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"Exploring Neolamarckia cadamba: A Review on its Biological Activities and Medicinal Applications"

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Abstract: Neolamarckia cadamba known as cadamba tree or Kadam is commonly referred as the "miracle tree," as it has been widely recognized in Indian traditional medicine for its therapeutic potential in treating a variety of ailments. It is a significant species in tropical and subtropical ecosystem. In many developing countries, cadamba and its natural products continue to play a vital role in traditional medicine due to their accessibility, effectiveness, and minimal toxicity to healthy human cells. It is notable for its rapid growth, attractive appearance and various applications. This review examines its botanical characteristics, ecological roles, economic importance and cultivation methods. It also provides diverse studies focusing on the physiological, ecological, phytochemical, and pharmacological characteristics. Although it faces challenges like sterilising its explants that are obtained from the field is very difficult because of the abundance of endophytic microbes in them, contamination has hampered its tissue growth in the field and is challenging to overcome. It brings researchers to study more about this plant to overcome the challenges as it serves as a valuable model organism in research, owing to its relatively small genome (~800 Mb), fast growth, and ability to flower and produce fruit within four years.

Keywords: Neolamarckia cadamba, Rubiaceae, Phytochemicals, Pharmacological activities, Therapeutic

Introduction

Indian subcontinent is home to about 3000 officially recognised plants with significant therapeutic potential. Neolamarckia cadamba (Roxb.) Bosser, an evergreen tropical tree in the Rubiaceae family, is one such understudied plant (Pandey and Negi 2016).It is a big, deciduous, and rapidly growing tropical tree species that is extensively dispersed throughout South China and South Asia. It belongs to the Neolamarckia tribe in the Rubiaceae family (Zhao et al. 2017).The French naturalist Jean-Baptiste Lamarck is honoured with the genus name. Typically,

flowering starts when the tree is 4–5 years old (Sakthivel et al. 2022).The tree's lovely orange blossoms are what make it so lovely. In addition to being circular, the flowers include dense clusters of white globes (Balan et al. 2025). Below 1000 meters above sea level, the Neolamarckia cadamba thrives on alluvial, fertile river soil. This lush, nutritious soil provides a lot of nutrients for it (Wei and Zhu 2019). For the Kadam tree, to flourish, it requires an abundance of sunlight. It prefers temperature between 25 and 30 degrees Celsius. The tree is found in low-lying places and plains because it is extremely intolerant of cold temperatures (Devanand et al. 2024).N. cadamba has been used for industrial plantations, reforestation, and afforestation due to its advantageous silvicultural traits and lack of harmful pests and diseases. Additionally, this species is anticipated to play a bigger role in wood-based businesses, especially as natural forest supplies of plywood decline (Matra et al. 2011).N. cadamba produces fruit in the shape of tiny, fleshy capsules that are packed closely together to form a fleshy, yellow-orange infructescence that contains about 8,000 seeds (Sakthivel et al. 2022)The World Health Organisation (WHO) reports that many nations, especially developing nations, continue to employ plants and products derived from natural sources for medicinal purposes. It is a tree that has long been used to cure a variety of ailments since its natural components are easily accessible, typically more tolerable, and thought to be non-toxic to healthy human cells (Yang et al. 2024). In India's Ayurvedic medical system, this underappreciated tropical evergreen plant has been used extensively to treat eye infections, skin conditions, dyspepsia, gum disease, cough, stomatitis, anaemia, fever, blood abnormalities, and stomach aches (Razali et al. 2021). This medium- to large-sized deciduous tree has a rounded crown, clean cylindrical branches, and a height of 20–40 m with a girth of roughly 2-2.5 m. The plant's bark is used to cure fever and eye irritation because it is said to have pungent, bitter, sweet, acrid, astringent, anti-inflammatory, tonic, febrifugal, digestive, diuretic, carminative, constipating, expectorant, and antiemetic qualities (Ghosh and Abdullah2024). The flowers have a vegetable use. Although the leaves have a disagreeable taste and a mild scent, their decoction is effective in treating wounds and ulcers. It is also helpful in treating snakebite injury (Dubey et al. 2011). People can use the leaf extract as mouthwash. Its leaves have been utilised for purposes other than medicine, such as cattle feed (Selvan et al. 2019).With its exceptional morphological, anatomical, and chemical traits, N. cadamba is a fast-growing tree with significant ecological and economic importance. It is listed as a common traditional herbal remedy in Indian traditional medicines that is clinically used to treat a variety of illnesses (Li et al. 2019).Another name for it is the "miracle tree". It is a model organism due to its short genome (about 800 Mb), rapid development, flowering, and fruit production inless than four years. Rubisco is the most prevalent and significant protein; it is also most likely the most prevalent protein in plant cells. An enzyme called rubisco aids in the process of

