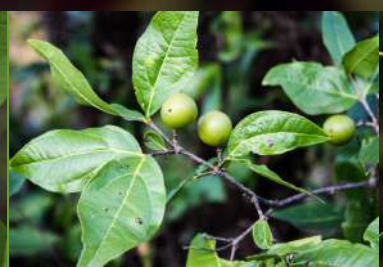
TECHNICAL DATABASE

A Compendium of Lesser Known Forest Plants: Insights and Opportunities






ICFRE-Forest Research Institute, Dehradun
(Indian Council of Forestry Research & Education, Dehradun)
P.O.: New Forest, Dehradun-248006,
(Uttarakhand), India

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Lesser Known Forest Plants: Insights and Opportunities

ICFRE-Forest Research Institute, Dehradun
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P.O.: New Forest, Dehradun-248006
(Uttarakhand), India

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Citation

ICFRE-FRI (2025): A Compendium of Lesser Known Forest Plants: Insights and Opportunities,
ICFRE- Forest Research Institute, Dehradun

Published by

ICFRE- Forest Research Institute, Dehradun
(Indian Council of Forestry Research & Education)
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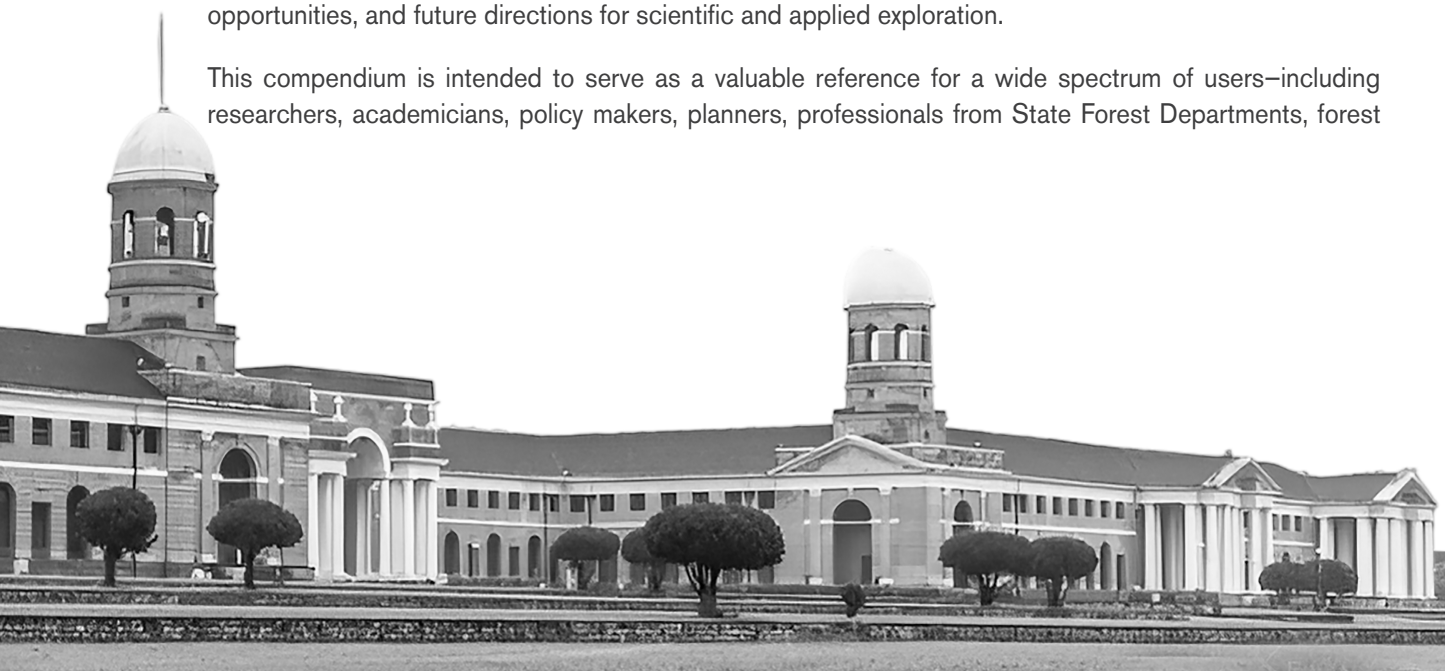
Preface

India's forests, with their vast and varied flora, are home to an extraordinary number of plant species–many of which remain lesser known, under-researched, and underutilized. Yet these species hold untapped promise for their pharmacological, nutritional, aromatic, ecological, and industrial potential. Recognizing the need to explore and document such valuable forest resources, the Indian Council of Forestry Research and Education (ICFRE) launched the All India Coordinated Research Project titled *"Bioprospecting for Industrial Utilization of Lesser Known Forest Plants."* This compendium is one of the key outputs of that national-level initiative. Financial support from the National Authority CAMPA, Ministry of Environment, Forests & Climate Change, Government of India, to the ICFRE, Dehradun for this project under the scheme *"Strengthening Forestry Research for Ecological Sustainability and Productivity Enhancement"* is gratefully acknowledged.

We, as editors of this compendium, feel privileged to present *"Lesser Known Forest Plants: Insights and Opportunities,"* a consolidated scientific account of 50 lesser known forest plant species investigated under the project. Each chapter in this compendium is the outcome of extensive efforts undertaken by dedicated scientists across multiple ICFRE institutes, involving the compilation, analysis, and synthesis of information drawn from both online and offline resources. The Forest Research Institute (FRI), Dehradun served as the nodal institute and led this initiative in coordination with seven participating institutes and one centre–Arid Forest Research Institute (AFRI), Jodhpur; Himalayan Forest Research Institute (HFRI), Shimla; Institute of Forest Biodiversity (IFB), Hyderabad; Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore; Institute of Forest Productivity (IFP), Ranchi; Rain Forest Research Institute (RFRI), Jorhat; Tropical Forest Research Institute (TFRI), Jabalpur; and Forest Research Centre for Eco-Rehabilitation (FRCER), Prayagraj.

The chapters are structured to present a comprehensive profile of each species, encompassing nomenclature, taxonomy, botanical characteristics, geographical distribution, ethnobotanical uses, phytochemical composition, biological activities, and industrial relevance. Importantly, each chapter concludes with a dedicated section on *Scope of Further Research and Development,* highlighting existing gaps, emerging opportunities, and future directions for scientific and applied exploration.

This compendium is intended to serve as a valuable reference for a wide spectrum of users–including researchers, academicians, policy makers, planners, professionals from State Forest Departments, forest



managers, industry professionals, and students–who seek to understand and utilize India's lesser known forest plant diversity in a sustainable and innovative manner. It is also envisioned as a step toward encouraging value addition, rural livelihood enhancement, and bioresource-based enterprise development.

We gratefully acknowledge the visionary leadership and continued encouragement of Smt. Kanchan Devi, Director General, Indian Council of Forestry Research and Education, which greatly inspired and guided the development of this publication. We also sincerely acknowledge the consistent support and institutional facilitation provided by Dr. Renu Singh, Director, Forest Research Institute, Dehradun, during the preparation of this compendium. We also extend our gratitude to all contributing scientists and research staff for their dedicated efforts in compiling and presenting their findings with scientific rigor and clarity.

It is our hope that this compendium will not only serve as a foundation for future research and innovation, but also inspire a renewed focus on the immense, often underrecognized, value of India's forest flora.

Editors

Dr. K. Murali
Dr. V.K. Varshney
Dr. Y.C. Tripathi

Acknowledgement

This compendium has been developed under the All India Coordinated Research Project titled *"Bioprospecting for Industrial Utilization of Lesser Known Forest Plants"*, initiated by the Indian Council of Forestry Research and Education (ICFRE), Dehradun. The project received financial assistance from the National Authority CAMPA, Ministry of Environment, Forests & Climate Change, Government of India, under the scheme *"Strengthening Forestry Research for Ecological Sustainability and Productivity Enhancement."* The generous support of the funding agency is gratefully acknowledged.

We express our sincere gratitude to Smt. Kanchan Devi, Director General, ICFRE, for her visionary leadership, continued encouragement, and strategic direction that were crucial in conceptualizing and steering this initiative toward successful completion.

We extend our heartfelt thanks to Dr. Renu Singh, Director, Forest Research Institute (FRI), Dehradun, for her consistent support, insightful guidance, and institutional facilitation throughout the project and publication process.

We gratefully acknowledge the Directors of all participating ICFRE institutes and centre- Arid Forest Research Institute (AFRI), Jodhpur; Himalayan Forest Research Institute (HFRI), Shimla; Institute of Forest Biodiversity (IFB), Hyderabad; Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore; Institute of Forest Productivity (IFP), Ranchi; Rain Forest Research Institute (RFRI), Jorhat; Tropical Forest Research Institute (TFRI), Jabalpur; and Forest Research Centre for Eco-Rehabilitation (FRCER), Prayagraj for their administrative support, facilitation, and encouragement, that enabled the effective implementation of the project at their respective institutions.

We thankfully acknowledge the valuable guidance, administrative facilitation, and timely support provided by the Deputy Director General (Research), Deputy Director General (Extension), Assistant Director General (Research and Planning), and Assistant Director General (Media and Publication) of the ICFRE at various stages of the project and in bringing this compendium to publication.

Our sincere appreciation goes to all Principal Investigators, Co-investigators, and their research teams from the participating ICFRE institutes and centre. Their tireless efforts in data collection, analysis, and synthesis, along with their commitment, have shaped the quality and comprehensiveness of this compendium.

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Contents

Executive Summary

This compendium, *"Lesser Known Forest Plants: Insights and Opportunities,"* presents a consolidated scientific exploration of fifty lesser known forest plant species from across India's diverse ecological landscapes. These species, often overlooked in mainstream research and forestry practices, possess unique biological, pharmacological, aromatic, nutritional, and industrial attributes with significant potential for sustainable utilization.

Each chapter offers a detailed scientific profile of a selected species, encompassing taxonomy, botanical description, ecological distribution, traditional uses, phytochemical properties, biological activities, and commercial relevance. Additionally, a dedicated section in each profile outlines avenues for future research and development, enabling targeted scientific inquiry and innovation.

The compendium is the result of collaborative efforts among scientists across multiple ICFRE institutes, integrating traditional knowledge and contemporary scientific analysis. It serves as a comprehensive resource aimed at promoting evidence-based conservation strategies, fostering value-added utilization of forest plant diversity, and supporting initiatives for rural development and bio-economy growth.

Intended for researchers, forest professionals, policy makers, entrepreneurs, students, and all those who are engaged in biodiversity-based innovation and sustainable resource management, this compendium aspires to stimulate greater scientific interest and practical engagement with India's lesser known forest resources. By illuminating the potential of these underutilized species, the compendium contributes meaningfully to national goals of biodiversity conservation, sustainable development, and the advancement of green industry.

Introduction

Forests in India represent a vast reservoir of biological diversity, encompassing a wide range of species that contribute to ecological stability, cultural practices, and economic development. Among these, a significant number of plant species remain lesser known–either under-documented, underutilized, or unrecognized for their full potential. These Lesser Known Forest Plants (LKFPs), although not prominent in mainstream forestry or agriculture, often possess unique biochemical and industrial properties, making them worthy of systematic exploration.

Recognizing the need to identify and explore such forest-based bioresources, the Indian Council of Forestry Research and Education (ICFRE), Dehradun, initiated the All India Coordinated Research Project titled *"Bioprospecting for Industrial Utilization of Lesser Known Forest Plants."* With financial support from the National Authority CAMPA, Ministry of Environment, Forest and Climate Change, Government of India, the project was aimed to assess 50 such LKFPs across ecological zones for their scientific and bioeconomic potential. The Forest Research Institute (FRI), Dehradun served as the nodal institute for the project, coordinating with seven ICFRE institutes and one regional centre across diverse forest regions of the country to carry out this multi-institutional effort.

As part of the project's initial phase, the selection of the 50 LKFPs was guided by traditional knowledge and key recommendations of the *National Workshop on 'Conservation and Sustainable Utilisation of Lesser-Known Tree Species'* organized by ICFRE in Dehradun from March 8 to 10, 2004. These priorities shaped the direction of collaborative efforts across the participating institutes and led to the generation of structured, evidence-based content presented in this compendium.

This compendium presents detailed monographs of the 50 selected LKFPs, compiled through rigorous data collection from both online and offline sources. Each LKFP species is documented covering taxonomy, morphology, distribution, ethnomedicinal uses, phytochemical properties, biological activities, and commercial

relevance. A dedicated section on "Scope of Further Research and Development" concludes each chapter to guide future inquiry and innovation.

This compendium seeks to serve not only as a scientific reference but also as a strategic tool for researchers, academicians, policy makers, planners, professionals from State Forest Departments, forest managers, industry professionals, and students to engage more deeply with India's forest plant diversity–particularly those plants that have remained on the periphery of mainstream attention. In doing so, it contributes to the broader national agenda of mainstreaming lesser known forest plants into the frameworks of sustainable development, biodiversity conservation, and green economy.

By presenting scientifically validated knowledge in a unified format, the compendium seeks to catalyze targeted research, promote value addition, and support evidence-based decision-making across forestry and allied sectors.

Adenanthera pavonina L.

Synonyms:
Adenanthera gersenii Scheff., *Adenanthera polita* Miq., *Corallaria parvifolia* Rumph., *Adenanthera pavonina* var. *pavonina*

Local/Common/Popular Name(s):
Red Bead Tree.

Vernacular Names:
Hindi: Raktchandan, ***Bengali:*** Raktkambal, ***Odisha:*** Mainda Kaincha, ***Kannada:*** Manjuti, Chenna kai, Manjatti kai, ***Tamil:*** Aanaikkundumani, ***Telugu:*** Gurivenda, Bandigurivenda, ***English:*** Red Sandalwood tree, Peacock Flower fence, Bead tree, Coral tree, Redwood, Red-bread tree, Carolina tree, Pigeon's eye, and Dragon's eye.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Fabales
Family	:	Fabaceae
Genus	:	*Adenanthera*
Species	:	*Adenanthera pavonina*

Botanical Description: *A. pavonina* is a deciduous tree with pale pinkish-grey bark and is usually erect with a height ranging from 18-24 m and diameter up to 60 cm. (Pandhare and Sangameswaran, 2012; Mujahid et al., 2013). The tree is known to grow rapidly and has a smooth bark with many fissures (Rodrigues et al., 2009; Ara et al., 2010a; Dash et al., 2010; George et al., 2017). The leaves of the tree are bipinnate with lengths ranging from 30-60 cm and possess numerous oblong leaflets with measurements of 2-5 cm x 0.7-2.5 cm. The leaflets are rounded at both ends and have a pointed apex with the leaf axis channeled on the upper surface. The flowers have a corolla of length approximately 4 mm. The fruit is a pod with measurements of 22cm x 1.6 cm and contains hard seeds (George et al., 2017). The tree produces a large number of red-colored seeds with the average weight of a single seed being 0.27 g. (Olajide et al., 2004; Soomro and Sherazi, 2012). The flowering and fruiting in trees occur from March-October every year (Pullaiah, 2015).

Distribution: *A. pavonina* is a species native to tropical Asia. It was first reported to appear in India and is well-suited to grow in a variety of soils in humid and seasonally humid tropical climates (Olajide et al., 2004). It is found in India, Malaysia, Western and Eastern Africa, and Southern China (Roshetko and Gutteridge, 1996). In India, it is found in the eastern Sub-Himalayan tract, in South India along the Western Ghats, and in the Andaman Islands (Olajide et al., 2004).

Habitat: *A. pavonina* grows well in tropical regions where mean annual rainfall ranges from 3000 mm to 5000 mm and the mean annual temperature is around 25-30°C, where the mean maximum of the hottest month ranges from 28-35°C and the mean minimum of the coolest month ranges from 14-22°C. The plant is suited to grow in a variety of soil conditions varying from deep, well-drained soils to shallow and rocky soils having neutral to slightly acidic pH. *A. pavonina* is mostly propagated through seeds but has a slow germination rate due to the presence of a hard seed coat.

Ethnobotanical Significance: *A. pavonina* is reported to have numerous traditional uses in treatment of asthma, diarrhea, gout, inflammations, rheumatism, tumor, and ulcers (Watt & Breyer-Brandwijk, 1962; Kirtikar & Basu, 1981; Burkil, 1994; Duke's, 2009). In the Siddha system of medicine, *A. pavonina* seeds are

identified as Anaikundrumani/Anaikundumani and are used in the treatment of various ailments like cholera (Visoochi), swellings (Veekam), abscesses (Thadippu) and arthritis (Vayvu) and general paralysis (Vatham). It is reported that seed decoction has been used in treatment of pulmonary affections and is applied externally in chronic ophthalmia (Muduliar, 1988). It is also reported that the seeds are ground with honey and applied to abscesses to hasten suppuration and are also used to treat prickly heat (Geronço et al., 2020). The seed emulsion acts as a cooling agent for headaches (Gennaro et al., 1972). The seeds are threaded together to create ornaments and are also used as a measure of weight since they show a near-constant weight of 0.26g each (4 grains=1g) (Orwa et al., 2009).The leaves or bark decoction is used as a cure for chronic rheumatism, gout, hemorrhages from bowels, sprains, and snake bites. *A. pavonina* bark and leaves are used in Indian folk medicine as astringent, anthelmintic, and aphrodisiac (Warrier, 2003). The bark is also reportedly used for washing hair and clothes (Warrier, 2003) as well as for treatment of leprosy. The roots are also used as emetic and purgative (Basu and Chakraverty, 1986). The red heartwood is used as a substitute to red sandalwood (*Pterocarpus santalinus*) (Gennaro et al., 1972) and the powdered wood is used as an antiseptic (Smith, 1985).

Phytochemistry:

Seeds: O-acetylethanolamine (Hayman and Gray, 1987; Pandhare et al., 2017), myristic acid arachidic ester, stearic acid stearyl ester, nonadecanic acid stearyl ester, arachidic acid oleoyl ester, henicosanoic acid stearyl ester, arachidic acid arachidic ester, henicosanoic acid arachidic ester, arachidic acid behenyl ester, behenic acidbehenyl ester, heptacosanyl stearyl ester, behenic acid lignoceryl ester, lignoceryl acid lignoceryl ester (Soomro and Sherazi, 2012), galactomannan (Macêdo et al., 2013), γ-methylene glutamic acid, γ-methylene glutamine, and traces of γ-ethylidene glutamic acid, 3,5,7,3',4'-pentahydroxy flavone-3'-O-α- L-rhamnopyranosyl-(1→4)-O-a-L-arabinopyranosyl-1→3)-O-β-D-xylopyranoside, 2,4,7-trihydroxyisoflavone, isovitexin (Yadava and Vishwakarma, 2013) lignoceric acid, linoleic acid, oleic acid (Huml et al., 2020) stigmasterol, stigmasterol glucoside, β-sitosterol glucoside (Nigam et al., 1973), β-sitosterol, α-spinasterol glucoside (Misba et al., 1975), 2, 4-dihydroxybenzoic acid (Gennaro et al., 1972)

Root: Oleanolic acid (Yadav et al., 1976) echinocystic acid (Chandra et al., 1982)

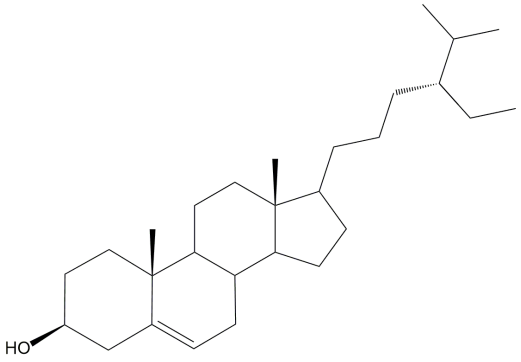
Stem: Aridanin, 3-[(2-acetamido-2-deoxy-β-D-glucopyranosyl)-oxy)-16α-hydroxyolean-12-en-28-oic acid, isoliquiritigenin, sucrose, pinitol (Su et al., 2007), isovitixin (Yadava and Vishwakarma, 2013), dulcitol (Misba et al., 1975),

Bark: Methyl oleanolate, methyl echinocystate (Yadav et al., 1976), robinetin, chalcone, butein, ampelopsin (dihydromyricetin), and dihydrorobinetin (Gennaro et al., 1972), ethyl 3,3-dimethyl-13-hydroxytridecanoate, stigmasta-5,22-dien-3β-ol, t-butyltridecanoate, 6-α-hydroxy stigmast-20(21)-en-3-one, 18-(2′, 3′- dihydroxyphenyl) nonadec-17-en-2-ol , 1-(N-propyl amino)-2-henecosanone, stigmast–5(6), 20(21)-diene-3- one (Ara et al., 2019), stigmasterol glucoside (Yadav et al., 1976), oleanolic acid, echinocystic acid (Chandra et al., 1982), 3-[(2'-acetamido-2'-deoxy- β-D-glucopyranosyl)oxy]-olean-12-en-28-oic acid, 3-[(2'-acetamido-2'-deoxy-β-D-glucopyranosyl)oxy]-16-α-hydroxyolean-12- en-28-oic acid, 3-O-β-D-glucopyranosyl-21-methylcarboxy-olean-12-en-28-oic-acid, 3-O-β-D-glucopyranosyl-21-methyl carboxy-olean-18-en-28-oic acid, 2-hydroxy-1,2-diphenyl ethenone, 7-methoxycatechin, 3-O-β-D-glucopyranosyl-7-O-methyl catechin (Ara et al., 2020), 3- ethynyl, 5(2, 3-dehydropyrrole) pyridine (Abdu and Adamu, 2020), chalcone (Gennaro et al., 1972)

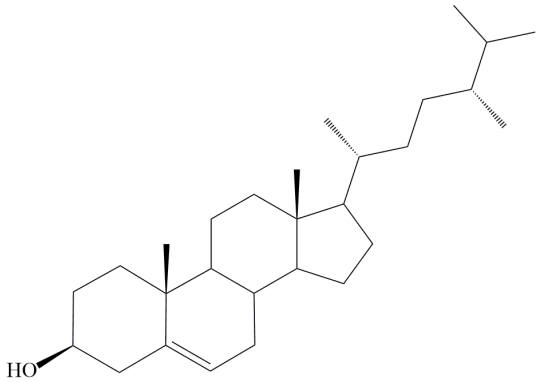
Leaves: Quercetin 3-O-α-dirhamnopyranosyl-(1‴→2″,1‴→6″)-β-glucopyranoside-4′-methoxy, kaempferol-3-O-α-dirhamnopyranosyl-(1‴→2″,1‴→6″)-β-glucopyranoside, isovitexin, quercetin-3-orhamnopyranosyl(1‴→4″)-β-glucopyranoside,quercetin-3-O-β-glucopranoside-4′-O-rhamnopyranoside, kaempferol-3-O-α-rhamnopyranosyl(1‴→2″)-β-glucopyranoside, quercetin-3-orhamnopyranosyl (1‴→2″)-β-glucopyranoside, quercetin-3-O-β-glucopyranoside, kaempferol, and quercetin (Mohammed et al., 2014), squalene, n- hentriacontane, phytol, 2,2-diethoxy ethanamine, methyl hexadecanoate, methyl 9,12,15- octa decatrienoate, methyl icosanoate, methyl-9- octadecenoate, methyl 9,12-octadecadienoate, stigmasterol, β-sitosterol, campesterol, cholesterol 22 -hydroxyhopan-3-one, 24-methylene cycloartenol, betulinic acid (Zeid et al.,2012), octacosanol, dulcitol (Mayuren and Ilavarasan, 2009; Moniruzzaman et al., 2015). n-tricosanol, α-D-glucopyranosyl- (2→1')-α-D-glucopyranosyl-(6'→2' 2)-α-D-glucopyranosyl-(6"→1' 2 →2)-α-D-glucopyranoside, hexatetracontan-1-ol and n-octanyl-1β-D-glucopyranosyl-(6"→ 1')-β-D-

glucopyranoside (Mujahid et al., 2016), stigmasterol glucoside, β-sitosterol glucoside, dulcitol, octacosanol (Nigam et al., 1973) aridanin-[(2-acetamido-2-deoxy-β-D-glucopyranosyl)-oxy)-16α-hydroxyolean-12-en-28-oicacid, isoliquiritigenin, sucrose, pinitol (Su et al., 2007), ethyl palmitate quebrachitol, nonacosane, hentriacontane (Mesbah et al., 2002), n-tricosanol (Mujahid et al., 2016)

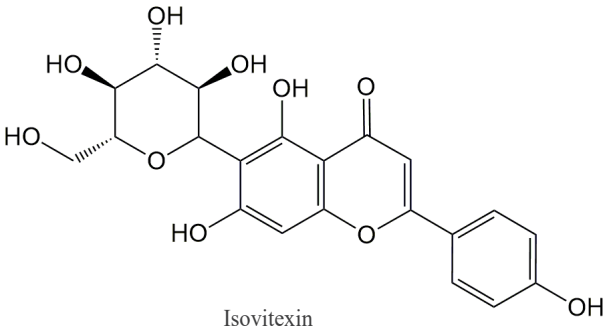
Fruit: Quercetin 3-O-α-dirhamnopyranosyl-(1‴→2″,1‴→6″)-β-glucopyranoside-4′-methoxy, kaempferol-3-O-α-dirhamnopyranosyl-(1‴→2″,1‴→6″)-β-glucopyranoside, isovitexin, quercetin-3-orhamnopyranosyl(1‴→4″)-β-glucopyranoside, quercetin-3-O-β-glucopranoside-4′-O-rhamnopyranoside, kaempferol-3-O-α-rhamnopyranosyl(1‴→2″)-β-glucopyranoside, quercetin-3-orhamnopyranosyl (1‴→2″)-β-glucopyranoside,quercetin-3-O-β-glucopyranoside, kaempferol, and quercetin (Mohammed et al., 2014), squalene, n- hentriacontane, phytol, 2,2-diethoxy ethanamine, methylhexadecanoate, methyl 9,12,15- octadecatrienoate, methyleicosanoate, methyl-9- octadecenoate, methyl 9,12-octadecadienoate, stigmasterol, β-sitosterol, campesterol, cholesterol 22 -hydroxyhopan-3-one, 24-methylene cycloartenol, betulinic acid (Zeid et al.,2012), octacosanol, dulcitol (Mayuren and Ilavarasan, 2009; Moniruzzaman et al., 2015).



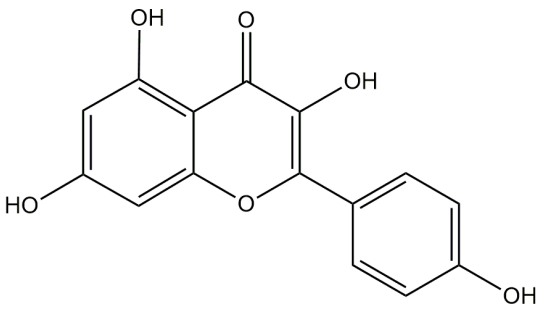
β-Sitosterol



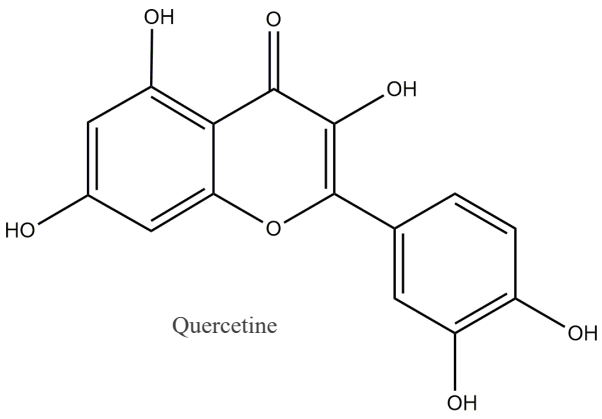
Campesterol



Isovitexin



Kaempferol



Quercetine

Structures of Important and Characteristic Chemical Constituents of *Adenanthera pavonina*

Biological Activity:

Anti-diarrheal activity: The aqueous extract of seeds of *A. pavonina* (50, 100, and 200 mg/kg) has been tested for antidiarrheal test in animal trials along with the standard drug loperamide. Castor oil and magnesium sulfate were used to induce diarrhea. The extracts showed good results and reduced the number of diarrheal feces as well as the total weight of feces in a dose-dependent manner (Pandhare et al., 2017).

Antimalarial activity: Methanol seed extract of *A. pavonina* (100, 200, 400, 600, and 800 mg/kg) was tested on mice infected with *Plasmodium berghei* along with chloroquine as the reference drug. The results revealed that the percentage of parasitemia decreased in a dose-dependent manner i.e. crude extract at a dose of 800mg/kg exerted an antimalarial effect (92.11%) greater than that of the chloroquine (88.73%) (Adedapo et al., 2014).

