***Sterculia villosa* Roxb. ex Sm.:A Versatile Tree Species Warranting Conservation Focus**

**Abstract:**

*Sterculia villosa,* commonly known as the Elephant Rope Tree or Hairy Sterculia, is a culturally, ecologically, and economically important species native to the Indian subcontinent. This study aims to assess its ethnobotanical relevance, phytochemical profile, ecological significance, and propagation potential with a view toward its conservation and sustainable utilization. Phytochemical screening confirms the presence of diverse bioactive compounds such as flavonoids, terpenoids, and alkaloids, highlighting its therapeutic potential. Traditional medicinal uses across India further emphasize its significance in community health practices. In addition to its medicinal applications, S. villosa is used for fiber production, edible roots and seeds, and wood and gum extraction—making it a species of economic interest. Field observations and literature review indicate a sharp decline in population in parts of central India. Although currently listed as Least Concern on the IUCN Red List, the species faces regional threats including habitat loss and climate variability. This paper presents insights into its phenology, propagation techniques (such as seed and vegetative methods), and cultivation practices, contributing to effective conservation planning. We advocate for integrated conservation strategies to ensure the long-term survival of S. villosa, recognizing its broad utility and ecological importance.

**Keywords:** Elephant Rope Tree, Hairy Sterculia, Phytochemistry, Pharmacological Properties, Cultivation, Conservation, SDGs

**Introduction:**

*Sterculia villosa* Roxb. is a culturally, ecologically, and economically significant species belonging to the family Malvaceae (formerly Sterculiaceae). This deciduous tree, characterized by its large lobed leaves and distinctive yellow flowers, is native to the tropical and subtropical regions of South and Southeast Asia, including India, Bangladesh, and Myanmar (Hasnat et al., 2019; Lyzu et al., 2022). Traditionally, it has been used in Indian ethnomedicine as a diuretic, aphrodisiac, and anti-inflammatory agent (Kumar et al., 2004; Namsa et al., 2009), reflecting its relevance in local healthcare systems.

The primary objective of this study is to review and synthesize existing knowledge on the botanical characteristics, phytochemistry, medicinal applications, propagation techniques, and conservation status of S. villosa, with a focus on its potential for sustainable utilization. This review aims to bridge the research gap surrounding its declining population trends, especially in central India, and the underexplored pharmacological potential of its bioactive compounds. Although categorized as Least Concern by the IUCN Red List (IUCN, 2022), recent field observations suggest a marked decline in its natural population in central India due to habitat loss, overharvesting, and climate change (Rai et al., 2020; Das et al., 2017).

While earlier literature (e.g., Ghani, 2003) provides baseline knowledge, updated insights from recent studies (e.g., Lyzu et al., 2022; Hossain et al., 2016; Das et al., 2017) are essential to reassess the plant's current ecological and pharmacological relevance. The review also addresses the plant’s contributions to various Sustainable Development Goals (SDGs), including SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 3 (Good Health and Well-being), through its integration into local economies and traditional knowledge systems.

This paper emphasizes the urgent need for systematic conservation strategies, sustainable cultivation practices, and further research into the therapeutic properties of S. villosa. By consolidating multidisciplinary evidence, it provides a foundation for promoting the species as a candidate for community-based agroforestry systems, traditional medicine, and sustainable livelihood enhancement.

**Methods**

A comprehensive literature review was undertaken to collate information related to the utility, botany, conservation, and cultivation of Sterculia villosa Roxb. The selection of databases—PubMed, Web of Science, Springer Nature, and Google Scholar—was based on their wide acceptance, credibility, and access to peer-reviewed scientific literature across fields such as plant sciences, pharmacognosy, ecology, and ethnobotany. PubMed was specifically used to access biomedical and pharmacological research, while Web of Science and Springer Nature provided high-impact multidisciplinary scientific resources. Google Scholar facilitated access to grey literature and region-specific publications that might not be indexed in other databases.

To ensure the retrieval of relevant and comprehensive information, a combination of specific and broad keywords was used, including: Sterculia villosa, ethnobotany, phytochemistry, medicinal uses, conservation status, traditional medicine, propagation, and sustainable cultivation. Boolean operators (AND, OR) and truncation symbols were applied to refine and expand the search results.