carbon fixation during photosynthesis (Li et al. 2018).Tree improvement on N. cadamba was first started in June 2010 at IFGTB (Institute of Forest Genetics and Tree Breeding) in recognition of the species' significance (Vijayaraghavan et al. 2015).In addition to triterpenes, triterpenoid glycosides, flavonoids, and saponins, indole alkaloid is a significant component of Neolamarkia species. Numerous extremely complicated heterocyclic compounds were compromised by indole alkaloids (Qureshi et al. 2021).

Botanical description

Morphology

The Indian subcontinent's vast plant diversity can be attributed to a variety of topographies, climates, and environmental factors. Since the scientific names were originally based on geographic location, the botanical name of this plant (Neolamarckia cadamba) has been the focus of a protracted taxonomic argument. Jean-Baptiste Lamarck called it Cephalanthus chinensis in 1785 and claimed that Madagascar was the place of origin. In 1830, Achille Richard identified a specimen from Asia that resembled Lamarck's specimen as Anthocephalus indicus. At about the same time, William Roxburgh suggested a new name for this specimen: Naucleacadamba. The tree was given its name since the International Code of Nomenclature forbids changing a plant's name due to its geographic location (Pandey et al. 2016). A well-known species in the Rubiaceae family, N. cadamba is distinguished by its unique botanical traits. The tree can grow up to 45 meters tall and 100–160 cm in diameter. Its cylindrical, straight trunk is frequently buttressed at the base. When a tree is young, its bark is smooth; as its ages, it becomes rough and cracked, and it can be grey to dark brown in colour. Large, opposite, simple, and widely oval, N. cadamba leaves are 15–50 cm long and 8–25 cm wide. The glossy, dark-green leaves have a pointed tip and noticeable veins. Stipules are big and interpetiolar, whereas petioles are short. The tree bears globose, very scented inflorescences that range in colour from yellow to orange. Each inflorescence, which is made up of many tiny flowers, can have a diameter of up to 5 cm. The blooms have many stamens and a corolla with five lobes, making them hermaphrodite. N. cadamba produces syncarps, which are made up of several tiny, joined drupelets (Yadav et al. 2022). The establishment of rapidly expanding and high-yielding tree plantations is frequently anticipated to have two beneficial effects: the indirect preservation of wild forests and the direct mass production of wood or other target items (Wei et al. 2019).The tree is cultivated for its wood, paper, and aesthetic value. Its leaves and bark are said to have therapeutic properties, and its blooms are used to make perfumes. Additionally, the species is known to work well with short-fiber pulp, plywood, packing cases, and toys. Thus, it is crucial to provide large quantities of high-quality N. cadamba planting material in order to support this species'

plantation effort (Rahman et al. 2015). Climate variables that affect tree species growth include temperature, light levels, and precipitation (Que et al. 2022).