Anti-inflammatory activity: Methanol extract of the seeds of *A. pavonina* (50, 100, and 200 mg/kg) have been tested against carrageenan-induced rat paw edema, acetic-acid-induced vascular permeability in mice, carrageenan-induced pleurisy in rats, acetic-acid induced writhing in mice, and formalin-induced paw licking in mice. Indomethacin was used as a standard drug. All doses showed statistically significant inhibition of the carrageenan-induced paw edema in the rat. The extract also produced a significant reduction in licking time in both the early and late phases of the formalin-induced paw licking in mice, in a dose-dependent manner (Olajide et al., 2004). The ethanolic extract of *A. pavonina* leaves was also evaluated for their anti-inflammatory effects in Wistar rats at doses of 250 and 500 mg/kg in carrageenan-induced hind paw edema tests. The chronic inflammation was measured using the cotton pellet-induced granuloma formation assay and the results revealed significant anti-inflammatory activity by extracts (Mayuren and Ilavarasan, 2009). The extracts of *A. pavonina* leaves were prepared with different solvents in the carrageenan-induced rat hind paw edema model and analyzed for anti-inflammatory activity. This anti-inflammatory activity of the leaves might be due to the presence of active constituents such as β-sitosterol and stigmasterol. The methanolic leaves extract of the leaves were studied using the formalin-induced rat paw edema model for acute inflammation (200 and 400 mg/kg body weight) and cotton pellet granuloma model for chronic inflammation (400 mg/kg body weight) (Jayakumari et al., 2012) and it was reported to exhibit significant anti-inflammatory activity. In another study, bark extract of *A. pavonina* (using petroleum ether, dichloromethane, ethyl acetate, and methanol) was evaluated for the anti-inflammatory effect using the carrageenan-induced rat hind paw edema model. The extracts were given orally at doses of 200 and 400 mg/kg, and diclofenac sodium was the standard drug. The results exhibited that the fractions showed significant anti-inflammatory effects in a dose-dependent method (Hayman and Gray, 1987; Pandhare et al.,2017). The anti-inflammatory activity of the seed extract of *A.pavonina* on lipopolysaccharide-stimulated rat peritoneal macrophages was also analyzed to determine the mechanism of action for anti-inflammatory activity (Koodalingam et al., 2015). It is reported that *A. pavonina* seeds have O-acetyl ethanolamine which acts as an active anti-inflammatory agent (Hayman and Gray, 1987; Pandhare et al.,2017).

Anti-nociceptive activity: The ameliorative effect of aqueous extract of *A. pavonina* seeds in attenuating neuropathic pain in streptozotocin-induced diabetic rats during twelve weeks of treatment was assessed where the doses were given orally (50, 100, or 200 mg/kg) per day along with pregabalin as a standard drug. The study revealed that extract increased tail-flick latency significantly in diabetic rats but did not produce any significant effect on motor coordination, and spontaneous motor activity of rats. The extract also decreased superoxide anion and total calcium levels in a dose-dependent manner and also reduced histopathological variations in the sciatic nerve. The results concluded that *A. pavonina* seed extract may attenuate the development of diabetic neuropathy in diabetic rats when compared with pregabalin and therefore be effective in the prevention of the progression of diabetic nephropathy (Pandhare et al. 2012a). In another study, the ethanol extract of leaves of *A. pavonina* at doses of 50, 100, and 200 mg/kg b.w. (p.o.) was evaluated to test the antinociceptive activity using different nociceptive models in mice, including thermal tests (hot plate and tail immersion), acetic acid-induced writhing, and glutamate and formalin-induced licking protocols. The analysis confirmed that the extract triggered the reduction of nociceptive responses in a dose-dependent manner. A significantly increased latency time was also witnessed in both thermal tests and a reduction in the number of abdominal constrictions induced by acetic acid in all tested doses, evidencing the inhibition of acetic acid-induced visceral

nociception and glutamate and formalin-induced nociception (Moniruzzaman et al. 2015).

Anti-cancer activity: The ethanolic fruit extract of *A. pavonina* was reported to exhibit an absence of cytotoxicity against the HeLa cell line (Sowemimo et al., 2009). The cytotoxic potential of the ethanolic extract of *A. pavonina* seeds (50 µg/mL) in cancer cell lines was assessed and a low inhibition of cell proliferation against human cancer cells was observed after 72 h along with colon HCT-8, glioblastoma SF-295, melanoma MDA/MB-435, and leukemia HL-60 cells (Ferreira et al., 2011). The ethanolic leaf extract showed significant cytotoxic activity against human hepatoma HepG2 cells (IC50 = 2.50 µg) compared to cisplatin (IC50 > 10 µg) (Mohammed et al.,2014). *A. pavonina* leaf extracts (chloroform, ethylacetate, acetone, methanol, and ethanol) have been tested for the antiproliferative effect the in four cancer cell lines (HCT116, NCIH460, U251, and MCF7) by sulphorhodamine B (SRB) assay with camptothecin used as a positive control. All the extracts demonstrated significant growth inhibition against MCF 7 cancer cell line. However, the chloroform extract exhibited strong growth inhibition while the ethanol extracts exhibited significantly lower growth inhibition against all the cancer cell lines (Sophy et al., 2016). A decoction prepared using the bark of *A. pavonina* and *Thespesia populnea* in equal proportion demonstrated antiproliferative activity and induced apoptosis in the Hep-2 cancer cells after 24 hours of treatment (Lindamulage and Soysa, 2016). The *A. pavonina* seed powder treated enzymatically with amylase, cellulase, and protease was assessed for antiproliferative activity against cancer cells. The enzymatic treatment of *A. pavonina* seed powder with protease and cellulase showed improved anti-proliferative activity against the prostate (PC-3) and kidney (786-0) tumor cell lines (Araujo et al., 2019).

Hepatoprotective activity: The methanolic extract of leaves of *A. pavonina* has been analyzed for hepatoprotective effect on isoniazid and rifampicin-induced liver damage in rats. The extract at a dose of 100 or 200 mg/kg along with silymarin as a reference drug was administered orally once daily for 28 days. After treatment, the serum enzymatic activities of glutamic oxalic acetic transaminase, glutamate pyruvate transaminase, alkaline phosphatase, bilirubin, and lactate dehydrogenase were reestablished to almost normal levels in a dose-dependent manner. A rise in the levels of total protein and albumin towards normal levels was also observed and the hepatic antioxidant function was also restored by a substantial increase in the levels of glutathione, catalase, and superoxide dismutase (Mujahid et al. 2013).

Anti-microbial activity: The antimicrobial activity of oil extracted from seeds of *A. pavonina* was analyzed and showed weak activity against *Bacillus anthracis, Salmonella paratyphi*, and *Bacillus mycoides*. (Chourasia and Rao, 2005). The antimicrobial activity of *A. pavonina* bark extracts (petroleum ether, dichloromethane, ethylacetate and methanol) was evaluated at different concentrations (100, 200, and 400 µg/disc) against 13 test bacteria *viz*. five Gram-positive (*Bacillus megaterium, Bacillus subtilis, Staphylococcus aureus, Sarcina lutea, Bacillus sereus*), eight Gram-negative (*Escherichia coli, Pseudomonas aureus, Salmonella paratyphi, Salmonella typhi, Shigella dysenteriae, Shigella boydii, Vibrio mimicus, Vibrio parahemolyticus*), and three fungi (*Candida albicans, Aspergillus niger, Saccharomyces cerevisiae*). The methanolic extract demonstrated inhibition against *S. aureus, S. lutea*, and *V. mimicus* while all other extracts were insensitive to all tested microorganisms at a dose of 100 µg/disc (Rodrigo et al., 2007).

In another study, *A. pavonina* bark extract at the concentration of 25, 50, and 75 mg/well was tested and showed effective inhibition against both Gram-positive (*Bacillus subtilis* and *Staphylococcus epidermidis*) as well as gram-negative bacteria (*Enterobacter aerogenes, P.aeruginosa, Salmonella typhimurium*) assessed by disc diffusion method (Hussain et al., 2011). The antibacterial activity of aqueous, ethanolic, and hexane extracts of *A. pavonina* leaves was analyzed against foodborne pathogens using *Campylobacter jejuni*, and erythromycin-discs (10 µg/disc) as a reference against Gram-positive (*Bacillus cereus, Listeria. monocytogenes, Staphylococcus aureus*) and Gram-negative (*Campylobacter jejuni, Escherichia coli, Salmonella typhimurium*) bacteria. The aqueous extract was found to be the most effective (Dholvitayakhun et al., 2012). Significant antibacterial activity was also observed in the aqueous leaf extract against *S. aureus* and *E. coli*. (Thippeswamy et al., 2015). The antifungal activity of *A. pavonina* seeds peptides was assessed and demonstrated significant inhibition in the growth of *S. cerevisiae* and *C. albicans* (Soares et al., 2012). A novel promising synthetic antimicrobial peptide, Adenovin based on seed proteinase inhibitor (ApTI) obtained from *A. pavonina* has been developed

(Rodrigues et al., 2009). The hexane and ethanolic extracts of *A. pavonina* were tested for the antibacterial property against *Enterro coccus spp., S. aureus, P. aeruginosa, S. typhi, E. coli, Proteus spp., Klebsiella pneumonia,* and *Acinetobacter baumanii* through well-diffusion assay and micro-dilution method and time-kill tests were conducted for the antibacterial potential of extracts against *E. coli*. The results revealed that the extracts had significant antibacterial potential (Abbas et al., 2017).

Anthelmintic activity: The ethanolic extracts of *A. pavonina* bark were assessed for anthelmintic activity at concentrations of 25, 50, and 100mg/mL against *Pheretima posthuma* and *Ascaridia galli*to measure the time of paralysis and time of death of the worms in comparison to piperazine citrate which was used as a positive control. The results revealed that the ethanolic extract triggered paralysis and death of worms at a comparable time to piperazine citrate, especially at a higher concentration of 100 mg/mL (Dash et al., 2010).

Anti-oxidant activity: A significant antioxidant activity was observed in the case of stem bark methanolic extract while moderate activity was observed in the case of root methanolic extract of *A. pavonina* assessed by the standard 1,1-diphenyl-2-picrylhydrazyl (DPPH) method (Rodrigo et al., 2007). It is suggested that the antioxidant activity may be due to the presence of flavonoids and tannins extracts of bark (Ara et al., 2010a). The antioxidant activity of the *A.pavonina* leaf ethyl acetate extracts was analyzed and showed the highest free radical scavenging activity followed by the ethanol extract at 100 mg/kg b.w. and chloroform extract in comparison to vitamin E (Mohammed et al., 2014). The antioxidant activity of methanolic extracts of leaf and bark (200 mg/mL) was analyzed and a radical scavenging activity of 32.31% and 30.23% respectively were observed (Partha and Rahaman, 2015). The antioxidant activity of water and toluene extracts derived from leaves was assessed and the results showed significant antioxidant activity for both extracts (Thippeswamy et al., 2015). The antioxidant activity of sulfated galactomannan isolated from the endosperm of seeds of *A. pavonina* was analyzed. The galactomannan displayed great scavenging activity suggesting that the antioxidant activity could be related to the sulfation degree and the mechanism of action may be associated with the intrinsic hydrogen-donating ability of sulfate groups (Marques et al., 2015).

Anti-hypertensive activity: The antihypertensive effects of the methanolic seed extract of *A. pavonina* at a dose of 200 mg/kg on the blood pressure of normotensive Wistar rats was recorded for 28 days where propranolol (1 mg/kg) was used as the positive control. On the 29th day, the mean arterial blood of the groups cured with normal saline, propranolol, and seed extract were 60, 23, and 30 mm of Hg respectively. On the other hand, total bilirubin, total protein, and globulin fraction were higher in the extract-treated groups compared to the control group which suggested that the extract has a tonic effect on the kidney and liver (Adedapo et al., 2009).

Anti-hyperglycemic and anti-hyperlipidemic activities: The antihyperlipidemic activity of *A. pavonina* ethanolic bark extract fractions (Petroleum ether, diethyl ether, ethyl acetate, and n-butanol fraction) at a dose of 400 mg/kg was analyzed on Triton WR-1339-induced hyperlipidemic Wistar rats. Other groups were administered either 0.3% w/v carboxy methylcellulose or CMC as the vehicle control group or atorvastatin which acted as the positive control group at a concentration of 1 mg/kg. It was observed that the ethyl acetate fraction and n-butanol fraction inhibited the increase in serum cholesterol and triglyceride levels in Triton WR 1339 administered rats and also decreased the raised serum total cholesterol and triglycerides in high-fat diet-induced hyperlipidemic rats (Das et al., 2011). The antihyperglycemic and antihyperlipidemic effects of *A. pavonina* seed aqueous extract at 50, 100, and 200 mg/kg/day in rats were analyzed where the control group was given distilled water. The results revealed that the extract at all doses significantly modified the blood glucose of the normoglycemic rats as well as reduced the blood glucose level in the animals that received glucose significantly after 3 h of oral administration. The extracts also reduced the lipid profile in diabetic rats (Pandhare et al., 2012a). Galactomannan obtained from *A. pavonina* seeds was assessed for the antidiabetic effect in mice with streptozotocin-induced diabetes. The results revealed that the feed enriched with 1% and 2% galactomannan decreased the glycemia, total cholesterol, and triacylglycerol of the animals (Vieira et al., 2018).

Renal protective activity: *A. pavonina* seed aqueous extract has been tested at doses of 50, 100, and 200 mg/kg/day in streptozotocin-induced diabetic rats. It was observed that after 13 weeks of treatment, the seed extract significantly decreased proteinuria, albuminuria,

lipid levels, and HbA1c deposition in diabetic rats. Thus, the use of the extract has the potential in the reduction in the progression of diabetic nephropathy (Pandhare and Sangameswaran, 2012).

Anti-convulsant and anti-depressant activity: The *A. pavonina* seed methanolic extract at 50, 100, and 200 mg/kg doses was used in two protocols i.e. for evaluation of anticonvulsant activity (induced by picrotoxin, pentylenetetrazole, and strychnine) and for evaluation of depressant activity in Swiss albino mice. The potential of the extract to stop the seizures or delay/ prolong the latency of or onset of the hind limb extension was measured as a sign of the anticonvulsant effect. The dose-dependent effects against picrotoxin and pentylenetetrazole-induced convulsions suggest that the anticonvulsant activity of the seed extracts could be linked to GABAergic neurotransmission interference orin the stabilization of nerve cells membrane in the brain (Oni et al., 2009).

Anti-viral activity: The *A. pavonina* seed and fruit aqueous extracts was tested for antiviral effects against adenoviruses (ADV) and herpes simplex viruses (HSV). It was found that the aqueous extracts were effective against ADV (Chiang et al., 2003). The sulfated galactomannan from *A. pavonina* has also been shown to have a relevant antiviral activity against dengue virus (Marques et al., 2015), herpes simplex virus (Godoi et al., 2015), and poliovirus type1 (PV-1) (Godoi et al., 2014).

Anti-emetic activity: The crude methanol extract of the leaves of *A.pavonina* were assessed for anti-emetic activity in male chicks, and emesis was induced by copper sulphate in a concentration of 50 mg/kg body weight. The anti-emetic activity was determined by calculating the mean decrease in the number of retching in comparison to the control. The extract (150 mg/kg body weight administered orally) showed an antiemetic activity of 50.17% in comparison to the standard chlorpromazine at the same dose (Hasan et al., 2012).

Anti-larvicidal activity: *A. pavonina* seed proteinase inhibitor (ApTI) exhibited a bio-insecticidal effect against *Diatraeasaccharalis* (Silva et al., 2012) and also triggered an inhibitory effect on *Aedes aegypti* larvae exposed to a non-lethal concentration of ApTI during short- and long-duration assays, decreasing survival, weight, and proteinase activities of midget extracts of larvae (Sasaki et al., 2015) and also the growth inhibition of *Anagasta kuehniella* (Lepidoptera: Pyralidae) (Macedo et al., 2010b).

Toxicology: The leaf extracts of *A. pavonina* were found to be toxic to brine shrimp *Artemia salina* (Wickramaratne et al., 2016) while the root and stembark extracts displayed cytotoxicity against *A. salina* (Rodrigo et al., 2007; Zeid et al., 2012). An acute oral toxicity test of the ethanol extract of *A.pavonina* leaves was performed on mice which revealed nontoxicity up to 5000 mg/kg demonstrating the safety of the extract (Mayuren and Ilavarasan, 2009). The methanolic extract of the leaves was found to be safe or non-toxic up to a dose of 2000 mg/kg (Mujahid et al., 2013). The methanolic extract derived from seeds of *A. pavonina* (200 mg/kg) demonstrated the absence of toxicity in the kidney, liver, and testes of rats (Adedapo et al., 2009). The toxic potential of the purified trypsin from seeds of *A. pavonina* was evaluated using an *A. salina* lethality test which revealed that a concentration of 0.16 mg/mL was adequate to kill 100% of *A. salina* after 72 hours (Souza et al., 2016). The absence of toxicity of the seed biopolymer derived from *A. pavonina* was reported by the *A. salina* test (Melo et al., 2018).

Patent and Commercial Products (if any)

- Biodegradable film based on banana peel and galactomana extracted from seeds of *Adenanthera pavonina L.*, Patent No: *BR102018001266B1.*
- Procedures for obtaining movies from *Adenanthera pavonina* galactomananes and galactomanan blendas with other biopolymers, Patent No: BRPI0925163A2.
- Use of parenally hydrolized galactomanana of *Adenanthera pavonina* as a stabilizer, fat substitute and food source in dairy dairy type mousse and its extraction, hydrolisation processes, Patent No: BR102017027235A2.
- Cream for the treatment of gelactomannan based hyperkeratosis. (*Adenanthera pavonina* L.) and aloe vera (aloe barbadensis m.), Patent No: BR102015017019A2.
- Topical formulations containing *Adenanthera pavonina* sulphated polysaccharide with anti-herpetic effect and its production process, Patent No: BR102020013294A2.
- Production of biodegradable glue from *Adenanthera pavonina L.* seed, Patent No: BR102015017021A2.

- Galactomannan extracted from *Adenanthera pavonina L.* crosslinked with glutaraldehyde, Patent No: BR102015017020A2.
- Procedures for obtaining sponges from galactomananes of *Adenanthera pavonina* and blends of this galactomanan with other biopolymers, Patent No: BRPI0910090A2.
- Method for preparing *Adenanthera pavonina Linn.* var.microsperma extract and application of adenanthera pavonina Linn.var.microsperma extract, Patent No: CN111150751A.\
- High-efficiency energy-saving *Adenanthera pavonina* linn washing equipment, Patent No: CN108606338A.
- Method for rapidly cooking *Adenanthera pavonina* plant, Patent No: CN106819773A

Scope of Further R&D: *A. pavonia* is a deciduous tree belonging to family Fabaceae and detailed population of the species is yet to be surveyed. Natural generation of the plant is limited due to problem associated with its seed germination and seed forming. Therefore, propagation techniques of *A. pavonina* must be explored for future conservation and sustainable utilization. The seeds of the *A. pavonina* have been used as a biopolymer in several industries such as textile, pharmaceutical, biomedicine, cosmetics, soap and food industries while several other uses of the plant can be explored with research and analysis. The LC-MS/MS profile of *A. pavonina* may lead to obtain fingerprinting of species which can be useful for identification of species in unexplored regions. Apart from this, additional investigation of *A. pavonina* with respect to nitrogen fixing ability of the plant along with research on fuel wood production and fodder usage is necessary. Along with this, further and extensive research and studies may be performed for identification of new phytoconstituents from the plant for determination of their potential benefits.

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Aglaia edulis (Roxb.) Wall.

Synonyms:
Aglaia acida Koord. & Valeton, *A. barberi* Gamble, *A. cambodiana* Pierre, *A. curranii* Merrill, *A. diffusa* Merrill, *A. indica* (Hook. F.) Harms, *A. Khasiana* Hiern, *A. Latifolia* Miq., *A. Magnifoliola* C.DC, *A. Minahassae* Koord., *A. Montrouzieri* Pierre, *A. motleyana* Stapf ex Ridl, *A. mucronulata* C.DC., *A. oblonga* Pierre, *A. pirifera* Hance, *A. rugosa* Pierre, *A. samarensis* Merrill., *A. sulingi* Blume, *A. testicularis* C.Y.Wu, *A. undulata* Miq., *A. verrucosa* C.DC., *Beddomea indica* Benth & Hook. f., *B. sarmentosa* Hook. f. ex Beed, *Camunium bengalense* Buch & Hum, *C. bengalense* Buch. -Ham. ex Wall. *Lepiaglaia montrouzieri* Pierre, *Milnea cambodiana* Pierre, *M. edulis* Roxb, *M. pirifera* (Hance) Pierre, *M. racemosa* (Dennst.) Peterm, *M. racemosa, M. Roem, M. rugosa* Pierre, *M. sulingi* (Blume) Teijsm & Binn, *M. undulata* Wall., *M. verrucosa* (C.DC.) Pierre, *Nyalelia racemosa* Dennst.

Local/Common/Popular Name(s):
Chu-lan tree, Aglaia.

Vernacular Names:
Assamese: Momailateku,
Khasi: Dieng-soh-longar,
Mikir: Khrang,
Lepcha: Sinakedang.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Sapindales
Family	:	Meliaceae
Genus	:	*Aglaia*
Species	:	*Aglaia edulis*

Botanical Description: *A. edulis* is an evergreen, mid-canopy tree found in tropical forests of Asian nations and can grow up to 33 m in height. The tree possesses a bole buttress for support and has a reddish-brown, yellowish-brown, or greyish-green outer bark. The inner bark is pink or brown in color and has white-colored exudes. The young branches of the tree are generally pale brown and covered with reddish-brown stellate hairs, scales, and inconspicuous lenticels. The leaves are imparipinnate, alternate, and estipulate. The rachis is long (10-12.5 cm), slender, swollen at the base, and covered with hairs or reddish-brown lepidote scales. The leaflets vary from 5 to 13 in number and are opposite or sub-opposite with the petiole 5-18 mm in length and are grooved above. The measurements of the lamina are 4.5-23 cm X 2-8 cm and may be elliptic, elliptic-oblanceolate, elliptic obovate, or ovate with oblique, cuneate, acute, or attenuate base. The apex is either acuminate or obtusely acuminate and has an entire margin and varies from membranous to coriaceous in texture and has a glabrous papillate above and a stellate pubescence beneath with the midvein abaxially prominent and adaxially conspicuously depressed. The secondary veins vary from 9 to 12 in number on each side of the midvein and are slender, pinnate, prominent, intercostae scalariform in arrangement. Flowers are polygamodioecious arranged in axillary inflorescence and are yellow or orange in color. The male flowers have inflorescence up to 38 cm in length and are covered with brown stellate hairs. The calyx is cup-shaped with 4 to 6 lobes and is imbricated and covered in scales. The petals are 4 to 6 in number and the staminal tube is cup-shaped, thick, and crenulate at the mouth and anthers are 5-6 in number. The female inflorescence is 5 cm in length with a peduncle 2.5 cm in length and the calyx has 5 lobes is ovate and covered with hairs. The ovary is superior with up to 1 mm length and is covered with scales and carries 3-celled ovules varying from 1 to 2 in number in each locule. The fruit is an elliptic, indehiscent berry that is brown in color having a measurement of 3.2 x 3.8 cm. It is subglobose and covered with thin buff scales with an inconspicuous persistent calyx. The seeds are ellipsoid with ca. 4 cm, hilum to 3 cm, and 1-3 in number in each fruit (Deb, 1981; Pannell, 1992;

Useful Tropical Plants, 2014). The flowering in *A. edulis* occurs from January to March with fruiting from February to March and the fruit reaches its maturity in August.

Distribution: *A. edulis* is common in tropical deciduous to evergreen forests height from sea level up to 1700 m altitude (Plant Use, 2010). It is regarded as a 'Near Threatened (NT)/Lower risk (LR)' species as its population is declining and severely fragmented. According to 'IUCN Red List it is critically endangered in Bangladesh (Pannell, 1998). It is globally distributed in Indo-Malaya, in the Lesser Sunda Islands, Maluku Islands, Sulawesi, Java, and Sumatra in Indonesia, Philippines, Malaysia, Borneo, Fiji Islands, Thailand, and dense, semi-evergreen and evergreen forests of Cambodia (Chhenga et al., 2016). In India, it is found in Nicobar Islands, Assam (Soudangpothar in the Doyang Reserve, Sibsagar; Dilli Reserve Forest, Jaypur hills, Darrang, Barak valley), Meghalaya, Tripura and Arunachal Pradesh (Namdapha) (India Biodiversity Portal).

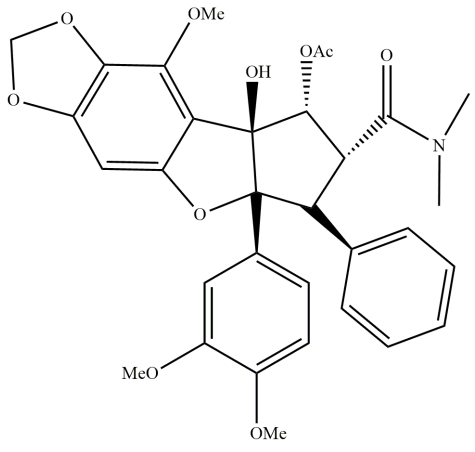
Ethnobotanical significance : The timber of *A. edulis* is red, and hard, and is used for making carts, boats, and furniture (Schneider, 1916). Fruit pericarp has medicinal properties and is used in the treatment of diarrhea (Pannell, 1998).

Phytochemistry:

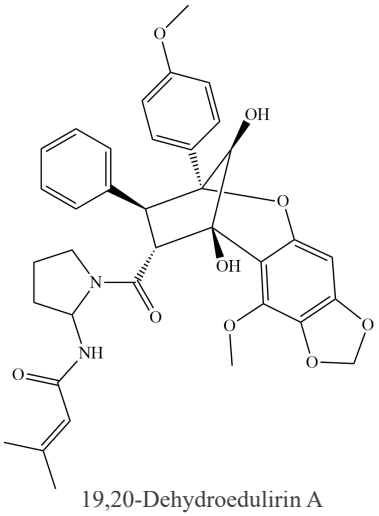
Bark: Edulisone A, Edulisone B (Kim et al., 2005), Aglaroxin A, Aglaroxin A 1-O-acetate, 3'-Methoxyaglaroxin A 1-O-acetate, 19,20-Dehydroedulisone A, Edulirin A, Edulirin A 10-O-acetate, 19,20-Dehydroedulirin A, Isoedulirin A, and Isoedulirin B (Kim et al., 2006).