Rather than relying on an arbitrary claim of exhaustiveness, the literature search was systematically conducted and documented to ensure transparency and reproducibility. Inclusion criteria prioritized peer-reviewed articles, recent publications (particularly from the last 10 years), and studies with relevant empirical data or reviews. Thesis works, institutional reports, and verified web resources were also consulted to fill knowledge gaps, especially where published literature was limited.

Collected data were organized thematically under sub-headings: taxonomy and distribution, phytochemistry, traditional and pharmacological uses, propagation techniques, and conservation concerns. The reliability of each source was assessed based on its citation frequency, publication venue, and consistency with other findings. Discrepancies were addressed by cross-referencing multiple studies.

This multi-source, multi-method approach ensured a well-rounded synthesis of current knowledge while identifying gaps for future research on S. villosa.

**Discussion:**

**Phytochemistry:**

*Sterculia villosa* exhibits diverse pharmacological properties, including anti-inflammatory, antimicrobial, antioxidant, and analgesic effects. Below are the specifics of the identified phytochemicals (Table 1) and the pharmacological properties (Table 2):

**Table 1: Phytochemicals identified in *Sterculia villosa***

|  |  |
| --- | --- |
| **Phytochemicals identified**  | **References** |
| Flavonoids, terpenoids, coumarins, alkaloids, phenolic acids, and steroids | Muqarrabun *et al*., 2015; Harborne, 1989 |
| Tannins support astringent and antimicrobial potential | Muqarrabun *et al*., 2015 |
| Luteolin 3'-methyl ether, chrysoeriol 7-O-β-D-glucoside, luteolin 4'-methyl ether (diosmetin) | Hossain *et al*., 2012; Alfaro *et al*., 2009 |
| Fifty-two compounds identified in bark extract | Lyzu *et al*., 2022 |

**Table 2: Pharmacological Properties in *Sterculia villosa***

|  |  |
| --- | --- |
| **Pharmacological Properties** | **References** |
| Anthelmintic Properties | Haque *et al*., 2012; Paul *et al*., 2014 |
| Antithrombotic Activity | Tania *et al*., 2013 |
| Antiprotozoal Activity | Nwodo *et al*., 2015 |
| Antioxidant and Anti-inflammatory properties, Astringent and Antimicrobial | Muqarrabun *et al*., 2015 |
| Anti-inflammatory, antimicrobial, antioxidant, analgesic effects | Hossain *et al*., 2013 |
| Antileishmanial potential  | Das *et al*., 2017; Hossain *et al*., 2016; Nwodo *et al*., 2015 |
| Antioxidant activity | Lyzu *et al*. (2022) |

**Medicinal Uses:**

The medicinal uses of *Sterculia villosa* emphasize its significant role in traditional Indian medicine, reflecting its therapeutic potential and contribution to overall well-being within local communities. The plant's traditional uses (Table 3) are well-established, with *S. villosa* serving as a diuretic, cooling agent, and aphrodisiac herb in Indian traditional medicine.

**Table 3: Medicinal Uses of *Sterculia villosa***

|  |  |
| --- | --- |
| **Medicinal Uses**  | **References** |
| Gastrointestinal Disorders | Hossain *et al*., 2013 |
| Wound Healing, Membrane Stabilization | Tania *et al*., 2013 |
| Treatment of Inflammation | Kumar, 2004; Namsa, 2009 |
| Antidiabetic Properties | Hossain *et al*., 2013 |
| Cooling and Aphrodisiac Properties | Kumar *et al*., 2004 |
| Diuretic Agent | Kumar *et al*., 2004 |
| Skin Diseases | Hossain *et al*., 2013; Kunwar *et al*., 2010 |
| Rheumatism | Kumar *et al*., 2004 |
| Urinary Problems | Kumar *et al*., 2004 |
| Rheumatism, urinary problems, and seminal weakness | Hossain MM *et al*., 2013 |

**Other uses:**

*Sterculia villosa* stands out as a versatile and valuable resource, playing a vital role in culinary, ecological, and economic aspects. Its impact extends from traditional uses to various industrial applications, highlighting its cultural and ecological importance. Responsible conservation efforts are essential to ensure the sustained existence of this botanical wonder for future generations.

