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A Review of *Spondias pinnata* (L.f.) Kurz's Phytochemical Constituents, Traditional Uses, and Pharmacological Activities: An Important Medicinal Plant in Ayurveda

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Abstract

Spondias pinnata (L.f.) Kurz, commonly known as wild mango or hog plum, is a medicinal tree belonging to the family Anacardiaceae, extensively utilized in traditional systems and codified systems of medicines across the Indian subcontinent and Southeast Asia. Plant parts including roots, bark, leaves, fruits, and seeds are used for medicinal purposes to treat a variety of ailments. Phytochemical analysis has revealed that the presence of various bioactive compounds such as flavonoids, tannins, phenolic acids, saponins, and essential oils, which contribute to its pharmacological activities. Essential oil is rich in monoterpene and sesquiterpene compounds such as α-pinene, caryophyllene, and geraniol. Additionally, other phytoconstituents including β-sitosterol, gallic acid, caffeic acid, and alantolactone have been identified from different parts of the plant. Recent research highlights its antioxidant, anti-inflammatory, antimicrobial, and antidiabetic properties, further validating its traditional uses and suggesting potential for the development of novel therapeutic agents. This review provides a comprehensive overview of the phytochemical properties of S. pinnata, offering insights that may be valuable for future research and the establishment of effective natural drugs.

Keywords: *Anacardiaceae, Anti-diabetic, Essential oil, Traditional medicine, Traded medicinal plant, Wild mango.*

Introduction

Plants have long been a cornerstone of human civilization, fulfilling essential needs such as food, shelter, and medicine. Traditional medicine systems have incorporated plants for thousands of years, favouring natural drugs due to their efficacy and minimal side effects. One such plant, *Spondias pinnata* (L.f.) Kurz, commonly known as wild mango or hog plum, belongs to the family Anacardiaceae. Ayurveda and other traditional systems of medicine extensively use this important medicinal tree across the Indian subcontinent, Southeast Asia, and beyond. Botanically, *S. pinnata* is a deciduous tree that thrives in tropical and subtropical climates, found across India, Sri Lanka, Malaysia, the Philippines, and several other regions [1]. The tree adapts well to a wide range of environmental conditions, such as dry

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plains, humid forests, and coastal areas, demonstrating its versatility and resilience. One cannot overstate the significance of *S. pinnata* in traditional medicine. Diverse medicinal formulations utilize various parts of the plant, including its bark, leaves, fruits, and roots, to treat a wide array of ailments [2]. For instance, people use the bark, known for its astringent properties, to treat dysentery, diarrhoea, and ulcer, while they employ the leaves to alleviate inflammation and respiratory disorders. People consume the fruits not only as a food source, but also for their therapeutic benefits, particularly in treating digestive disorders. Concoctions of *S. pinnata* roots are often used to treat fever and other inflammatory conditions.

Phytochemical investigations on *S. pinnata* have revealed that the presence of a greater spectrum of bioactive compounds. These include flavonoids, tannins, phenolic acids, saponins, and terpenes, which contribute to the plant's pharmacological activities. Besides, phytochemical constituents such as β-sitosterol, gallic acid, caffeic acid, and alantolactone (ref) have been found, along with monoterpenes and sesquiterpene compound such as α-pinene, caryophyllene, and geraniol [3,4]. Various studies have documented its antioxidant, anti-inflammatory, antimicrobial, and antidiabetic properties linked to these compounds. Recent research has further expanded our understanding of *S. pinnata* medicinal potential, highlighting its role in modulating immune responses, protecting against oxidative stress, and inhibiting the growth of pathogenic microorganisms. Despite its widely used in traditional medicine and promising findings from phytochemical studies, *S. pinnata* remains underexplored in modern scientific research. A large number of plants, including *S. pinnata*, have yet to be fully examined for their medicinal properties, and they represent untapped sources of potentially active compounds that could lead to the development of new drugs. Therefore, there is a compelling need to review the available literature on the phytochemical constituents and pharmacological activities of *S. pinnata*. By addressing the gaps between its ethnomedicinal uses and the findings of modern scientific studies, this review aims to provide a comprehensive overview that could guide future research. Such an endeavour would be invaluable not only for phytochemists and pharmacologists but also for clinicians, toxicologists, and other researchers seeking to develop novel therapeutic agents derived from this versatile plant.