Leaves: Aglamides A, Aglamide B, Aglamide C, Aglamide D; Aglalactone, Scopoletin, and 5-Hydroxy-3,6,7,4′-tetramethoxyflavone (Kim et al., 2006; Saifah et al., 1999). p-hydroxyphenyl phosphoric acid, benzene acetaldehyde, mequinol, ethyl 3-methyl-2-butenoate, 2-naphthyl-β-D-galactopyranoside, 7-propylquinolinine, 5-hydroxypipecolic acid, m-tolu aldehyde, β-methyl-α,α-diphenyl-4-morpholine butyric acid, [3-(dimethylamino) phenyl] methanol, Copaene, 1,2,3,4,4a, 5,6,8a-Octahydronaphthalene, 1-(3,6,6,-Trimethyl-1,6,7,7a-tetrahydrocyclopenta [c] pyran-1-yl), 2,5-Octadecadienoic acid methyl ester, Isocaryophyllene, Cis-isoeugenol, γ-Himachalene, Himachala-2,4-diene, Aciphyllene, Cedrelanol, 3-methoxymethyl-2,5,5,8a-tetramethyl-6,7,8a-tetrahydro-5H-chromene, 9-Methoxycalamenene, Gitoxigenin, Urs-12-en-28-al,(3-acetoxy)-3β, 4,4,6a, 6b, 8a, 11,11,14b-octamethyl-1,4,4a, 5,6,6a, 6b, 7,8,8a, 10,11,12,12a, 14,14b-octadecahydro-2H-picen-3-one, Lambda-8 (17),14-diene-13,17-diol, 2,5-Bismethyl-1-silacyclobutyl)-p-xylene, Abieta-6,13-diene, Agathic acid, Bicyclo [9.3.1] pentadeca-3,7, dien-12-ol, 3β-Pregn-5-ene-3,17, 20-triol, O- methyl psychotrine, 2, 2', 6, 6, 6', 6', 9, 9'-Octamethyl-8, 8'-bitricyclo [5.4.0] undecane, Lupeol acetate, D-alpha-tocopherol, 4,4-dimethyl-cholesta-22, 24-dien-5-ol, γ-Sitosterol (Ravindran and Thoppil, 2020), aglaiduline, aglaidithioduline, aglaithioduline (Saifah et al., 1999)

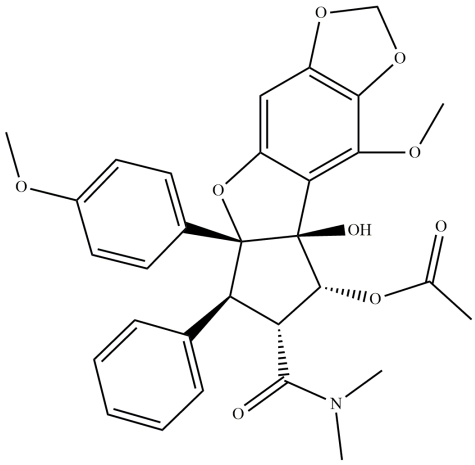
Roots: Aglaroxin A, Pannellin, Thapsakin B, Isothapsakin B, Homothapsakin A, Thapsakin A 10-O-acetate, Thapsakon A, Thapsakon B, Thapoxepine A, Homothapoxepine A, Thapoxepine B (Bacher et al., 1999)



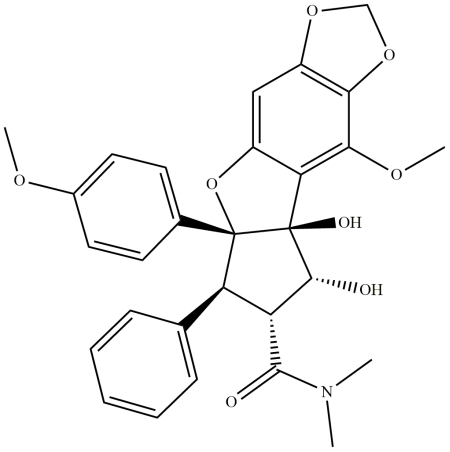
3' -methoxyaglaroxin A 1-O-acetate



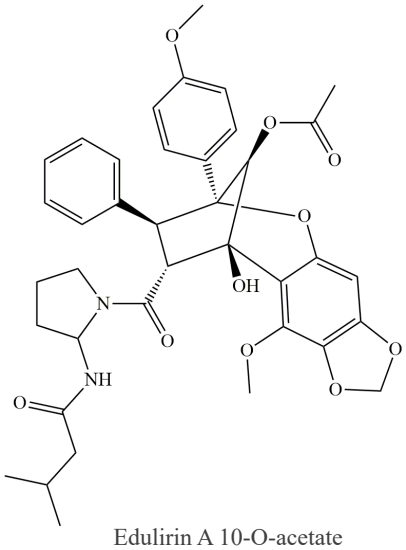
19,20-Dehydroedulirin A



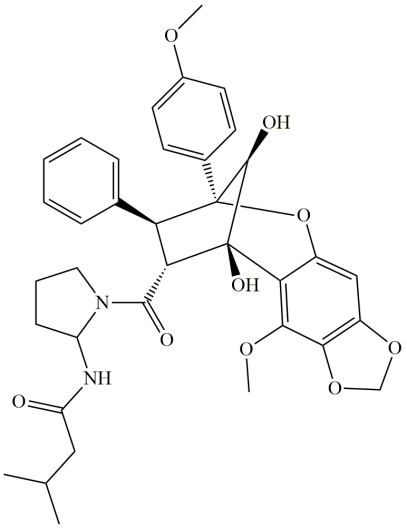
Aglaroxin A 1-O-acetate



Aglaroxin A



Edulirin A 10-O-acetate



Edulirin A

Structures of Important and Characteristic Chemical Constituents of *Aglaia edulis*

Biological activities:

Anti-cancer activity: Aglaroxin A, Aglaroxin A 1-O-acetate, 3'-Methoxyaglaroxin A 1-O-acetate isolated from bark displayed cytotoxicity against human cancer cell lines (Lu1, LNCaP, and MCF-7) and a nontumorigenic (HUVEC) cell line (Kim et al., 2006).

Anti-viral activity: The sulfur-containing amides aglaithiodulie and aglaidithioduline were reported to display slight antiviral activity against Herpes simplex virus 1 and 2. (Saifah et al., 1999)

Larvicidal activity: The bioactive compounds from *A. edulis*, *Jasminum brevifolium,* and *Pogostemon auricularis* were evaluated for their mode of action against reactive oxygen species and microbial inhabitants. The compounds induced high levels of reactive oxygen species leading to oxidative stress and death. The compounds also demonstrated strong inhibitory effect against *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, *Klebsiella pneumonia,* and *Proteus mirabilis* and also larvicidal effects against *Aedes aegypti* larvae. (Anoop kumar et al., 2020)

Anti-inflammatory activity: The extracts isolated from fruits i.e. Agleduline C, 11α-acetoxygedunin demonstrated significant cytotoxic and anti-inflammatory activities while Agleduline I and

11α-acetoxygedunin showed the capability of reversing multidrug resistance in MCF-7/Dox cells (Plant Use, 2010).

Antifungal activity: Flavaglines isolated from *Aglaia odorata*, *Aglaia elaeagnoidea,* and *A. edulis* were tested against plant pathogenic fungi, *Pyricularia grisea*, *Alternaria citri* and *Fusarium avenaceum*, where the flavaglines demonstrated antifungal property. (Engelmeier et al., 2000)

Insect toxicity: Aglaroxin A and Pannellin exhibited strong insect toxicity against neonate larvae of *Spodoptera littoralis* (Bacher et al., 1999).

Toxicology: There is no reported literature available on the toxicity of *A. edulis and* its derived products.

Patent and Commercial Products (if any): There is no literature available regarding patent and commercial products on *A. edulis* species and its products.

Scope of further R&D: *A. edulis* is an evergreen tree belonging to the family Meliaceae. The literature survey for the species revealed that the plant was used in treatment of skin diseases and tumors traditionally. Therefore, the antimicrobial and anti-tumor properties of the plant need to be evaluated through researches and trials. Marker compounds assisted chemical screening of the existing population of *A. edulis* can be carried out for identification of chemically superior genotype(s) for conservation of the plant species as it is categorized as a near threatened species. Further researches and evaluations should also be carried out for identification of potential uses of the plant.

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Alangium salviifolium
(L.f.) Wangerin

Synonyms:
Alangium acuminatum Wight ex Steud., *A. decapetalum* Lam., *A. lamarckii* Thwaites, *A. latifolium* Miq. ex C. B. Clarke, *A. mohillae* Tul., *A. salviifolium* subsp. *decapetalum* (Lam.) Wangerin, *A. sundanum* var. *miqueliana* Kurz, *A. tomentosum* Lam., *Karangolum mohillae* (Tul.) Kuntze.

Local/Common/Popular Name(s):
Commonly known as sage-leaved alangium. It is also commonly known as Ankolam in Malayalam, Ankola in Kannada, Akola or Ankol in Hindi and Alanji in Tamil.

Vernacular Names:
Hindi: Akol, Dirghakila, Nedishth, Tamraphala, ***Kannada:*** Kallumavinamara, ***Malayalam:*** Ankolam, Karankolam, Valli, Ankolam, ***Marathi:*** Ankol, ***Oriya:*** Ankota, lamba Karnna, Pita sara, ***Pali:*** Ankol, ***Sanskrit:*** Ankola, ***Tamil:*** Eralincil, ***Telugu:*** Nallaankolamu, Nallauduga, ***Tibetan:*** Kang kara, ***Tulu:*** Ankole-da mara.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Cornales
Family	:	Cornaceae
Genus	:	*Alangium*
Species	:	*Alangium salviifolium*

Plant Description: *Alangium salviifolium* is a sage-leaved small, bushy tree with a short trunk which offers a dense canopy bearing white colored fragrant flowers with green buds. The petals of flowers typically curl backwards and expose multiple stamens and linear stigma. The fruits of *A. salviifolium* are spherical berry shaped and red in color. The white colored prominent remains of calyx are distinctly visible. The leaves are simple, alternate and oblong-lanceolate (Krisnan et al., 2013 and Neginhal et al., 2011). The stunted branches have sharp ends which appear like thorns. Flowering in *A. salviifolium* occurs between February and April and fruits arise between March and May prior to rainy season. The tree sheds the leaves entirely during flowering and new leaves appear during fruiting (Kavitha et al., 2013).

Distribution: *A. Salviifolium* is native to Western Africa, Madagascar, Southern and Eastern Asia (China, Malaysia, Indonesia, India and Philippines), tropical Australia, the western Pacific Ocean islands and New Calendonia (Singh et al., 2014). In India, it is found in Andhra Pradesh, Bihar, Chhattisgarh, Goa, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand and West Bengal (Saraswathy et al., 2013).

Habitat: *A. salviifolium* is mostly found in dry regions in plains and low hilly areas (Krisnan et al., 2013 and Neginhal et al., 2011). In India, this tree is mostly found near sandy riverine tracts (Krisnan et al., 2013).

Ethnobotanical significance: In Ayurveda, the roots and the fruits are used for treatment of rheumatism and hemorrhoid. It can also be used for treatment of bites by rabbits, rats and dogs (Rajesh et al., 2011). The root and bark of the tree is also used in traditional medicine for treatment of skin problems and in snake bites (Krisnan et al., 2013). The root and bark are also used for removing parasitic worms (platy-helminthes) and other internal parasites from body. It is also used as an emetic and purgative (Saraswathy et.al 2013). The stems of *A. salviifolium* are used as spears in Kenya due to their sharp ends. The twigs are used as toothbrush in India. It is considered to be good for making musical instruments and for making furniture as well (Singh et al., 2014).

Phytochemistry:

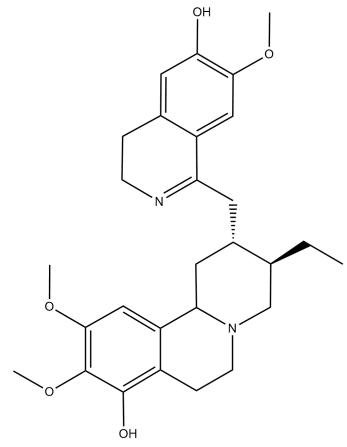
Leaves: Alangidiol, Alangicine, Alangimarckine, Alamaridines, Dimethyl aptaline, Isoalamarin, Alangimarinone, Dimethyl phycotrine, Ankorine) Marckidine, Marckine, Tubulosine, Alangicine, Cephaeline, Psychotrine, Alangol, Alengol, Lactam, Alangiside, Loganic acid, Venoterpine, dl-Salsoline and Isocephaeline, Salicin, Kaempferol, and Kaempferol-3-O-β-D-glucopyranoside, Salviifosides A, Salviifocides B, Salviifosides C (Ramni et al., 2003 and Tran et al., 2009)

Root: Cephaeline, Tubulosine, Isotobulosine, Psychotrine, Alangiside, Alkaloid A, Alkaloid B, Alangicine, Dimethyl psychotrine, Marckine, Marckidine, Lamarckinine, Alangidiol, Alangimarckine, Alamaridines, Dimethyl aptaline, Isoalamarin, Alangimarinone, Ankorine, Alangol, Alengol, Lactam, Alangiside, Loganic acid, Venoterpine, dl-Salsoline,Isocephaeline (Ramni et al., 2003).

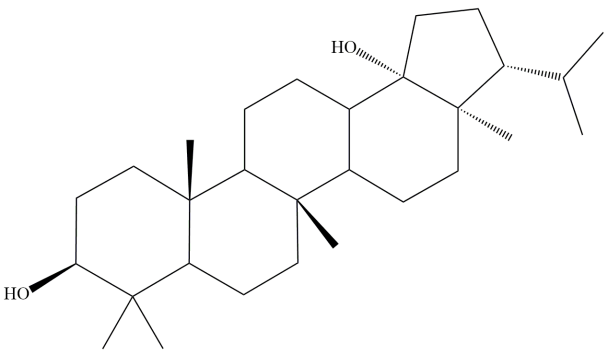
Bark: Alkaloid A, Alkaloid B, Alangicine, Dimethylpsychotrine, Marckine, Marckidine, Lamarckinine, Emetine, Cephaeline, Psychotrine, Tubulosine, Isotubulosine, Alangium A, Alangium B, Alangine, Myricyl alcohol, de-Me-psychotrine, Stigmasterol, β-Sitosterol, Alangine, Akharkantine, Akoline (Itoh et al., 1994 and Itoh et al., 1995).

Fruits: Alangimarkine, Ankorine, Deoxytobulosine, Alangiside, Alangine, Cepheline, N-Methylcephaeline, Deoxytobulosinelactam, Loganic acid, Venoterpine, dl-Salsoline and Isocephaeline (Tran et al., 2009)

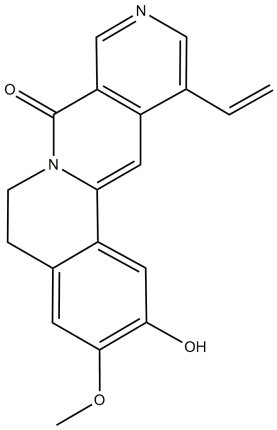
Seeds: Alangimarine, Alamanine, Alangimaridine, Emetine, Cephaeline, Psychotrine Alangidiol, Alangicine, Alangimarckine, Alamaridines, Dimethyl aptaline, Isoalamarin, Alangimarinone, Dimethyl phycotrine, Ankorine, Marckidine, Marckine, Tubulosine, Alangicine, Cephaeline, Psychotrine, Alangol, Alengol,N-methylcephaeline, Betuline, Betulinaldehyde, Lipeol, Betulinic acid, β-Sitosterol, Stigmasta- 5, 22, 25- trien-3β-ol, Myristic acid, N- Benzoyl-L-Ph-alaninol(Jain et al., 2002, Itoh et al., 2000, Tanwar et al., 2014, Ramni et al., 2003 and Tran et al., 2009).



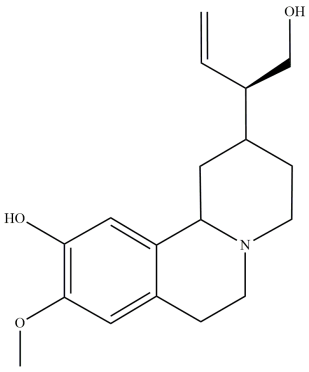
Alangicine



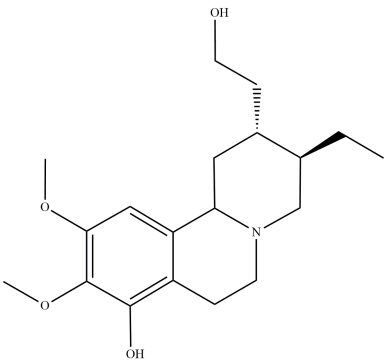
Alangidiol



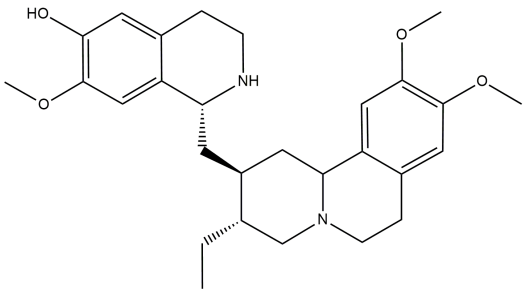
Alangimarine



Alangine



Ankorine



Cephaeline

Structures of Important and Characteristic Chemical Constituents of *Alangium salviifolium*

Biological Activities:

Anti-oxidant activity: The components of the essential oil obtained from the roots of *Alangium salviifolium* have been reported to contain a chemical compound that is (—) -7, 8-dihydroxycalamenal, which is a novel cadinane-type sesquiterpenoid. This compound was tested for its antioxidant activity and inhibition of tyrosinase, and showed particularly strong inhibition effects (Yagi et al., 2014). The antioxidant activity of alcoholic root extract of *A. salviifolium* was tested using DPPH and nitric oxide radical inhibiting activity methods. The alcoholic extract was found to exhibit significant antioxidant activity due to presence of high phenolic and flavonoid content (Upadhyay et al., 2011).The petroleum ether, benzene, ethyl acetate, methanol and ethanol extracts of leaf of *A. salviifolium* were evaluated for in vitro antioxidant activity using various model systems i.e. DPPH, hydroxyl, superoxide, ABTS and reducing power. The ethanol extract demonstrated strong hydroxyl, superoxide radical scavenging activity while methanol extract demonstrated potent DPPH, ABTS radicalcation scavenging activities (Sakthidevi et al., 2014).

Anti-diabetic activity: The ethanol extract obtained from leaves and bark of *A. salviifolium* at the doses of 200 and 400 mg/kg b. wt. was administered orally to streptozotocin induced diabetic Wistar rats and it was observed that the blood glucose levels reduced significantly to near normal while also lowering elevated TC, TGL, LDL levels and increasing HDL level. The ethanol extract of leaves was found to exhibitantidiabetic activity higher than the bark extract. The hypoglycemic action of the plant may be by potentiating the insulin effect of plasma by increasing either the pancreatic secretion of insulin from existing beta cells or by releasing insulin from bound form (Rajesh et al., 2011; Meenakshi, 2005; Kalarani et al., 2012; Dinkar et al., 2011). The anti-diabetic activity of stem bark of *A. salviifolium* was evaluated in rats wherein the bark was subjected for successive extraction with petroleum ether, chloroform, methanol and distilled water. The results revealed that the aqueous extract exhibited lowering of blood glucose level. The cardiac effects and anti-diabetic activity of extracts obtained from *A. salviifolium* flower were evaluated by analysis on frog-heart in-situ preparation. The extracts produced significant positive ionotropic and negative chronotropic actions on frog heart and therefore exhibited anti-diabetic property (Kumar et al., 2010).

Anti-ulcer activity: The petroleum ether, chloroform, methanol and aqueous root extracts of *A. salviifolium* at the doses of 100, 200 and 400 mg/kg were tested on pylorus ligated Wistar rats. Among the extracts, the petroleum ether extract was found to reduce the total acidity, free acidity, peptic activity and ulcer index significantly as compared to other extracts. This activity of *A. salviifolium* might be by blocking the acid secretion on H^+-K^+-ATPase proton pump by inhibition of H^+- K^+-ATPase activity of the parietal cells (Mohanty et al., 2011; Shreekanth, 2011).

Anti-arthritic activity: The anti-arthritic activity of *A. salviifolium* stem bark was evaluated in Wistar rats using Fruend'sadjuant arthritis model. The petroleum ether, chloroform, methanol, ethyl acetate and aqueous extracts were administered at a dose of 100 mg/kg for 21 days. The paw volume and paw thickness were measured and all the extracts of *A. salviifolium* showed significant anti-arthritic activity with chloroform extract being more effective followed by ethyl acetate extract followed by aqueous extract followed by petroleum ether followed by methanol extract in effectiveness. The steroids present in the plant extracts may be responsible for the anti-arthritic activity by inhibiting the inflammation due to the Fruend's adjuant (inflammogen) (Jubie et al., 2008; Shivanand et al., 2010).

Anthelmintic activity: *A. salviifolium* bark extract at doses 50, 100 and 150 mg/ml was tested against earthworms (*Pheretima posthuma*) for evaluation of anthelmintic activity. The methanol and chloroform extracts exhibited significant anthelmintic activity at the concentration 150 mg/ml. The mode of action for anthelmintic activity may be by increasing chloride ion conductance of worm muscle membrane thereby producing hyper polarization and decrease in excitability leading to muscle relaxation and flaccid paralysis (Pandey 2012). The hexane, ethyl acetate, chloroform and methanol extract of *A. salviifolium* bark were evaluated against earthworms (*Pheretima posthuma*) for paralysis and death period of worm. The results revealed that the methanol and chloroform extracts exhibited significant anthelmintic activity (Pandey 2012)

Anti-microbial activity: To evaluate the anti-microbial activity, agar cup plate test was used to determine the sensitivity of the samples and the well

micro-dilution was used to determine the minimum inhibitory concentration. Aqueous and alcohol extracts were tested on gram positive bacteria (*Staphylococcus aureus* ATCC 25925, *Bacillus subtilis* ATCC 6633, *S. epidermis* ATCC 12228 and *Micrococcus luteus* ATCC 10240) and gram-negative bacteria (*Entero bacteraerogens* ATCC 13048, *Escherichia coli* ATCC 25922, *Salmonella typhi* ATCC 51812 and *Shigelladysenteriae* ATCC 25931). The results of antimicrobial assays showed that all tested extracts were active against all tested microbial species. The extract contains phenolic compounds and flavonoids which may be responsible for anti-microbial activity bydamaging the cell membrane of bacteria (Udayaprakash et al., 2013;Pandian et al., 2006). The phytoconstituents such as 1-methyl-1H pyrimidine-2, 4-dione and 3-O-β-glucopyranosyl-24(β)-ethyl chalesta-5, 22, 25-triene isolated from flowers of *A. salviifolium* exhibited significant anti-bacterial activity against gram positive and gram negative bacteria (Anjum et al., 2002).

Anti-fertility activity: The total alkaloid fraction of *A. salviifolium* stem bark methanol extract was used for evaluation of androgenic and non-androgenic activity in male wistar rats which were administered at doses of 10 and 20 mg/kg b.wt. total alkaloid fraction orally for 7 days. The results of the study showed a significant increase in the weight of testis, seminal vesicles, ventral prostate and epididymis in the treated rats. The total alkaloid fraction had potential for abortifacient and less anti-implantation activities (Murugan et al., 2000).

Analgesic activity: Analgesic activity of methanol extract of *A. salviifolium* root evaluated using albino mice which was administered at doses of 100 and 200 mg/kg i.p.30 minutes prior to writhing induction where acetylsalicylic acid at a dose of 400 mg/kg was used as standard. The study showed analgesic activity at a dose of 200 mg/kg (i.p.) (Zahan et al., 2013).

Anti-inflammatory activity: The anti-inflammatory study was performed using carrageenan- induced paw edema model. The methanol extract of *A. salviifolium* root at doses of 100 and 200 mg/kg and standard acetylsalicylic acid (400 mg/kg) were intraperitoneally injected to rats 30 min before carrageenan induction. It was found that the methanol extract inhibited the carrageenan-induced rat paw edema at 100 and 200 mg/kg b. wt. The anti-inflammatory effect may be due to the presences of salviifoside B in extract which inhibits the production of nitric oxide, prostaglandin E2, and tumor necrosis factor-α, which are the mediators of inflammation (Ahad et al., 2012).

Diuretic activity: The benzene and ethyl acetate extracts of *A. salviifolium* root at a dose of 250 mg/kg were evaluated for diuretic activity using Lipschitz method which involved the evaluation of total urine volume and Na^+, K^+ and Cl^- concentration in urine. The results showed increased urine volume and concentration of Na^+, K^+ and Cl^- in urine. The diuretic activity may be due to inhibition of sodium reabsorption through a mechanism which does not involve Na^+/H^+ exchanger or $NaKCl_2$ transporter, leading to more sodium and consequently more water retention in the tubes (Tanwar et al., 2014).

Anti-epileptic activity: The leaf extract of *A. salviifolium* was reported to exhibit anti-convulsant activity. The anti-epileptic effect was attributed to the delayed onset of pentylenetetrazol (PTZ) induced seizures and protection from mortality due to seizures was also observed in test subjects. This activity may be due to presence of tannins, triterpene and steroids. The anti-convulsant activity of methanol extract of stem bark has been evaluated in various mice models such as maximum electroshock seizure (MES), PTZ-induced convulsion and lithium pilocarpine induced model in rats. On the basis of dose dependent study, it was found that the methanol extract of stem bark shows significant anti-epileptic activity as indicated by delayed onset of convulsion in case of PTZ induced and lithium pilocarpine induced model. However, no such activity was observed in case of MES model (Ambawade et al., 2002; Parida et al., 2010). The anti-convulsant activity of aqueous and ethanol extracts of leaves of *A. salviifolium* was evaluated on maximal electroshock induced seizures and pentylenetetrazole induced seizures in mice. The results revealed that both extracts proved to exhibit anti-convulsant effect (Balakrishna et al., 2010)

Anti-fungal activity: The aqueous leaf extract of *A. salviifolium* was reported for its growth inhibitory activity against *Trichothecium roseum*, a fungal pathogen, however the effect was not found to be much significant. The ethanol extract of roots has been reported to possess inhibitory activity against

Aspergillus niger, *A. fumigatus*, *A. flavus*, *Fusarium oxysporum*, *Penicillumsps* and *Rizopussps*. The lyophilized powder extract of pulverized wood showed inhibitory effect against various isolates of dermatophytes and *Candida albicans*. The inhibitory effect on dermatophytes was found to be comparable to ketoconazole in agar disc diffusion assay, however significant activity was not observed in case of *Candida albicans* (Thippeyswami et al., 2003; Wuthi-udomlert et al., 2002)

Hepatoprotective activity: The hepatoprotective activity of methanol and aqueous extracts of leaves of *A. salviifolium* was studied in CCl_4 induced liver injury model in rats. It was observed that administration of the extract resulted insignificant protection as indicated by reduction in SGOT, SGPT, alkaline phosphatase and total bilirubin concentration. The extract was also shown to prevent the rise in lipid peroxidases levels in liver tissue homogenate. This activity may be due to conditioning of hepatocytes to protect the membrane integrity against CCl_4 induced leakages of marker enzymes into the circulation (Prusty etal., 2012). The ethanol extract of *A. salvifoilum* leaf was evaluated for hepatoprotective activity on CCl_4 induced rats and the results revealed that the extract had potential hepatoprotective activity (Chander and Reddy, 2014).

Anti-cancer activity: The *in vivo* anti-cancer potential of crude extract of *A. salviifolium* flowers was evaluated in Ehrlich Ascites Carcinoma model in mice where intraperitoneal administration of extract resulted in significant reduction in tumor growth as compared with control mice. The anticancer activity of chloroform extract was also investigated which showed similar results. The study indicated a significant increase in the lifespan of the tumor bearing mice by 32 days. Similarly, *in vitro* anti-tumor activity was tested against Dalton's ascitic lymphoma murine cell lines using different doses of methanol extract. The extracts significantly decreased tumor volume, weight and viable cells and increased non-viable cells after 14 days of oral administration (Ronok et al., 2011; Venkateshwarlu et al., 2012).

Insecticidal activity: The methanol extract of *A. salviifolium* had insecticidal activity against *Spodopteralitura* Fab. and had potential larvicidal activity against different larval stages of *S. litura* (Selin-Rani et al., 2016). The hexane, chloroform and ethyl acetate extract of *A. salviifolium* demonstrated significant larvicidal activity against *S. litura* (Pavunraj et al., 2012). The mode of action for insecticidal and larvicidal activity might be enzyme inhibition and midgut damage of *S. litura* (Selin-Rani et al., 2016).

Patents and Commercial products:

A composition comprising extract of *A. salviifolium* having anti-adipogenic or anti-obesic activity, Patent No: WO2015198346A1.

Scope of further R&D: *Alangium salviifolium*, a small bushy tree with significant medicinal properties, offers vast potential for further research and development. Detailed investigations into its phytochemical composition and bioactive compounds could enhance understanding of its antioxidant, anti-diabetic, anti-ulcer, anti-arthritic, anthelmintic, antimicrobial, anti-inflammatory, and anticancer activities. Research should focus on optimizing extraction methods to maximize bioactive compound yields. Clinical trials are necessary to validate traditional uses and explore new therapeutic applications. Additionally, studies on cultivation techniques and genetic diversity can support sustainable supply and conservation efforts. Exploring its use in pharmaceuticals, nutraceuticals, and agrochemicals could lead to innovative commercial products and wider therapeutic applications.

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Amoora wallichii King

Synonyms:
Aglaia spectabilis (Miq.) S. S. Jain & Bennet, *Aglaia dasyclada* F.C. How & T.C. Chen; *Aglaia hiernii* M. V. Viswan. & K. Ramach., *Aglaia ridleyi* (King) Pannell, *Amoora dasyclada* (F.C.How & T.C. Chen) C.Y. Wu, *Amoora gigantea* Pierre, *Amoora ridleyi* King, *Amoora spectabilis* Miq., *Amoora stellatosquamosa* C.Y.Wu & H.Li, *Aphanamixis wallichii* (King) Harid. & R.R. Rao, *Sphaerosacmes spectabilis* Royle.

