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A phyto-pharmacological review on a versatile medicinal plant: *Pongamia pinnata* (L.) Pierre

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Abstract
Medicinal herbs are used in both contemporary pharmaceutical medications and traditional treatment. Numerous pharmacological characteristics are displayed by *Pongamia pinnata*. Plant parts such as leaves, stems, seeds, and even entire portions are utilized to cure patients in traditional medicine. Many ailments are traditionally treated with the leaves, seeds, and entire plant. Anti-inflammatory, anti-plasmodial, anti-bacterial, antiviral, anti-lice, anti-ulcer, and antidiarrheal are some of its applications. This review covers all of the existing research on *Pongamia pinnata*, including its pharmacognostic characteristics, physicochemical parameters, pharmacological activity summary, and traditional use. This endeavor offers guidance for future investigation.

Keywords: Physicochemical parameters, pharmacological activities, *Pongamia pinnata*

1. Introduction
The medium-sized, quickly growing *Pongamia pinnata* Linn Pierre tree, also known as a kanuga in Telugu, belongs to the Fabaceae family. Asia's tropical and warm climates are home to this plant. The entire plant has been used as a crude medication to cure tumors, piles, skin conditions, itching, abscess, wounds, ulcers, tooth cleaning, dermatomy, vagainotherapy, and painful rheumatic joints (Tanaka *et al.* 1992) [1]. In addition, the food can be composted, utilized as fish poison, green manure, and animal feed. Applications in the fields of agriculture and the environment have also been acknowledged.
The plant's seed powder is used as an expectorant to treat bronchitis. *Pongamia* leaf infusion is used to treat rheumatism. *Pongamia* seed oil is used as a cholagogue and stomachic to treat dyspepsia. Biodiesel can be produced from *Pongamia pinnata* seed oil by the trans-esterification process. Antidiarrheal, anti-plasmodium, anti-inflammatory, anti-ulcer, and wound-healing characteristics were among the activities that were reported (Chopade *et al.* 2008) [6]. *P. pinnata*, an exceptional medicinal plant, has the potential to be a therapeutic plant, according to the literature review.

Synonyms
Pongamia pinnata linn pierre is also known by various synonyms such as
- *Millettia pinnata* (L.) Panigrahi
- *Pongamia glabra* vent
- *Derris indica* (Lam)

Taxonomical classification
Kingdom: Plantae
Order: Fabales
Family: Fabaceae
Genus: Pongamia (Millettia)
Species: Pinnata
Binomial name: Pongamia pinnata Linn pierre

Vernacular names [3]
Different vernacular names of *P. pinnata* have been reported as follows
Hindi - Karanj, pongam oil tree, kanji, Bengali - Karach, Sanskrit - Naktamala, Kannada - Honge, hulagilu, Urdu - Karanj, Malayam - Pungu, ungu, unu, avittal, Oriya - Koranjo, Telugu - Kanuga, Tamil - Punagai, dalkaramacha, pongam, punku.

Origin and geographical distribution
Originally native to Asia, it is currently found in Australia, Florida, Hawaii, India, Malaysia,

Oceania, the Philippines, and the Seychelles (Edward *et al.* 2004) [7]. Throughout India, it was typically planted in coastal woods close to rivers and streams.

Ecology
Well-drained sandy loams with guaranteed moisture yield the optimum growth. Although it can withstand saline conditions, alkalinity, and soils that are water-locked, it does not thrive on dry sands. Heavy clay soils that swell will also support its growth. When the pH of these species rises above 7.5, they experience nutritional deficiencies.

Propagation
For these seeds, in-situ germination is ideal, and it must occur within 1–5 weeks of seeding. When the seedlings are roughly 60 cm tall, at the start of the following rainy season, they should be planted in the field. It is advised to space young plants 7.5 by 15 cm apart because they can withstand shade effectively. Seeds and root suckers are the most common natural reproduction methods. Critical weed issues might arise from spontaneous seedlings and root suckers.

Temperature
This plant can thrive in temperatures ranging from a minimum of 1 to 16 °C to a maximum of 27 to 38 °C. This plant can resist temperatures as high as roughly 50 °C and as low as slightly below 0 °C (32°F).