1. **Culinary Uses:**

**Edible Resource:** *Sterculia villosa* serves as a valuable dietary resource, enhancing culinary diversity and nutritional well-being.

**Root Powder Preparation:** The powdered root, mixed with rice flour, is used to create a bread-like doughnut known for its soft texture and pleasant taste (https://tropical.theferns.info/viewtropical.php?id=Sterculia+villosa).

**Nutrient-Rich Seeds:** Roasted or cooked seeds are consumed, similar to pulses, contributing to dietary sustenance and food security (Facciola, 1998).

**Gum Substitute:** The gum from the bark is used as a substitute for gum tragacanth in confectionery, highlighting its role in food production (Facciola, 1998).

**Traditional Drink Ingredient:** The plant is a popular ingredient in locally made drinks during hot summers, promoting a feeling of freshness, relaxation, and sound sleep (Manandhar, 2002).

1. **Ecological Contributions:**

**Nectar Source:** The flowers of *Sterculia villosa* provide nectar for pollinators like bees and butterflies, supporting local biodiversity.

**Wildlife Food Source:** Fruits with edible pulp contribute to wildlife food sources, enhancing overall regional biodiversity.

1. **Economic Contributions:**

**Wood Utilization:** The soft wood is used in tea boxes, toys, guitars, matchboxes, and commercial plywood, contributing to various industries (Ghosh & Baruah, 1997).

**Fiber Production:** Coarse fiber from inner bark is used in ropes, bags, and cordage, fulfilling industrial needs.

**Gum Production:** The plant produces gum karaya, used in lozenges for sore throats, emphasizing its medicinal and commercial significance (Verma & Kharakwal, 1977).

**Paper Pulp Potential:** *Sterculia villosa* is suitable for paper production, with its fibrous material exhibiting a remarkable pulp yield and wood fiber properties. The fibrous material contributes significantly to the pulp and paper industry, supporting sustainable paper resources (Ghosh & Baruah, 1997; Barua & Rabha, 1992).

1. **Cultural and Ecological Significance:**

**Botanical Wonder:** *Sterculia villosa* symbolizes the intricate connection between nature and human culture, emphasizing responsible land management and conservation efforts for its sustained existence.

**Versatile Resource:** From traditional medicine to diverse industrial applications, *Sterculia villosa* proves its versatility and value, impacting various sectors.

**Economic and Cultural Relevance:** Beyond economic significance, the plant holds cultural and ecological relevance, underlining its importance in various contexts.

**Taxonomy**:

The genus *Sterculia* belongs to the subfamily Sterculioideae of family Malvaceae (Wilkie *et al*., 2006). It was previously placed in the now obsolete Sterculiaceae, which comprised approximately 200 species distributed mainly in tropical and subtropical regions. Some of the *Sterculia* species are classified under different genera based on distinct morphological features.

**Taxonomic Classification:**

Kingdom: Plantae

Phylum: Streptophyta

Class: Equisetopsida

Order: Malvales

Family: Malvaceae

Genus: *Sterculia* L.

Species: *Sterculia villosa* Roxb. ex Sm.

**Synonyms:**

*Clompanus armata* (Mast.) Kuntze

*Clompanus villosa* (Roxb. ex Sm.) Kuntze

*Sterculia armata* Mast.

*Sterculia lantsangensis* Hu

*Sterculia ornata* Wall. ex-Kurz

**Vernacular names:**

*Sterculia villosa*, commonly known as the Elephant-rope tree, hairy sterculia, or woolly ordure tree, boasts a rich diversity of vernacular names across various regions (Table 4), showcases the extensive regional diversity in nomenclature for this versatile and widely recognized tree species (Sankara Rao, 2019).