Local/Common/Popular Name(s):
Malayalam **:** Punyav,
Hindi **:** Lalchini,
Assam **:** Amari, Bhoto- mayna

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Division	:	Tracheophyta
Class	:	Magnoliopsida
Order	:	Sapindales
Family	:	Meliaceae
Genus	:	*Amoora*
Species	:	*Amoora wallichii*

Botanical Description : *Amoora wallichii* (Family: Maliaceae), a dioecious plant with both male and female forms, is an evergreen tree. The heartwood is reddish-brown in colour while the sapwood is pinkish in colour. The wood is hard and close-grained. The bark is smooth and is reddish-brown in colour with pink blaze and the branchlets are covered with brownish scales with thickness about 3-4 mm. The grey or rusty leaves are imparipinnate, alternate, estipulate and are crowded at ends of twigs with microscopic fimbriate scales and minute stellate hairs in young leaves. The leaflets are 5-7 and are elliptic, elliptic-obovate, lanceolate or oblanceolate with the apex as acute, acuminate or caudate-acuminate and base oblique, acute or attenuate and margin being entire, chartaceous, foveolate above and lepidote above and beneath with measurements 6-10 cm x 3-4.5 cm. The petiolule has lepidote scales and is 10-18 mm in length. The rachis is stout, swollen at base and is grooved above with 60-80 mm length. The lateral nerves are parallel and prominent occurring in 5-12 pairs with intercostae obscure secondary laterals. The yellow flowers are polygamodioecious and occur in axillary branching panicles. The 5 lobed calyx is campanulate and scaly with ciliate margins. The petals are free, imbricate and 5 in number (Haines, 1920). The staminal tube is entire at apex with 5 anthers. The 1-2 celled ovary is small, superior and slightly depressed with 1-2 ovules in each cell. The buff-coloured fruit is a globose berry measuring 1-15 cm across and contains 1-2 seeds.

Distribution : *Amoora wallichii* is distributed from its native range in China (S. & SE. Yunnan) to Tropical Asia and N. Queensland and is also found from Indo-Malaysia to Pacific Islands. In India, it is found in Eastern Himalayas, Western Ghats and the Andaman Islands.

Habitat : The tree is found in evergreen forests, in sacred groves in the plains, an upper canopy in secondary forests, riverine forests and coastal swamps at height of 650 m mean above sea level.

Ethnobotanical Significance : *A. wallichii* is a forest-based tree whose wood possesses some medicinal activity. The plant is used to treat

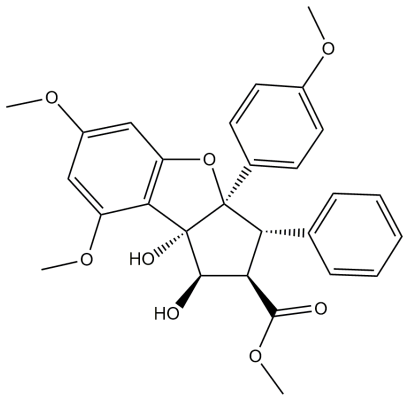
various diseases like skin allergies, astringency and diarrhoea (Lavanya et al., 2006). Traditionally, the extracts from *A. wallichii* are used as an insect repellent due to their strong insecticidal activity (Schneider et al., 2000).

Phytochemistry:

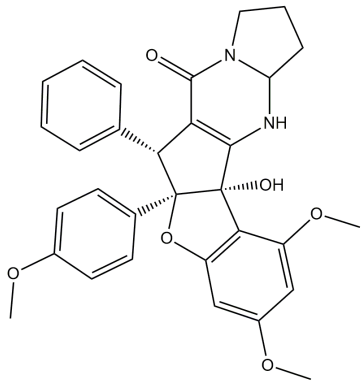
Leaves: Dammaranes, pregnanes (Yang et al., 2008a, 2008b), cyclopenta [b] benzofurans (Bacher et al, 1999; Brader et al., 1998, Dumontet et al., 1996), flavaglines (King et al., 1982; Cui et al., 1997), rocaglamide (Proksch et al., 2001), aglafoline (Wu et al., 1997), cyclopenta (b) tetrahydro benzofuran

Seed: Linoleic acid, oleic acid (Kakti *et al.,* 2016).

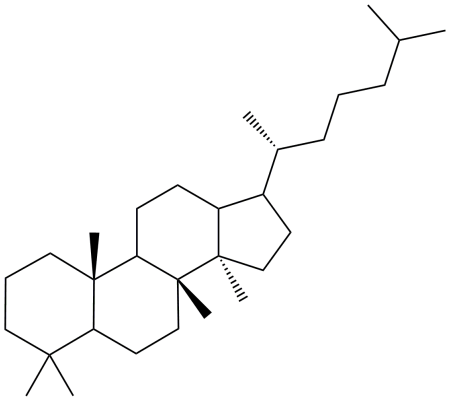
Bark: Methylrocaglate,C-3′-hydroxylmethylrocaglate (Schneider, 2000).



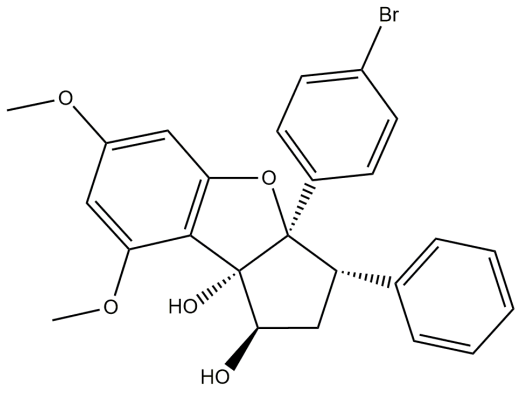
Aglafoline



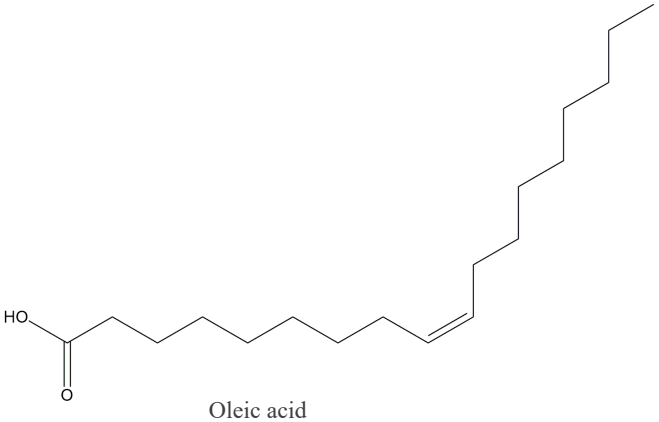
Aglaiastatin



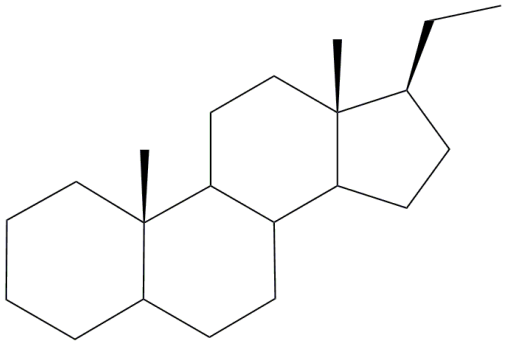
Dammarane



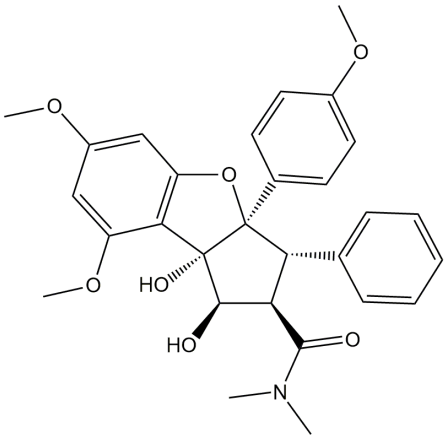
Flavagline



Oleic acid



Pregnane



Rocaglamide

Structures of Important and Characteristic Chemical Constituents of *Amoora wallichii*

Biological Activities:

Antimicrobial Activities: The petroleum ether, methanol, benzene and aqueous extracts of the leaves were tested for their antibacterial and antifungal activity. The methanol and aqueous extracts were found to be most effective against most of the tested organisms (Lavanya *et al.,* 2006)

Cytotoxic activity: Cytotoxic activity towards human cell lines was detected in fractions obtained from *A. wallichii* with LNCaP cell proliferation stimulating activity while inhibiting PC-3 cell proliferation (Claudia et al., 2014).

Insecticidal activity: The bark was extracted with distilled water and the extract was bioassayed at 2% and 5% concentrations for insecticidal and antifeedant activity against 3rd instar of rice leaf folder (*Cnaphalocrocis medinalis* Guenee-Pyralidae: Lepidoptera) by poison food assay under laboratory conditions. It was found that the extract showed around 20-50% larval mortality (Suhasini and Arivudainambi, 2019).

Patent and Commercial Products (if any): No records are available.

Scope of further R & D: *Amoora wallichii* presents a promising avenue for further research and development due to its varied biological activities and ethnobotanical applications. Future studies should focus on isolating and characterizing the bioactive compounds responsible for its reported antimicrobial, cytotoxic, and insecticidal properties. Detailed pharmacological investigations are needed to validate the traditional medicinal uses of its extracts, particularly in treating skin allergies, astringency, and diarrhea. Additionally, exploring the tree's potential as a natural insect repellent could lead to eco-friendly pest management solutions. Given its distribution across various ecosystems, ecological studies on its role within these habitats and its conservation status are also essential. Advances in sustainable harvesting and propagation techniques could ensure the preservation and utilization of this valuable species.

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Anogeissus acuminata
(Roxb. ex DC.) Wall. ex Guill. & Perr.

Synonyms:
Conocarpus acuminata Roxb. ex DC.,
Anogeissus tonkinensis Gagnep.,
Anogeissus pierrei Gagnep.,
Andersonia acuminata Roxb. ex Wight & Arn.,
Conocarpus hirtus Buch.-Ham. ex Wall.,
Conocarpus lanceolatus Heyne ex Wall.

Local/Common/Popular Name(s):
Button-tree, ***Hindi:*** Dhau, Dhoy, Dhaura, ***Tamil:*** Nunnera, ***Malayalam:*** Panchman, Vekkali, ***Bengali:*** Itchri, ***Telugu:*** Pasi Chettu, Pedda Manu, Bu-Chakaram, ***Urdu:*** Pasi.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Tracheophyta
Class	:	Magnoliopsida
Order	:	Myrtales
Family	:	Combretaceae
Genus	:	*Anogeissus*
Species	:	*Anogeissus acuminata*

Plant Description: *Anogeissus acuminata* tree can grow up to a height of 20 meters and have a trunk diameter of one meter. When young, the branchlets are slightly drooping and slender with golden villous petioles and leaf blades. The leaf blade is lanceolate and measures approximately 4 to 8 cm X 1 to 3 cm. The abaxial surface of the leaf is gray-green and pilose mostly in the axils of lateral veins whereas the adaxial surface is green and glabrous to glabrescent. The base of the leaf is narrow or obtuse while the apex is acuminate. The capitula is 9 to 13 mm in diameter and bracts are deciduous and linear measuring about 4 to 5 mm. In sessile flowers, the calyx tube is about 5 mm long, abaxially yellow pubescent and densely so on the ovary and tubular part and sparsely so on the cupular part. The filaments measure 3 to 4 mm. The fruit ca. 6 × 5 mm including beak and ferruginous pubescent distally. The leaf fall occurs from December to January, new foliage appears from April to May, flowering occurs from August to March and fruiting occurs from September to April (Pullaiah & Pullaiah, 2007).

Distribution: *A. acuminata* is widely distributed in South Asia, India, Bangladesh, Myanmar, Thailand, Cambodia, Laos, Vietnam Arabian Peninsula, and Africa. In India it is found in Palakkad district in Kerala, Khurda district in Odisha, Vishakapatnam district, East Godavari district, Krishna district, West Godavari district, Srikakulam district, Kadapa district, Kurnool district in Andhra Pradesh (Rao et al., 2019).

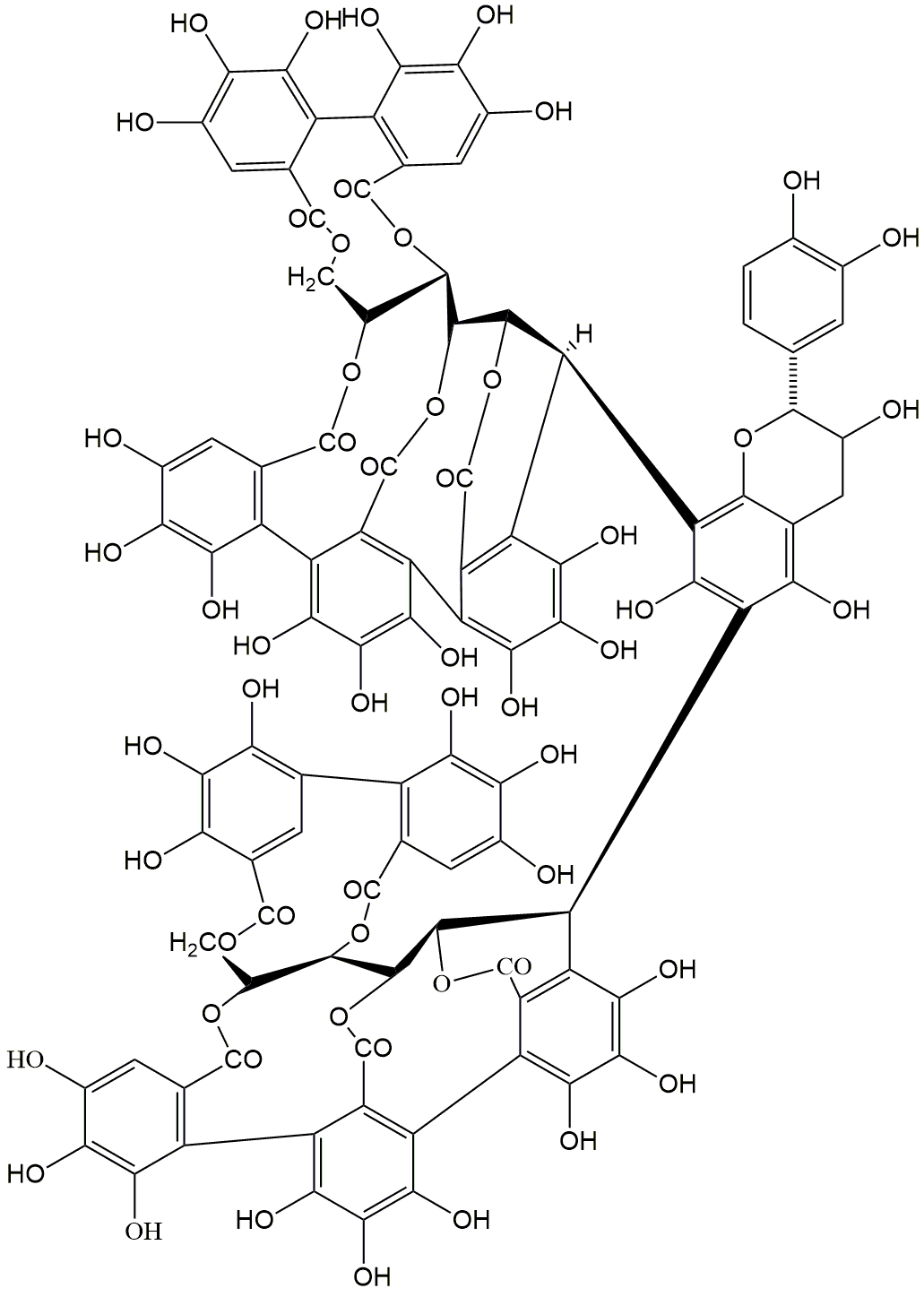
Habitat: *A. acuminata* grows in tropical lowland open forests or semi-deciduous forests at heights below 700 meters above mean sea level. It grows mainly in deep, humus-rich, loamy soils along streams or river banks (Fern, 2018).

Ethnobotanical Significance: *A. acuminata* is popular all over the world for its medicinal uses in skin diseases like eczema, dermatitis, and skin ulcers (Hemamalini et al., 2010). It is widely used in the treatment of painful inflammatory conditions in India. Its anti-HIV and anti-snake venom activities have been well documented (Dahare et al., 2010).

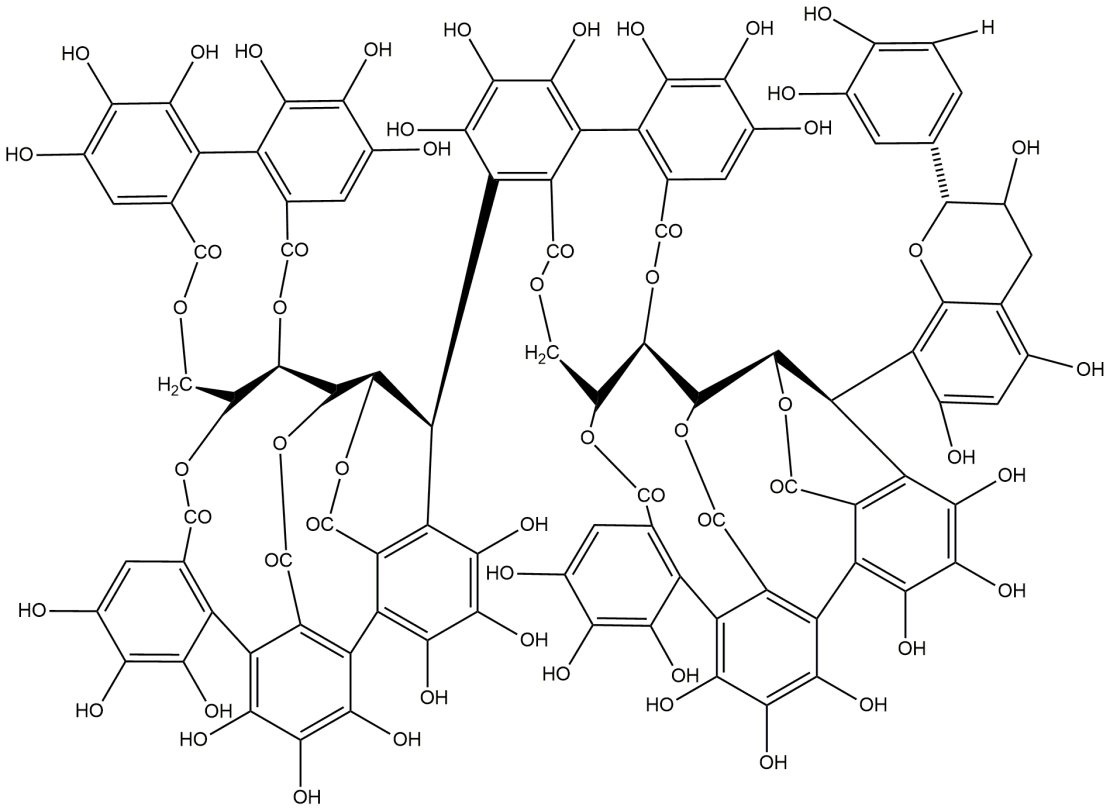
Phytochemistry:

Stem bark: Anogeissinin, anogeissusins A, and anogeissusins B, acutissimins A, acutissimins C, eugenigrandin A, castalin, castalagin, vescalagin carboxylic acid, castamollinin, grandinin (Rimando et al., 1994; Lin et al., 1991).

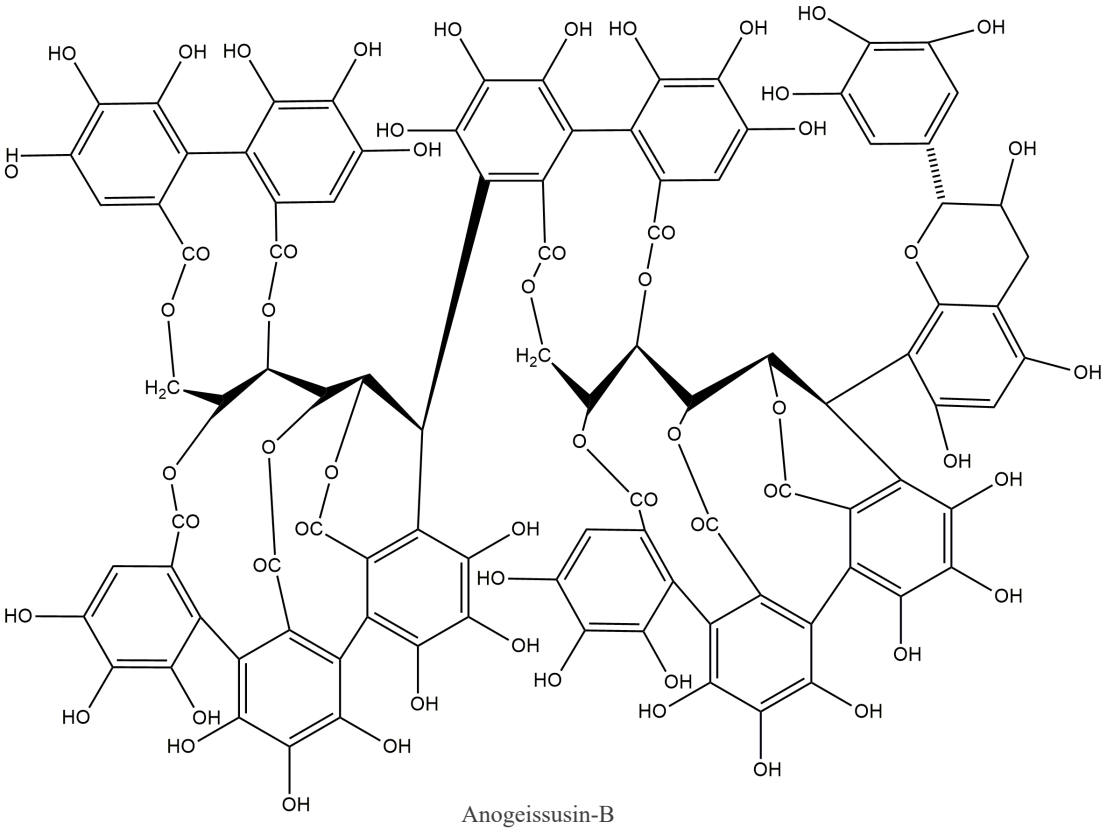
Stem: Conocarpan, dihydrodehydrodiconiferyl alcohol, stilbene, pterostilbene, anolignan A, anolignan B, anolignan C, (-)-secoisolariciresinol (Rimando et al., 1994; Lin et al., 1991).



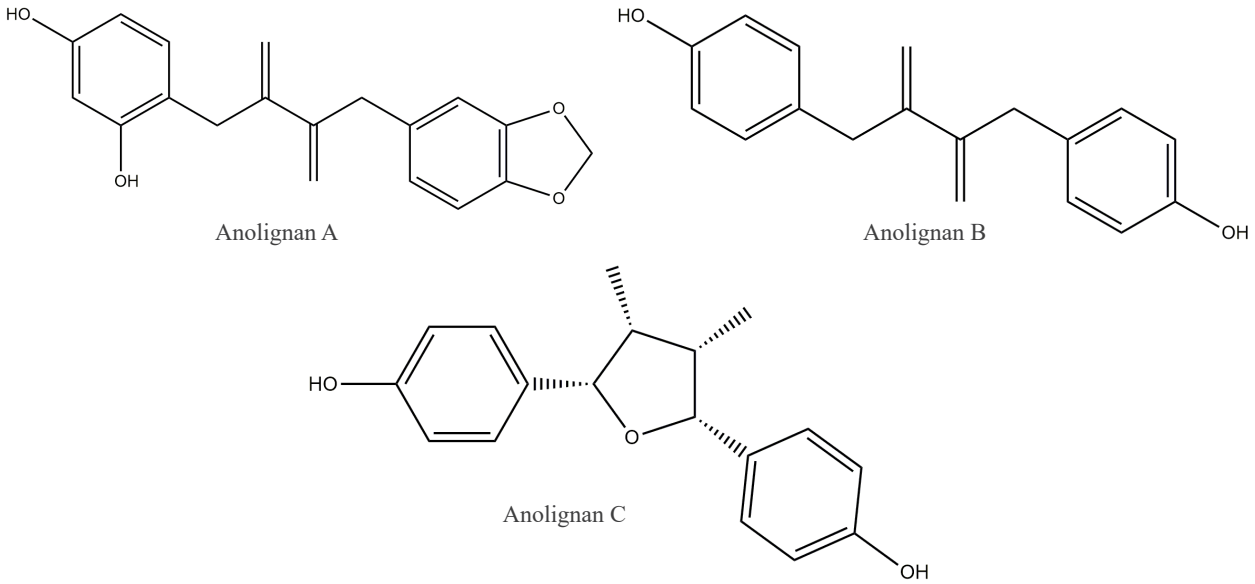
Anogeissinin



Anogeissusin-A



Anogeissusin-B



Structures of Important and Characteristic Chemical Constituents of *Anogeissus acuminata*

Biological Activities:

Anti-oxidant activity: The antioxidant activity of the methanol extract was evaluated through the DPPH scavenging assay and found that it had higher antioxidant potential than vitamin E with IC_{50} of 51 µg/ml. It is attributed to the higher concentration of xanthones, tannins, and glycosides in *A. acuminata* (Zaruwa et al., 2009; Zaruwa, 2012). Similarly, the aqueous extract of stem bark showed significant DPPH scavenging activity where ascorbic acid was used as standard (Manosroi et al., 2011). The methanol extracts of the leaves and bark were evaluated for *in vitro* antioxidant activity which was analyzed by 1,1-Diphenyl-2-picrylhydrazyl (DPPH) radical scavenging assay, reducing power assay and TBA (thiobarbituric acid) assay where vitamin C was used as a standard. The results revealed that the extracts possessed significant anti-oxidant activity (Navale & Paranjape, 2016).

Anti-microbial activity: The methanol extract of the leaves was investigated against clinically isolated gram-positive bacteria and gram-negative bacteria and was found to possess anti-bacterial activity (Mishra et al., 2017; Mishra & Padhy, 2013). Using leaf extract of *A. acuminata*, Ag nano particles were synthesized which demonstrated antibacterial activity against MDR bacterial pathogens *in vitro*, isolated from clinical samples. Moreover, non-toxicity to humans was assessed with lymphocytes cultured *in vitro* from human umbilical cord blood with the MIC value of 500 mg/l for synthesized AgNPs and the LC_{25} value was 2951.21 mg/l (Hemamalini et al., 2012; Hemamalini et al., 2010)

Anti-diabetes activity: In alloxan-induced diabetic mice, significant hypoglycemic activity was observed with the maximum fasting blood glucose reduction shown at the fourth hour. The hypoglycemic activity of *A. acuminata* was comparable to insulin but more potent than glibenclamide. This study confirmed the traditional use of *A. acuminata* in diabetes (Zaruwa, 2012). The hypoglycemic efficiency of its aqueous extract has earlier been reported and observed to be comparable to insulin with fivefold free radicals scavenging activity of ascorbic acid (Manosroi et al., 2011). The methanol extract of the leaves and the bark were evaluated for antidiabetic activity which was analyzed by *in vitro* protein tyrosine phosphatase 1B (PTP 1B) inhibition assay where suramin was used as standard. The extracts demonstrated significant PTP 1B inhibitory activity. Since PTP 1B is a downregulator of insulin, signaling inhibition of PTP 1B may improve insulin sensitivity and glucose utilization by tissues and thereby prevent long-term complications of diabetes mellitus (Navale & Paranjape, 2016).

Cytotoxicity: Conocarpan, dehydrodiconiferyl alcohol, and pterostilbene isolated from the stem showed *in vitro* cytotoxicity in various cancer cell lines. Cytotoxicity of the isolated compounds from the stem was evaluated and conocarpan showed

ED_{50} of 17.6, 15.7, 3.0, and 8.7 g/ml against LU-1, COL-1, P388, and ZR-75-1 cell lines respectively (Rimando et al.,1994).

Hepatoprotective activity: The phenol-enriched ethyl acetate fraction of *A. acuminata* (AAE) was evaluated for hepatoprotective activity against ethanol-induced liver toxicity in rats. The results revealed higher levels of key serum biochemical injury markers i.e. ALT, AST, ALP, GGT, and TBL. The oral administration of AAE lowered the elevated levels of biochemical markers and interleukin, and enhanced the level of enzymatic antioxidants while downregulating the expression level of proapoptotic genes and upregulating the expression levels of antiapoptotic genes along with improved liver histopathology (Pal et al., 2022).

Cardioprotective and Hypotensive activity: The crude extract of *A. acuminata* produced positive effects in left ventricular hypertrophy in Sprague Dawley rats observed hemodynamically by a decrease in cardiac cell size and fibrosis along with the absence of inflammatory cells along with reduced levels of angiotensin-converting enzyme (ACE) and renin concentration along with increased concentration of nitric oxide (NO) and cyclic guanosine monophosphate (cGMP). The *in vivo* and *ex vivo* studies provided evidence of vasorelaxant, hypotensive, and cardioprotective properties facilitated through blockage of voltage-gated Ca^{++} ion channel (Saqib et al., 2020).

Patents and commercial products :

- Compositions containing zinc PCA and *Anogeissus* extract, Patent No: WO2012050745A2.
- Use of *Anogeissus* extract for fibrillin production in skin, Patent No: CA2828955A1.
- Compositions containing DNA repair enzyme and *Anogeissus* extract, Patent No: CA2799194A1.

