

Chapter 6

Pongamia pinnata (L.) Pierre: versatile tree for sustainability and medicine

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Abstract: *Pongamia pinnata*, commonly known as Karanja or Indian beech, is a versatile and multipurpose tree with significant ecological, medicinal, and economic importance. The tree is a remarkable source of biofuel, with its seeds producing non-edible oil rich in polyunsaturated fatty acids, which can be converted to biodiesel. Furthermore, *P. pinnata* has a rich history in traditional medicine, where its various parts are utilized to treat ailments such as skin diseases, rheumatism, ulcers, diabetes, and tumors. The tree exhibits pharmacological properties, including anti-inflammatory, antioxidant, anti-diarrheal, and anti-hyperglycemic effects, attributed to its diverse phytochemical composition. With its potential to address global challenges like climate change, energy security, and sustainable agriculture, *P. pinnata* emerges as a crucial resource for ecological restoration and medicinal innovation.

Keywords: Karanja, medicinal plants, traditional medicine, ecological significance

Introduction

Pongamia pinnata, commonly known as Indian-beech, Karanja, or Poonga oil tree, is a medium-sized, perennial tree belonging to the Fabaceae family. It is an important non-edible minor oilseed tree primarily found in semiarid regions

and is believed to have originated in India (Yadav *et al.*, 2011; Siddanna *et al.*, 2022). The tree grows naturally in India, Pakistan, Bangladesh, Malaysia, Vietnam, Thailand, Sri Lanka, northeastern Australia, Japan, Fiji, Samoa, Taiwan and Philippines. Commercially cultivated in India, *Pongamia* seeds are typically available from December to April. The tree thrives in diverse environmental conditions, including drought-prone, saline, alkaline, and waterlogged soils, at elevations up to 1200 meters, and is especially common in coastal and alluvial regions (Divakara *et al.*, 2012; Ramadevi *et al.*, 2018). Known for its medicinal, environmental, and economic significance, all parts of the plant have been traditionally used in Ayurveda and Unani medicine to treat ailments such as tumors, piles, skin diseases, wounds, abscesses, rheumatism, bronchitis, and ulcers. Its phytochemical composition includes alkaloids, flavonoids, tannins, glycosides, and fixed oils, which exhibit properties like anti-inflammatory, antioxidant, anti-diarrheal, anti-plasmodial, anti-ulcer, and anti-hyperglycemic activities (Thakur *et al.*, 2021). In addition to its medicinal uses, *Pongamia pinnata* has significant environmental applications. Its dense lateral root network prevents soil erosion and stabilizes sand dunes, while its leaves and press cake serve as bio-pesticides and insect repellents for stored grains (Kumar *et al.*, 2017). The seeds, which contain 28-40% oil rich in polyunsaturated fatty acids like linoleic and stearic acids, are a promising source of biodiesel. The oil can be converted to biodiesel through trans-esterification, and it blends well with conventional diesel, requiring no engine modifications for blends as high as 20% (Scott *et al.*, 2008).

Morphology

Pongamia pinnata, is a medium-sized, deciduous, or semi-evergreen tree that grows to a height of 15–25 meters with a spreading, dome-shaped canopy.