**Table 4: Vernacular name of *Sterculia villosa* across different languages**

|  |  |
| --- | --- |
| **Vernacular Name** | **Language** |
| Udhal | Hindi |
| Bilidali | Kannada |
| Muruthan, Vakkai, Anai-nar | Tamil |
| Kummari puliki | Telugu |
| Kodalo | Oria |
| Kudal, Kuthada, Sardol | Marathi |
| Oudal | Assamese |
| Ubak | Garo |
| Sardol | Gujarati |
| Dieng star | Khasi |
| Sardol | Konkani |
| Vakka | Malayalam |
| Hei-rit | Manipuri |
| Khau-pui | Mizo |
| Khava, Odani | Nepali |
| Massu | Punjabi |
| Anai-nar, Vakku-nar | Tamil |
| Kummarapoliki, Kavili, Narapoliki, Vakkunara Akkanarumaram | Telugu |

**Botanical Description:**

Medium-sized monoecious deciduous tree, typically grows to a height of 10-20 meters with a girth of about 1.4-1.6 meters. Described by its thick, gnarled trunk and a distinctive, irregular crown providing ample shade, the tree's often spreading and wide canopy contributes to its regal appearance. In dry deciduous jungles, it can reach significant heights, displaying rapid growth (Kanjilal et al., 1934; Barua et al., 1992).

**Bark:** The mature tree of *Sterculia villosa* is recognized by its grey bark, which is about 2.5 to 2.65 centimeters thick. The bark texture and thickness contribute to the tree's resilience and protection against various environmental factors.

**Wood:** The wood of *Sterculia villosa* is notably soft and lightweight. It exhibits a range of colors, from pale yellowish or greyish white to light greyish or brown. This lightweight wood makes it a versatile resource for various uses.

**Leaves:** large, simple, and palmately lobed leaves (as depicted in Figure 1) are covered with sparsely stellate-hairs above, tomentose below, Petiole of about 25–40 cm and a lamina composed of 5-7 lobes, approximately 20–40 cm in both length and width, (Ghani, 2003; Kumar et al., 2004).



**Figure-1: Leaf morphology of *Sterculia villosa***

**Flowers**

Flowers unisexual, pinkish yellow, 1–2 cm wide, much branched rusty pubescent, terminal, drooping panicles, male and female flowers intermixed.

Pedicel 4 to 8 mm long, deciduous.

Calyx and Corolla: Calyx campanulate, pinkish inside, 5-lobed, hairy, lobes spreading; tube 3 mm ♂: staminal column 2-3 mm long, curved; anthers 10. ♀: Ovaries 5, 2-3 mm long, gynandrophore hairy, globose with sterile anthers at base; styles 2 mm long, recurved; stigmas 5-lobed.Follicles: 3-5, 2.5–4 cm long, oblong, spreading, rusty villous, red inside; seeds 3-5 in each follicle, 7-10 mm long, oblong, smooth, black (Britto, 2019).

**Seed Morphology:**

The seeds of *Sterculia villosa*, with specific characteristics and structural components, play a crucial role in the tree's reproductive success and ecological significance (Ghani, 2003). The detailed description of seed morphology includes:

Shape and Size: Predominantly oblong, the seeds exhibit an elongated and slightly oval shape, of moderate size, contributing to the overall seed-bearing capacity of the tree. The approximate seed number per kilogram is 5400-6000 (Ghani, 2003).

Surface Texture: The seeds have a smooth surface, lacking prominent ridges or indentations, enhancing efficiency in seed dispersal and germination (Ghani, 2003).

Color: Typically dark black, the seeds provide a visual contrast, aiding in their identification within the fruit or in the surrounding environment (Ghani, 2003).

Endospermic Content: The seeds are endospermic, containing a nutrient-rich tissue surrounding the embryo. This endosperm serves as a vital source of nourishment for the developing plant during germination and initial growth stages (Ghani, 2003).

The distinctive seed morphology of *Sterculia villosa*, characterized by its oblong shape, smooth surface texture, dark black color, and endospermic seeds, contributes significantly to the tree's reproductive cycle, and facilitates the dissemination and establishment of new seedlings within its native habitat (Ghani, 2003).