Scope of further R&D: *A. acuminata* holds significant potential for further research and development, given its diverse medicinal properties and phytochemical composition. Future studies should focus on isolating and characterizing the bioactive compounds responsible for its antioxidant, antimicrobial, antidiabetic, cytotoxic, hepatoprotective, cardioprotective, and hypotensive activities. Investigating the molecular mechanisms underlying these biological effects can provide insights into novel therapeutic approaches for managing oxidative stress, infections, diabetes, cancer, liver diseases, and cardiovascular conditions. Additionally, exploring the safety profile and potential side effects through rigorous toxicological assessments will be crucial for developing standardized extracts or compounds for clinical use. Ecological studies to understand its role in various habitats and efforts to cultivate and sustainably harvest *A. acuminata* can ensure its conservation and continued availability for medicinal and therapeutic applications.

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Anogeissus pendula
Edgew.

Synonyms:
Anogeissus myrtifolia Wall.,
Conocarpus myrtifolius Buch.
-Ham. ex Wall.

Local/Common/Popular Name(s):
Kardhai, Dhok, Dhonk, Dhao, Dhau, Dhaunkra, Dhaukra, Dhav, Kala dhaura, Kala dhavda, Button tree.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Dicotyledons
Order	:	Myrtales
Family	:	Combretaceae
Genus	:	*Anogeissus*
Species	:	*Anogeissus pendula*

Plant Description: *Anogeissus pendula* is a slow-growing deciduous tree belonging to the family Combretaceae. It is generally small to medium in size, seldomly attaining height of 9–12 m and a girth of 1.5 m. The bark of the tree is extremely variable, smooth and silvery initially becoming grey and rough with dark, chapped patches in old trees with pendulous or drooping branches. The leaves are small, usually only 1–2 cm long, narrowed at both ends arranged in opposite or near opposite pairs. New leaves are soft and velvety with silvery hairs that smooth out over time. The flowers are tiny and grouped in spherical heads with each flower being 8–14 mm in diameter, greenish-yellow in colour and stamens sticking out in all directions without petals and a prominent and cup-shaped calyx. The fruits are flat and nearly circular in outline with a long beak packed together in round heads (Rai and Rai, 2009; Hocking, 1993; Singh, 1982; Mathur, 1956). The leaf fall in the tree occurs from December to March, with flowering occurring from August to September and fruiting occurring in November (Krishen, 2013).

Distribution: *A. pendula* is distributed throughout tropical Asia and Africa. It grows in dry, hot regions of India, commonly occurring in the dry tropical forests and dry mixed deciduous forests of Rajasthan, part of Gujarat, Madhya Pradesh, and Haryana and Bundelkhand region of Uttar Pradesh. It is a dominant tree and abundant in many parts of Rajasthan including the Aravalli hills and Ajmer-Marwar forests. It is also found in the Sabarkantha and Banaskantha divisions of Gujarat. Furthermore, it is distributed naturally in crevices of rocks of the Bundelkhand region especially northwards to the Jhansi, Hamirpur, and Banda districts of Uttar Pradesh. The plant is also distributed in regions of the river Narmada in Nimar valley, Gird zone, and Kymore Plateau and Satpura Hill regions of Madhya Pradesh (Rai & Rai, 2009; Singh, 1982).

Habitat: *A. pendula* grows on regions with relatively poor C/N ratio (10 or less). It grows well in soils with pH ranging from 5.5 to 7.0, silt plus clay proportion of 10 - 30%, base exchange

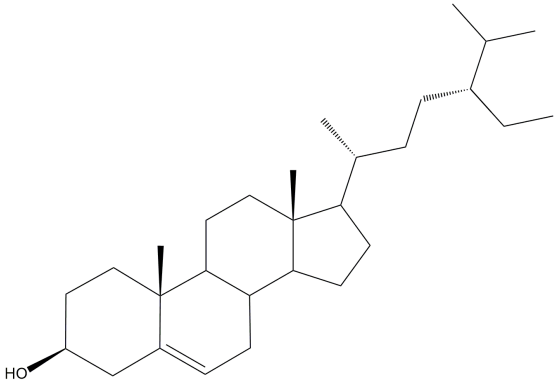
capacity of 2.2–10.4 mcq/100g, organic matter of 1.7%, and available phosphorous around 140–180 kg/ha, K_2O of 220–300 kg/ha and total nitrogen of about 0.003– 0.004% (Gupta, 1967). It also grows in different soil types such as gneiss rock giving rise to a thin layer, sandy red soils and bare rocky outcrops. However, good growth is obtained where the soil is deep and the underlying rocks gneiss and schist were observed (Bhargava, 1951). It can withstand a tropical climate with an annual rainfall of 400 to 950 mm and extreme temperatures ranging from -3 to 47°C (Troup, 1986; Srivastav et al., 2004; Rai, 2017).

Ethnobotanical Significance: Traditionally, different plant parts of *A. pendula* i.e. stem bark, seeds, fruit and twigs have been used for treating various ailments such as gastric disorders, wound healing, skin diseases, diarrhoea, dysentery, cough, and burns (Nainwal & Verma, 2018; Singh et al., 2016). Several tribal communities like Kol, Gond, Mawasi, etc. residing in and around the Chitrakoot forest areas of Madhya Pradesh often use the decoction prepared from the twigs of *A. pendula* for applying on body burns to clear burn scars (Mishra, 2015). In Kalinjar Hill, Banda District (U.P.), the seeds and barks of *A. pendula* are used for treatment of dysentery (Singh & Shahi, 2008). *A. pendula* is also used for obtaining fodder, timber, gum, in dye production and tanning along with other ethnomedicinal uses. The leaves paste of *A. pendula* is used in reducing external swelling (Vardhana, 2008).

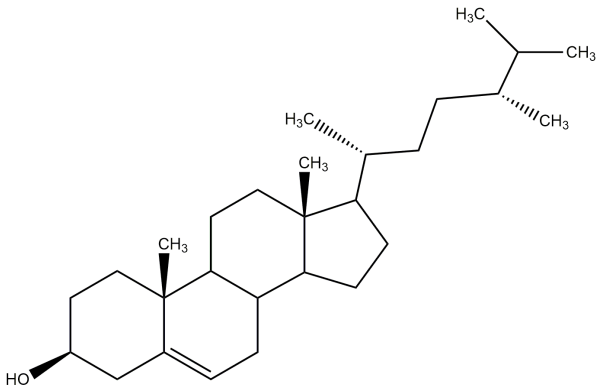
Phytochemistry:

Leaves: Chromone-substituted dihydrotriflavonol, β-sitosterol, stigmasterol, campesterol, (Lata & Bhadoria, 2010; Saxena & Dhavan, 2001; Sharma & Saini, 2019) (2R, 3R)- (+)-gallocatechin-(4β → 8)4-(2R, 3R)-(+)-gallocatechin, 3-O-galloyl-(2S, 3S)-(–)-epicatechin- (4α → 8)-[3-O-galloyl-(2S, 3S)-(–)-epicatechin (4α → 8)] 2-(2S, 3S)-(–) -epicatechin (Lata et al., 2023).

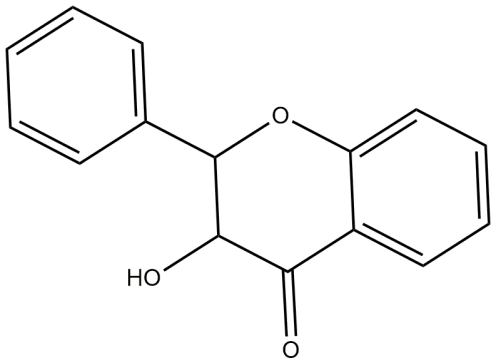
Bark: β-sitosterol, stigmasterol, campesterol (Sharma & Saini, 2019).



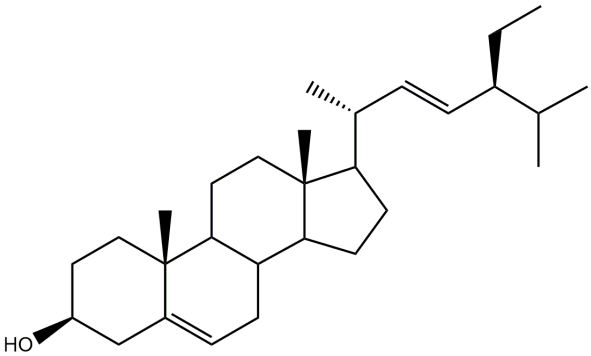
β-Sitosterol



Campesterol



Dihydroflavonol



Stigmasterol

Structures of Important and Characteristic Chemical Constituents of *Anogeissus pendula.*

Biological Activities:

Anti-oxidant activity: The methanol and hydroalcoholic extracts of the leaf and stem of *A. pendula* were evaluated for anti-oxidant activity using 1,1-diphenyl-2-picrylhydrazyl (DPPH), hydrogen peroxide radical scavenging tests (H_2O_2) and Ferric reducing antioxidant power (FRAP) assay. The extracts demonstrated scavenging capabilities against them and therefore exhibit potential anti-oxidant activity (Danai et al., 2021; Arunadevi et al., 2010).

Anti-bacterial activity: The phytosterols isolated from the leaves and the bark of the plant demonstrated antimicrobial activity against some pathogenic microbes where the leaves exhibited maximum antibacterial potential against *Streptomyces grisveus* and minimum antibacterial potential against *Escherichia coli* while the tested bacterial strains i.e. *Bacillus subtilis*, *Staphylococcus aureus*, *E. coli,* and *S. grisveus* were found to be resistant in bark (Sharma & Saini, 2019). The leaf and stem extracts of *A. pendula* were evaluated for anti-bacterial activity using the disc diffusion technique and minimum inhibitory concentration (MIC) was investigated against the bacterial strains i.e. *E. coli*, *B. subtilis*, *Pseudomonas putida,* and *S. aureus*. The results revealed that the extracts limited the development of strains (Danai et al., 2021).

Anti-fungal activity: The phytosterols isolated from leaves and bark of plant demonstrated antifungal activity against some pathogenic microbes where the leaves exhibited maximum antifungal potential against *Aspergillus niger* and minimum antifungal potential against *Trichoderma reesei* while the tested fungal strains i.e. *T. reesei, Fusarium oxysporum, Penicillium funiculosum,* and *A. niger* were found to be resistant in bark (Sharma & Saini, 2019).

Hepatoprotective activity: The polyphenolic compound 5, 7, 3′, 4′, 5′-penta hydroxy di hdro flavanol-3-O-(2″-O-galloyl)-β-D glucopyranoside isolated from *A. pendula* was tested for its neuroprotective effect in transient focal cerebral ischemia in rats. The study revealed that it can be used as a neuroprotective agent in stroke as it reduced apoptosis and was found to possess significant antioxidant and anti-inflammatory potential (Arunadevi et al., 2010).

Anti-ulcerogenic activity: The anti-ulcer activity of *A. pendula* was evaluated in pylorus-ligated albino Wistar rats. It was found that at doses of 200 and 400 mg/kg, the stem hydroalcoholic extract demonstrated substantial inhibition of gastric lesions and the results revealed that the hydroalcoholic extract has considerable antioxidant potential (Danai et al., 2021).

Cytotoxicity: The cytotoxicity of organic (CH_2Cl_2: MeOH in ratio 1:1) and aqueous extracts of seeds of *A. pendula* against brine shrimp (*Artemia salina*) was evaluated and LC_{50} was found to be 55 µg/ml and 127 µg/ml, respectively which indicates significant cytotoxic potential (Cantrell et al., 2003).

Anti-diabetic activity: The aerial parts of *A. pendula* were used for the treatment of diabetes and inflammation (Marles & Farnsworth, 1995; Maheshwari, 1963). The ethyl alcohol extract of aerial portions is said to have diuretic and cardiovascular stimulating properties (Jain et al., 2009). The seeds also possess haemagglutinating properties against the human A, B, and O red cells (The Wealth of India, 2003). The ethyl alcohol extract from aerial parts was found to be a diuretic and cardiovascular stimulant (Pullaiah, 2006). Normal antidiabetic activity was also reported in aerial parts of the plant (Marles & Farnsworth, 1995).

Toxicology: The ariel parts of the plant were found to be non-toxic through the oral route in rodents (Marles and Farnsworth, 1995).

Patents commercial products:

- A nonsteroidal anti-inflammatory compound from tree: *Anogeissus pendula* Edgew, Patent No: 1484/DEL/2009
- Compositions containing Zinc PCA and *Anogeissus* extract, Patent No: WO2012050745A2
- Use of *Anogeissus* extract for fibrillin production in skin, Patent No: CA2828955A1
- Compositions containing DNA repair enzyme and *Anogeissus* extract, Patent No: CA2799194A1.

Scope of Further R&D: The scope for further research and development on *A. pendula* is extensive due to its diverse pharmacological properties and ethnobotanical uses. Investigating its bioactive

compounds such as β-sitosterol, stigmasterol, and campesterol can lead to novel therapeutic agents for conditions like gastric disorders, wound healing, skin diseases, and dysentery. Detailed studies on its antioxidant, antibacterial, antifungal, and anti-ulcerogenic activities could yield new treatments for oxidative stress-related diseases and microbial infections. The tree's hepatoprotective and cytotoxic potentials warrant exploration for liver protection and cancer therapy. Moreover, its traditional use in treating diabetes and inflammation suggests potential for developing antidiabetic and anti-inflammatory medications. Evaluating its safety and efficacy in various clinical models will be crucial. Additionally, the plant's adaptability to different soil types and climatic conditions makes it suitable for ecological conservation projects. Research on its growth requirements and environmental benefits could enhance its application in reforestation and sustainable agriculture. Further, exploring its economic value for timber, gum, dye production, and as fodder can provide sustainable livelihood opportunities for local communities. Finally, examining existing patents and developing new commercial products based on *A. pendula* could significantly impact the pharmaceutical and cosmetic industries.

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Arnebia euchroma
(Royle ex Benth.) I.M.Johnst.

Synonyms:
Arnebia endochroma Aitch.,
Arnebia euchroma var. *grandis* (Bornm.) Kazmi,
Arnebia perennis (Schrenk) A.DC.,
Arnebia tingens A.DC.,
Lithospermum euchromon Royle,
Macrotomia euchromon Paulsen,
Macrotomia grandis Bornm.,
Macrotomia oginoi Kitam., *Macrotomia perennis* Boiss

Local/Common/Popular Name(s):
Nepal: Dimok or Khamed; ***Iraq:*** Abu-Khalsa; ***Laddakh:*** Gaozaban; ***China:*** Xinjiang-Zicao or Ruan-Zicao; ***Japan:*** Nanshikon, kampoand; ***India, Nepal, Tibet:*** Ratanjot (trade name) (Devi and Kaundal, 2017, Bhatia et al., 2011, Bo et al., 2019, Nonami et al., 2002).

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Boraginales
Family	:	Boraginaceae
Genus	:	*Arnebia*
Species	:	*Arnebia euchroma*

Plant Description: *Arnebia euchroma* is a perennial erect herb with height about 30-40cm and thick rootstock of purple dye (Ambrish et al., 2014). The roots of the plant are purple in colour and used in preparations of several herbal medicines (Devi and Kaundal, 2017). The plant has several stems arising from root base and axils of leaves with the stems densely covered with thick trichomes and white tuberculate bases. The basal leaves with petioles are lanceolate and ciliate base and are acute at apex with entire margins and densely covered with thick trichomes of white tuberculate bases on both surfaces and have measurements of 2.8-14.5 cm X 0.5-1.2 cm. The cauline leaves are sessile, ovate-lanceolate with upper leaves shorter and broader than lower ones and subcordate at base with acute apex and glandular-hairy on both surfaces with entire margins and measurements of 2.5-8.5 cm X 1-2.1 cm. The inflorescence is terminal with sub-globular cymes of width 5-6 cm. The bracts are leafy and shorter than calyx. The flowers are funnel-shaped and colour varies from purple to mauve to yellowish. The calyx is hispid, lobed with lobes linear-oblong or lanceolate and length of 0.8-1.0 cm. The corolla is tubular with tube growing up to 1.5 cm in length. The anthers are linear bifid. The style is short and stigma are 2 in number. The nutlets are ovoid, grayish and tuberculate with length 3-4mm (Ambrish et al., 2014). The reproductive cycle of the plant ranges from June to August (Devi and Kaundal, 2017) while the flowering and fruiting occur during July to August (Ambrish et al., 2014).

Distribution: *A. euchroma* grows in several alpine regions of the world including North Africa, the Himalayas and several other parts of Asia (Nasiri et al., 2016). The plant is widely distributed in Xinjiang and Tibet regions of China, North-West India, Pakistan, Nepal and Afghanistan (Cao et al., 2020), the Central Asia area of the Soviet Union and Siberia (Lu et al., 2010). In India, it grows in regions of Jammu & Kashmir, Himachal Pradesh and Uttarakhand (Ambrish et al., 2014) and is most abundant in Himachal Pradesh particularly, in the wild in Lahaul-Spiti area at an altitude of 3000-4200 m (Huang et al., 2019) and Nako and Chango in Kinnaur (Devi and Kaundal, 2017).

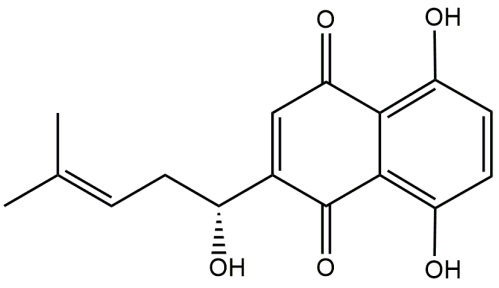
Habitat: *A. euchroma* grows in well-drained sandy soil but can also grow in nutritionally poor soil but cannot grow in shade (Devi and Kaundal, 2017).

Ethnobotanical Significance: *A. euchroma* has several ethnobotanical uses in various countries like China, India, Tibet, Japan, Mongolia, and Korea. In China, *A. euchroma* is a traditional Chinese herbal medicine (TCM) recorded in the Pharmacopoeia of China and has been extensively used in China and other countries for the treatment of various diseases. It is a traditional medicinal drug, called "Zicao" or "Ruanzicao" in China. It is used as an herbal medicine for the treatment of wounds and inflammation, for healing burns, and also used as a colorant in cosmetics, medicines, fabrics, and food in diverse cultures. Zicao (literally translated as ''Purple Herb'') is the dry root of *Lithospermum erythrorhizon* or *A. euchroma* (Bhatia et al., 2011). Arnebiae Radix (the root of *A. euchroma*), a common herbal medicine in China, is often utilized to treat blood-heat syndrome and has been reported to exert an effect on the heart. Its root is also used as a traditional medicine to treat eruption, smallpox, jaundice, burns, eczema, and constipation since ancient times (He et al., 2019). *A. euchroma* is one of the vasoactive antithrombotic herbal medicines in China (Ko et al., 1995). It is often used for the treatment of bovillae, exanthema maculosum, aurigo, peliosis, apostaxis, bloody stranguria, eczema, fire burns etc., (Lu et al., 2010). In Japan, it is used as a medicine for antipyretic and antibacterial purposes (Nonami et al., 2002). In Korea, it is used as an herbal medicine for the treatment of wounds and inflammation and for healing burns. It is also used for the production of traditional liquor (Jindo hongju) (Bhatia et al., 2011; Fu et al., 1999). In Mongolian traditional prescription, *A. euchroma* has been used to treat lung heat and haemostasis (Bo et al., 2019). In India, it is a highly valued, critically endangered medicinal plant of the Himalayas. The extract from roots has been used as a dark maroon natural colorant in syrups, tonics, ointments, and hair dyes and also for dyeing fabrics. It is also a well-recognized ingredient in herbal oils used for the massage of babies. The roots are used in toothache, earache and eye diseases as well as for healing of cuts, wounds and fire burns. The purple roots are also used as a hair tonic by the local people and are often dug out for sale. The roots of *A. euchroma* have a long history of use in treating bacterial infections in various folk medicines. (Cao et al., 2020).

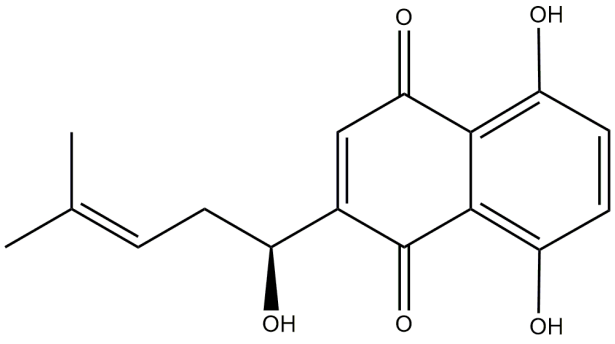
Phytochemistry:

Roots: Alkannin, shikonin, β,β-dimethylacrylshikonin, acetylshikonin, propionylshikonin, deoxyshikonin, isobutyrylshikonin, isovalerylshikonin (He et al., 2016; Ge., et al., 2006), β-acetoxyisovaleryl shikonin, isobutylshikonin, 2-methyl-n-butyryl shikonin, β-hydroxyisovaleryl shikonin (Bhatia et al., 2011), teracrylshikonin (Ko et al., 1995), acetyl alkannin, β-acetoxyisovaleryl alkannin, deoxyalkannin, β, β- dimethylacryl alkannin, α-methylbutyryl alkannin, isovalerylalkannin (Fan et al., 2012), isobutyrylalkannin, β-hydroxy isovaleryl alkannin, propionylalkannin, teracrylalkannin (Damianakos et al., 2012), methyl jasmonate, arnebiabinone (Damianakos et al., 2012)

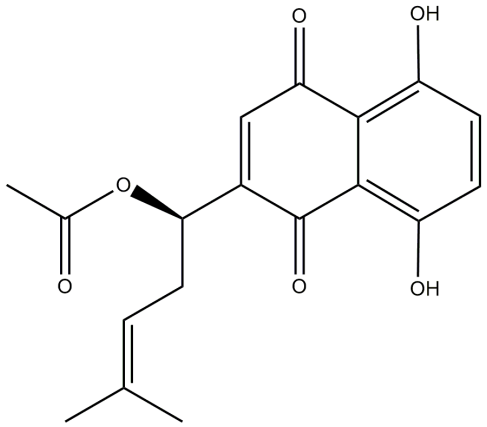
Leaves: Tormentic acid, 2α-hydroxyursolic acid (Optics et al., 2008)



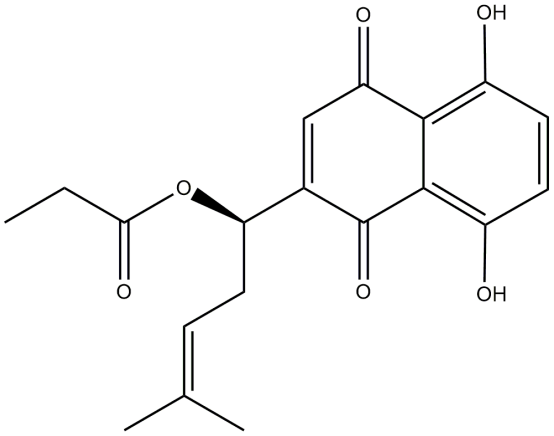
Shikonin



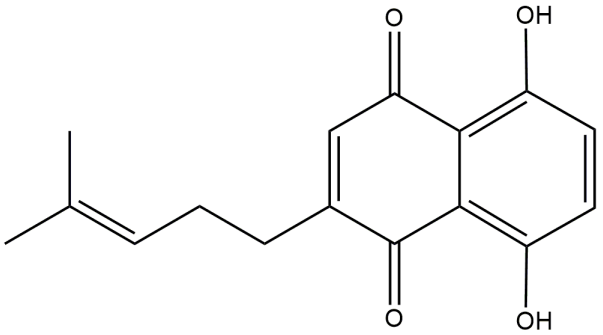
Alkannin



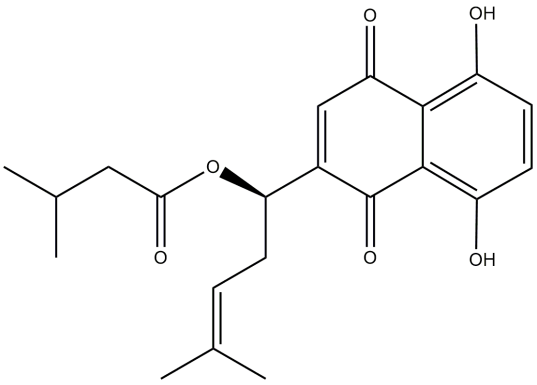
Acetylshikonin



Propionylshikonin



Deoxyshikonin



Isovalerylshikonin

Structures of Important and Characteristic Chemical Constituents of *Arnebia euchroma.*

Biological Activities:

Anti-cancer activity: β, β-Dimethylacrylshikonin (DMAS), an active ingredient of *A. euchroma* is reported to possess anti-neoplasm properties and to stimulate autophagy in lung adenocarcinoma cells. It is found that cytoprotective autophagy was triggered by DMAS via a signaling cascade in human lung adenocarcinoma cells. Therefore, the combination of DMAS and autophagy inhibitors as novel therapeutic options for lung adenocarcinoma will be helpful for treatment and prevention of lung cancer (Jang et al., 2014). It is observed that shikonin from *A. euchroma* decreased the expression of human androgen receptor (AR) at both mRNA and protein levels in human prostate cancer cells and induced the inhibition of cell growth through modulation of AR in androgen-responsive prostate cancer cells. The mechanism is believed to be that shikonin decreased the transcriptional activity of AR and AR protein levels in both the nucleus and cytoplasm which in turn blocked gene expression and growth inhibition of prostate cancer cells. The results indicated that shikonin decreases the AR protein level in a dose, time-dependent manner effectively and hence can be recommended as a candidate in cancer chemotherapy for human prostate cancer (Bo et al., 2005; Ko et al., 1995).

Anti-arthritic activity: Hydroxynaphthoquinones are the major anti-inflammatory active constituents in *A. euchroma*. The anti-arthritic activity of a hydroxylnaphthoquinone mixture (HM) of *A. euchroma* was evaluated alongwith its anti-inflammatory and analgesic effects. The anti-arthritic efficacy of HM was examined using complete Freund's adjuvant- and bovine type II collagen-induced arthritic models. Its anti-

inflammatory and analgesic effects were analyzed using Rat Paw. The paw edema, polyarthritis index, and histopathological change were evaluated. The analgesic effect was assessed using the chemical and thermal models of nociception. HM was able to suppress the joint inflammation and synovitis in rats and also proved to be effective in reducing the degree of cartilage and bone destruction while also lowering the levels of TNF-α and IL-1β in serum and reduced inflammatory cell infiltration such as macrophages in synovial tissues. The protection of HM was superior to that of reference drugs such as prednisone acetate or etanercept, and showed no direct deleterious effect. Similarly, HM showed significant analgesic effects (Fan et al., 2012).

Anti-inflammatory activity: The petroleum ether, chloroform, alcoholic and aqueous extracts (500 mg/kg, p.o., each) of *A. euchroma* roots were evaluated for anti-inflammatory activity using rat paw edema model and were found to exhibit 61.2%, 45%, 27.5%, and 60% of edema inhibition, respectively. The activity possessed by petroleum ether and aqueous extracts was comparable to the reference drug, ibuprofen (50 mg/kg, orally) (Kaith et al., 1996). Percentage edema inhibition increased with an increase in a time interval and was found to be maximum at 5 h after carrageenin injection. The probable reason for anti-inflammatory activity may be presence of phytoconstituents such as sterols, steroidal glycosides and triterpenes which act as active anti-inflammatory agents at lower doses (Kaith et al., 1996).

Burn healing activity: *A. euchroma* due to its wound-healing properties is tested as an ointment for second-degree burns. The *A. euchroma* ointment (AEO) was made according to an Iranian traditional medicine formula with certain modifications to obtain a homogenous ointment. The healing time was significantly shorter in the site treated with AEO than sulfadiazine (SSD). The severity of pain and burning was reduced in the AEO site compared with the SSD site at the time of the dressing change, while the warming score was significantly higher in the AEO wound area. Side effects were lower in the site treated with AEO. The reason behind this was that naphthoquinine derivatives from *A. Euchroma* possess anti-inflammatory and wound-healing properties (Nasiri et al., 2016).

