KARANJ (PONGAMIA PINNATA) – AN AYURVEDIC AND MODERN OVERVIEW

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ABSTRACT

Pongamia pinnata is one of the significant herbal plants with different therapeutic medicinal properties. P. pinnata is a potential medium-sized legume tree, also known as Karanja. It is widely distributed in Indian Western Ghats. This plant is mostly cultivated around coastal areas, riverbanks, tidal forests, and roadsides. Conventionally, the leaves, seeds, and the whole plant were utilized in the treatment of many ailments. There are various phytochemicals isolated from the P. pinnata plant. Karanjín is the principal furanoflavonoid of the plant. It was known to be the first crystalline compound isolated from this plant. The plant is therapeutically important in traditional medicine as well as in modern drugs. Oil extract from the P. pinnata seeds is utilized in agriculture and pharmacy. Seed oil is also proved to be a biofuel in recent studies. There are various therapeutic uses of the P. pinnata, including antifungal, anti-diarrheal, anti-inflammatory, anti-viral, anti-bacterial, anti-lice, and others. The karanja seeds contain 27-40%(w/w) oil. Commercially, the seed oil of the P. pinnata is used as biodiesel. The present review article reveals the overall ayurvedic and modern therapeutic information of P. pinnata with various reported ayurvedic literature and scientific pharmacological studies.

Keywords: Karanj, Pongamia pinnata, Anti-inflammatory, Anti-plasmodial, Folk uses.

INTRODUCTION

Medicinal plants play an important role in human lives for many years to treat various diseases all over the world. Plants are the diverse producer of bioactive compounds that make them a rich source of different types of medicines [1]. Today, there is widespread interest in drugs obtained from natural plants for their various therapeutic properties. Pongamia pinnata Linn Pierre (Fabaceae) is a fast-growing medium-sized tree that belongs to the Leguminosae family [2]. It is an important non-edible minor oilseed tree. It is also called as “Karanj Tree” or “Poonga Oil Tree” in English [3]. It is native mainly to hot arid regions of Asia. The trees are cultivated commercially in India. Therapeutic uses of this plant are also found in the literature of the traditional medicinal system. Karanja (P. pinnata) (Fig. 1) is an ancient plant of Veda, Samhita, and almost in all Nighantu (Dictionary) [4]. It includes various chemical compounds such as alkaloids, flavonoids, tannins, glycosides, hormones, karanjin, glabrin, kanugin, fixed oils, and others [5] that possess various potential anti-inflammatory, anti-oxidative, antitumor, anti-diabetic, anti-ulcer, anti-oxidative, anti-hyperglycemic, and analgesic functions [6,7]. All parts of the plant P. pinnata have been considered as a crude drug [8]. It is also used in the field of environment and agriculture. The seeds of the plant are known as potential biodiesel sources [9] that contain around 28–34% oil with a high concentration of polyunsaturated fatty acids [10]. P. pinnata contains a dense network of lateral roots that have been known to prevent soil erosion. There are several methods reported for the cultivation of plants, including direct seed sowing or by raising the seedling in the nursery and planting by stump cuttings. However, seed sowing is most common because it does not require pre-treatment and grows within 1 week to a month [11]. The tree has a vast medicinal, economical significance due to widespread usage of every part, especially seeds and roots [12]. This review paper aims to provide whole information on the general information, phytochemicals, and various medicinal application of the plant P. pinnata. Taxonomy and vernacular names of P. pinnata (L.) are given in Tables 1 and 2, respectively.

BOTANICAL DESCRIPTION OF P. PINNATA

According to Allen and Allen (1981), the plant P. pinnata is a fast-growing tree that grows up to 40 feet in height and spreading a canopy casting moderate shade. It is a medium-sized, evergreen, perennial, and deciduous tree (Fig. 1) and its height range up to 35–40 feet, fast-growing and medium texture. Leaves are alternate, odd pinnately compound, wide up to 2–4 inches, evergreen, and hairless. Flowers are lavender, pink, and white, 2–4’’ long, 2–4’’ together having short-stalked, peel, and indented, 10–15 cm long. Lateral roots are numerous and well-developed and taproot is thick and long. Bark changes its color from thin gray to gray-brown and is yellow from inside [14].