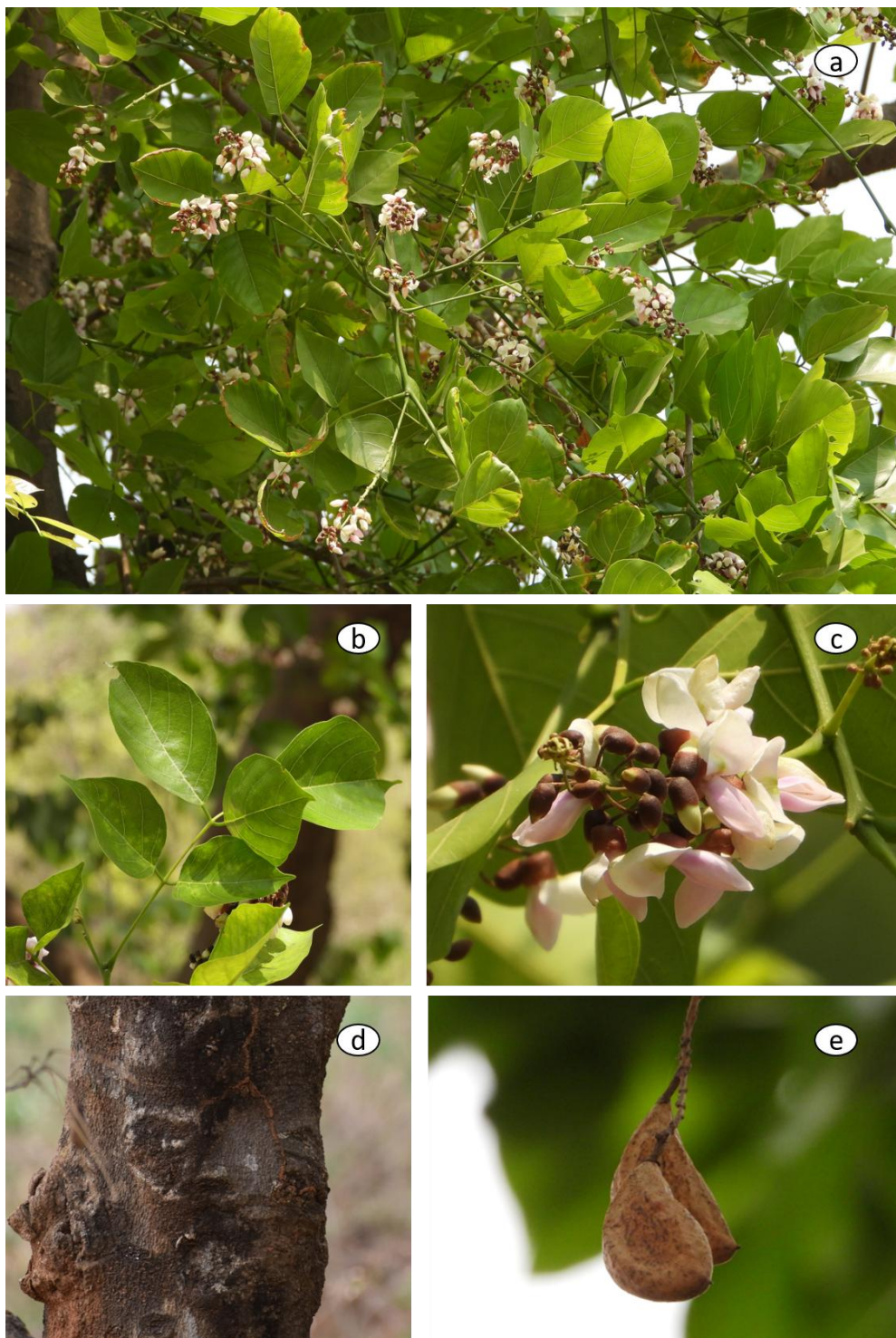


Plate 1: Vegetative parts of *P. pinnata*, a) canopy, b) leaves, c) flowers, d) bark, e) fruits

The branches form a dense, shady crown (Pulipati *et al.*, 2018; Kumar *et al.*, 2022; Nayak and Kumar, 2023; Plate 1).

Trunk and Bark: The trunk is short and typically straight, with a diameter ranging from 50 to 80 cm. The bark is thin, grey-brown, and fissured, exuding a reddish-brown sap when cut.

Leaves: Leaves are pinnately compound, alternate, and imparipinnate. Each leaf consists of 5–7 glabrous leaflets that are oval, oblong, or elliptic in shape, with a smooth texture. The leaflets are dark green on the upper surface and pale green underneath, with a length of 5–10 cm.

Flowers: Flowers are bisexual, fragrant, and arranged in axillary racemes. They are small, pinkish-white to lavender in color, resembling pea flowers, and measure about 1.5–2 cm in length. The flowering season typically occurs between March and May.