Toxicology: There are no reports on the toxicity of *A. euchroma.*

Patents and commercial products (if any):

- Method for producing alkannin by utilizing *A. euchroma* (Royle) Johnst hairy root, Patent No: CN101869591B
- Method for propagating isolated roots of *A. euchroma*, Patent No: CN115191351A
- Anti-liver cancer active substance of *A. euchroma* (Royle) Johnst and preparation method thereof, Patent No: CN114404467A
- Use of *A. euchroma* total polysaccharides in preparation of drug for preventing and treating acute lung injuries and acute respiratory distress syndrome, Patent No: CN103006739A
- Seedling transplanting method for *A. euchroma*, Patent No: CN114097559A
- Liquid chromatography-circular dichroism (LC-CD) identification method of *A. euchroma* and Radix Lithospermi, Patent No: CN103175928A
- Method for extracting isovalerylshikonin from *A. euchroma* and application of isovalerylshikonin in preparation of anti-liver cancer medicine, Patent No: CN115160137A
- Strain of cultivated cells of *A. euchroma* (Royle) Jonst. - producer of shikonin, Patent No: UA42151A
- Composition comprising mixture extract of *Ephedra sinica, Rheum palmatum* L and *A. euchroma* for preventing or treating obesity, Patent No: KR20150105552A
- *A. euchroma* dye preparation method, Patent No: CN102516801A
- Hui-nationality traditional Chinese medicine *A. euchroma* and rhizoma curcumae pills for treating lung cancer and preparation method thereof, Patent No: CN106668755A
- Composition comprising mixture extract of *Ephedra sinica, Rheum palmatum* L and *A. euchroma* for preventing or treating fatty liver disease, Patent No: KR20150105545A
- Preparation method of plaster containing traditional Chinese medicine *A. euchroma* component, Patent No: CN104523800A
- *A. euchroma* (Royle) Johnst. cell cultivation and prodn. process by solid two step method, Patent No: CN1058290C
- Hui-nationality Chinese herbal rhizoma curcumae- *A. euchroma* lung-protecting tablet

and preparation method thereof, Patent No: CN106668742A

- Method for transformation of Arnebia species, patent no: 2483/del/2004
- A process for production of naphthoquinone red pigments from adventitious roots of *A. euchroma*, patent no: 202111045278
- Use of *A. euchroma* total polysaccharides in preparation of drug for preventing and treating acute lung injuries and acute respiratory distress syndrome, Patent No: CN103006739A
- Strain of cultivated cells of *A. euchroma* (Royle) Jonst. - producer of shikonin, Patent No: UA42151A
- Method and culture medium for tissue culture and rapid propagation of *A. euchroma* (Royle) Johnst., Patent No: CN111194692A
- *A. euchroma* caffeic acid and rosmarinic acid glycosyltransferase, coding gene and application thereof, Patent No: CN114058602A
- Endophytic fungi of *A. euchroma* and application of endophytic fungi, Patent No: CN104745482A
- Culture medium capable of promoting *A. euchroma* cells to synthesize shikonin and preparation method of culture medium, Patent No: CN106754631A
- Method for establishing *A. euchroma* johnst fingerprint spectrum based on hpce (high-performance capillary electrophoresis) and application of *Arnebia euchroma* johnst fingerprint spectrum, patent no: cn107525840

Scope of further R&D: *A. euchroma*, with its rich ethnobotanical history and diverse medicinal properties, presents a significant opportunity for further research and development (R&D). Given its traditional use in treating wounds, burns, and inflammation across various cultures, exploring its phytochemical constituents can uncover new bioactive compounds. For instance, the hydroxynaphthoquinone mixture (HM) has shown promising anti-arthritic, anti-inflammatory, and analgesic effects, making it a candidate for developing new therapeutic agents. The plant's anti-cancer properties, particularly the activity of β, β-dimethylacrylshikonin (DMAS) and shikonin, against lung and prostate cancers warrant deeper investigation. The potential to use these compounds in combination therapies, especially with autophagy inhibitors, could lead to more effective cancer treatments. Further R&D could also focus on optimizing extraction and purification processes for these bioactive compounds to enhance their efficacy and safety. Additionally, exploring sustainable cultivation and propagation methods, such as those described in existing patents, could ensure a steady supply of raw material without overharvesting wild populations. The development of standardized herbal formulations and clinical trials will be crucial in transitioning from traditional use to evidence-based modern medicine. This approach could lead to the commercialization of new drugs and health products, leveraging the diverse therapeutic potentials of *A. euchroma*.

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Balanites aegyptiaca
(L.) Delile

Synonyms:
Agialida abyssinica Van Tiegh, *Agialida arabica* Van Tiegh, *Agialida aegyptiaca* (L.) Kuntze, *Agialida barteri* Van Tiegh, *Agialida cuneifolia* Tiegh, *Agialida glomerata* Tiegh, *Agialida latifolia* Van Tiegh, *Agialida membranacea* Tiegh, *Agialida nigra* Van Tiegh, *Agialida palaestinaca* Tiegh, *Agialida roxburghii* Kuntze, *Agialida schimperi* Van Tiegh, *Agialida tombouctensis* Van Tiegh, *Balanites aegyptica* Wall, *Balanites arabica Blatter, Balanites fischeri* Mildbraed & Schlechter, *Balanites indica* Van Tiegh, *Balanites jacquemontii* Van Tiegh, *Balanites latifolia (*Van Tiegh.*)* Chiov, *Balanites roxburghii* Planch, *Balanites suckertii* Chiov, *Balanites zizyphoides* Mild braed & Schlechter, *Ximenia aegyptiaca* L, *Ximenia agihalid* Mill.

Local/Common/Popular Name(s):
Desert date, Soapberry tree.

Vernacular Names:
Ayurvedic: Ingudi, Angaar Vrksha, Taapasadrum, Taapasavrksha, Dirghkantaka., ***Unani:*** Hingan, Hanguul., ***Siddha:*** Nanjunda., ***Folk:*** Hingol, Hingota, Hingothaa., ***English:*** Desert date, Soapberry tree, Thorn tree, Egyptian balsam, ***Arabic:*** Heglig, ***French:*** Dattier du desert, Hagueleg, Balanite, ***Spanish:*** corona di Jesus

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Zygophyllales
Family	:	Zygophyllaceae
Genus	:	*Balanites*
Species	:	*Balanites aegyptiaca*

Botanical Description: It is a multi-branched, spiny shrub or tree up to l0 m tall. Crown spherical, in one or several distinct masses. Trunk short and often branching from near the base. Bark dark brown to grey, deeply fissured. Branches armed with stout yellow or green thorns up to 8 cm long. Leaves with two separate leaflets,leaflets obovate, asymmetric, 2.5 to 6 cm long, bright green, leathery, with fine hairs when young. Flowers in fascicles in the leaf axils and are fragrant, yellowish-green. Fruit is a rather long, narrow drupe, 2.5 to 7 cm long, 1.5 to 4 cm in diameter. Young fruits are green and tormentose, turning yellow and glabrous when mature. Pulp is bitter-sweet and edible. The seed is Pyrenees (stone), 1.5 to 3 cm long, light brown, fibrous, and extremely hard. It makes up 50 to 60% of the fruit. There are 500 to 1500 dry, clean seeds per kg. Flowers are small, inconspicuous, hermaphroditic and pollinated by insects. Seeds are dispersed by ingestion by birds and animals. The tree begins to flower and fruit at 5 to 7 years of age and maximum seed production is when the trees are 15 to 25 years old (Chothani et al., 2011).

Habitat: It is an evergreen tree found in many kinds of habitats, tolerating a wide variety of soil types, from sand to heavy clay and climatic moisture levels, from arid to sub-humid and grows well in alluvial sites with deep sandy loam and with uninterrupted access to water such as valley floors, riverbanks or the foot of rocky slopes (Orwa, et al., 2009). It is a lowland species growing up to 1000 m altitude in areas with a mean annual temperature of 20 to 30°C and mean annual rainfall of 250 to 400 mm (The Wealth Of India, 1998).

Distribution: Natural distribution is obscured by cultivation and naturalization. It is believed indigenous to all dry lands south of the Sahara, extending southward to Malawi in the Rift Valley the Arabian Peninsula and introduced into cultivation in Latin America and India. It has wide ecological distribution but is mainly found on level alluvial sites with deep sandy loam and free access to water. After the seedling stage, it is intolerant to shade and prefers open woodland or savannah for natural regeneration. It is a lowland species, growing up to 1000 m altitude in areas with a mean annual

temperature of 20 to 30°C and mean annual rainfall of 250 to 400 mm (Schmidt et al., 2001 The wealth of India, 1998).

Ethnobotanical Significance: In Egyptian folk medicine, the fruits are used as oral hypoglycemic (Kamel et al., 1998) and antidiabetic. An aqueous extract of the fruit mesocarp is used in Sudanese folk medicine in the treatment of jaundice (Kamel et al., 1998). The plant is used in food preparations and herbal medicine, especially in Africa and some developing Countries (Sarker et al., 2000). The fresh leaf of the plant Acalypha is pounded with a small amount of root of *B. aegyptiaca* and *Cissus quadrangular* and then soaked in water for an hour or two. It is decanted and administered intranasally and orally. Latex of the plant is used in epilepsy, administered through the intranasal route (Obidah et al., 2009). A plant stem is used as a toothbrush (Seifu, 2004). Fruits are used to treat dysentery and constipation. The seed oil is used to treat tumors and wounds (Araya, 2007). Fruit is used to treat liver disease and as a purgative and sucked by school children as a confectionary in some countries (Ojo et al., 2006, Barley et al., 1962). The bark is used in the treatment of syphilis and roundworm infections, and as a fish poison. Seeds are used as anthelmintic and purgative. Ground seeds are given to camels to cure impaction and colic (Bashir et al.,1984). In Chifra District, the root of the plant is used for the treatment of render pests and anthrax. In East Africa, it is widely used as an anthelmintic. The root is used in various folk medicines for the treatment of abdominal pain and as a purgative, as well the bark is employed as a fish poison and also as a remedy for malaria and syphilis. In Sudanese folk medicine, this plant is used to treat jaundice (Khan.,2009). In Chad, fresh twigs are put on the fire in order to keep insects away. For intestinal worms, the fruits are dried and mashed in millet porridge and eaten (Kwuosa et al., 1993). In Libya and Eritrea, the leaves are used for cleaning infected wounds. In Sudan and chadthebar, *B. aegyptiaca* is a component of soap (Kela et al., 1989). Seed is used as an expectorant, antibacterial, and antifungal. Fruit is used in whooping cough, also in leucoderma and other skin diseases. The bark is used as a spasmolytic (Khare C.P., 2007). The seed is used as a febrifuge (Creach P. Le.,1940). In Kenya, a root infusion is used as an emetic (Beentje et al., 1994). In asthma, about 10 gm of seed powder is taken with a glass of water in the morning for 10 days (Jagtap et al., 2007). Tablets are prepared from roots mixed with 'Hing' powder (*Ferula asafoetida*); by adding *Piper beetle* leaf, juices are taken once with water for 9 days, soon after the menstruation to avoid unwanted pregnancy (Vijigiri et al., 2010). The use of kernel oil for the treatment of wounds has been reported in Nigeria (Nkunya.1990).

Phytochemistry:

Leaves: Quercetin-3-glucoside, quercetin-3-rutinoside; 3-glucoside, 3-rutinoside, 3-7-diglucoside and 3-rhamnogalactoside of isorhamnetin (Breyer et al.,1982, Oliver-Bever et al.,1986),. caffeic acid, ferulic acid, gentisic acid, p-coumaric acid, sinapic acid, 2-methoxy-4-vinylphenol, 2,6-dimethoxyphenol, 2-methoxy-3(-2-propenyl)-phenol, 2-methoxy-4-(1-propenyl) -phenol, kaempferol, myricetin, isorhamnetin-3-O-galactoside, isorhamnetin 3-O-robinobioside (Murthy et al.,2020).

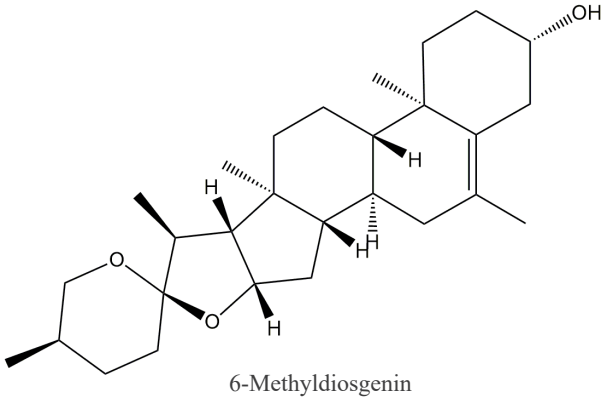
Fruit: 3-Rhamnogalactoside, diosgenin, 26-(O-β-D-glucopyranosyl)-3-β-[4-O-(β-D-glucopyranosyl)-2-O-(α-L-rhamnopyranosyl)-β-D-glucopyranosyloxy]-22, 26-dihydroxyfurost-5-ene (Nour et al., 1985), balanitoside (furostanol glycoside) and 6-methyldiosgenin, and balanitin-3, balanitin-6 and balanitin -7, diosgenyl saponins, pregn-5-ene-3β,16β, 20(R)-triol 3-O-(2,6-di-O-α-l-rhamnopyranosyl)-β-d-glucopyranoside (balagyptin), pregn-5-ene-3β,16β,20(R)-triol 3-O-β-d-glucopyranoside, di-, tri-, and tetra glucosides, 25 D-spirosta-3, 5-diene and 3-β-chloro-25-D-spirost-5-enebalanitin-1, -2, and -3 (Samuelsson et al., 1991 and Liu et al., 1982), 3-O-α-lrhamnopyranosyl- (1>2)-β -D-glucopyranosyl-(1>4)-β-D-glucopyranoside (Al-Thobaiti & Zeid, 2018).

Root: Yamogenin, 3β,12α,14β,16β)-12-hydroxycholest-5-ene-3,16-diylbis(*β*-D-glucopyranoside, (3β, 20S, 22R, 25R)-, and (3β, 20S, 22R, 25S)-26-(β-D-glucopyranosyloxy)-22-methoxyfurost-5-en-3-yl-β-D-xylopyranosyl-(1→3)-β-D-glucopyranosyl-(1→4) [α-L-rhamnopyranosyl-(1→2)]-β-D-glucopyranoside; (3β, 20S, 22R, 25R)- and (3β, 20S, 22R, 25S)-spirost-5-en-3-yl β-D-xylopyranosyl-(1→3)-β-D-glucopyranosyl-(1→4) [α-L-rhamnopyranosyl-(1→2)]-β-D-glucopyranoside (Hardman et al., 1970 and Pettit et al., 1991), rotenone (Murthy et al., 2020).

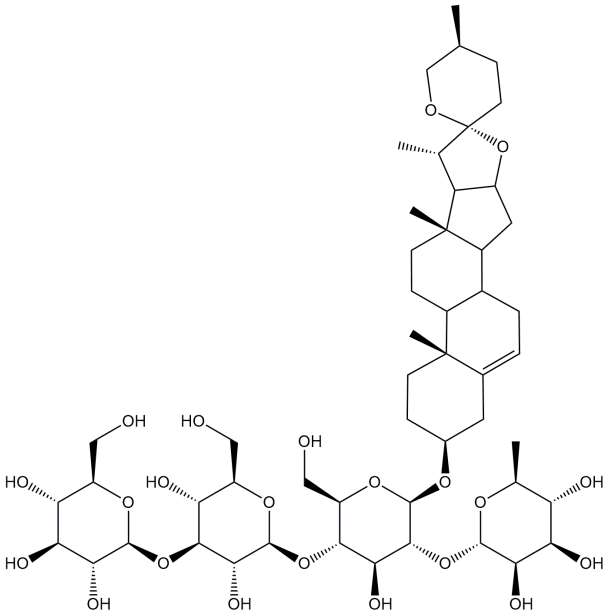
Bark: Furano coumarin bergapten, N-trans-feruloyl tyramine, N-cis-feruloyl tyramine, vanillic

acid, syringic acid; and 3-hydroxy-1-(4-hydroxy-3-methoxyphenyl)-1-propanone, 10-methyl-n-heptacosane, di glucosyl dirhamnoside, β-sitosterol, marmesin, balanitin-1,-2, and -3(Seida et al., 1981, Sarker et al., 2000, Ansari et al., 2006, Kapseu et al., 1997, Hardman et al., 1970, Breimer et al., 2007, Seida., 1979, Hammouda et al., 2005). syringic acid, vanillic acid, 3-hydroxy-1-(4-hydroxy-3-methoxyphenyl)-1-propanone (Murthy et al., 2020)

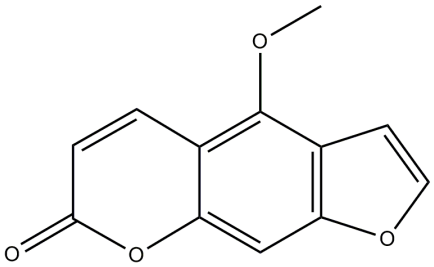
Seed: Balanitin-4, balanitin-5, balanitin-6, balanitin-7, deltonin, isodeltonin, (Al-Thobaiti and Zeid, 2018) 2,4-di-tert-butyl-phenol, 2,6-di-tert-butyl-phenol, campesterol, cholesterol, , β-sitosterol, stigmasterol (Murthy et al., 2020).



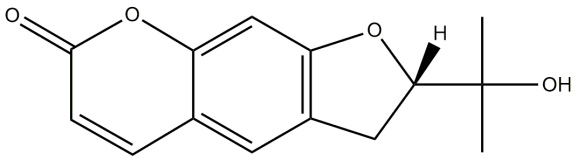
6-Methyldiosgenin



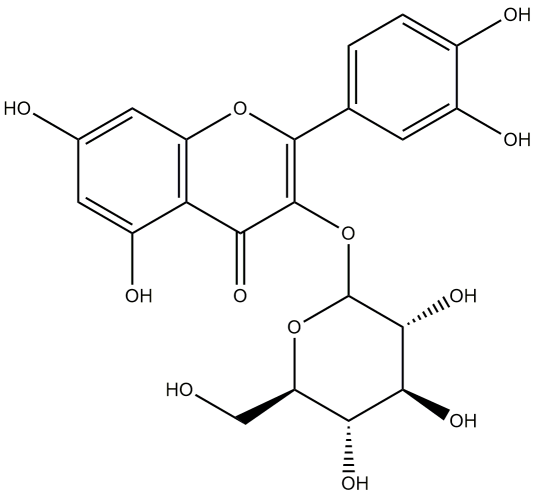
Balanitin 4



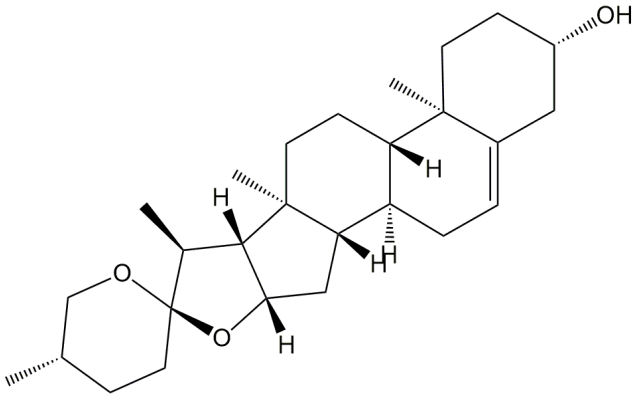
Bergapten



Marmesin



Quercetin-3-glucoside



Yamogenin

Structures of Important and Characteristic Chemical Constituents of *Balanites aegyptiaca.*

Biological activity:

Antioxidant activity: Literature data showed a wide range of bioactive compounds especially polyphenols and/or flavonoids responsible for the antioxidant potential of *B. aegyptiaca* fruit pulp of various origins (Hussain, et al., 2019). Balanitin-1 and balanitin-2 were derived from bark extracts and demonstrated antioxidant properties under in vitro conditions analysed on the basis of Briggs–Rauscher oscillating reaction. Polyphenols such as quercetin and kaempferol are the major components responsible for antioxidant activities. In addition, phytosterols including β-sitoterol, stigmasterol and campesterol have been reported to exhibit antioxidant activity. The polyphenols, phytosterols and saponins together might be responsible for the antioxidant activity (Murthy et al., 2020).

Hepatoprotective properties: The methanol extract of leaves was investigated for hepatoprotective activity against carbon tetrachloride (CCl_4)-induced hepatic damage in rats. Administration of the extract markedly reduced the CCl_4-induced elevation of serum marker enzymes such as glutamate pyruvate transaminase, glutamate oxaloacetate transaminase, alkaline phosphatase and bilirubin. Similarly, fruit mesocarp and stem bark aqueous extracts reduced CCl_4-induced hepatotoxicity in rats, as measured by liver enzyme activity, blood parameters and histopathology. The ethanol extract of bark protected hepatocytes against paracetamol and CCl_4-induced hepatotoxicity in rats (Murthy et al., 2020).

Cardioprotective cum antioxidant activity: The plant acts as an antioxidant against adriamycin-induced cardiotoxicity in experimental mice. Adriamycin when administered intraperitoneally, it causes elevation of serum lactate dehydrogenase, creatine phosphokinase, glutamate oxaloacetate transaminase, glutamate pyruvate transaminase, lipid peroxide, total nitric oxide, erythrocyte lysate superoxide dismutase (SOD), glutathione peroxidase (GPx) and plasma catalase (CAT) in mice heart tissue. Adriamycin drug reduced the activities of SOD, GPx, and CAT (El Mastry et al., 2010).

Anthelmintic activity: The crude aqueous extract of root bark of *B. aegyptiaca* showed a dose-dependent inhibition of spontaneous motility (paralysis) in adult earthworms and also possesses vermicidal activity (Dwivedi et al., 2009). It is reported that stem bark water extract (9 g/kg body weight) of *Albizia anthelmintica* and fruit mesocarp water extract (9 g/kg body weight) of *B. aegyptiaca* shows significant anthelmintic activity compared with albendazole (20 mg/kg body weight) against *Fasciola gigantica* adult worm (Koko et al., 2000). A single dose of 200 mg/kg body weight of *B. aegyptiaca* fruit mesocarp also showed activity against *Schistosoma mansoni* in infected mice when compared with praziquantel (Koko et al., 2005). Balanitin-7 is isolated from an aqueous extract of *B. aegyptiaca* seed and reported as an anthelmintic agent when tested by *in vitro* means of an original anthelmintic assay, using *Caenorhabditis elegans* as a biological model (Gnoula et al., 2007). The methanol extract of *B. aegyptiaca* fruits was reported to have anthelmintic action against different stages of *Trichinella spiralis* in rats compared with the anthelmintic drug albendazole (Shalaby et al., 2010). The aqueous extract of *B. aegyptiaca* also has a molluscicidal agent for juvenile and adult *Bulinus globosus* and *Bulinus truncates* (Anto et al., 2005).

Antibacterial effects: The aqueous and organic leaf extracts of *B. aegyptiaca* and *Moringa oleifera* were reported to have an antibacterial effect against *Salmonella typhi* isolated from blood clot culture using the disc diffusion method. The extracts of *B. aegyptiaca* plants demonstrated the highest activity of *M. oleifera*. The ethanol extracts of both plants demonstrated the highest activity whereas the aqueous extracts of both plants showed the least activity at 100 mg/ml as compared with ethanol extracts. The activities of these plant extracts were comparable with those of antibiotics, ciprofloxacin, cotrimoxazole and chloramphenicol, commonly used for treating typhoid fever. The antibacterial activity appears to increase when extracts of the two plants were used in combination at 100 mg/ml each. The antibacterial activities of the extracts on *S. typhi* were reasonably stable when treated at 4, 30, 60, and 100°C for 1 hour. However, it reduces significantly when the pH was altered toward alkalinity (Doughari et al., 2007). The aqueous leaf extract and saponins isolated from its kernel cakes have antibacterial activity (Croach et al.,1962, Zarroug et al., 1988). The leaf extracts of *B. aegyptiaca* demonstrated antibacterial activity

against *S. typhi*. The preliminary phytochemical analysis reported the presence of saponins, tannins, phenols and anthraquinones which may be responsible for antibacterial properties. The flavonoid extracts, quercetin and kaempferol of callus tissue showed antimicrobial activity against *Escherichia coli, Proteus vulgaris, Pseudomonas aureginosa, Citrobacter amalonaticus, Staphylococcus aureus, Micrococcus lylae, Bacillus subtilis* and *Sporolacto bacillus.* The hydroethanolic extract of the bark of *B. aegyptiaca* limited the growth of *Pseudomonas aeruginosa* and *Staphylococcus aureus* under in-vitro conditions. The bark was reported to contain furanocoumarin-bergapten which had anti-inflammatory, antioxidant and antimicrobial properties. The crude extract of *B. aegyptiaca* demonstrated reduced bacterial growth in untreated well water whose phytochemical analysis revealed the presence of saponins, coumarins, triterpenes, steroids and tannins which may be responsible for this property **(Al-Thobaiti and Zeid, 2018).**

Antifungal activity: The ethanol and methanol extracts of root, bark and fruit were reported to exhibit antifungal activity against *Aspergillus niger*, *Candida albicans*, *Penicillium crustosum*, and *Saccharomyces cerevisiae* (Murthy et al., 2020)

Antivenin activity: The acetone and methanol extracts of the stem bark of the plant have been reported to exhibit an antivenin activity against saw-scaled (*Echis carinatus*) viper venom concentration at a lethal dose (0.194 mg/ml) when administered intramuscularly to Wistar albino rats. Both extracts were found to be effective at 75 and 100 mg/ml concentrations (Wufen et al., 2007).

Anticancer activity: A mixture of steroidal saponins: balanitin-6 (28%) and balanitin-7 (72%), isolated from *B. aegyptiaca* kernels, demonstrated appreciable anticancer effects in human cancer cell lines *in vitro* by using against A549 non–small-cell lung cancer (IC50, 0.3 μM) and U373 glioblastoma (IC50, 0.5 μM) cell lines. Balanitin-6 /7 displayed higher antiproliferative activity than etoposide and oxaliplatin, markedly less active than taxol (Gnoula et al., 2008, Pettit et al., 1991). Several steroidal saponins derived from *B. aegyptiaca* tissues were reported for anticancer activities. For example, a mixture of balanitin-6 and balanitin-7 (28:72) isolated from kernels demonstrated inhibited growth of a human cancer cell line under *in-vitro* conditions (Murthy et al., 2020).

Anti-inflammatory and analgesic activity: The ethanol and petroleum ether extracts of aerial parts of *B. aegyptiaca* have been reported to have significant anti-inflammatory action on carrageenan-induced hind paw edema in rats, the paw volume was measured plethysmometrically at 0 and 3 hours after injection, and analgesic activity by using Eddy's hot plate method and tail-flick method in albino rats. The ethanol and petroleum ether extracts showed greater anti-inflammatory and analgesic effects compared with the standard drugs, indomethacin, and diclofenac sodium, respectively. It also indicated that the ethanol extract of *B. aegyptiaca* exhibited more significant activity than petroleum ether in the treatment of pain and inflammation (Gaur et al., 2008).

Antidiabetic activity: Different extracts of *B. aegyptiaca* were tested for antidiabetic and hypoglycemic effects. The aqueous extract derived from the mesocarp of fruits was analyzed and revealed to possess lowered blood sugar levels in STZ (Streptozotocin) induced diabetic mice. The ethyl acetate extract (EAE) from *B. aegyptiaca* also showed counter-effects against oxidative stress induced by streptozocine with reduced blood glucose levels, HbA1c, malondialdehyde as well as vascular endothelial growth factor (VEGF) in subjects. The fruit extract of *B. aegyptiaca* also showed a decline in blood glucose level by 24% with decreasing liver glucose-6-phosphatase activity in diabetic mice. The aqueous and ethanolic extracts of fruits also reduced levels of components of diabetes including serum glucose, glucagon, total lipids, total cholesterol, triglycerides and transaminases. It is reported that the antidiabetic activity was due to the presence of steroidal saponins in the extracts while the hypoglycemic effect is believed to be due to trigonelline present in fruit. Another study aimed to analyze the antidiabetic efficacy of 70% ethanol extract of the pericarp of fruit alongside nutritional intervention in elderly people revealed a 26.88% decrease in postprandial plasma glucose while a 10.3% decrease in fasting plasma glucose providing evidence for antidiabetic effects in humans (Al-Thobaiti and Zeid, 2018).

In vitro antioxidant, xanthine oxidase, and acetylcholinesterase inhibitory activities:

It is reported that the galls and leaf extracts and fractions of *B. aegyptiaca* showed significant antioxidant, xanthine oxidase and acetylcholinesterase inhibitory activities. The total phenolics and flavonoids were measured using Folin-Ciocalteu and $AlCl_3$ reagents, respectively. Two methods, that is, FRAP (Iron (III) to Iron (II) reduction activity) and ABTS (2,2-azinobis-3-ethyl benzothiazoline-6-sulphonate) assay were used to estimate the total antioxidant capacity of the plant materials. Dichloromethane fractions of the Gall and ethyl acetate fractions of the leaves were reported to have the highest antioxidant activity. The antioxidant activities were correlated significantly with the total phenolic and flavonoid contents. The study also showed that *B. aegyptiaca* galls and leaves fractions exhibited a moderate xanthine oxidase inhibitory activity compared with the acetylcholinesterase which was weakly inhibited by the tested extracts and fractions (Meda et al. 2010).