GEOGRAHICAL DISTRIBUTION OF P. PINNATA

P. pinnata is widely distributed in Asia. This is now found in Australia, Florida, Hawaii, India, Malaysia, Oceania, the Philippines, and Seychelles [15]. It is found in South India up to an altitude of 1200m. It is naturally grown near streams and rivers. Its best growth is found in drained sandy loams with assured moisture [16].

PHYTOCHEMICAL CONSTITUENTS OF P. PINNATA

There are various chemical constituents isolated from the plant P. pinnata. Flavonoid and its derivatives are the most common constituents for isolation. The derivatives of flavonoids are flavones, flavans, and chalcones. Sesquiterpene, diterpene, triterpene, steroids, amino acids, disaccharides, fatty acids, and ester compounds are also detected in this plant.

Flavones

These are the most common constituents extracted from P. pinnata. The flavone class of compounds is distributed in all parts of this plant. Karanjín was considered the first compound to be extracted from this plant. Simple flavones, methylenedioxy flavones, furanoflavonones, chromeno flavones, glycosidated flavones, glycosidated isoflavones, isofuranoflavanones, prenylated flavones, and flavones with modified rings such as coumestan, rotenoids and pterocarps, and a flavone...
have been isolated from the seed, flowers, fruits, stem bark, and root-like 3,4-methylenedioxyflavone, kanugin, 3-methoxy furano [8,7:4′,5′]flavone, pongaglabol methyl ether, pachycarin D, Pongol, Pongaglabol, kanjone, 6-methoxyisopongaglabol, 6-methoxyisopongaglabol methyl ether, Pongapinol C, Pongapinol D; 2′,5′-dimethoxy fur [8,7:4′,5′] flavone, Millettocalyxin C, Pongapinol B, Pongapinol A; 3′,3′-trihydroxy-4H-furo[2,3-b]chromen-4-one, Pongaglabrone, Pongapin, 5-methoxy-3′,4′-methylenedioxyfurano (8,7-4′,5′)flavone, 2′-methoxy-4′,5′-methylenedioxyfurano [7,8-4′,5′]-flavone; 3′-methoxy pongapin; Pinnatin, Glabone, Ponganone XI, and Pongamone D [6,24-27]. No flavones are found to be present in the leaves. Pongaglabrol is a new compound isolated from the flower. Pongachromene, a methylenedioxy chromenoflavone, was the first chromenoflavone to be reported from P. pinnata. Karanjachromene is also known as Pongaflavone, is isolated from the plant [26]. Other chromenoflavones were reported in a period of 27 years from 1983 to 2003 [29].

Glycosidated flavones were also isolated from this species [30]. Pongamoside A, Pongamoside B, Pongamoside C, and Pongamoside D are the first four glycosidic flavones isolated from the fruit of this plant. It was the first time such compounds were found as naturally occurring ones. Kaempferol 3-O-β-D-rutinoside, Rutin, Vicenin-2, 4′-O-methylgenistein 7-O-β-D-rutinoside, and 2′,5′-dimethoxy-genistein 7-O-β-D-Dapiofuranyl (1′-5′)-O-D-glycosopranoside are the flavonoid diglycosides isolated from the leaves [31,32]. Furaneoflavone and isoflavones in prenylated form were isolated from the root and stem bark [33,34]. Coumestan, retinoids, and pterocarpans are the flavone-related compounds obtained from this plant. Pongamiaflavonylflavonol is the first diflavone found from this species [35,36]. It is a compound having 6 carbons in flavone skeleton, bound to carbon B of the other flavone one [2]. The structures of flavones of P. pinnata are shown in Fig. 2.