**Phenology of *Sterculia villosa*:**

Flowering: The flowering phase of *Sterculia villosa* occurs from January to March.

Fruiting: Fruiting phase from March to April

Fruit/Seed Collection Time: The ideal time for collecting the fruits or seeds of *Sterculia villosa* typically falls between May and June, allowing for the collection and propagation of viable seeds for various purposes.

Pollination Method: The tree primarily relies anemophily pollination method, utilizing the natural movement of air currents to facilitate the transfer of pollen between flowers.Mode of Dispersal: The dispersal of seeds is mainly facilitated by wind, enabling the seeds to be carried over distances and dispersed within the surrounding ecosystem, contributing to the tree's reproductive success and population distribution.

**Habitat:**

A plant of lowland, subtropical to tropical areas, where it is found at elevations from sea level to 1,050 metres. It grows best in areas where annual daytime temperatures are within the range 30 – 42°C, though it can tolerate 7 – 47°C. It can be killed by temperatures of -2°c. It prefers a mean annual rainfall within the range 1,300 – 1,900 mm, but tolerates 750 – 4,000 mm, usually growing in areas with a distinct dry season. Requires a sunny position, though seedlings are shade tolerant. Grows best in a light, well-drained soil and also tolerate poor, rocky soils. Established plants are very drought tolerant. Prefers a pH in the range 6.5 – 7.5, but tolerates 6–8. The trees can be tapped for their gum about 5 times during their lifetime. (Tropical Plants Database, 2022).

**Distribution:**

*Sterculia villosa,* native to diverse regions in Indian subcontinent, including India, Sri Lanka, Myanmar, Thailand, Malaysia, China, and Indo-china regions, thrives in tropical and subtropical forests, often near riverbanks and areas with well-drained soil (Ghani, 2003; Manandhar, 2002). Commonly found in dry deciduous jungles, it prefers cool, moist valleys (as depicted in Figure 2), and is observed along forest edges or in cleared patches in the wild, particularly in regions like Bhutan, India, Nepal, Pakistan, and East Asia (Manandhar, 2002).



**Figure-2: Natural Habitat within the hilly region of a river basin area in Madhya Pradesh.**

In India, the species is widely distributed across various states, such as West Bengal, Assam, Odisha, and the North Eastern states, ascending to altitudes of up to 1000 meters (Ghani, 2003). The plant's adaptability is evident in its prevalence in diverse ecosystems, including *Terminalia tomentosa* forests and alluvial savanna forests, showcasing a preference for light sandy or gravelly soils and an annual rainfall ranging between 750 – 4000 mm (Ghani, 2003). Its presence extends to South Asian countries like Bangladesh, Bhutan, and Myanmar, as well as East Asian countries such as Nepal, Thailand, and Cambodia, reflecting its widespread distribution and adaptability to various ecological conditions (Ghani, 2003). In China, *Sterculia villosa* is distributed in the southern regions, emphasizing its adaptability to diverse climatic and ecological conditions within the country (Ghani, 2003). The tree's widespread distribution across these regions underscores its role in contributing to local biodiversity and ecological balance as depicted in Figure 3 (Ghani, 2003; Manandhar, 2002, GBIF 2023).

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**Figure-3: Occurrences of *Sterculia villosa*** (Source: GBIF.org (31 December 2023) GBIF Occurrence Download <https://doi.org/10.15468/dl.gmbyet>)

**Conservation Status**

*Sterculia villosa,* classified as a species of Least Concern according to the IUCN Red List ver 3.1 (Year Published: 2022), exhibits extensive geographical spread and a substantial population with no substantial current threats or foreseeable risks. Despite this favorable classification, conservation efforts are deemed critical, especially in the face of regional threats such as deforestation and climate change. The urgency for preservation is highlighted by the dwindling number of trees in central India, emphasizing the need for dedicated propagation and cultivation initiatives. Ongoing deforestation and habitat degradation necessitate monitoring of populations and habitats, underlining the importance of conservation measures to ensure the continued presence of *Sterculia villosa*. These efforts are vital not only for the survival of this unique tree but also for its significant contributions to local ecosystems and cultures.