Spondias pinnata (L.f.) *Kurz* (Anacardiaceae)

Vernacular Names

Tamil - Kincam, Pulima; English - Wild Mango, Andaman mombin, Indian hog plum, Indian mombin; Hindi - Ambara, Ambari, Amra, Bhringi-phal, Metula, Pashu-haritaki, Pitan; Kananada - Ambabte, Amate, Poondi, Tindeeka; Manipuri - Heining; Nepal - Amaro; Telugu - Adavimamidi; Mallayalam Ampazham; Assamese - Aamrata; Tangkhul - Khursongthei.

Taxonomy

The genus *Spondias* L. comprises of about 18 species, widely distributed in Tropical and Subtropical regions of the Americas, Madagascar and Asia to South West Pacific [5-8]. Species of this genus are used as food, medicine and economic values; i.e. potential ornamental and wild relative of cultivated crop [6,7]. In India it is represented by single species *S. pinnata* growing in deciduous forests ascending up to 1650 masl. It is widely distributed in Indian Subcontinent to China and Malaysia [6].

Description

Deciduous, aromatic trees, up to 15 m tall. Branchlets glabrous; bark smooth, peeling

papery. Leaves alternate, imparipinnate, *c.* 30 cm long; leaflets 9 – 11, lateral leaflets oblong, 5 – 9.5 × 3 – 4 cm; terminal leaflets obovate, 9 – 10 × 4 – 6 cm, cuneate at base, entire at margins, abruptly acuminate to cuspidate at apex; glabrous, glaucous beneath; lateral nerves c. 20 pairs, penniparalal, intramarginal prominent; petiole *c.* 7 cm long; petiolule *c.* 4 mm long. Panicle in terminal axiles, *c.* 25 cm long; peduncle *c.* 7.5 cm long; pedicel *c.* 2 mm long. Flowers polygamodioecious, *c.* 4 mm across, pale pink. Calyx 5-lobbed; lobes free, ovate-triangular, *c.* 1.5 × 1 m. Petals 5, ovate, *c.* 2.5 × 1.8 mm, acute at apex, yellow-pink. Stamens 10, inserted below the crenate disc; filaments c. 2 mm long. Ovary conical, *c.* 3 × 2 mm; style 5-fid at apex, *c.* 2 mm long. Drupes oblong-obovoid, *c.* 1.5 × 1 cm (Figure 1).

Taxonomy (as per APG IV)

Kingdom	:	Plantae
Clade	:	Tracheophytes
Clade	:	Angiosperms
Clade	:	Eudicots
Clade	:	Rosids
Order	:	Sapindales
Family	:	Anacardiaceae
Subfamily	:	Spondiadoideae
Genus	:	*Spondias* L.
Species	:	*S. pinnata* (L.f.) Kurz

Figure 1. Plant Reference Picture of *Spondias pinnata*

Ethnopharmacology

S. pinnata is a highly valued medicinal plant that is widely used in traditional medicine across various cultures. Its ethnopharmacological applications are particularly notable in digestive, ocular, dermal, and musculoskeletal health [9]. In digestive care, people commonly use the powdered and dried leaves to treat gastroenteritis, diarrhea, and dysentery, and they also employ infusions made from the stem and bark for these ailments. Fresh leaves consumed with raw sugary candy help manage acid reflux, and leaf extracts treat other digestive disorders. India uses pulverized, ripened fruits as an antidote against poison arrows, while Bangladesh consumes the fruits to strengthen vision and prevent eye infections. Topically, people use fruit paste from *S. pinnata* to treat lesions, wounds, and sores. Applying the bark as a paste helps with sprains and rheumatism, while its decoction

treats gonorrhea. In regions like Belize and Nigeria, people apply fresh leaf decoctions for dermal afflictions, and concoctions from the leaves alleviate diarrhea and constipation [2]. People also use the bark as a rubefacient for sore joints and in root bark solutions to treat gonorrhea and regulate the menstrual cycle. The plant's anti-scorbutic properties further underscore its importance in traditional medicine.