**Flavans**

Flavans are distributed in almost every part of the species, especially in leaves [37]. Only 2 compounds are non-flavonone from this class and they are Pongamone E and pongafavanol, both flavan-4-ol derivatives. A new compound (2S)-5,7-dimethoxy-8-formylflavone is a simple flavone containing formyl group also isolated from this plant [38]. Flavans present in various part of the plant are:

1. **Stem**: The flavones isolated from stem and stem bark are (2S)-5,7-dimethoxy-8-formylflavone, Pongamone E, 3,4-methylenedioxy-(4′,5′,7,8)- furanoflavone; Pongachin; Pongamone B; Pongafavanol; Ovallifavanon A; Candidone; (2S)-5,7-dimethoxy-8-(2R-hydroxy-3-methyl-3-butenyl) flavone; (2S)-5,7-dimethoxy-8-(2S-hydroxy-3-methyl-3-butenyl) flavone; (2S)-5,7-dimethoxy-8-(2S-hydroxy-3-methyl-3-butenyl)-3′,4′,5′-methylenedioxyflavone; Pongamin; Pongamone C, and 6,7,2′,3′-dimethoxychromeno-8′-dimethylaryl flavone [39]. Chemical structures of some flavones of P. pinnata are shown in the Fig. 3.

2. **Fruits**: (2S)-2′,3′,7,8-furanoflavonol categorized as furano flavone isolated from the fruit part of the plant [40].

3. **Root**: Four compounds are isolated Pongamone III; Pongamone IV; (4′)-isoglabromene and Pongamone V from the root and root bark of the plant [41].

4. **Flower**: Ovalichromene B is the only flavon compound isolated from flowers of P. pinnata [42].

**Chalcones**

Twenty-five compounds are dominated by furanochalcones and chromenochalcones and come under chalcone class. They are written below:

- **Root Bark**: 2′-hydroxy-3,4,4′, 6′-tetramethoxychalcone, Pongamone X Milletenone, Pongamone VII, Dihydropyronenon methyl ether, Ovalienin B, Pongamone IX, Glabromchene, and Ovalienone are the chalcones compounds isolated from P. pinnata.

- **Stem**: Tunicatachalcone, 7-methoxypracansone B, Pongapinone A, Glabromchene, and Ovalienone
• Seed/Flower/Root: Pongamol, Obovatachalcone, and Glabrachalcone [43]
• Leaves: Pongagallone A and Pongagallone B [44]
• Pods: Pongamiaibaurone [45]
• There are some unique facts to be observed about the flavonoids found in this species. From the three classes of flavonoids (flavones, flavans, and chalcones), neither furano nor chromene compounds are found in the leaves of this plant. Furthermore, glycosidated compounds only exist as flavones and were only found in the fruit and the leaf part. Chemical structures of chalcones of *P. pinnata* are shown in Fig. 4.

**Miscellaneous compounds**
Several miscellaneous compounds were also reported to occur in all parts of this plant [27]. Terpenoids exist as sesquiterpene, diterpene, and triterpene. Most of the terpenes are detected in the stem bark except Cyclosart-23-ene-3β,25-diol and Friedelin, which were isolated from the flower part. β-sitosterol and stigmasteryl along with their acetate are
distributed in the flower and seed. Furthermore, glycosidated forms of the sterols also occur in the species. β-sitosterol galactosides and stigmasterol galactosides along with β-sitosterol-3-O-β-D-glucoside and Stigmasterol-3-O-β-D-glucoside and sucrose were reported for the first time in this plant by Shameel et al. (1996). Bis (2-methylheptyl) phthalate, an aromatic ester, was the only miscellaneous compound found in this plant reported to occur in the leaves [2,46].

TRADITIONAL AND MODERN VIEW

Folk view
Karanja plant is a medicinal plant since ancient times. According to Hartwell (1967–1971), in India, the sprouts and fruits are utilized in folk remedies for abdominal tumors, the seeds for keloid tumors in Sri Lanka and plant powder are utilized for tumors in Vietnam [17]. Every part of the plant having ethnobotanics properties. The seed oil of P. pinnata is utilized in itching, abscesses, and other skin diseases [47]. Flowers are used as a remedy for diabetes problems [19]. Bark of the plant is used internally for bleeding piles, beriberi and diabetes, and anti-hepatoprotective activity [20]. Leaves were used as a medicated bath for relieving rheumatic pains and for cleaning ulcers in gonorrhea and scrofulous enlargement [48]. Roots are used for cleaning gums, teeth and ulcers, and other dental problems [49].