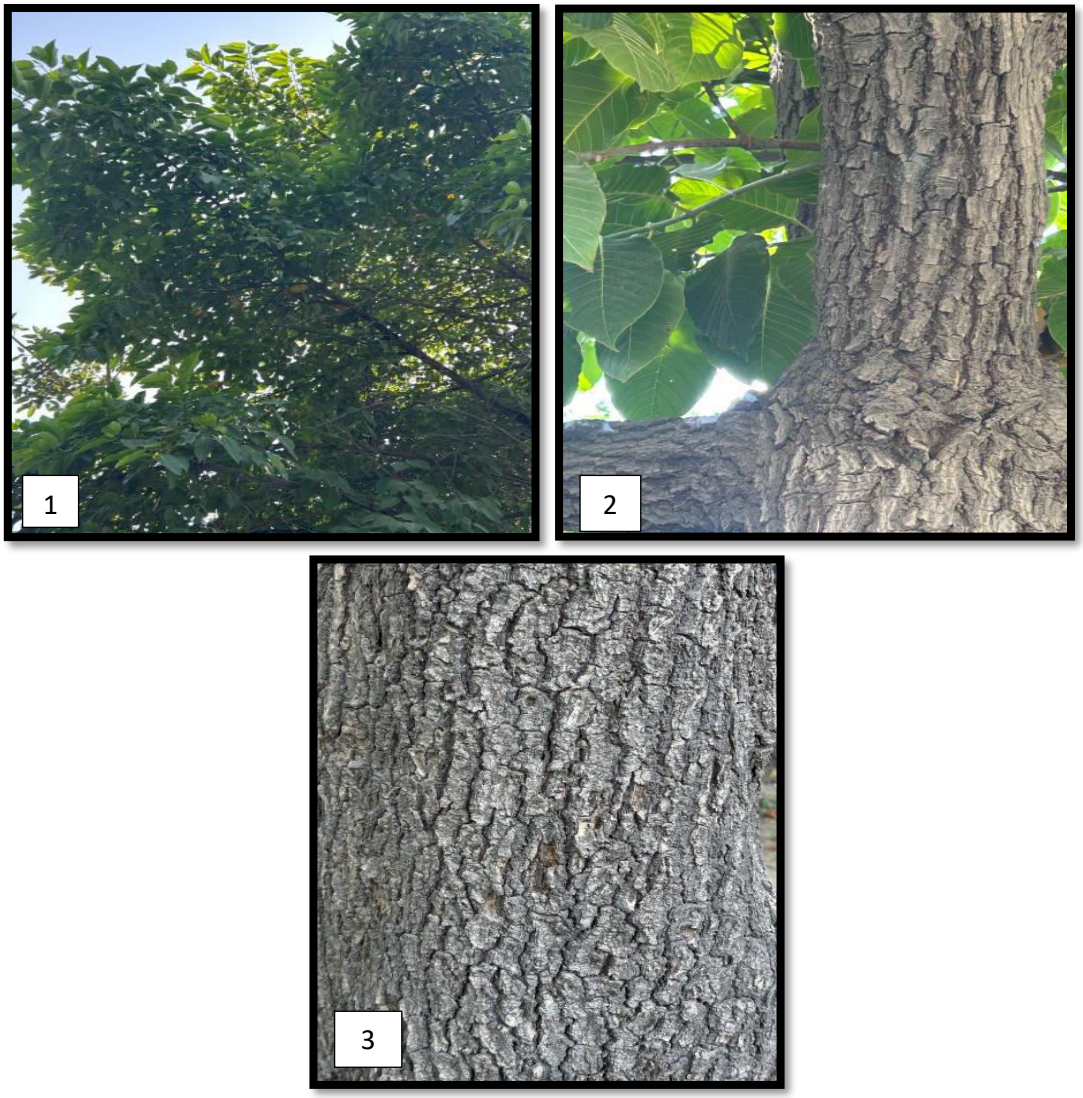


Fig. 1Showing a) Leaves of N. cadamba, **b)** Leaves and bark**, c)** Bark

Ecological significance

Biodiversity and Habitat

In its natural habitats, the kadam tree is essential. Numerous birds, insect, and other wildlife species find food and shelter under its thick foliage. Pollinators like bees, butterflies, and beetles are drawn to the tree's blooms, enhancing the area's biodiversity (Yadav et al. 2022).

It is commonly found on the 500-meter-high slopes of evergreen forests throughout India. It is widespread in the sub-Himalayan region from Nepal eastward on the lower Darjeeling Terai hills in West Bengal; it is also found in the Andamans, in

Chota Nagpur (Bihar), Orissa, and Andhra Pradesh, as well as in damp areas along large streams in Karnataka and Kerala on the west coast, and in low-lying, wet areas of the western ghats. Additionally, it is found in Thailand, Indo-china, and the Malaysian archipelago, which extends east to Papua New Guinea (Dubey et al. 2011).It is noted that "Neolamarckia cadamba" is an unusual species that prefers deep and wet alluvial soils. It is commonly found in secondary woodlands along riverbanks and the area between marshy and continually flooded areas while discussing its ecological behaviour. Although it may grow on a wide variety of soils, well-accelerated fertile soils are more abundant and dominant, and this is why soil condition is so important to its productivity. In leachable or insufficiently aerated soils, it may not always flourish despite the perfect physical circumstances(Singh et al. 2023).Because of its high economic and ecological value, it has been grown and brought to Puerto Rico, Surinam, Venezuela, South Africa, Costa Rica, and other tropical and subtropical nations. Its wood is used to make plywood, veneer, pulp, paper, and furniture as well as for light construction. Both contemporary medicine and traditional Indian ethnomedicine make extensive use of N. cadamba's leaves, bark, flowers, and fruits. In addition, its leaves are turned into silage, its pollen is used as honey bee food, its fruits are used to make juice, and the entire tree is utilised for landscaping. Breeders strive to enhance N. cadamba's growth characteristics and wood qualities due to its commercial significance. Crucially, N. cadamba is a tree species that grows quickly; under typical circumstances, it can reach a height of about 18 meters and a DBH (Diameter at Breast Height) of 25 cm at the age of 9. As a result, it has been called "a miraculous tree" and could be a good substitute tree species to grow in appropriate areas to satisfy the growing demand for wood products **(**Que et al. 2021).