Phytochemical Constituents

Spondias pinnata is a phytochemical powerhouse with a wide array of bioactive compounds, making it a valuable resource in traditional medicine and a potential candidate for developing new therapeutic agents. *S. pinnata* is a rich source of diverse phytochemicals, each contributing to the plant's therapeutic properties [10]. This species is known for its high energy content, providing 348 kcal per 100 grams, and is abundant in essential nutrients such as phenolic compounds, natural antioxidants, minerals, ascorbic acid, malic acid, calcium, and phosphorus. Flavonoids are among the most prominent phytochemicals in *S. pinnata*, particularly in the leaves, which are rich in quercetin, kaempferol, and rutin. These compounds are well-known for their antioxidant activity, which protects cells from oxidative stress and associated diseases such as cardiovascular disease and cancer. Quercetin changes the pathways that cause inflammation and stops lipid peroxidation; kaempferol kills microbes and cancer cells; and rutin makes blood vessels stronger and less fragile [11]. Tannins are also abundant in *S. pinnata*'s bark and leaves. These polyphenolic compounds, including ellagitannins and gallotannins, have strong astringent properties, making them effective in wound healing and as antimicrobial agents. Tannins can also help treat diarrhea and dysentery by reducing intestinal inflammation. Phenolic acids, such as gallic acid, ellagic acid, and caffeic acid, are crucial antioxidants found in the bark and fruit. Gallic acid exhibits anti-inflammatory, antimicrobial, and anticancer activities, while ellagic acid is known for its ability to inhibit cancer cell proliferation. Caffeic acid, commonly found in the leaves, also has antioxidant and anti-inflammatory properties, aiding in the prevention of chronic diseases. Essential oils extracted from the leaves, bark, and fruits of *S. pinnata* contain volatile compounds like limonene, α-pinene, and β-caryophyllene [9]. The antimicrobial, anti-inflammatory, and analgesic properties of these oils make them potential therapeutic agents for managing pain and inflammation [12]. Saponins, glycosidic compounds found in the roots, bark, and leaves, are known for their cholesterol-lowering effects, immunomodulatory properties, and anticancer activity. Due to their surfactant properties, saponins also enhance the immune system, promote cardiovascular health, and traditionally treat respiratory disorders. Carotenoids such as β-carotene, lutein, and zeaxanthin are pigments responsible for the orange and yellow coloration of *S. pinnata* fruits [13]. These compounds are vital for maintaining vision, immune function, and skin health. β-Carotene is a potent antioxidant that helps neutralize free radicals, while lutein and zeaxanthin protect the eyes from age-related macular degeneration. *S. pinnata* also has other bioactive compounds, such as steroids, alkaloids, saponins, triterpenoids, glycine, cysteine, serine, alanine, leucine, sitosterol, and β-amyrin. These bioactive compounds help it have a wide range of pharmacological effects, such as lowering blood sugar, relieving pain, killing bacteria, and killing cancer cells [14]. Natural antioxidants in the plant, such as vitamins E and C, bolster its capacity to combat oxidative stress, a factor associated with a range of chronic diseases like cancer, atherosclerosis, diabetes, and

neurodegenerative disorders like Alzheimer's and Parkinson's [13].

Traditional Uses in Ayurveda

Ayurveda reveres pinnata for its ability to balance the three doshas: Vata, Pitta, and Kapha. The classification of the plant as a cooling and astringent herb makes it useful in treating a variety of conditions. The following are some of the traditional uses of *S. pinnata* in Ayurvedic medicine. People commonly use the fruit and bark of *S. pinnata* to treat digestive ailments like diarrhea, dysentery, and indigestion [15]. The fruit serves as a digestive tonic to enhance appetite and digestion, while the astringent properties of the tannins tighten the intestinal lining and reduce inflammation. The bark and leaves of *S. pinnata* topically to treat skin conditions like eczema, psoriasis, and wounds. The phytochemicals in the plant have antimicrobial and anti-inflammatory properties that help reduce infection and promote wound healing [2]. People use *S. pinnata*'s leaves and bark to treat respiratory conditions like coughs, colds, and bronchitis. The plant's essential oils and saponins help to reduce inflammation and clear mucus from the respiratory tract. Because of the plant's anti-inflammatory properties, it is effective in treating rheumatic pain and arthritis. Decoctions often use the bark to relieve pain and inflammation in the joints. *S. pinnata*'s bark and leaves serve as an antipyretic and analgesic, reducing fever and alleviating pain. Flavonoids, essential oils, and saponins in the plant contribute to its ability to reduce inflammation and pain.