Morphological characteristics
The legume plant *Millettia pinnata* has a broad canopy and reaches a height of 15 to 25 meters. Its diameter ranges from 50 to 80 cm, and its trunk can be either straight or bent.

Leaves: When they are young, they are soft and shiny, reddish-purple, and with age, they become glossy. As the season goes on, their colour deepens and their veins become more noticeable. The tree's imparipinnate leaves alternate, have short stalks, and are oval or oblong along their length, with a rounded or cuneate base.

Flowers: Throughout the year, little clusters of pink, purple, and white flowers typically bloom. The inflorescence, which resembles a raceme, has two to four fragrant blooms that are 15-18 mm long. Usually, flowering begins three to four years later.

Calyx: These are bell shaped and truncate.

Corolla: It has an ovate, rounded shape with basal auricles and a green patch in the middle.

Seeds: The brittle, oily-coated seeds, which are 1.5 to 2.5 centimeters long, are indigestible to herbivores. After flowering, brown seed pods emerge right away and need 10 to 11 months to mature. Thick-walled, smooth, oval, and somewhat flattened, the pods have a short, curled point. When seedlings are between five and seven years old, pod production starts. Usually, the pods must decompose before the seeds may sprout because they do not open naturally.

Stem: The stem has a slight green hue and a bothersome smell. It is somewhat difficult to break and herbaceous. Its surface has a smooth texture.

Root: The plant contains lateral roots that grow widely and a long, thick taproot. Compared to most other species, this one has a larger root spread-roughly 9 meters in 18 years-and produces a lot of root suckers. These qualities make *Pongamia* inappropriate for agroforestry and have the potential to turn into a weed if not controlled.

Medicinal value of different parts of the plant
Flower: Used to treat bleeding hemorrhoids, or piles.

Fruit: Assist in the treatment of hemorrhoids, ulcers, female genital tract infections, and abdominal tumors.

Seed: Extracts can be used to treat anemia, excessive blood pressure, and scar tissue tumors. Powder lowers fever and aids in the treatment of whooping cough and bronchitis.

Oil (extracted from seed): used to eradicate parasitic worms and as an astringent beneficial in the treatment of leprosy, piles, liver ache, prolonged fever, ulcers, and whooping cough relieves arthritis and painful muscles and joints. When combined with zinc oxide, it is used to treat eczema and other skin irritations.

Leaf: Whole leaves are used to cure wounds and inflammation, as well as a laxative and digestive aid. Leprosy, gonorrhea, diarrhea, flatulence, coughs, and colds can all be treated with leaf juice. Extracts and infusions of leaves reduce itching and rheumatism, respectively.

Stem: Extracts that are used to calm the central nervous system and reduce or eliminate fever.

Bark: Alleviates mental disorders, spleen inflammation, and coughs and colds. beneficial in treating bleeding piles.

Root: Used to cure skin and vaginal disorders, as well as to eliminate parasitic worms and as a toothbrush for dental hygiene. Juice for healing open sores and cleaning ulcers Juice can be used to treat gonorrhea when combined with coconut milk and lime water.

Phytochemistry
In addition to eighty fatty acids (three saturated and five unsaturated), *Pongamia pinnata* seeds contain six compounds: two sterols, three sterol derivatives, and one disaccharide. Physicochemical approaches and spectroscopic techniques were used to clarify their structures. Karangin, pongagalabrone and pongapin, pinnatin and kanjone have been isolated from seeds. The leaves and stem of the plant consists of flavones and chalcone derivatives such as Pongone, Galbone, Pongalbol, Pongagallone A and B5.
Five flavonoids, known as pongamones A–E, were isolated and characterized from *Pongamia pinnata* stems. By comparing their spectra data with comparable compounds that have been described in the literature and using spectroscopic analysis, their structures were clarified. The root bark of P. pinnata contains about 18 flavonoid compounds, including 9 novel ones called pongames III–XI. The structures were determined to be (2S)-3′,4′-dimethoxy-6″,6″-dimethylpyrano[2″,3″:7,8]- flavanone (III), (2S)-6,3′,4′-trimethoxy-6′ ′,6′ ′ - dimethylpyrano [2″,3″7,8]- ß avanone (IV), (2S)-7-methoxy6-O-γ,γ-dimethylallyl-3′,4′-