Ayurvedic view
The "pongam tree" is known as one of the richest and brightest trees in India. The word “pongamia” has derived from the Tamil word “pinnata” that refers to the “leguminosae” family. In Hindi and Bengali, it is known as Karanj or Paper or Kanji [50]. It is classically categorized in Charaka Samhita as a “Kandughna” that means a group of herbs that relieve itching, Katuka Skandha is a pungent tasting group of herbs. Charaka has mentioned it as a major source of oil [51,52]. Rasa Panchak of Karanj as per Ayurveda is shown in Table 3.

Ayurvedic Uses of Karanj (P. pinnata) [53-55]

Yonidoshahrut (योनिदोहरहुत) – Detoxifies vaginal diseases, useful in uterine disorders
Kushtaghna (कुष्ठघ्न) – Useful in skin diseases
Udavartahara (उदावर्तारा) – relieves bloating
Gulmahara (गुलमोहर) – relieves abdominal tumor, bloating
Arshahara (अराशाहारा) – useful in piles/hemorrhoids
Krumihara (कृनमहारा) – relieves worm infestation

P. pinnata leaves
Kaphavataghna (कफवताहार) – balances kapha and vata
Arshahara (अराशाहारा) – Useful in piles/hemorrhoids
Krumihara (कृनमहारा) – relieves worm infestation
Shotahara (शोताहार) – relieves inflammation
Bhedena (भेडेना) – induces diarrhea, relieves constipation
Pittala (पिट्टला) – increases Pitta

P. pinnata Fruits are
Kaphavataghna (कफवताहार) – balances Kapha and Vata
Mehahaha (मेहाहा) – Useful in urinary tract disorders and diabetes
Arshahara (अराशाहारा) – Useful in piles/hemorrhoids
Krumihara (कृनमहारा) – relieves worm infestation

Pongamia oil is a major source of bio-diesel and is used in Ayurveda for external application to shrink the pile mass, to heal wounds and abscesses quickly. It is useful in acne vulgaris, pimples, and secretions [56].

MODERN VIEW
The consumption of herbal medicines has increased nowadays world widely. Reported studies have revealed an increased growth in the sale of herbal products from the year 2000 to 2008 ranges from 3% to 12% per year [57]. Due to the increased demand of herbal products, the risk with herbal medicines also rises. The quality of the end product compromises because of the contamination of raw material with toxic metals, microbes, other residues, and adulteration (addition of fake or inferior plant material, orthodox drugs, foreign material) which results in poor quality of medicinal products [58]. Internal issues such as non-uniformity (risks due to environmental factor and geographical distribution, use of pesticides, fertilizers) and complexity in the
PHARMACOLOGICAL AND THERAPEUTIC USES

Several scientific research/studies showed that this plant consists of various pharmacological activities such as antioxidant, antimicrobial, anti-parasite, anti-inflammatory, anticonvulsant, anti-diabetic, anti-hyperammonemic, cytoxicity, anthelmintic, and many others. They are mentioned below:

1. Anti-oxidant properties: The ethanolic extract of the leaves mainly possesses anti-oxidant properties. The experiment was conducted in NH₄Cl-induced hyperammonemia rats and results showed that oral administration (300 mg/kg wt) significantly reduced the level of TBARS, HP, and CD and increased the level of superoxide dismutase, catalase, glutathione (GSH) peroxidase, and GSH in the liver and kidney [61]. The flavonoids and polyphenol present in the extract have anti-oxidant properties. One more research states that methanolic extract of the seed increases the level of ferric reducing/antioxidant power [62].

