led to reduced seed sources and declining mature populations [58].

The species' lianescent growth habit presents an additional challenge, as successful establishment requires suitable host trees or artificial support structures, limiting its suitability for conventional plantation systems (Plants of the World Online, 2025).

Genetic erosion is also a concern due to the lack of systematic germplasm collection and molecular characterization. Furthermore, variability in propagation success across techniques and environments complicates the development of standardized protocols [32].

3.6.5 Integrated propagation framework

An integrated propagation strategy combining seed, vegetative, and in vitro approaches is essential for large-scale restoration and sustainable utilization of *P. vahlii*. Seed propagation is suitable for large-scale afforestation, while vegetative methods enable clonal multiplication, and micropropagation supports conservation of elite germplasm. A conceptual overview of propagation pathways and decision points is presented in Fig. 4.

3.7 Marketing and commercial potential

The marketing and commercial potential of Mahul/Siali (*Phanera vahlii*) has expanded significantly in recent years, driven by the convergence of environmental policy, rising

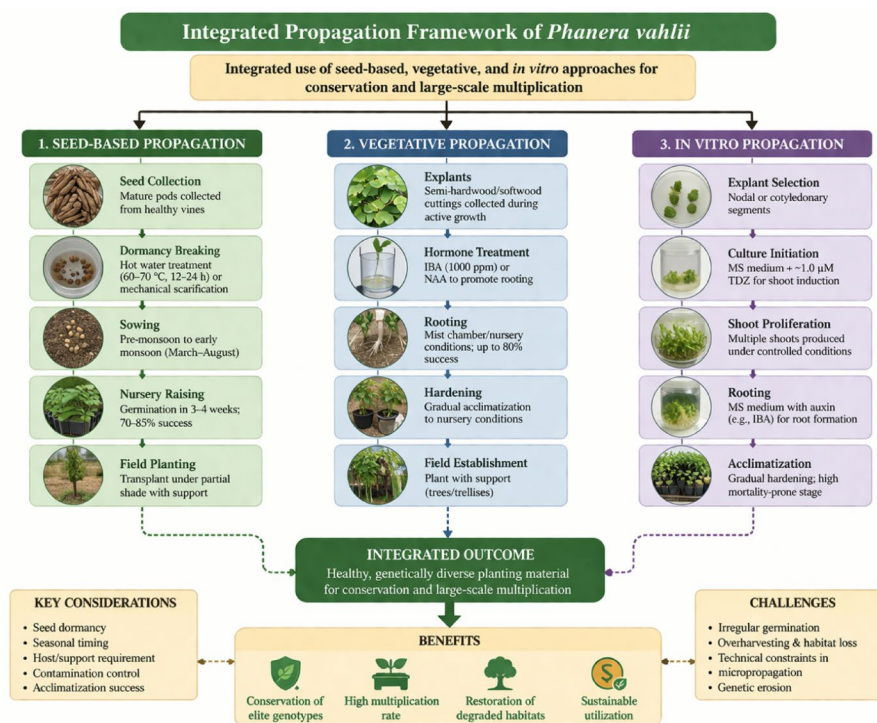


Fig. 4 Integrated propagation framework of *Phanera vahlii* illustrating seed-based, vegetative, and *in vitro* approaches for conservation, restoration, and large-scale multiplication. The framework highlights key stages including dormancy breaking, clonal propagation, micropropagation, and field establishment, along with associated challenges and management considerations

consumer demand for sustainable products, and increasing participation of women-led forest-based enterprises. India's regulatory transition toward eliminating single-use plastics has been a key catalyst, with the Plastic Waste Management Rules and subsequent policy directives promoting biodegradable alternatives in temples, food services, eco-tourism circuits, and community events [26, 49].

Siali leaf plates, characterized by zero-energy production, complete biodegradability, and cultural acceptability, align well with emerging preferences for low-carbon and nature-based packaging materials. Compared to industrially processed alternatives such as areca palm sheath, sugarcane bagasse, bamboo fibre, and molded pulp, Siali products offer a decentralized, low-input production model with minimal environmental footprint [70], Social [79].

3.7.1 Market structure and pricing dynamics

Available market data indicate a steadily expanding domestic trade. Wholesale prices typically range from ₹150–₹200 per 100 pressed plates, while retail and online platforms report per-piece prices between ₹7 and ₹12.60, depending on size, processing quality, and supplier networks [36].

Producer collectivization through Self-Help Groups (SHGs), Farmer Producer Organizations (FPOs), and Community Forest Resource (CFR) governance systems has significantly improved market access and value realization. These institutional arrangements—supported by organizations such as PRADAN (Professional Assistance for Development Action), ORMAS (Odisha Rural Development and Marketing Society), Vasundhara, and SPREAD (Society for Promotion of Rural Education and

Development)—enable bulk procurement, mechanized processing, standardized grading, and direct linkage with urban and institutional markets [47, 66, 74].

As a result, producer margins have increased substantially, with earnings rising from ₹10–₹30 per 100 plates under intermediary-driven systems to ₹45–₹90 under collective marketing models. In some regions, seasonal income for women participants reaches ₹10,000–₹15,000 per month, highlighting the role of Siali-based enterprises in strengthening rural livelihoods [26, 74].