Fruit: The fruit is a flat, elliptical or oblong, and slightly curved pod measuring 5–7 cm in length. The pods are thick, leathery, indehiscent, and contain one or two seeds. When mature, they turn brown and remain on the tree for several months.

Seeds: Seeds are kidney-shaped, brownish-red, and about 1–2 cm in size. They contain 28–40% oil, rich in unsaturated fatty acids, making them a valuable resource for biodiesel production.

Traditional medicinal uses

Pongamia pinnata (L.) Pierre, widely recognized in traditional medicine systems such as Ayurveda and Unani, has been extensively used for its therapeutic, medicinal, and practical applications. The fruits and sprouts of the tree are employed in folk remedies for abdominal tumors in India, keloid tumors in Sri Lanka, and general tumors in Vietnam. The seeds, which are rich

in bioactive compounds, have been traditionally used to treat skin ailments and are now valued for their powdered form in addressing bronchitis, chronic fever, whooping cough, and skin diseases (Yadav *et al.*, 2011; Pulipati *et al.*, 2018). The oil derived from the seeds is used as a liniment for rheumatism and as a treatment for scabies, leprosy, piles, ulcers, liver pain, and lumbago (Figure 1). Additionally, it has alternative uses as biodiesel, fuel for cooking, and lamp oil (Rout *et al.*, 2009; Pavithra *et al.*, 2010). The leaves exhibit antibacterial activity, especially against *Micrococcus*, and their juice is used for colds, coughs, diarrhea, dyspepsia, flatulence, gonorrhea, and leprosy (Pulipati *et al.*, 2018). The bark is used internally for bleeding piles, while the roots are utilized for cleaning gums, teeth, and ulcers. Juices from the plant and its oil possess antiseptic properties and are effective remedies for itch, herpes, and pityriasis versicolor (Pavithra *et al.*, 2010). Flowers are used to manage diabetes, and the bark has been employed in treating beriberi. The juice of the root is applied to cleanse foul ulcers and close fistulous sores, while young shoots are recommended for rheumatism (Pavithra *et al.*, 2010; Nayak and Kumar, 2023). In Ayurvedic practices, the root and bark are regarded as alexipharmic, anthelmintic, and effective against abdominal enlargement, ascites, biliousness, diseases of the eyes, skin, and vagina, as well as for treating piles, splenomegaly, tumors, ulcers, and wounds (Akram *et al.*, 2021). The sprouts are considered useful for inflammation, piles, and skin diseases, while the leaves are valued as digestive aids and laxatives. The flowers help alleviate biliousness and diabetes, and the fruit and seed are beneficial for conditions like keratitis, urinary discharges and, brain and skin diseases. Unani medicine uses ash from the plant to strengthen teeth and the seed for chest complaints, earaches, hydrocele, and lumbago (Jeelani *et al.*, 2023). The oil of *Pongamia pinnata* is widely used in the soap-making, tanning, and pesticide industries. It is also recognized for its role in enhancing

the pigmentation of skin affected by leucoderma or scabies and is a source of biofuel (Jeelani *et al.*, 2023). The tree, with its rich phytochemical composition of flavonoids, fixed oils, and other bioactive compounds, holds significant pharmacological potential with properties such as anti-inflammatory, anti-plasmodial, anti-ulcer, antioxidant, and CNS depressant activity, making it a vital resource in traditional and modern medicinal systems (Kumar *et al.*, 2023).