Pesticidal Effect: *B. aegyptiaca's* saponins were investigated for bio-pesticidal value against *Tribolium castaneum* (red flour beetle or bran bugs). The saponins were extracted using Soxhlet and maceration extraction methods with aqueous and other solvents. The study was conducted at different concentrations ranging from 1%–5% to higher 2.5%–17.5%. The results obtained were found to be dosage dependent as, at 5% concentration 100% mortality was observed in the period of 8 days while 17.5% concentration showed 100% mortality in the period of 24 hours (Alnadif et al., 2017).

Larvicidal activity: The aqueous extract of the fruit pulp, seed kernel, roots, barks and leaves of *B. aegyptiaca* was assessed against the larvae of the *Culex pipiens* mosquito. Early fourth instars larvae of *C. pipiens* mosquitoes were exposed, for up to 3 days, to a dilution of 0, 0.1, 0.25, 0.5, 1.0, and 2.0% aqueous root extract. The lowest concentration of root extract (0.1%), showed 100% larval mortality. Aqueous extract of fruit pulp, seed kernel and leaves showed less larval mortality compared to the root and/or bark extracts. A saponin extract and water extract from the fruit kernel of *B. aegyptiaca* were investigated as a mosquito larvicide. Both extracts were tested against second and fourth-instar larvae of the mosquito species, namely *Anopheles arabiensis* and *C. quinquefasciatus*. Second-instar larvae were more susceptible than fourth-instar larvae in all cases. The larvae of *A. arabiensis* were more susceptible than *C.quinquefasciatus*. The saponin extract was found to be more active than the water extract. The main reason behind the larvicidal activity of plant extract may be the interaction of saponin molecules with the cuticle membrane of the larvae, ultimately disarranging these (Alnadif et al., 2017).

Other activities: Aqueous extract of the fruits showed spermicidal activity without local vaginal irritation in human beings up to 4% of sperms becoming sluggish on contact with the plant extract and then immobile within 30 s; the effect was concentration-related. Protracted administration of the fruit pulp extract produced hyperglycemia-induced testicular dysfunction in dogs. The root, bark, kernel, and fruit have been shown to be lethal to molluscs (Doughari et al., 2007). Root extracts have proved 'slightly effective' against experimental malaria (Karel et al., 1951, Watt et al., 1962).

Toxicology: No reports are available

Patent and Commercial Products (if any):

Patent Documents:

- *Balanites aegyptiaca* method of treatment, Patent No: WO1997023234A1.
- *Balanites aegyptiaca* extracts for treatment of HIV/AIDS and leukemia, Patent No: WO2001049306A1.
- Production of biodiesel from *Balanites aegyptiaca*, Patent No: EP1885823A2
- *Balanites aegyptiaca* saponins and uses thereof, Patent No: US20080287662A1
- Production of biodiesel from *Balanites aegyptiaca*, Patent No: US20080271364A1
- A synergistic herbal extract composition for use in treating bloating, Patent No. WO2012137223A1
- Herbal sterite product which reduces the number of aidsviruses and activates immunity system, Patent No: WO2012055422A1
- Plant snail-killing agent, Patent No: CN1066017C
- Herbal composition for prevention and control of insect and leaf curl in brinjal and chilly crops, Patent No: 261/MUM/2010

- Herbal composition for nutrient supplement, an appetite enhancer, hepatoprotectant or a liver tonic, Patent No: 1051/MUM/2011
- Organic farming composition and process thereof, Patent No: 1311/MUM/2011
- Herbal composition for melasma, Patent No: 201621010190
- A potential composition for treating hemorrhoids and irritable bowel syndrome, Patent No: 201721044520.
- Synthesis of nanoparticles using Balanites aegyptiaca, Patent No: US9889170B1
- Effect of *Balanitis aegyptiaca* on the regression of liver fibrosis and cirrhosis, Patent No: WO 2019221645a2
- Utilizacion cosmetica de un extracto de almendras de balanites para la resistencia de los cabellos, Patent No: P130100850
- Isolation and purification of pharmaceutical active ingredients from *Balanitees aegyptiaca* del and its use in mediccal prepartions, Patent No: EG 29811
- Organic farming composition and process thereof, Patent No: IN1311/mum/2011
- A potential composition for treating hemorrhoids and irritable bowel syndrome, Patent No: IN 201911054167
- Synthesis of nanoparticles using *Balanites aegyptiaca,* Patent No: US09889170
- Cosmetic use of an extract of Balanites almonds to improve hair strength, Patent No: US 10137075 B2

Commercial Products

- Nacomi Botanic Cleansing Foam
- Nacomi Face Cleansing Foam Avocado
- Nacomi Face Cleansing Foam Blueberry
- Nacomi Face Cleansing Foam Marshmallow
- Tulura Revealing Botanical Oil Cleanser
- AG Hair Natural Balance Apple Cider Vinegar Sulfate-free Shampoo
- Marti Derm Purifying Gel Acniover
- The Chemist Look Limpiador
- Ivy Aïa Micellar Cleansing Water
- Forever Living Sonya Gel Cleanser
- Kristin Ess Cleansing Co-wash
- Merumaya Luxury Facial Wash
- Medik8 Cream Cleanse Shea Moisture Peace Rose Oil Complex Sensitive Skin Cleansing Oil
- Freshly Cosmetics Rose Quartz Facial Cleanser
- hif (Hair is Fabric) Volume Support
- HIF Anti-Brass Support
- hif (Hair is Fabric) Intensive Detox
- Arket Body Wash Verbena
- The Body Shop Tea Tree Squeaky-Clean Exfoliating Face Scrub
- Medik 8 Micellar Mousse
- Murad Pore Extractor Pomegranate Mask
- Soap & Glory The Fab Pore Foaming Cleanser
- St. Tropez Gradual Tan Mousse
- hif (Hair is Fabric) Curly Hair Support
- hif (Hair is Fabric) Colour Support
- D'Alchemy Purifying Facial Cleanser Nk01
- Merle Norman Anti Redness Foaming Cleanser (*Balanites aegyptiaca Fruit Extract (with Product List)*, n.d.) Products with *Balanites aegyptiaca* Leaf Extract
- Immunocologie Hyaluronic Serum (*Balanites aegyptiaca Leaf Extract (with Product List)*, n.d.)
- Products with *Balanites aegyptiaca* Kernel Oil
- LOLI Date Nut Brûlée
- LOLI Miracle Balm
- Shea Moisture Peace Rose Oil Complex Sensitive Skin Facial Cleansing Oil
- Shea Moisture Peace Rose Oil Complex Nourish & Silken Shampoo
- Oolution Feet Good Comforting Foot Cream
- Shea Moisture Peace Rose Oil Complex Sensitive Skin Facial Moisturizer (*Balanites aegyptiaca* Kernel Oil (with Product List), n.d.).

Scope of further R&D: The extensive ethnobotanical applications and diverse phytochemical constituents of *Balanites aegyptiaca* open numerous avenues for future research and development. Investigating the detailed mechanisms of its various bioactive compounds such as saponins, flavonoids and polyphenols can yield insights into their antioxidant, hepatoprotective, cardioprotective, anthelmintic, antibacterial, antifungal, antivenin, anticancer, anti-inflammatory and antidiabetic properties. Moreover, expanding studies on its less-explored

phytochemicals may reveal new medicinal applications. The seed oil of *B. aegyptiaca*, which has not been much explored from its chemistry and applications point of view should be included in future R&D. Given its adaptability to various environmental conditions, exploring sustainable cultivation methods in different ecological settings could enhance its availability for both medicinal and agricultural purposes. Additionally, bioprospecting its pesticidal and larvicidal potential could contribute to natural pest management solutions. Integrating modern pharmacological techniques with traditional knowledge may lead to the development of novel therapeutics and promote its use in contemporary medicine.

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Buchanania axillaris
(Desr.) Ramamoorthy

Synonyms:
Buchanania angustifolia Roxb.,
Cambessedea axillaris Kunth.

Local/Common/Popular Name(s):
Kannada: Emmemurukalugida, Maradimara, ***Tamil:*** Kattuma, Kolamaavu, Mudamaa, Sara paruppu, Kola-mavu, Kattuma, Mudama, ***Malayalam:*** Malamavu, ***Telugu:*** Sarapappu, Chara, Peddamorali (Rao et al., 2019) (Flora of Peninsular India, 2019).

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Sapindales
Family	:	Anacardiaceae
Genus	:	*Buchanania*
Species	:	*Buchanania axillaris*

Plant Description: *Buchanania axillaris* is a medium tree that can grow up to 8m in height. The branchlets are stout, glabrous, and deeply fissured. The leaves are oblong elliptic, acute at the base with an undulate margin, and emarginated conscious apex possessing about 15 pairs of lateral nerves and measurements of 5-10 cm x 3-6 cm. The white flowers occur in axillary and terminal panicles which are 5 lobed, ovate, glabrous calyx, and oblong, reflexed petals which are 5 in number. The stamens are 10 in number with subulate filaments and oblong anthers having a disc of 1.5 mm in diameter. The ovary is sub-oval with a short style and truncate stigma. The drupes are compressed-globose with a single, gibbose seed. The flowering and fruiting occur in June-December. The seeds of *B. axillaris* are the major source of regeneration but the hard seed coat leads to low germinating capability of the plant. The bark is typically dark brown to blackish in color. It is smooth in younger trees but becomes rough and fissured with age, developing deep vertical cracks and ridges. The bark is moderately thick, providing a protective layer for the tree (Pullaiah, 2015).

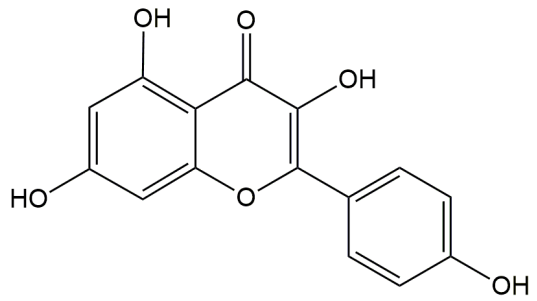
Distribution: *B. axillaris* is a plant native to India and Sri Lanka (Rao et al., 2019). It is distributed in the dry deciduous forests of Telangana and in hilly forest areas in Adilabad, Warangal, Karimnagar, Mahabubnagar, Mulugu, Nagarkarnool, Bhupalpally, Kotthaguddam district of Telangana, (Pullaiah, 2015; Suthari and Raju, 2018) Chittoor district, Kurnool district, Kadapa district, Srikakulam district, Vishakapatnam district, Veligonda hill of Andhra Pradesh, (Reddy et al., 2009; Stephen et al., 2012; Basha and Reddy, 2017), Ballari district, Kolar district of Karnataka, Kottayam district of Kerala, Namakkal district, Salem district, Vellore district of Tamil Nadu (Rao et al., 2019).

Ethnobotanical Significance: *B. axillaris*is a traditional medicinal plant. The leaves have been used for the treatment of hyperdipsia, burning sensation cough, bronchitis, dyspepsia, leprosy, and constipation (Pullaiah, 2006; Madhavachetty et al., 2008). The leaf juice has been used as an expectorant, aphrodisiac, purgative, depurative, blood purifier, and thirst-quencher and cures digestive disorders (Mohamed et al.,2009). The

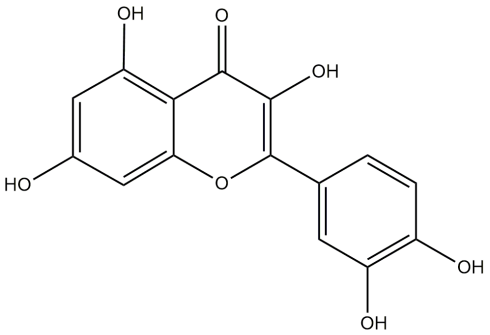
seed kernel of *B. axillaris* is edible and mainly collected and sold by the tribal people (Rani et al., 2003; Omkar et al., 2012). The kernels are used as a brain tonic and aerial parts are used to cure itch and remove blemishes (Sakthivel et al., 2010). *B. axillaris* nut has been eaten to increase sperm quality by the Yandies and Yerukalas tribes of Lankamalleswaram Wild Life Sanctuary, Andhra Pradesh (Maheshwari et al., 2012). *B. axillaris* bark and gum are used for the treatment of skin disease, back pain, and veterinary purposes by the ethnic people of Warangal North Forest Division, Northern Telangana (Suthari et al., 2014). The gum has anti-diarrhoeal properties and is also used for treating rheumatism, diarrhea, and intercostals muscles (Khare, 2004). *B. axillaris* gum is mixed with ash, garlic, asafoetida and made into a paste with goat milk, and applied externally in the treatment of rheumatism by the ethnic people of Andhra Pradesh (Ratnam et al., 2019). *B. axillaris* gum has also been given orally with hot water for diarrhea by the Yandies and Yerukalas tribes of Lankamalleswaram Wild Life Sanctuary of YSR District, Andhra Pradesh (Maheshwari et al., 2012). The gum and kernels are used for wound healing by Yerukalas and the Lambadis of Pocharam Wildlife Sanctuary, Telangana (Saidulu et al., 2015). Chenchu and Nakkala tribes of Japali Hanuman theertham, Tirumala, Andhra Pradesh orally administered gum decoction for the treatment of diarrhea (Savithramma et al., 2014). The gum is swallowed as a tablet for the treatment of chest and body pains by the Maha-Mutharam and Yamanpally tribes (Murthy et al., 2008). The flowers of *B. axillaris* have been used as ethnomedicine for wound healing in the Warangal and Nalgonda areas of Telangana and Andhra Pradesh (Sreeramulu et al., 2013). *B. axillaris was* used as firewood by the Malayali tribes in the Yercaud hills of the Eastern Ghats, Salem district, Tamil Nadu, India. The stem bark is also used for healing bone fractures (Rekha and Senthil Kumar, 2014).

Phytochemistry:

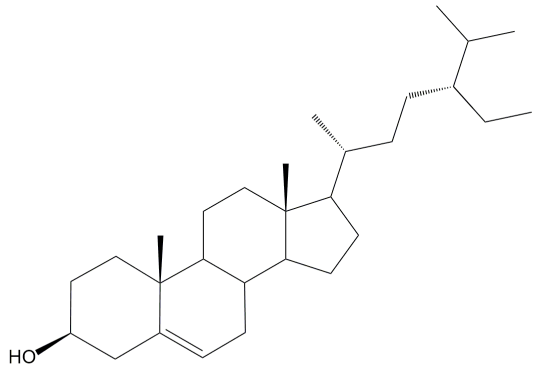
Leaves: β-sitosterol, quercetin, kaempferol, Stigmasterol (Dorababu et al., 2018).



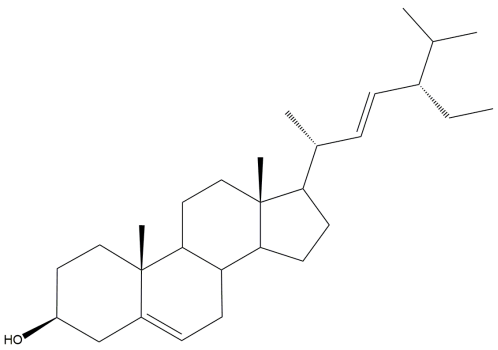
Kaempferol



Quercetin



β-sitosterol



Stigmasterol

Structures of Important and Characteristic Chemical Constituents of *Buchanania axillaris.*

Biological Activities:

Anti-oxidant activity: The percentage scavenging activity of the n-butanol extract of *B. axillaris* leaf was the highest followed by a methanol and aqueous extract (Vani et al., 2018). The hydro-alcoholic extract of the *B. axillaris* aerial part showed more antioxidant and hepatoprotective activity (Talluri et al., 2018). The active chloroform fraction of methanol extract showed significant cell viability at high concentrations (400 µg). Moreover, in the MTT assay, the active fraction displayed excellent neuroprotective effects against oxidative stress-induced cell death and was significant (Penumala et al., 2018).

Anti-cancer activity: The cytotoxicity (anti-cancer) activity of *B. axillaris* methanol extract was evaluated against breast cancer (MCF-7 and MDA-MB) and colon cancer (HT-29) cell lines and it was found that IC_{50} values (µg/mL) i.e. 350.13±27.03 and 118.97±0.99 for MCF-7 and MDA-MB, respectively which revealed significant cytotoxic activity (Dorababu et al., 2016). Silver nanoparticles biosynthesized using fresh *B. axillaris* leaves n-butanol extract was evaluated for anti-cancer potential for breast cancer against MCF-7 cell lines. The results revealed that the nanoparticles exhibited significant cytotoxicity in the MTT assay against cell lines (Khateef et al., 2019).

Anti-ulcer activity: The antiulcer activity of methanol extract of *B. axillaris* leaves was investigated in pylorus ligation-induced ulcer model, ethanol-induced ulcer model, and indomethacin-induced ulcer model, ulcer index and percentage inhibition of ulceration in the albino rats where omeprazole (20 mg/kg) was used as the standard drug. The methanol extract of *B. axillaris* leaves at a concentration of 400mg/kg showed significant antiulcer activity. This anti-ulcer property could be attributed to the presence of phytochemicals like flavonoids (quercetin), and tannins present in the extract (Venkatanarayana et al., 2016).

Anticholinesterase and anti-diabetic activity: The chloroform fractions of *B. axillaris* leaf methanol extract with IC_{50} (µg/mL) of 12.29, 9.94, 16.65, and 27.38 were found to be most prominent with regards to inhibition potential against acetylcholinesterase (AChE) and butyrylcholinesterase (BuChE), α– and β–glucosidase, respectively. The strong anticholinesterase, anti glucosidase, antioxidant, and neuroprotective activities of methanol extracts and their derived chloroform fractions indicate the potential of *B.axillaris*, as multifunctional therapeutic remedies for the dual therapy of type 2 diabetes and Alzheimer's disease (Penumala et al. 2018).

Aphrodisiac activity: The methanol extract of *B. axillaris* leaves at a higher concentration (400 mg/kg body weight) showed significant aphrodisiac activity in male Wister albino rats as evidenced by an increase in the number of mounts and mating performance (Dorababu et al., 2017).

Anthelmintic activity: The methanol extract of *B.axillaris* bark has been reported to exhibit anthelmintic activity. Various concentrations of crude extract (25, 50, 100mg/ml) have been used for anthelmintic activity which involved the determination of the time of paralysis and time of death of worms. The methanol extract shows significant activity when compared to the standard piperazine citrate. The paralysis and death times were 50, 31, 17, 76, 52, and 34 minutes, respectively, at concentrations of 25, 50, and 100mg/ml whereas there were 31, 18, 10, 63, 41, and 22 minutes for piperazine citrate (Dorababu et al., 2018).

Anti-bacterial activity: The anti-bacterial activity was exhibited by butanol, methanol, and aqueous extracts of *B. axillaris* against *Escherichia coli, Klebsiella pneumonia, Bacillus subtilis, Pseudomonas aeruginosa* and *Staphylococcus aureus* at the concentrations, 25, 50, 75, 100 µg respectively. The extracts showed maximum antibacterial activity against both Gram-positive and Gram-negative bacteria. The antibacterial studies revealed the following sequence of inhibitory action: *E. coli* (27 mm) >*K. pneumonia*>*B. substilis*>*P. aeruginosa*>*S. aureus* in butanolic extract and the sequence of inhibition as *E. coli* > *B. substilis*>*K. pneumonia* > *S. aureus*> *P. aeruginosa* in case of methanol extract. The aqueous extract exhibited the following sequence of anti-bacterial activity i.e. *B. substilis*> *E. coli* > *S. aureus*> *P. aeruginosa*>*K. pneumonia* (Vani et al., 2018). The antibacterial activity of extract of endophytic fungus *Diaporthe caatingaensis* MT192326 grown in *B.axillaris* based on disc diffusion assay was evaluated. The extract exhibited a growth inhibition range of 15–22 mm in nutrient agar plate medium at a lower concentration of 12.5–25 µg/ml as compared to the

control streptomycin (3.125 µg/ml) concentration which revealed the anti-bacterial potential of the fungus (Madhan Kumar et al., 2021).

Diuretic activity: It was found that *B.axillaris* had a better diuretic activity at a concentration of 500mg/kg which showed significant diuretic properties resulting in the superior urine excretions of Na+ and K+ ions as compared with that of the standard drug Frusemide (Hullatti et al., 2014).

Patent and Commercial Products (if any): No reports are available.

Scope of further R&D: The extensive ethnobotanical applications and scanty phytochemical investigations of *Buchanania axillaris* present numerous avenues for future research and development (R&D). Investigating the detailed chemistry of different parts of the plant can yield novel molecules. Evaluation of biological activities of these molecules and the reported ones followed by mechanisms of their actions can yield insights into their therapeutic properties, including antioxidant, anti-cancer, anti-ulcer, anticholinesterase, anti-diabetic, aphrodisiac, anthelmintic, antibacterial, and diuretic activities. Moreover, exploring the bark's potential medicinal properties, especially considering its traditional use in treating skin diseases, back pain, and wound healing, could uncover new therapeutic applications. Given its distribution in India and Sri Lanka, further studies on its ecological requirements, genetic diversity, and conservation strategies are essential for sustainable utilization. Additionally, integrating traditional knowledge with modern pharmacological techniques may lead to the development of novel therapeutic agents and promote its use in contemporary medicine. Further research could also focus on addressing challenges such as the low germination rate of its seeds and enhancing its cultivation practices to meet increasing demand for both medicinal and agricultural purposes.

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Canarium strictum Roxb.

Synonyms:
Canarium sikkimense, Pimela stricta Bl.,
Canarium subcordatum Ridl.,
Canarium subrepandum Miq.,
Canarium subtruncatum Engl.,
Canarium resiniferum Bruce ex-King

Local/Common/Popular Name(s):
Hindi: Black Dammar, Black Dhup, Raal Dhup, Kala Dammar, ***Assamese:*** Dhuna/ Dhup, ***Tamil:*** Karunkungiliyam, Karangkunthrikam, ***Malayalam:*** Pantham, Pantappayan, Thelli, Viraka, Marathi: Dhup, Ral-Dhup

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Sapindales
Family	:	Burseraceae
Genus	:	*Canarium*
Species	:	*Canarium strictum*

Plant Description: *Canarium strictum* is a polygamodioecious tree species which can grow up to 30-40 meters in length and is buttressed at the base. The leaves are compound, bipinnate, opposite or sub-opposite, spiral, and clustered at twig ends with the new leaves being red in color and a ferruginous pubescent rachis. The leaflets occur in 3-13 pairs with the odd pair at the apex and the size of leaflets increasing in size towards the apex. The petiole is 0.3-0.7 cm long and the lamina is usually oblong, sometimes ovate with acuminate apex and asymmetric-rounded base and serrate or serrulate margin and coriaceous, rusty tomentose or pubescent beneath and glabrous above measurements 5-15 X 2.5-7 cm. The secondary nerves are strong with 11-18 pairs while the tertiary nerves are weakly percurrent. The mildly fragrant yellow to dull white flowers are bisexual or polygamous occurring in shortly branched axillary panicles with around 1 cm length and the branches cymose, densely tomentose with shortstalk. The cup-shaped calyx is 3- 3-lobed and the oblong corolla is also 3-lobed. The monadelphous stamens are 6 in number with up to half of the filaments enclosing the disk. The ovary is 3-celled. The stone-hard, aromatic fruits measuring 2.5 to 5 cm in length are ellipsoidal or ovoid drupe with pointed ends and fleshy mesocarp containing 3 seeds where each seed is trigonous and is usually 3-celled (Hooker, 1990; Deb, 1981; Kanjilal et al., 1934).

Distribution: It is found in India, Bangladesh, Myanmar, and parts of Southeast Asia. In India, it is distributed in Western India, Sikkim, Arunachal Pradesh, Assam, Meghalaya, Orissa, Maharashtra, Karnataka, Kerala, Tamil Nadu and in the Andaman Islands.

Habitat: *C. strictum* is an evergreen tree categorized as a red-listed medicinal tree species with a declining population. It is found in moist mixed deciduous to tropical moist evergreen to semi-evergreen forests and can grow up to 40 m at altitude in the range of 750-1,400 m above mean sea level.

Ethnobotanical Significance: *C. strictum* is used in rituals (often believed to keep evil spirits

at bay) and as a mosquito repellent. The species is a rich source of Sambrani which is used to cure various bronchial ailments. The dried resin is burned to ward off insects and resin powder is traditionally applied to cure joint pain (Sanjeev et al., 1997). The traditional herbal medicines practiced by the ethnic people in the Sathyamangalam forests of Western Ghats for the cure of joint pain contain *C. strictum* (Silambarasan et al., 2017; Meena et al., 2012). The plant also neutralizes the effect of the venom of insects like wasps, scorpions, and snake bites. The powder of resin is given for rheumatism, fever, cough, epilepsy, asthma, psoriasis, and pityriasis. Fresh resin is melted and applied on skin areas exposed to poisonous hairs of caterpillar larvae. It is reported to be used in the Siddha system of medicine, and in Ayurveda under the name 'Raladhupa' and 'black dammar resin'. It also finds use as incense, as a substitute for burgundy pitch in making medicinal plasters, and in varnish industries. It has been effective in the long-term treatment of skin conditions such as psoriasis and acne (Quan et al.,2019). Its gum powder is given orally to treat infections, fever, epilepsy, asthma, syphilis, heartburn, various toxins, hernia, bleeding, and healing of the skin (Yang et al., 2018).

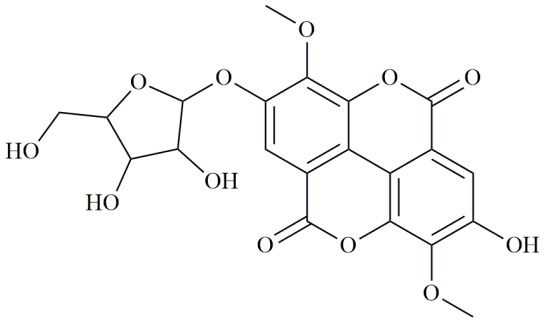
Phytochemistry:

Bark: Gallic acid, methyl gallate, scopoletin, 3,3′-di-*O*-methylellagic acid 4-*O*-α-arabinofuranoside and 3,3′,4′,5,6,7,8-heptahydroxyflavan (Dongmo et al., 2010).

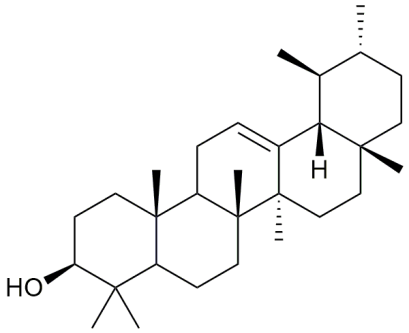
Resin: Junenol, canarone, epi-khusinol, α-amyrin, 11-keto-α-amyrin, β-amyrin, lupeol, ψ-taraxasterol, epi-ψ-tarastanonol, and epi-ψ-taraxastanediol (Nagawa et al., 2015).

Dammer Oil: Azulene, n-heptane, heptene, α-pinene, and damarene (Tahir et al., 2021).

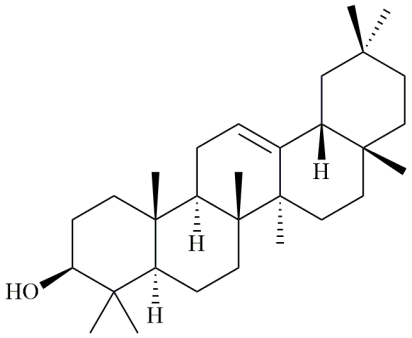
Essential oil from resin: α-tricyclene, 1S- α -pinene, 1R-(+)- α -pinene, camphene, 1S-(-)-β-pinene, (R)-(+)-limonene, γ-terpinene, α-terpinolene, p-cymenene, 1,3,8-p-menthatriene, berbenol, α-campholenal, 4-acetyl-1-methylcyclohexene, (E)-p-2,8-menthadien-1-ol, (+)-2-bornanone, myrtenal, trans-dihydrocarvone, (S)-verbenone, 4,7-dimethylbenzofuran, trans-carveol, cis-carveol, (-)-carvone, 2-isopropyl-5-methyl-3-cyclohexen-1-one, bornyl acetate, (+)-cyclosativene, α-copaene, (E)-β-caryophyllene, β-copaene, megastigmatrienone, germacrene D, α-muurolene, bicyclogermacrene, (+)-δ-cadinene, trans-calamenene (Tahir et al., 2021).