A summary of market characteristics and economic indicators is provided in Table 6.

3.7.2 Emerging demand and global opportunities

At the national level, demand for Siali-based products continues to grow due to expanding eco-tourism, corporate sustainability initiatives, festival-based consumption, and increasing urban demand for eco-friendly products.

Internationally, markets in Europe, North America, Australia, and the Gulf countries offer significant opportunities, driven by stringent environmental regulations and consumer preference for biodegradable and ethically sourced products. The positioning of Siali products as “forest-friendly,” “handcrafted,” and “women-led” further enhances their appeal in premium green markets [78].

3.7.3 Constraints to commercial expansion

Despite its strong potential, large-scale commercialization of Siali products is constrained by several structural and regulatory challenges. Key limitations include:

- Lack of quality standardization and product uniformity
- Absence of microbial and food-contact safety certification
- Inadequate moisture-proof packaging and storage infrastructure
- Limited traceability and labelling compliance for export markets

These issues have gained prominence following regulatory actions such as the U.S. FDA’s post-market assessment of natural leaf tableware, which highlighted safety and compliance gaps affecting export potential [31, 71].

Additional constraints include variability in leaf size, seasonal availability, storage losses, absence of branding, and limited digital marketing capacity among rural producers [47, 74].

Table 6 Key economic indicators, market drivers, and constraints influencing the commercialization of Siali (*Phanera vahlii*) products in domestic and international markets

Parameter	Observation	Implication	References
Wholesale price	₹150–₹200 per 100 plates	Stable domestic demand	TradeIndia [36]
Retail price	₹7–₹12.60 per plate	Expanding consumer market	TradeIndia [36]
Producer income	₹10–₹90 per 100 plates	Improved margins via collectivization	Ghosh [37], Vasantdhara [27]
Peak income (women)	₹10,000–₹15,000/month	Strong livelihood support	Ghosh [37], Vasantdhara [27]
Market drivers	Plastic ban, eco-tourism, CSR demand	Sustained demand growth	Press Information Bureau [65]
Export potential	High (EU, USA, Gulf)	Requires certification compliance	Talukdar et al. [78]
Key constraints	Quality, certification, storage	Limits scaling and exports	KNN India [47], FDA [29]

Abbreviations: EU = European Union; USA = United States of America; CSR = Corporate Social Responsibility

3.7.4 Value chain strengthening and policy opportunities

Addressing these constraints requires targeted investments in decentralized processing infrastructure, including community warehouses, solar drying units, mechanical stitching and pressing technologies, and improved packaging systems.

The development of standardized certification frameworks—such as a potential “National Siali Certification Scheme”—could enable quality assurance, traceability, and market differentiation. Integration with eco-tourism supply chains, CSR procurement systems, and green public procurement policies could further expand market access [9, 47].

Branding strategies emphasizing attributes such as “CFR-certified,” “forest-friendly,” and “women-made” products may enhance value in both domestic and export markets.

3.7.5 Future outlook

Siali-based enterprises demonstrate strong potential to transition from traditional subsistence activities to organized green-market systems. The species occupies a unique position at the intersection of sustainable forestry, circular economy principles, and women-centered entrepreneurship.

However, realizing this potential requires coordinated efforts in quality standardization, certification, infrastructure development, and market integration. With appropriate policy support and institutional strengthening, *P. vahlii* can evolve into a globally competitive, sustainable forest-based commodity while simultaneously supporting biodiversity conservation and rural livelihoods [26, 68, 74].

3.7.6 Conservation status

Phanera vahlii (Wight & Arn.) Benth. is widely distributed across the Indian subcontinent and is recognized in major taxonomic databases such as Plants of the World Online (POWO). However, the species has not yet been formally evaluated under the IUCN Red List and is currently categorized as “Not Evaluated (NE)” in global and regional assessments [62].

Despite its broad geographic range, emerging evidence from field surveys and regional studies indicates localized population decline and regeneration constraints, particularly in central and eastern India. These trends are primarily associated with intensive harvesting of leaves and bark for the leaf-plate (patravali) and fibre industries, destructive collection practices, removal of host trees, seed predation, and ongoing habitat fragmentation [16].

3.7.7 Regional status and threat patterns

In central India, *P. vahlii* is reported from multiple states, including Madhya Pradesh, Maharashtra, and Chhattisgarh, where herbarium records and field observations confirm its occurrence across diverse forest landscapes. However, state-level reports indicate increasing pressure on natural populations due to commercial extraction and land-use change [69].

Localized depletion, reduced recruitment, and declining mature individuals have been observed in several forest divisions, suggesting that the species may be undergoing gradual population decline despite its wide distribution.

3.7.8 Existing conservation efforts

Current conservation efforts remain largely fragmented and site-specific, with limited coordination at national or regional scales. Initiatives implemented by research institutions, forest departments, and non-governmental organizations include:

- Community-based forest management and regulated harvesting practices
- Development of sustainable harvest guidelines
- Nursery-based propagation and micropropagation trials for ex situ conservation

While these efforts contribute to localized conservation, they are not yet supported by a comprehensive national strategy or long-term monitoring framework [25].