methylenedioxyß avanone (V), 2′- hydroxy-3,4,5′-trimethoxy-6″,6″-dimethylpyrano[2″3″:4′3′] chalcone (VI), 2′,4′-dimethoxy-3,4-methylene dioxy dioxydihydrochalcone (VII), 2′,5′,β-trimethoxy-3,4- methylenedioxy-6″,6″-dimethylpyrano[2″,3″:4′,3′] dihydrochalcone (VIII), 2, β-dimethoxy-3, 4- methylenedioxy-furano[2″,3″:4′,3′]-dihydrochalcone (IX), βhydroxy-2′,4′,6′-trimethoxy-3,4-methylenedioxychalcone (X) and 3-methoxy-furano-[2″,3″:7,6] flavone (XI), respectively, by means of spectral analysis and synthesis (Tanaka *et al.* 1992) [25].

Three new furnoflavanoid glucosides, pongamosides A–C, and a new flavanol glucoside, pongamoside D, are found in *Pongamia pinnata* fruits. Spectroscopic analyses were used to determine the structures of these substances. *Furanoflavone glucosides* are being discovered as naturally occurring chemicals for the first time (Ghufran *et al.* 2004) [12].

Pharmacological activities

(i) Antioxidant activity

Pongamia pinnata leaf extract's preventive function against oxidative stress during ammonium chloride-induced hyperammonemia was investigated by assessing the degree of oxidative damage and antioxidant state (Essa and Subramanian, 2006) [9]. Ethanolic extract of *Pongamia pinnata* (PPEt) leaves was administered orally (300 mg/kg body weight) and the effects of PPEt on the levels of thiobarbituric acid reactive substances (TBARS), hydroperoxides (HP), conjugated diene (CD), superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), and reduced glutathione (GSH) were studied in liver and kidney of ammonium chloride-induced hyperammonemic rats. On treatment with PPEt, a significant reduction in the levels of TBARS, HP, and CD and a significant increase in the levels of SOD, CAT, GPx, and GSH in liver and kidney of ammonium chloride-induced hyperammonemic rats were observed, which clearly shows the antioxidant property of PPEt. These results demonstrate PPEt's ability to prevent lipid peroxidation and imply that it has antioxidant potential that could be applied therapeutically. The extract's flavonoids and polyphenols may be the cause of its antioxidant qualities (Patil *et al.* 2010) [16].

The impact of *Pongamia* leaf extract on circulatory lipid peroxidation has been noted. The antioxidant status of ammonium chloride-induced hyperammonium rats was assessed, and the elevated lipid peroxidation in the circulatory ammonium chloride-treated rats was explained by a notable drop in vitamin C, vitamin E, reduced glutathione peroxidase, and superoxide dismutacatalase levels. Because of its antioxidant properties and ability to detoxify excess ammonia, urea, and creatinine, PPEt has been shown to modify by correcting the oxidant-antioxidant imbalance during chloride-induced hyperammonemia (Punitha and Manohar, 2006) [10].

(ii) Antimicrobial activity

Petroleum ether and ethyl acetate were used in turn to remove the plant materials' leaves, bark, and seeds. The disc diffusion method was used to assess the extracts' antibacterial activity against Bacillus subtilis, Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, and Candida albicans. The leaf, bark, and seed extracts all displayed a good zone of inhibition. With the exception of petroleum extract of bark, neither extract had any effect on *E. coli* or *C. albicans*, but both demonstrated maximum zone inhibition against Bacillus subtilis (Ujwal *et al.* 2007) [26].