Economic importance

One of the most profit-driven plantation species is N. cadamba, sometimes referred to as Kelempayan (Peninsular Malaysia and Sarawak), Laran (Sabah), Jabon (Kalimantan), or Kadam (India) in certain experimental plantings in Peninsular Malaysia overseen by the Forest Plantation Development Programme (Khatta et al. 2023).Although it is most commonly grown in tropical nations, kadam is a plant of choice for reforestation and agroforestry initiatives (Afolabi et al. 2021).Because of its analgesic, anti-inflammatory, antibacterial, antioxidant, antidiabetic, Alzheimer's, and anticancer qualities, Kadamba is widely used in traditional medicine (Lv et al. 2023). Its bark, leaves, blossoms, and fruit are among the parts of the tree that are used in Ayurvedic and other medical systems (Yadav et al. 2022). Additionally, the leaves of N. cadamba have been applied topically to treat breast cancer(Razali et al. 2021).

Cultivational practices

1. Climate and soil requirements

Deep, damp, alluvial locations are ideal for its growth; these are frequently found in secondary woods beside rivers and in the area that lies between marshy, constantly flooded, and occasionally flooded environments (Vijayaraghavan et al. 2015).The plant can thrive in environments with limited rainfall, but it can also thrive in environments with an average annual rainfall of 1500 to 5000 mm. The species thrives in elevations between 300 and 1000 meters, and occasionally as high as 1400 meters. Its optimal temperature range is between 25 and 35 degrees Celsius. Moreover, it can withstand pH values ranging from acidic to neutral (5.5–7.5)(VIGYAN 2019).

2. Propagation and plantation

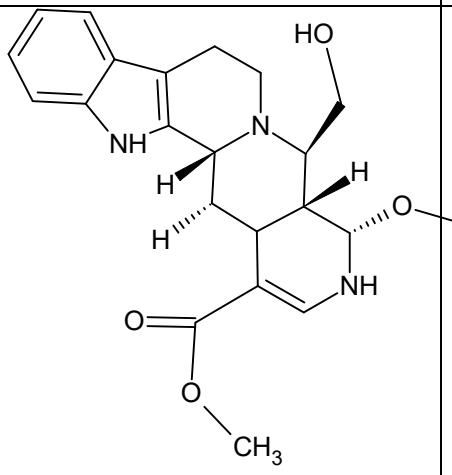
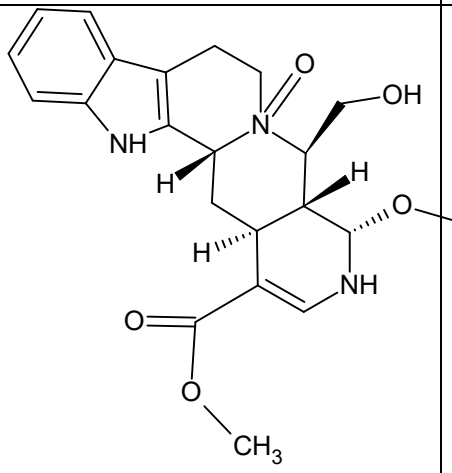
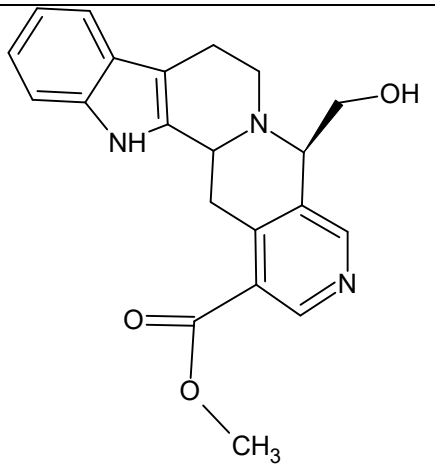
Typically, tissue culture or seeds are used for propagation, with seeds being used more frequently. It is best to gather seeds from healthy, older trees and plant them in nurseries with shade. Usually,it takes ten to fifteen days for them to sprout. To produce homogeneous and disease-free plants, tissue culture techniques are used.