2. Anti-microbial: The various extracts of the plant consist of the antibacterial activity against a different spectrum of gram-negative and gram-positive bacteria such as Proteus vulgaris, Staphylococcus epidermidis, Staphylococcus aureus, Enterobacter aerogenes, Bacillus subtilis, Salmonella typhimurium, Escherichia coli, Propionibacterium acnes, Yersinia enterocolitica, Listeria monocytogenes, Shigella flexneri, and Vibrio cholerae [63]. Chalcone, triterpenes, and aromatic carboxylic acid are the major compounds that possess antimicrobial activity [64]. A test was conducted to evaluate the antifungal property of the plant, and it was found that seed oil showed maximum activity against Aspergillus niger followed by Aspergillus terreus and Candida albicans [65]. Cycloart-23-ene-3β,25-diol is a triterpene compound of this plant which is tested for its antifungal activity. The result showed strong activity against C. albicans and no any activity against Penicillium notatum [66]. The crude aqueous extract of the seed hindered the growth of herpes simplex virus type-1 (HSV-1) and HSV-2 [67] and showed no any activity against rotavirus [68]. An experiment has shown that oral administration of ethanolic extract of leaves hinders the growth of white spot syndrome virus and increased the survival rate in shrimp up to 40–80%, respectively [69,73].

3. Antiprototoxil: Reported studies revealed that the bark and leaf extract with low IC₅₀ values dry extract showed anti-malarial, anti-amebiasis activity against Plasmodium falciparum [74]. Lupeol is the main constituent that blocked the invasion of P. falciparum merozoites [75,76] and also inhibited the growth of Trypanosoma cruzi and Leishmania [77].

4. Anti-inflammatory: An experiment was conducted in the rats to evaluate the anti-inflammatory activity of methanolic extract of the seeds which were administered orally in the dose of 12–50 mg/kg for the 5 days. The results showed protective effects against a gastric ulcer in the rats [78,79].

5. Another study was conducted to evaluate the anti-inflammatory activity against Freund’s complete adjuvant-induced arthritis in rats. It was found that the model injected with this polyherbal formulation containing roots of Cassiaspeos pareira Linn, leaves of M. pinnata (L.) Pierre, and leaves of Vitex negundo Linn, possesses anti-inflammatory properties [80]. This formulation reduces the hind paw swelling and body weight with other improvements in the model.

6. Anticonvulsant activity: The experiment was conducted for the treatment of maximal electroshock-induced seizure in Wistar albino mice with the ethanolic extract of the leaves. It was found anticonvulsant property by lowering the duration of extension phase when compared with a control group. Hence, the ethanolic extract of the leaves of this plant have anticonvulsant activities [81,82].

7. Anti-hyperammonemic activity: The level of blood ammonia, circulating urea, uric acid, non-protein nitrogen, and creatinine decreased significantly in the rats treated with the extract and ammonium chloride. No significant change in the body of the model was found when compared with the control [69].

8. Cytotoxicity: 100 mg/ml methanolic extract was screened to know the cytotoxicity against the pancreatic adenocarcinoma cell line Panc-1 (human pancreatic cancer) for cytotoxicity. It was used as a label-free biosensor assay. The extract of this plant exhibited anti-proliferation activity [85]. Carcache-Blanco et al. state that all the flavonoid compounds were possessing cytotoxicity against cancer cells [84].

9. Anthelmintic activity: The methanolic extract and ethyl acetate extract of the seeds possesses anthelmintic property. It was reported that it needed less time to cause the paralysis and death of adult earthworms, Pheretima posthuma than the extracts of other parts of the plant such as leaves, wood, bark, and fruits [85].

10. Immune modulatory: Reported studies revealed that the aqueous extract of the leaves possesses immunomodulating activity [86].

11. Cardioprotective activity: A study was conducted for the investigation of the cardioprotective activity of P. pinnata in diabetic rats. Diabetes in rats was induces with streptozotocin-nicotinamide. As a result, it was found that the stem bark petroleum ether extract was effective on cardiomyopathy in rats [87].