Proteus vulgaris, Staphylococcus epidermidis, Staphylococcus aureus, Enterobactor aerogenes, Bacillus subtilis, Salmonella typhimurium, Escherichia coli, Propionibacterium acne, Yersinia enterococcai, Listeria monocytogens, Shigella flexneri and *Vibrio cholera* were among the many gram-positive and gram-negative bacteria that were susceptible to the plant's extracts (Arote *et al.* 2009, Bajpai *et al.* 2009, Brijesh *et al.* 2006, Chandrashekar and Prasanna, 2010, Kesari *et al.* 2010, Kumar *et al.* 2007, Wagh *et al.* 2007) [1, 3, 4, 5, 13, 15, 27]. Numerous phytoconstituents, including triterpenes, chalcone, flavones, flavans, and aromatic carboxylic acids, are present in the plant. These substances appear to be in charge of the antibacterial properties of some *Pongamia pinnata* preparations. Significant antifungal activity was demonstrated by the seed oil against the investigated fungus. After *Aspergillus terreus* and *Candida albicans, Aspergillus niger* had the highest inhibition. Against all investigated fungi, the pure oil (100%) demonstrated the highest inhibition and the lowest inhibition by 40–45% of extracted oil (Kesari *et al.* 2010) [13]. Triperpene 118 is the first antifungal chemical to be identified from a plant. It had no activity against *Penicillium notatum*, poor activity against molds, and significant antifungal activity against yeast Badole *et al.* 2011) [2].

The agar well diffusion method was used to test the antimicrobial efficacy of an ethanolic extract of *Pongamia pinnata* stems (PPEE) at concentrations of 250 µg, 500 µg, 750 µg, and 1000 µg against specific Gram-positive pathogens, including *Staphylococcus aureus, Bacillus subtilis, Bacillus megaterium, Enterococcus faecalis, Gram-negative Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Proteus vulgaris* and the fungus *Aspergillus niger*. The PPEE has significant amounts of flavonoids and tannins, with 41.2±1.7 mg of rutin and 39.7±2.6 mg of GAE/gm of extract, respectively. *Bacillus subtilis* was the organism against which the plant extract showed the most activity, followed by *Escherichia coli* and *Bacillus megaterium*. Significant action was also shown by the plant against *Aspergillus niger* (Shameel *et al.* 1996) [21]. The MIC ranges from 31.2 to 62.5 mg/ml.

Pongamia pinnata stems were tested for their antibacterial activity against dental caries pathogens, including *Pseudomonas aeruginosa, Lactobacillus acidophilus, Escherichia coli, Streptococcus mutans, Staphylococcus aureus, Enterococcus faecalis,* and *Candida albicans* (Sowjanya *et al.* 2016) [23]. At varying concentrations, the zone of inhibition's widths vary from 15.33±0.57 to 28.0±1.0 mm. Tetracycline and fluconazole were used as benchmarks to compare the antibacterial activity. Maximum activity against *S. aureus* (26.0±1.0 mm), moderate activity against *E. faecalis* (25.66±1.15 mm), and minimum activity against *P. aeruginosa* (21.66±1.52 mm) were all demonstrated by the crude ethanolic stem extract. Additionally, the plant successfully inhibited *C. albicans* (28.0±1.0 mm). The current study's findings show that *Pongamia pinnata* stems have antibacterial properties that can help prevent tooth cavities. The agar dilution method was used to determine the MIC, which ranged from 31.2

mg/ml to 62.5 mg/ml.

(iii) Antiviral activity

The crude aqueous seed extract showed antiviral activity. It completely inhibited growth of herpes simplex virus type1 (HSV-1) and (HSV-2) at the concentration of 1 and 20 mg /ml (w/v) respectively and showed complete absence of cytopathic effect (Elanchezhiyan *et al.* 1993) [8]. The crude dried leaves extract showed no activity against rota virus. *Pongamia pinnata* seed extract (Fiala *et al.* 1974) [10] showed the safety effect in acute and chronic toxicological studies conducted in Swiss albino rats.

Pongamia pinnata leaves were used to isolate bis (2-methylheptyl) phthalate, which was tested for its antiviral properties against the White Spot Syndrome Virus (WSSV) of *Penaeus monodon* Fabricius. Oral administration of ethanolic extract and bis (2-methylheptyl) phthalate, a purified chemical, has improved the survival rate of *Penaeus monodon* infected with WSSV. The shrimp were fed pelletized feed that had been treated with an ethanolic extract of *Pongamia pinnata* leaves at 200 and 300 mcg/g of shrimp body weight per day, both before and after WSSV infection. WSSV-infected shrimp fed 200 and 300 mcg extract/g had survival rates of 40% and 80%, respectively (Rameshthangam and Ramasamy, 2007) [20].