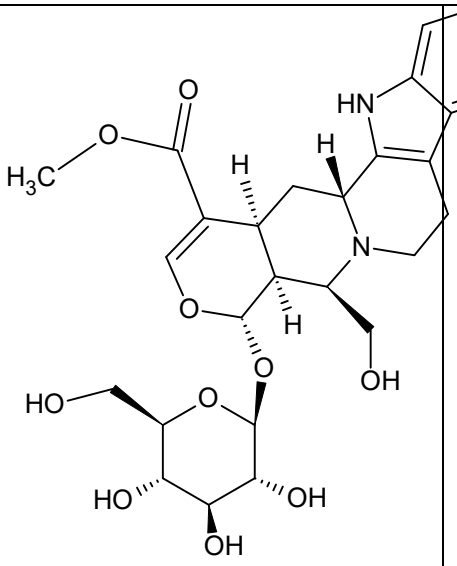
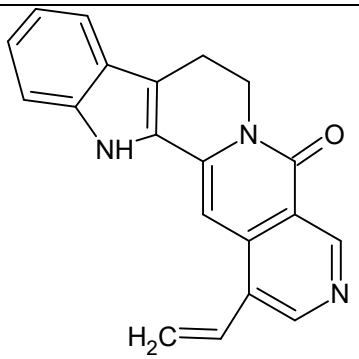
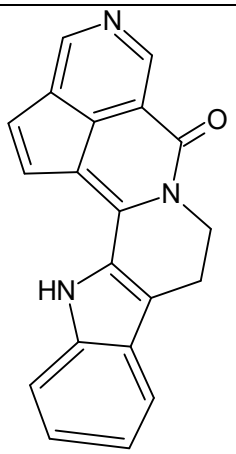
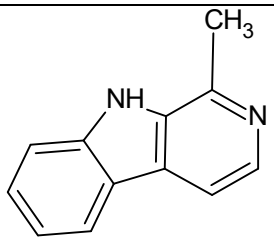
For best growth, seedlings should be placed around the start of the rainy season. The seedlings or trees that were planted grew well and began to flower and fruit normally around the fourth year. The planting hole measured 50 cm by 50 cm by 40 cm in size. Before planting, adding organic manure to the pits promotes early development (Wei and Zhu2019).

Phytochemicals present in Neolamarckia cadamba

A variety of treatment methods for a wide range of illnesses, including diarrhoea, inflammation, fever, haemoptysis, coughing, vomiting, ulcers, sores, debility, and antibiotics, are provided by the phytochemical analysis of the "cadamba plant." The primary ingredients of the "cadamba plant" are cadambine, cadamine, isocadambine, isodihydro cadambine, triterpenes, triterpenoid glycosides, flavanoids, saponins, and indole alkaloids (Singh et al. 2023)Although terpenoids, flavonoids, tannins, cardiac glycosides, and saponins were detected in the phytochemical analysis of N. cadamba fruits, steroids were not present at any of the maturity stages (Pandey et al. 2018).Neolamarckia cadamba produced seven indole alkaloids: neolarmarckine A, B, cadamine, 3β-isodihydrocadambine,naulafine, angustine, and harmane. In addition to triterpenes, flavonoids, triterpenoid glycosides and saponins, indole alkaloid is a significant component of Neolamarckia species(Qureshi et al. 2021).

Table 1showingstructure and compound ID of indole alkaloids of Neolamarckia cadamba

Important phytochemicals	Compound formula	Compound ID	Structure	Reference
Neolamarckine A	$C_{22}H_{27}N_3O_4$	51042543		(Qureshi et al. 2011)
Neolamarckine B	$C_{20}H_{19}N_3O_3$	51039307		(Qureshi et al. 2021)
Cadamine	$C_{27}H_{32}N_2O_{10}$	73657079		(Dubey et al. 2011)

3β-isodihydrocadambine	$C_{37}H_{44}N15O2$	188431		(Qureshi et al. 2021)
Angustine	$C_{20}H_{15}N_3O$	441983		(Dubey et al. 2011)
Naulafine	$C_{20}H_{13}N_3O$	14313083		(Qureshi et al. 2021)
Harmane	$C_{12}H_{10}N_2$	5281404		(Qureshi et al. 2021)

Pharmacological properties

Neolamarckia cadamba, also known as kadam, has been found to possess numerous pharmacological activities, making it a valuable plant in traditional medicine. Some of the key activities include:

Antidiabetic Activity: In diabetic rats, extracts from N. cadamba flowers showed notable blood glucose-lowering effects, indicating possible antidiabetic qualities (Munira et al. 2020).