Pharmacological Activities

The rich phytochemical profile of *S. pinnata* endows it with a wide range of pharmacological activities, some of which are detailed below:

Anti-oxidant Activity

High in flavonoids, tannins, and phenolic acids, *S. pinnata* has strong antioxidant activity. These chemicals help neutralize free radicals and lower oxidative stress, which stops cells from getting damaged. Studies have demonstrated that *S. pinnata* has significant potential in preventing chronic diseases such as cancer, cardiovascular diseases, and neurodegenerative disorders. One interesting finding was that out of fifteen fruits that can be eaten in Nepal, *S. pinnata* had a better ability to fight free radicals (16% at 5 g/mL) than ascorbic acid (5%). Total phenolic content (TPC) strongly correlated with the antioxidant properties of its methanolic and aqueous extracts, with correlation coefficients (R) of 0.7189 and 0.7246, respectively. Researchers in a different study looked at the antioxidant power of methanolic extracts from *S. pinnata* fruit using ABTS+ free radical scavenging. The extracts showed strong inhibition at different concentrations, with an IC50 of 66.54 μg/mL and a TEAC of 0.78. The plant extract also had a lot of phenolic and flavonoid content, with 91.47 mg/mL of gallic acid equivalent and 350.5 mg/mL of quercetin equivalent. This showed that it was a strong antioxidant [11, 12, 16, 17].

Anti-inflammatory Activity

S. pinnata demonstrates significant anti-inflammatory properties, making it valuable in treating inflammation-related conditions. Its fruit peel essential oil (EOSP) works especially well because it stops the production of nitric oxide (NO), a key inflammatory mediator, in RAW 264.7 cell lines without affecting the cells' ability to live or grow. Compounds like tannins, flavonoids, and essential oils, which also inhibit pro-inflammatory enzymes like COX-2, are responsible for this effect. Various studies have validated the plant's effectiveness in reducing inflammation, supporting its traditional medicinal uses [12, 18].

Antimicrobial Activity

S. pinnata has strong antimicrobial activity, especially through its methyl alcohol extracts, which are very good at killing E. coli, Salmonella typhi, and Vibrio cholerae bacteria. The aqueous extracts show moderate activity against the same bacteria. Additionally, the plant's resin exudates are effective against B. subtilis but less so against Gram-negative bacteria and S. cerevisiae. Extracts of *S. pinnata* roots in ethyl alcohol and chloroform are also very good at killing bacteria, especially Salmonella typhi and Vibrio cholerae [12, 17].

Antidiabetic Activity

Research on *S. pinnata* has demonstrated its significant antidiabetic properties. A 400 mg/kg methanolic extract of *S. pinnata* lowered blood sugar levels in Wistar rats that did not have diabetes after four days, just like the drug glibenclamide. Within 4 hours, the aqueous extract at the same dosage also showed a significant reduction in glucose levels. However, the trichloromethane extract had no notable effect. In glucose tolerance tests, both aqueous and methanolic extracts significantly lowered blood sugar levels within an hour, while the chloroform extract showed no impact. Additionally, in diabetic models, the methanolic extract controlled glucose levels by 53.88%, supporting the traditional use of *S. pinnata* for blood sugar regulation. The flavonoids in the plant probably have this effect because they make insulin work better, speed up the metabolism of glucose, and protect pancreatic β-cells from oxidative stress [9, 10, 19].

Anticancer Activity

Recent studies have highlighted *S. pinnata* significant anticancer potential, particularly its trunk, which exhibits notable anticarcinogenic effects. A 70% methanolic extract of *S. pinnata* bark was tested for its ability to combat cancer in human lung (A549) and breast (MCF-7) cancer cell lines. The extract was found to induce apoptosis in these cancerous cells, with IC50 values of 147.84 ± 3.74µg/mL for A549 cells and 149.34 ± 13.30µg/mL for MCF-7 cells. The extract, on the other hand, had a very low IC50 value of 932.38 ± 84.44 µg/mL for normal human lung fibroblast cells (WI-38). Flow cytometry and confocal microscopy both showed that the methanolic extract of *S. pinnata* bark was able to cause apoptosis in both types of cancer cells. Through immunoblotting, it was also found that the extract raised the Bax/Bcl-2 ratio. This activated the caspase cascade and caused the degradation of the PARP complex, which is important for DNA repair in cancer cells. *S. pinnata*'s phenolic acids, flavonoids, and saponins, which exhibit cytotoxic effects against various cancer cell lines by inducing apoptosis, inhibiting cell proliferation, and preventing metastasis, are responsible for its anticancer activity. This study underscores the need for further research to develop *S. pinnata* as a potential pharmaceutical anticancer agent [18, 20, 21].