(iv) Antidiarrhoeal Activity

By assessing the antibacterial properties of a crude decoction of dried *Pongamia pinnata* leaves, this activity was ascertained. It was also assessed for its impact on *Shigella flex* epithelial cells, enteropathogenic *E. coli* adhesion, invasion of enteroinvasive *E. coli*, and the synthesis and action of Enterococcus (cholera toxin, *Escherichia coli* labile toxin, and stable toxin). According to this investigation, *Pongamia pinnata* decoction shown specific anti-diarrheal activity against enteroinvasive bacteria that cause bloody diarrheal episodes and cholera (Brijesh *et al.* 2006) [4].

(v) Antiprotozoal activity

The plant's anti-plasmodial properties against Plasmodium falciparum have been documented (Simonsen *et al.* 2001) [22]. Because of its anti-plasmodial action, the bark and leaf extract with low $1C_{50}$ values of 9-43 mcg/ml has demonstrated promise as an anti-malaria treatment. Lupeol (120), which inhibited Plasmodium falciparum merozites' ability to infiltrate erythrocytes at an IC_{50} of 1.5 mcg/ml, may be the cause of this activity. Additionally, it documented that Leishmania and Trypanosoma cruzi growth was inhibited at an IC_{90} of 100 mcg/ml (Fournet *et al.* 1992) [11]. There was no effect of crudely decocting dried leaves on trophozites.

(vi) Anti-Inflammatory activity

According to reports, *P. pinnata* 70% ethanolic leaf extract has strong anti-inflammatory properties against the acute, sub-acute, and chronic stages of inflammation without having an adverse effect on the stomach mucosa. Additionally, the extract had a strong antipyretic effect against pyrexia caused by brewer's yeast (Srinivasan *et al.* 2001) [24].

(vii) Anti-Ulcer activity

After 10 days of therapy, the methanolic extract of *P. pinnata* roots has been shown to significantly protect against aspirin-induced mucosal damage and to have a tendency to lessen ulcers caused by acetic acid. By stopping mucosal defense factors such as mucin secretion, mucosal cell life span, mucosal cell glycoproteins, cell proliferation, and lipid peroxidation prevention, the extract demonstrated an ulcer-protective effect (Prabha *et al.* 2003) [17].

The ability of the seed methanolic extract to prevent and treat ulcers in rats was assessed. The extract demonstrated a dose-dependent (12.5–50 mg/kg for 5 days) ulcer-preventive efficacy when taken orally against gastric ulcers brought on by 2-hour cold-resistant stress. In contrast to ethanol-induced GU, the optimal effective dose of PPSM (25 mg/kg) demonstrated anti-ulcerogenic efficacy against acute stomach ulcers (GU) caused by pylorous ligation and aspirin, as well as duodenal ulcers caused by cysteamine (Prabha *et al.* 2009) [18].

(viii) Anti-hyperglycemic & anti-lipid peroxidative activity

Oral administration of *P. pinnata* flower ethanolic extract has been shown to significantly reduce hyperglycemia and lipid peroxidation, as well as improve the antioxidant defense system in rats with alloxan-induced diabetes (Punitha and Manoharan, 2006) [19]. The flower's ethanolic extract (300 mg/kg bw) demonstrated strong antihyperglycemic effects in alloxan-induced diabetic rats, significantly lowering blood glucose levels to a level comparable to that of the reference medication glibenclamide (600 microgram/kg bw). Based on the findings, *Pongamia pinnata* extract may be a safe substitute for anti-hyperglycemic medications in diabetic patients (Kirtikar and Basu, 1993) [14].

Conclusion

The plant *Pongamia pinnata* has been used extensively as a remedy for a number of illnesses in the old Ayurvedic medical system. Ayurvedic and Unani traditional medicine systems use the plant for its anti-inflammatory, anti-plasmodial, anti-nociceptive, anti-hyperglycemic, antilipid peroxidative, anti-diarrheal, anti-ulcer, antihyperammonic, antioxidant, and antibacterial properties.

According to a thorough review of the literature, *Pongamia pinnata* L. is a significant, adaptable medicinal plant with a wide range of pharmacological effects. Numerous chemical components found in the plant are what give it its diverse pharmacological and therapeutic qualities. However, *Pongamia pinnata* L. has to be evaluated in order to investigate the hidden regions and their useful clinical applications that can be utilized for the benefit of humanity.

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