12. Antinociceptive and antipyretic activity: Reported studies state that leaves have antinociceptive and antipyretic behaviors. An experiment was conducted to test the antinociceptive efficacy by injection of 70% ethanolic extract in the pain models in rats and mice. The finding showed that the leaves have antinociceptive and antipyretic activity [88].

13. Anti-diabetic activity: The flower extract of the P. pinnata administrated orally in diabetic rats significantly decreased blood glucose levels to a degree close to that of the drug glibenclamide. The finding displayed an anti-hyperglycemic effect and also raised the level of plasma insulin significantly [89].

14. Neuroprotective activity: A study showed the neuroprotective impact of stem bark ethanol extract on monosodium glutamate-induced neurotoxicity in albino rats [90].

15. Anti-llice activity: According to recent studies, this medicinal plant is the novel anti-llice agent. An experiment was conducted in which different extracts of P. pinnata leaves in the sample checked against head louse Pediculus humanus capitis. The outcome indicated the anti-llice activity [91,92].

16. Anti-ulcer: Reported studies showed that the methanolic extract of roots of P. pinnata tends to decrease acetic acid-induced ulcers. Ulcer protective effect of methanolic extract of P. Pinnata roots was due to augmentation of mucosal defensive factors such as mucus secretion, the life span of mucosal cells, mucosal cell glycoproteins, and cell proliferation [7]. Reported studies on P. pinnata are listed in Table 4.

SEED OIL AS BIOFUEL

P. pinnata plant is considered as a source of biodiesel. Oil is extracted from the seeds of the P. pinnata. Seed oil is a thick, yellowish, or reddish-brown having calorific value of 40.756 MJ/kg. The oil is extracted through expeller and solvent extraction. The seeds of karanja contain at least 27–40% of oil. There are many factors affecting the quality of the oil (biodiesel) such as viscosity, flash point, calorific value, specific gravity, and acid value/free fatty acid content [93]. The free fatty acid content is very high in seed oil of karanja. Biodiesel produced through 2-step transesterification process. The Karanja oil also undergoes in 2-step processes in which acid-esterification done before alkali transesterification [94]. In some supercritical conditions, both the steps can be carried out simultaneously because of the shortage of time [95].
Microwave and CaO as a heterogeneous catalyst are used to enhance the transesterification process \cite{104}. The transesterification process addresses some issues like high viscosity, same as other vegetable oils. Therefore, the karanja oil is not suitable for direct use in a diesel engine. After addressing these issues by this process, the quality of karanja oil methyl ester (biodiesel) is produced that is also cost-effective. There is a various method for the production of biodiesel from the karanja oil such as pyrolysis, micro-emulsion, and bleeding \cite{96}. In recent years, Karanja oil is considered as a good commercial option over other mineral fuels. Mofijur et al. showed in his research that the use of various anti-oxidants in the karanja oil improves the oxidation stability, cost-analysis of biodiesel \cite{97}.

**CONCLUSION**

Nature has been a good source of medicinal plant since immemorial time. At present, many modern drugs have been isolated from the plant source. Karanja has been recognized as a medicinal plant in a traditional system for the treatment of various diseases of human beings. Many scientific studies have proved the pharmacological activities of the \textit{P. pinnata} such as anti-ulcer, anti-diarrheal, antiplasmodial, anti-inflammatory, anti-viral, anti-bacterial, anti-fungal, and many more. Apart from the multiple biological effects, seed oil obtained from this plant is proved to be biodiesel as per recent studies. Conclusively this plant herbal plant is proved to be a multipurpose tree with good economic value.

**AUTHORS' CONTRIBUTIONS**

We declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by the authors. Dr. Gitika Chaudhary drafted the article and contributed in writing Ayurvedic view of the article Dr. Hemlata Kaurav contributed in drafting and writing pharmacological portion of plant. Shifali Thakur contributed in data collection and writing the paper. No potential conflicts of interest were reported by the authors.

**CONFLICTS OF INTEREST**

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