Analgesic and Anti-inflammatory Effects: The bark has long been used to treat pain and inflammation, and methanolic preparations of it have shown strong analgesic and anti-inflammatory effects in mouse models (Pandey et al. 2016).N. cadamba has been used historically to treat skin, throat, eye, and stomach inflammations. Four symptoms of inflammation include oedema, discomfort, erythema and fever, and different N. cadamba preparations are said to affect each of them (Pandey et al. 2016).

Antimicrobial Properties: Numerous plant parts, such as the leaves and bark, have demonstrated antibacterial action against a variety of diseases, suggesting that they may be a natural source of antimicrobial compounds (Dwevediet al. 2015).

Antioxidant Activity: Antioxidant-containing substances have been found through phytochemical investigations, which could support its medicinal effects (Verma et al. 2018).The phenolic compounds present in Neolamarckia cadamba extracts are thought to contribute to the overall antioxidant activity of various plant extracts due to their redox properties, which can be essential for peroxide breakdown, singlet and triplet oxygen quenching, and free radical absorption and neutralisation. N. cadamba bark, fruit, and leaves methanolic extract has strong in vitro antioxidant potential in terms of scavenging DPPH‡ radicals in a dose-dependent manner. Comparing leaf extract to fruit and bark extract, it is discovered that the former has the highest antioxidant activity (Pandey et al. 2016).

Sedative and Antiepileptic Activities: Bark from N. cadamba has long been used to treat neurological conditions, and ethanolic preparations of the bark have demonstrated sedative and antiepileptic properties (Dubey et al. 2011).

Hypolipidemic Activity: N. cadamba root extract significantly reduced triglycerides, phospholipids, total cholesterol, and lipid peroxides in rats with dyslipidaemia, indicating that it may be used to treat lipid diseases (Pandey et al. 2016).

Antidiarrheal Activity: The hydroethanolic extract of N. cadamba's flowering tops has shown promise as an antidiarrheal agent by reducing the frequency of faecal droppings in mice with castor oil-induced diarrhoea in a dose-dependent manner (Singh et al. 2023).

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Challenges

The regrowth of N. cadamba growing in the field has not been reported to be successful. This is due to the fact that sterilising N. cadamba explants that are obtained from the field is very difficult. Because of the abundance of endophytic microbes in them, contamination has hampered N. cadamba tissue growth in the field and is challenging to overcome (Li et al. 2024). Tree species productivity would be significantly impacted by limited soil nitrogen supply and shifting climatic conditions. It becomes more difficult to adapt to and successfully mitigate the effects of climate change through the forestry system in these conditions. Therefore, it is imperative to improve the carbon sequestration and mitigation capabilities of tree species and forestry. Through targeted forestry actions, this might be a powerful tool to combat global climate change. In nitrogen-deficient soils, nitrogen usage optimisation offers a useful strategy to increase the rate of carbon sequestration and productivity (Singh et al. 2024).For optimal use, the geographic genetic variation throughout its native distribution range in Southern China has not yet been described(Que et al. 2022).

Conclusion

Neolamarckia cadamba, sometimes called the burflower tree or kadamba, is a deciduous tree that grows quickly and is indigenous to South and Southeast Asia. Its ecological, therapeutic, and commercial significance make it valuable. In many areas, the tree is a sign of legacy due to its distinctive spherical blossoms, aromatic scent, and cultural connotations.

By giving different creatures a place to live and food, the tree promotes biodiversity. It contributes to soil protection and is frequently employed in reforestation initiatives. In traditional medicine, N. cadamba's bark, leaves, and fruits are used to treat a variety of conditions, including wounds, fever, and diarrhoea. Because of its low weight, its wood is perfect for the pulp, paper, and furniture sectors. The tree is revered and connected to gods like Lord Krishna in Buddhist and Hindu faiths.

Neolamarckia cadambais a multifunctional tree that offers economic, cultural, medical, and ecological advantages. For it to continue contributing to biodiversity and human wellbeing, conservation and sustainable management are essential.

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Statements & Declarations

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Sonam Kadian. The first draft of the manuscript was written by Sonam Kadian, and all authors commented on previous versions of the manuscript. Samander Kaushik and Sandeep Singh provided administrative support and supervision for this study. All authors read and approved the final manuscript.

Consent for publication

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Conflict of interest

There is no conflict of interest.

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