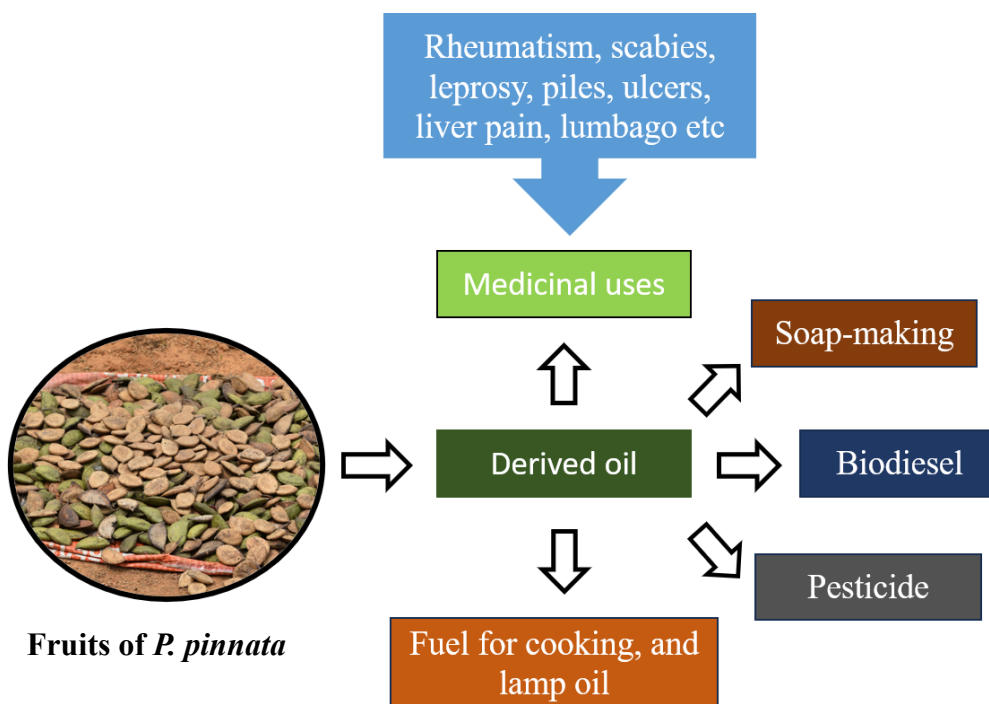


Figure 1: Uses of derived oil from *P. pinnata* seeds

Pharmacological potential

The pharmacological properties of *P. pinnata* are well-documented by scientific research, demonstrating its potential in treating various ailments, including inflammatory diseases, diabetes, microbial infections, liver disorders, and cancer. Its bioactive compounds are useful for future pharmaceutical applications.

Anti-inflammatory activity: Research indicates that the flavonoids and fixed oils in *P. pinnata* possess significant anti-inflammatory properties. Studies have demonstrated its effectiveness in reducing inflammation through mechanisms such as inhibition of inflammatory mediators like prostaglandins and cytokines (Jeelani *et al.*, 2023).

Antioxidant activity: Extracts from *P. pinnata* have been shown to scavenge free radicals and reduce oxidative stress. The presence of phenolic compounds and flavonoids contributes to its strong antioxidant capacity (Patil *et al.*, 2010).

Antidiabetic effects: Studies have reported hypoglycemic effects of *P. pinnata*, particularly its flowers, which help in regulating blood glucose levels and improving insulin sensitivity in diabetic models (Sikarwar and Patil, 2010).

Antimicrobial properties: The oil and extracts from the plant have shown antimicrobial activity against a range of pathogens, including bacteria (*Staphylococcus aureus*, *Escherichia coli*, and *Micrococcus luteus*) and fungi (*Candida albicans*). This activity is attributed to the presence of flavonoids, tannins, and alkaloids (Badole *et al.*, 2011).

Wound healing properties: The application of *P. pinnata* oil or extracts on wounds accelerates healing by promoting epithelialization and collagen deposition. Its antiseptic and regenerative properties are well-documented in wound management research (Dwivedi *et al.*, 2017).

Antidiarrheal effects: The ethanolic extracts of *P. pinnata* have demonstrated antidiarrheal activity by reducing intestinal motility and spasmogenic effects, likely through calcium-channel blocking mechanisms. Crude decoction of *P. pinnata* has also selective antidiarrheal action with efficacy against cholera

and enteroinvasive bacterial strains causing bloody diarrhea (Brijesh *et al.*, 2006).