**Propagation & cultivation**

The plant can be raised from seeds and also from stem cuttings. The aril surrounding the seed should also be removed - this is easiest when it has been softened through soaking in water. The seeds germinate optimally at temperatures between 20 – 30°C. They can be sown in a nursery seedbed or in containers. A germination rate of about 95%, occurring within about 2 weeks can be expected if the seed has been properly treated.

The application of seed pre-treatment methods involving 50-100 PPM GA3, 100 PPM Thiourea, and hot water treatment for 24 hours demonstrated superior results in promoting germination in *Sterculia villosa* when compared to the control group. The maximum germination (94.33) percentage of *Sterculia villosa* was obtained from the seeds treated with thiourea 100 ppm which was statistically at par with thiourea 50 ppm treated seeds (93.66) followed by cold water (91.66) and hot water (91.16) treatments. The particular concentration of thiourea probably helps to inhibit the activity of inhibitor chemicals present in seeds and resulting higher germination percentage. The superior effect of boiling water may be due to its combined effect in softening the seed coat and leaching out of the chemical inhibitors (Willan, 1985). All treatments showed a positive impact on the shoot length of *Sterculia villosa* seedlings. The maximum shoot length was recorded with GA3 100 ppm treated seeds (35.56 cm) which was statistically at par with GA3 50 ppm treated seeds (34.22 cm). The increased shoot length in auxin treated seeds can be attributed to its peculiarity to increase shoot growth by cell enlargement (Noggle and Fritz, 1986).

 In another germination study of *Sterculia villosa* seeds revealed that the maximum germination rate (80%) was achieved in a propagator house, surpassing the control group with a 76% germination rate (Hasnat et al., 2019).

Over the period from May 2014 to September 2019, the investigation cantered on exploring the germination, growth, and development of the uncommon tree species *Sterculia villosa*. The mature seeds displayed an 80% germination rate within a span of 21 days. The transplantation of twelve-month-old saplings yielded swift growth, culminating in a six-year-old specimen reaching a height of 249 cm. The study underscores the significance of conservation initiatives in promoting biodiversity (Rai et al., 2020).

**Future Perspectives:**

Future research on *Sterculia villosa* should encompass a comprehensive exploration of its pharmacological, morphological, conservation, and cultivation aspects. Pharmacological studies should aim to unveil its medicinal potential, exploring applications in traditional medicine or pharmaceutical development. Morphological analyses, including molecular investigations, are crucial for a nuanced understanding of the plant's structure and genetic diversity. Conservation efforts should focus on robust strategies, considering ecological significance, reintroduction programs, and sustainable harvesting. Cultivation techniques need optimization, with an emphasis on agroforestry models and sustainable practices. Assessing economic viability, community engagement, and climate resilience are pivotal components, ensuring a balanced approach that integrates ecological preservation, traditional medicine, and sustainable development. Interdisciplinary collaboration among pharmacologists, botanists, ecologists, and social scientists is essential for a holistic understanding and effective management of *Sterculia villosa*. These future perspectives aim to contribute significantly to biodiversity conservation, traditional medicine, and sustainable development, fostering a harmonious relationship between the plant species and the communities it influences.

**Conclusion:**

In conclusion, *Sterculia villosa* stands out as a plant of great significance, not only for its ecological role but also for its potential pharmacological applications. The studies discussed shed light on the plant's distinctive morphological features, distribution, and its role in supporting local ecosystems. While currently classified as a species of Least Concern, conservation efforts are deemed crucial, given regional threats such as deforestation and climate change. The comprehensive seed and fruit morphology descriptions provide valuable insights into the reproductive cycle and ecological interactions of *Sterculia villosa*. Additionally, the findings related to seed germination and seedling development present practical implications for propagation and cultivation. As evidenced by successful germination and growth trials, future research could delve into optimizing cultivation practices for enhanced yields and sustainability. Overall, the knowledge compiled here offers a foundation for informed conservation strategies and sustainable utilization of *Sterculia villosa*, ensuring its continued contribution to ecosystems and potentially benefiting pharmaceutical and agroforestry endeavors.

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