Future Perspectives

Ayurveda has well-established *S. pinnata*, but further research is necessary to fully explore its therapeutic potential (Figure 2). Key areas for future study include the isolation and characterization of novel bioactive compounds using advanced techniques like HPLC, MS, and NMR spectroscopy. Understanding the molecular mechanisms underlying the plant's pharmacological effects, such as its antioxidant, anti-inflammatory, and anticancer properties, is crucial. Additionally need to explore the genomic resources of *S. pinnata*, and its transcriptome profiling. Also, *S. pinnata* extracts need to be tested in clinical trials to make sure they are safe and effective in cell lines or zebrafish models, as well as to find out the right doses and any possible side effects. Standardized formulations should also be developed to ensure consistency, optimize

extraction methods, and improve the bioavailability and stability of active compounds.

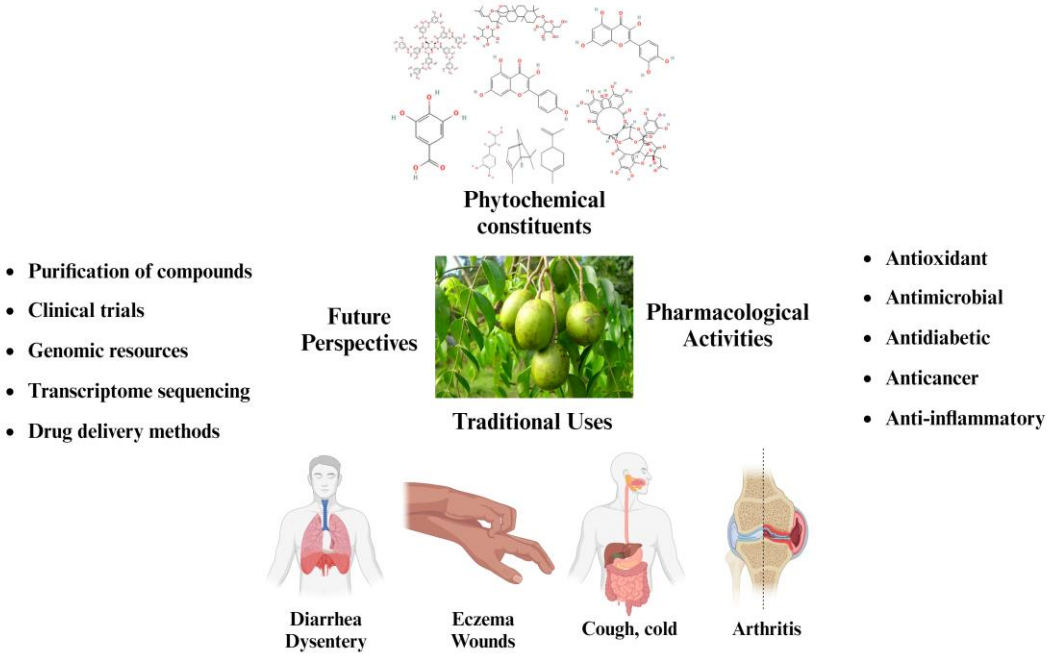

Figure 2. Applications and Significance of *Spondias pinnata*

Conclusion

S. pinnata is a valuable medicinal plant in Ayurveda, with a rich phytochemical profile that underpins its wide range of pharmacological activities. This plant's bioactive compounds offer promising avenues for the development of new therapeutic agents. As research progresses, *S. pinnata* could play a crucial role in modern medicine, bridging the gap between traditional knowledge and contemporary scientific validation. By combining traditional Ayurvedic practices with modern scientific research, we can unlock *S. pinnata*'s full potential and harness its benefits for human health.

Conflict of Interest

None.

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Credit Authorship Contribution Statement

Raju Balaji, Nitheesh S and Krishnamoorthy Devanathan: Conceptualization, Writing-original draft, Writing- review and editing.

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