3.7.9 Gaps in conservation assessment

Several critical gaps limit effective conservation planning for *P. vahlii*:

- Absence of a formal IUCN Red List assessment
- Lack of range-wide population and demographic data
- Limited long-term ecological monitoring
- Inadequate integration of harvesting impacts into conservation planning
- Insufficient documentation of genetic diversity and population structure

These gaps hinder the development of evidence-based conservation strategies and risk underestimating the species' vulnerability at regional scales.

3.7.10 Priority conservation actions

Given its ecological importance and high NTFP value, targeted conservation interventions are required to ensure long-term sustainability. Key priority actions include:

- Conducting a formal IUCN Red List assessment
- Implementing systematic population surveys, particularly in high-pressure regions (MP, MH, CG)
- Establishing provenance-based seed banks and clonal repositories
- Developing and enforcing standardized sustainable harvesting protocols
- Integrating *P. vahlii* into restoration, agroforestry, and afforestation programmes

Such measures would support both biodiversity conservation and livelihood security for forest-dependent communities [62].

Although *P. vahlii* is not currently classified as threatened at the global scale, increasing localized pressures and regeneration challenges highlight the need for proactive conservation planning. The species represents a critical link between forest ecology and rural livelihoods, and its conservation must therefore adopt an integrated approach combining ecological monitoring, sustainable utilization, and community participation (Table 7).

4 Conclusions, and future directions

Recent research has significantly enhanced the propagation, conservation, and utilization potential of *Phanera vahlii*. Advances in micropropagation—such as optimized auxin-mediated rooting, reduced phenolic browning, and improved acclimatization—have enabled efficient clonal multiplication and germplasm conservation. Ex situ

Table 7 Summary of conservation status, major threats, existing gaps, and priority actions for *Phanera vahlii*, highlighting the need for coordinated conservation strategies

Aspect	Key observation	Implication	References
Global status	Not Evaluated (IUCN)	Lack of formal risk assessment	POWO [62]
Distribution	Widely distributed in India	Broad range but uneven population density	POWO [62], Rao and Kumar [69]
Major threats	Overharvesting, habitat loss, host-tree removal	Declining populations in key regions	Devi et al. [16]
Regional hotspots	MP, MH, CG	High extraction pressure	Rao and Kumar [69]
Conservation efforts	Local, fragmented initiatives	Lack of national coordination	Vijay [25]
Key gaps	No monitoring, no genetic data	Weak conservation planning	Vijay [25]
Priority actions	IUCN assessment, seed banks, restoration	Urgent conservation need	POWO [62]

conservation efforts increasingly integrate sustainable harvesting practices, including regulated leaf collection and regeneration monitoring.

Phytochemical studies revealing antioxidant, antimicrobial, and antidiabetic properties have stimulated interest in domestication and value addition. Additionally, the application of molecular markers such as SSRs and SNPs offers promising tools for genetic diversity assessment and elite genotype selection. Practical propagation approaches—including seed treatment, vegetative propagation, and tissue culture—provide a scientific foundation for large-scale cultivation, agroforestry, and ecological restoration.

This review highlights *Phanera vahlii* as a taxonomically distinct and ecologically significant liana with substantial ethnobotanical, phytochemical, and socio-economic value. Widely utilized as a non-timber forest product, it contributes to food security, fibre production, traditional medicine, and sustainable livelihoods. Its role in producing biodegradable leaf products underscores its importance in promoting circular bioeconomy and environmentally sustainable alternatives to plastics. Despite its wide distribution, localized threats and the absence of a formal IUCN assessment necessitate targeted conservation and sustainable management strategies.

To unlock the full potential of *P. vahlii*, future research should focus on:

- *Genetic Diversity*: Molecular characterization and phylogeographic studies.
- *Ecology and Conservation*: Population assessments and IUCN Red List evaluation.
- *Propagation and Restoration*: Standardized seed protocols and improved micropropagation.
- *Phytochemistry and Pharmacology*: Clinical validation and bioactive compound standardization.
- *Livelihood and Value Chains*: Strengthening community-based enterprises and market development.
- *Policy Integration*: Inclusion in agroforestry, restoration, and climate-resilient development programmes.

Phanera vahlii represents a model species linking biodiversity conservation with sustainable livelihoods and green economic development. Integrating scientific innovation, traditional knowledge, and supportive policy frameworks will ensure its long-term conservation and utilization.

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Author contributions

Manish Kumar Vijay: Conceptualization; Methodology; Investigation; Data curation; Formal analysis; Writing—original draft; Visualization. Neelu Singh: Writing—review and editing; Supervision; Project administration.

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Data availability

All data are derived from published sources cited in the manuscript. The occurrence data supporting this study were obtained from the Global Biodiversity Information Facility (GBIF) and are publicly accessible at <https://doi.org/10.15468/dl.xwc3tz>.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

All authors consent to publication.

Competing interests

The authors declare no competing interests.

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