Anti-ulcer activity: Research has established the anti-ulcer effects of *P. pinnata* extracts, which help in reducing gastric ulcer formation by enhancing mucus secretion and reducing gastric acid output. The ethanol and petroleum ether leaf extracts showed significant reduction in the pylorus and aspirin induced ulcers in rats (Nagarathna *et al.*, 2007).

CNS depressant and anxiolytic activity: Studies suggest that extracts of *P. pinnata* possess sedative and CNS depressant properties, reducing anxiety and promoting relaxation through GABAergic modulation (Pulipati *et al.*, 2018).

Anti-hyperlipidemic activity: *P. pinnata* has been reported to reduce elevated lipid levels, including cholesterol and triglycerides, in experimental models, making it beneficial for cardiovascular health (Badole *et al.*, 2015).

Antifungal and antiviral activity: The oil derived from the seeds exhibits antifungal activity against species like *Aspergillus* and antiviral potential against *Herpes simplex* virus (Punitha and Manoharan, 2006).

Anti-cancer potential: Some studies have explored the anticancer effects of *P. pinnata* seed oil and extracts. The compounds demonstrate cytotoxic effects against cancer cell lines, particularly breast and liver cancers, by inducing apoptosis (Navyatha *et al.*, 2025).

Ecological Significance

P. pinnata plays a crucial role in soil conservation due to its dense lateral root system. Its roots stabilize soil, prevent erosion, and improve soil structure, particularly in degraded and arid lands. It is also used for stabilizing sand dunes along coastal areas. The seeds of *P. pinnata* produce oil with high potential as a sustainable biodiesel source. Its use as biofuel reduces reliance

on fossil fuels, mitigates greenhouse gas emissions, and contributes to renewable energy initiatives (Kumar *et al.*, 2017). It is an efficient carbon sink, as it grows rapidly and stores carbon in its biomass and soil (Bobade and Khyade, 2012). This makes it an excellent species for combating climate change and restoring degraded lands. The tree thrives in saline, alkaline, and waterlogged soils, making it ideal for reclaiming degraded lands (Leksono *et al.*, 2021). Its ability to grow in marginal areas contributes to ecological restoration and biodiversity enhancement. The dense canopy and foliage of *P. pinnata* provide shelter and nesting sites for birds and insects, thereby supporting local biodiversity (Degani *et al.*, 2022). The flowers attract pollinators such as bees and butterflies, contributing to ecological balance. Along with this, *P. pinnata* is a significant host tree for many epiphytic Orchid species (Present study). The leaves of *P. pinnata* are rich in nutrients and can be used as green manure to enhance soil fertility. Additionally, the leaves and seed cake have pesticidal and insecticidal properties, which reduce the dependency on synthetic pesticides. As a perennial tree, *P. pinnata* absorbs carbon dioxide and other pollutants from the atmosphere, improving air quality. It is also used as a shade tree in urban areas to reduce the urban heat island effect (Kumar *et al.*, 2017). The tree is highly drought-tolerant and can survive in arid regions with minimal water, making it suitable for water-scarce ecosystems. Its shade also reduces soil evaporation and retains soil moisture. Research has shown that *P. pinnata* can be used in phytoremediation to treat wastewater. The tree absorbs heavy metals and other pollutants from soil and water, thereby improving environmental quality (Degani *et al.*, 2022).

Conclusion

P. pinnata represents a sustainable solution to many of the world's pressing challenges, including environmental degradation, renewable energy needs, and healthcare demands. Its ability to thrive in marginal soils, fix nitrogen, and

prevent erosion makes it a valuable tree for ecological restoration and agroforestry systems. The biodiesel potential of its seed oil offers a renewable and environmentally friendly alternative to fossil fuels, aligning with global efforts to mitigate climate change. In addition, its rich phytochemical profile and proven pharmacological properties highlight its significance in traditional and modern medicine. Integrating *P. pinnata* in large-scale afforestation, biofuel production, and medicinal research can unlock its full potential, contributing to sustainable development and environmental conservation. As a tree of ecological and medicinal value, *P. pinnata* is truly a versatile resource for building a sustainable future.

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