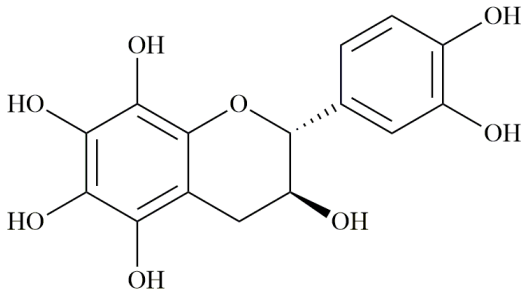
3,3'- di -O- methylellagic acid 4 - O- α-arabinofuranoside



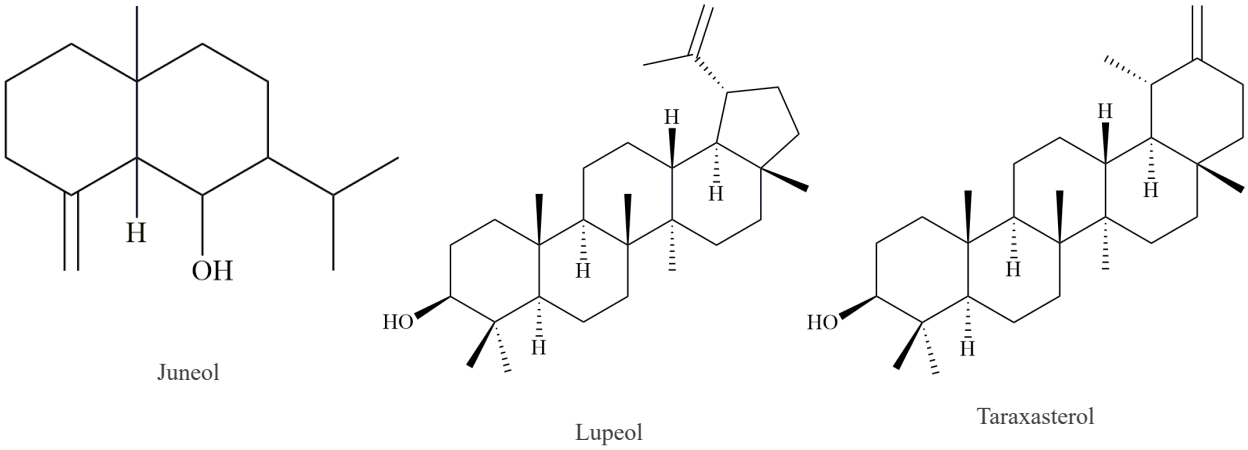
α-amyrin



β- amyrin



Elephantorrhizol



Structures of Important and Characteristic Chemical Constituents of *Canarium strictum.*

Biological activities:

Anti-bacterial activity: The essential oil obtained from resin of *C. strictum* was analyzed for anti-bacterial activity against five bacterial strains i.e. methicillin resistant *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, resistant *Escherichia coli* and non-resistant *Escherichia coli*. The oil was found resistant against all the strains with highest anti-bacterial activity against *E. coli* and *S. aureus* (Tahir et al., 2021, Prasannakumar et al., 2011 and Venkatachalapathi et al., 2016).

Anti-inflammatory activity: The resin and bark extracts of *C. strictum* were investigated for anti-inflammatory activity through DPPH radical scavenging, 15-lipooxygenase inhibition, and effects on nitric oxide (NO) production in LPS-activated dendritic D2SC/I cells. The radical scavenging, 15-lipoxygenase inhibitory activity and inhibition of NO production was observed from the resin and bark extracts. The high content of terpenoids in stem and resin might contribute to anti-inflammatory activity (Seethapathy et al., 2021).

Anti-pyretic activity: The methanol leaf extract of *C. strictum* was evaluated for anti-pyretic activity against wistar albino mice where pyrexia was induced in mice by Brewer's yeast suspension. The results revealed that the leaf extract significantly reduced body temperature of mice at doses 200 and 300 mg/kg and was found to be comparable with the standard, paracetamol (Venkatachalapathi et al., 2017).

Larvicidal activity: The methanol leaf extract of *C. strictum* was evaluated against 4th instar larvae of the filarial vector *Aedes aegypti* and *Culex quinquefasciatus*. The results revealed that the leaf extract exhibited moderate effects after 24h of exposure with high toxicity against larvae of *C. quinquefasciatus* followed by toxicity against *A. aegypti* (Muthuswami et al., 2014; Venkatachalapathi et al., 2016).

Toxicology: The resin and bark of *C. strictum* were investigated for toxicity against *Artemia salina nauplii*, and no toxicity was found (Seethapathy et al., 2021). The ethanol leaf extract of *C. strictum*, obtained by Soxhlet extraction, was evaluated for toxicity. The acute toxicity data revealed that the extract was safe up to a 2000 mg/kg dose in female albino mice. It was also found that the extract posed no harm during treatment for 13 weeks unless the dosage was quite high (Selvam et al., 2023)

Scope of further R and D: The extensive ethnobotanical applications and diverse phytochemical constituents of *C. strictum* open numerous avenues for future research and development. Investigating the detailed chemistry of different parts of the plant can yield novel molecules. Evaluating the biological activities of these novel molecules, along with the already reported ones, and studying the mechanisms of their actions can provide valuable insights into their therapeutic properties. Given its declining population and red-listed status, research into sustainable cultivation methods and conservation strategies is crucial. Furthermore, exploring the potential of *C. strictum*

in traditional and modern medicine could lead to the development of new pharmacological applications. Integrating advanced pharmacological techniques with traditional knowledge may result in novel therapeutic agents, enhancing the medicinal use of *C. strictum* in contemporary healthcare.

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Carallia brachiata
(Lour.) Merr.

Synonyms:
Carallia lucida Roxb, *C. integerrima* D.C, *C. arguta* Koord. & Valeton., *C. baraldeia* Wight & Arn., *C. calycina* Benth., *C. celebica* Blume, *C. cerisopsitolia* Miq., *C. ceylanica* Arn., *C. confinis* Blume, *C. corymbosa* Arn., *C. cuprea* Ridl., *C. cuspidata* Blume, *C. densiflora* Griff., *C. diplopetala,* Hand.-Mazz., *C. floribunda* Miq., *C. integerrima* DC., *C. integrifolia* J. Graham, *C. lanceifolia* Roxb., *C. madagascariensis* (DC.) Tul. *C. multiflora* Blume, *C. obcordata* Wight ex Walp, *C. octopetala* F. Muell. ex Benth., *C. scortechinii* King, *C. sinensis* Arn., *C. spinulosa* Ridl., *C. symmetria* Blume, *C. zeylanica* Arn., *C. viridiflora* Ridl., *C. timorensis* Blume., *Barraldeia madagascariensis* DC, *B. madagascariensis* Spreng, *Summetria obovata* Blume, *Petalotoma brachiata* (Lour) DC., *Eugenia cupuli* fera H. Perrier, *Diatoma brachiata* Lour., *Demidofia nodosa* Dennst

Local/Common/Popular Name(s):
Indian Oak, Carilla tree, Cork Wood, Butterfly tree, Freshwater Mangrove ***Assamese:*** Daini Jam, Mahi thekera, Kan thekera, ***Hindi:*** Maathang, ***Bengali:*** Kiabanj, Kierpa, ***Tripura:*** Kehuragach, ***Garo:*** Thekra Aga, ***Kannada:*** Andhimaragala, andhimuriyana, andhipunaaru mara, ***Khasi:*** Dieng-sohlangbali, ***Malayalam:*** Kare-kandel, vallabham, vankana, varangu, Varanga, ***Marathi:*** Kamdelo, Ponsi, Phanshi, ***Mizo:*** Theiria, ***Tamil:*** Andimiriam, ***Telegu:*** kaaralli, kaarvalli, gijuruchettu, ***Nepali:*** Kathe kera, ***Burmese:*** Maniauga, ***Burmese:*** Maniauga, ***Chinese:*** Ngo shenmuk, Nik ngatsai, ***Malaya:*** Kesinga, Meransi, Sisekpuyu.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Malpighiales
Family	:	Rhizophoraceae
Genus	:	*Carallia*
Species	:	*Carallia brachiata*

Plant Description: *Carallia brachiata* is a medium-sized evergreen tree which can reach up to 25 m in length with a straight, cylindrical bole of 25-70cmin diameter occasionally occurring with small buttresses and aerial roots with very lucid foliage (Digital Species, 2008). The branches are usually horizontal and sometimes with fleshy adventitious roots on the trunk. The bark is grey and smooth when young which possesses large and corky lenticels later with brownish blaze. The leaves are simple, opposite, and decussate with lanceolate, interpetiolar, and caducous stipules which leave scars. The glabrous petiole is 4-12 mm long and planoconvex in cross-section. The lamina is oblong to ovate, wide obovate or wide elliptic with apex acute to obtuse and base cuneate or acute with an entire margin and revolute, coriaceous, glossy, glabrous beneath and drying brown in color with measurements 6-15 X 3-8 cm. The petiole is short and stout with midrib canaliculate above and length up to 2.5 cm. The lateral nerves are 8-14 pairs with obscure tertiary nerves. The cymes are axillary, trichotomous, and 2-4 cm in length. The greenish-yellow/ white flower is subsessile and 4-5 mm wide with 6-8 orbicular petals and bracteates with 6-8 lobed calyx and valvate. The stamen is 10-16 in number with filiform filament and subulate style and 4-lobed stigma. The 3-5 celled ovary is half inferior. The red, globose drupe with 8-11mm width contains a single, reniform seed (Deb, 1981). The flowering occurs in February-March and the fruiting and seed maturity occurs in April. (http://www.flowersofindia.net/) ; accessed 6 December 2020)

Distribution: *C. brachiata* is found in Australia (Northern Territory, Queensland, and Western Australia), Bhutan, Burma, Thailand, Silhet, Sri Lanka, Cambodia, China (Fujian, Guangdong, Hainan, and Yunnan), Indonesia, Laos, Madagascar, Malaysia, Singapore, Myanmar, Nepal, New Guinea, Philippines, Salomon Islands, Thailand, and Vietnam. In India, it occurs in the forest of outer Sikkim, West Bengal, Assam, Chota Nagpur, along streams and remains in Singhbhum, Bihar, Orissa, Andhra

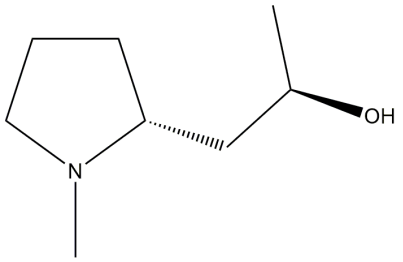
Pradesh, South Chandrapur in Maharashtra, the Western Ghats from Konkan and the Andamans (Barooah and Ahmed, 2014).

Ethnobotanical Significance: The juice from the macerated leaves is used in the treatment of fever. The pulverized bark is rubbed on the body in the treatment of smallpox. The leaves and bark are used in local medicine to treat septic poisoning and itch (Digital Species, 2008). Leaves are also used as fodder and have been found to be active against some tumors (Plant Resources of Tropical Africa, 2000. Useful plants of tropical Africa. *C. brachiata* is also used in traditional medicine to reduce inflammation.

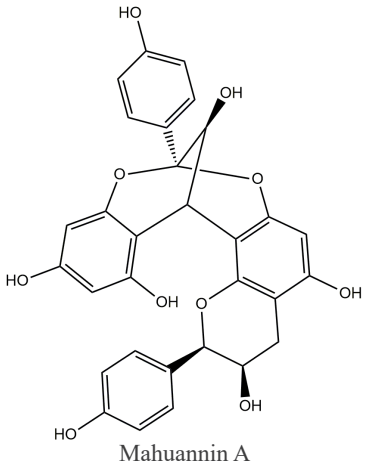
Phytochemistry:

Leaves: Hygroline (Fitzgerald et al., 1965), megastigmane glycoside (Ling et al., 2004).

Bark: Pro-anthocyanidins, hygroline, pseudohygroline, carallidin, para-hydroxybenzoic acid, mahuannin A (Phuwapraisirisan et al., 2006).



Hygroline



Mahuannin A

Structures of Important and Characteristic Chemical Constituents of *Carralia brachiata.*

Biological Activities:

Analgesic activity: The methanol extract of leaves of *C. brachiata* was evaluated for analgesic activity on swiss albino mice with diclofenac sodium as standard. The leaf extract demonstrated significant analgesic effects on acetic acid-induced writhing of mice in comparison to the control group (Islam et al., 2020).

Anti-diabetic activity: The methanol extract of leaves of *C. brachiata* was evaluated for anti-diabetic activity on alloxan-induced diabetic swiss albino mice with metformin as standard. It reduced blood lipid levels considerably and also exhibited a correlation of altered biochemical parameters i.e. SGOT and SGPT levels in diabetic mice which revealed significant anti-diabetic activity in extract (Islam et al., 2020).

Anti-microbial activity: The bark of *C. brachiata* was evaluated for anti-bacterial activity in gradient extraction and single extraction against ten bacterial strains i.e. *Bacillus cereus, Klebsiella pneumoniae, Serratia marcescens, Salmonella typhi, Streptococcus haemolyticus, Vibrio cholerae, Pseudomonas aeruginosa, Escherichia coli, Proteus vulgaris, P. rettgeri*. Anti-bacterial activity was observed at its maximum in the acetone extract prepared in a gradient fashion with the highest anti-bacterial activity against *Serratia marcescens*. (Abraham and Thomas, 2013, Arya et al., 2011; Krishnaveni et al., 2009; Neeharika et al., 2012; Patil et al., 2015)

Anti-inflammatory activity: The methanol extract of leaves of *C. brachiata* was evaluated for anti-inflammatory activity on swiss albino mice with standard diclofenac sodium. The extracts decreased carrageenan-induced paw edema in comparison to the control group (Islam et al., 2020, Arya et al., 2011, Krishnaveni et al., 2009, Neeharika et al., 2012, Patil et al., 2015).

Anti-oxidant activity: Hydro-alcoholic extract of the leaves of *C. brachiata* displayed anti-oxidant potential in diabetic rats (Junejo et al., 2020).

Patents and commercial products:

- Tissue culture virus elimination and rapid propagation method of Carallia brachiata, Patent No: CN105454043A

Scope of further R&D: *Carallia brachiata*, a medium-sized evergreen tree, offers significant potential for further research and development due to its phytochemistry and diverse biological activities. The plant contains bioactive compounds such as hygroline, pro-anthocyanidins, and mahuannin A, which may be responsible for its analgesic, anti-diabetic, anti-microbial, anti-inflammatory, and anti-oxidant properties. Traditional uses of its leaves and bark for treating fever, smallpox, septic poisoning, and inflammation highlight its therapeutic potential. Future research should focus on isolating and characterizing new compounds, understanding the mechanisms behind its pharmacological effects, and conducting clinical trials to assess safety and efficacy in humans. Additionally, exploring its agricultural benefits and environmental adaptability could enhance its role in sustainable practices. The plant's potential for commercial development, including herbal supplements and topical formulations, alongside existing patents for tissue culture methods, higlights its promise for scientific and commercial advancements.

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Careya arborea Roxb.

Synonyms:
Barringtonia arborea (Roxb.) F. Muell.,
Careya orbiculata Miers,
Careya sphaerica Roxb.,
Careya venenata Oken,
Cumbia coneanae Buch.-Ham. (The Plant List, 2012)

Local/Common/Popular Name(s):
Wild guava, Kumbi, Patana Oak, Ceylon Oak, Slow match tree, Kumbikha, Katabhi (Navya and Anitha, 2018), ***Hindi:*** Kumb, Kumbhi, Kaloikatbhi, ***Sanskrit:*** Katabhi, Svadupushpa, Madhurenu, Katambhara, Kumbhi, ***Marathi:*** Kumbha, ***Kannada:*** Daddala, Gudda, Daddippe, Dolli, Kaulu, Kaval, Kaulu, ***Tamil:*** Aya, Ayama, Ayima Kumbi, Peezhai, Puta-tanni-maram, ***Malayalam:*** Aalam, Alasoo, Peru, Pezhu, ***Telugu:*** Araya, Budatadadimma, Gadava, Dudippi, ***Bengali:*** Vakamba, Kumhi, Kumbhi, ***Assamese:*** Godhajam, Kumara.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Ericales
Family	:	Lecythidaceae
Genus	:	*Careya*
Species	:	*Careya arborea*

Plant Description: *Careya arborea* is a deciduous tree that grows up to 15 meters in height. The bark is 10-12 mm thick, fissured, dark grey, and rough, and the inner bark is red and fibrous with pubescent branchlets. The wood is medium coarse-textured, hard, heavy, and strong. The sapwood is white while the heartwood is reddish in color. The leaves turning red during cold are simple, alternate, glabrous, broadly obovate, and clustered at the tips of branchlets with each leaf being 15-30 cm in length and 5-15 cm wide. The yellow or white flowers are bisexual, large, ill-smelling, sessile, and borne in thick, swollen, hard, few-flowered terminal spikes with the flowers being 7.6-20 cm in length. The globose, green-colored fruit is a 5-7.5 cm wide berry with a persistent style, fleshy, glabrous, and rounded. The dark brown, oval ellipsoid seeds are exalbuminous (Matthew, 1983).

Distribution: *C. arborea* is found in India, Afghanistan, Pakistan, Sri Lanka, Nepal, Myanmar, Thailand, Laos, Malaysia, and Burma (Fern, 2014). In India, it is found in the Sub-Himalayan tract, throughout Bengal, the Central Provinces, and the Peninsular region, including areas such as Madhya Pradesh, Chhattisgarh, Maharashtra, Andhra Pradesh, Tamil Nadu, Karnataka, and Kerala (Satish et al., 2010; Sharma et al., 1996).

Habitat: *C. arboreya* is a deciduous tree found throughout India up to an altitude of 1500m. It grows well in moist and dry deciduous forests, grasslands, and plains. It also occurs on lateritic soils and trees that require sunny locations and do not perform well in shade. Apart from this, the tree also prefers well-drained, sandy, or even rocky soil (Matthew, 1983).

Ethnobotanical Significance: *C. arborea* is a medium-sized ethnomedicinal deciduous tree known as kumbhi in Ayurveda. It is a traditional medicinal plant extensively used in Indian traditional medicine for the treatment of various ailments. It has fruits with great nutritional value and is consumed daily as a fresh vegetable in Thailand. The whole plant and different parts of *C. arborea* have a long history of being used for enormous medicinal uses and it is used in Ayurveda and Chinese medicine. The whole plant is used as an astringent, demulcent, antipyretic, antipruritic, cough, cold,

fevers, smallpox, and snake bite. Gum exudates are used for jaundice, after delivery, and tongue ulcers. Koya tribes of Pakhal in Andhra Pradesh practice the plants in ethnoveterinary. The bark is used to cure debility in cattle. Tribal people make a paste by crushing the bark with curd and administering it orally to cattle to treat severe debility (Murthy et al., 2007). Traditionally, the fruits are used for cold and cough (Kapoor and Kapoor, 1980), as an astringent, demulcent (Mahapatra and Panda, 2009), and as a digestion promoter (Ahmed, 2002). The traditional use of bark is to treat tumors, and bronchitis, as an astringent, an antidote to snake venom, and skin diseases. In addition, the bark is also found useful as a demulcent, expectorant, and anthelmintic (Kumar, 2008) and in different conditions such as toothache, catarrh, dyspepsia, colic, hemorrhoids, diarrhea, dysentery, epilepsy, abscesses, eruptive fever particularly smallpox and as a tonic after childbirth (Anonymous, 1950; Nadkarni, 1998; Kirtikar and Basu, 2006). The bark of *C. arborea* is applied internally for the treatment of ear pain, antipyretic and antipruritic (Kumar et al., 2008), stomach disorders, wound healing and body pain, rheumatic pain, abortifacient and used by women to overcome body weakness after delivery. Juice of bark is taken in inflammation associated with cough cold and joint pain. Twigs are considered leech-repellent. The bark extract in hot water is used to take a bath for the lady for treatment of jaundice developed after delivery. The paste of flowers of *C. arborea* and fruits of *Terminalia chebula* and *Phyllanthus emblica*, prepared by macerating in ghee, is taken orally on an empty stomach to treat infertility (Mahishi et al., 2005). Flowers are used as a demulcent in cough and cold tonic, fever, colic, and loose motions. Flowers are also used for treatment to cure vaginal ruptures. The roots of *C. arborea* are used as an astringent and for the treatment of tuberculosis and skeletal fractures (Basak et al., 1975; Kumar et al., 2006). The powder of stem bark is mixed with honey or 50 g of bark is boiled with water and a glass of it is taken on an empty stomach for seven days to treat piles (Mahishi et al., 2005; Rout and Thatoi, 2009).

Phytochemistry:

Bark: Lupeol, betulin, 1-[5-(1,3- benzodioxol-5-yl)-1-oxo-2,4-pentadienyl piperidine, pyroligenous acid (Row and Sastry, 1964, Ahmed, 2002, Bhattacharjee and Das, 1969; Joshi and Sabnis, 1989).

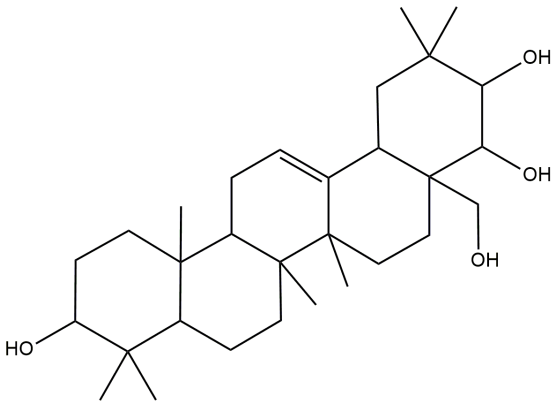
Leaves: Taraxerol, ellagic acid, n-hexacosanol, taraxerol acetate, quercitin, β-sitosterol, careaborin, α –spinasterol, taraxeryl acetate, valoneic acid dilactone, careyagenolide, maslinic acid, 2α-hydroxyursolic acid, arborenin, desacylescin III, careaborin, hydroquinone, resorcinol, syringic acid, vanillic acid, 4-hydroxy-3-(p-hydroxyphenyl)-5,7-dimethoxy-coumarin, 3-(o-hydroxyphenyl) coumarin, trans-2,3,cis-2,4-(+)-3′,4,4′,7-Tetramethoxy-3-flavanol, 2-methoxydibenzofuran (Talapatra et al., 1981, Das, 1982, Kalita et al., 2011, Mahato et al., 1967, Gupta et al., 1975, Gupta, 1981, Basak et al., 1976, Manda et al., 2006).

Fruits: Gallic acid, 3, 4-dihydroxybenzoic acid, quercetin 3-O-glucopyranoside, kaempferol 3-O-glucopyranoside, quercetin 3-O-(6-O-glucopyranosyl) -glucopyranoside (Ariyaratna et al., 2007).

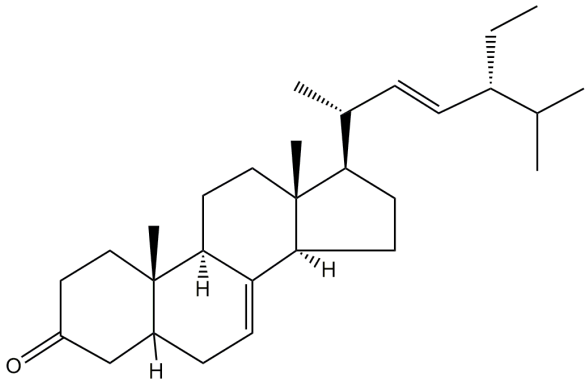
Seeds: Starch (Soni, 1991), α- spinasterone, α- spinasterol (Mahato and Dutta, 1972),16-desoxybarringtogenol C, barringtogenol C, barringtogenol D (Chakraborti and Barua, 1963; Nakano et al., 1969; Yosioka et al., 1967).

Biological Activities

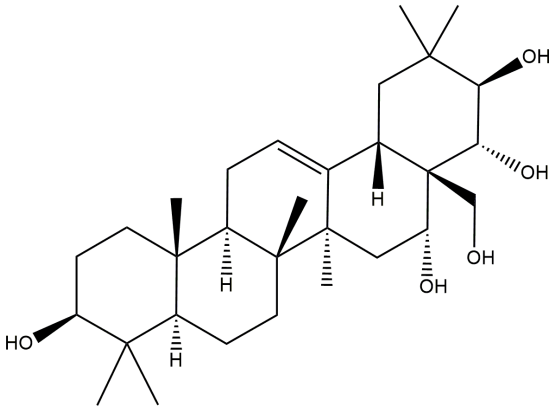
Anti-bacterial activity: The ethanol extract of the leaf was evaluated against *Streptococcus pyogenes*, *Escherichia coli*, *Salmonella typhimurium*, *Bacillus cereus*, *Pseudomonas aeruginos* and *Zymomonas mobiles* and has been reported to have antibacterial activities (Kumar et al., 2006, Prabhakaran et al., 2014; Fuad et al., 2012; Swain and Padhy, 2015; Rathod et al., 2013; Myint et al., 2020, Mali and Wadje, 2015). The methanol extract of stem bark was evaluated in several *in-vitro* systems and demonstrated significant antibacterial against all tested Gram-positive and Gram-negative bacteria (Kumar et al., 2006). The leaf extract exhibited significantly lower zones against *S. aureus* and *E.coli* (Behera et al., 2012). The petroleum ether, chloroform, methanol, ethanol, and water extracts of *C. arborea* were obtained by continuous hot extraction using Soxhlet assembly and were subjected to antimicrobial activity by agar diffusion method where methanol extract demonstrated significant antimicrobial activity against bacteria i.e.



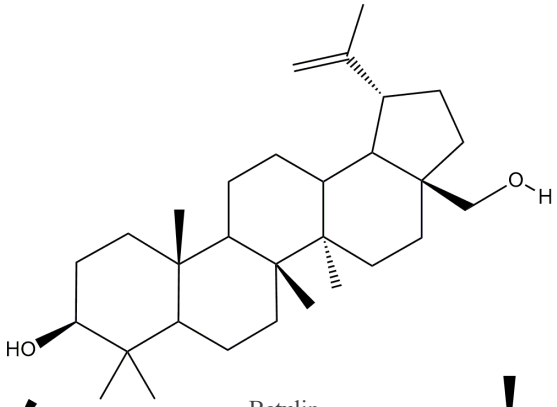
16- Desoxybarringtogenol C



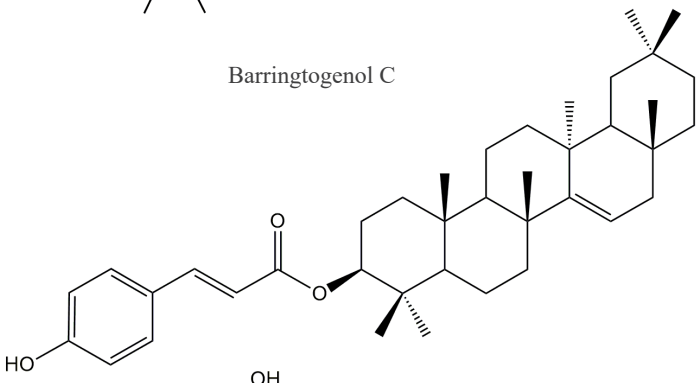
α- Spinasterone



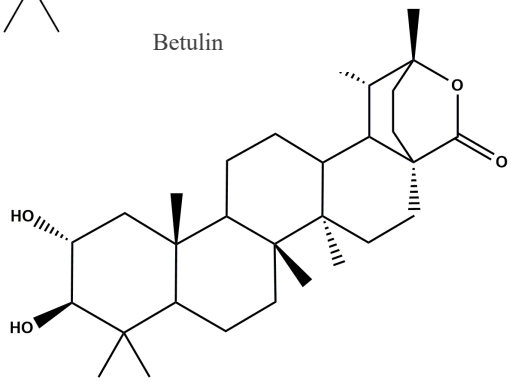
Barringtogenol C



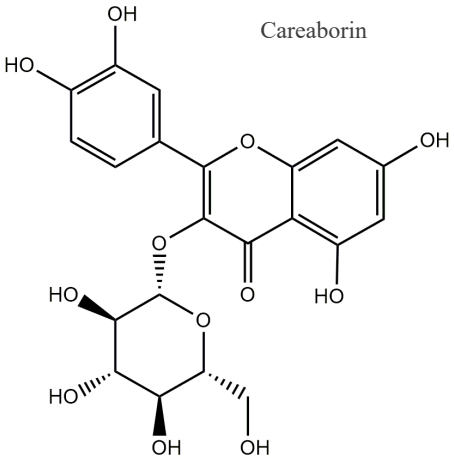
Betulin



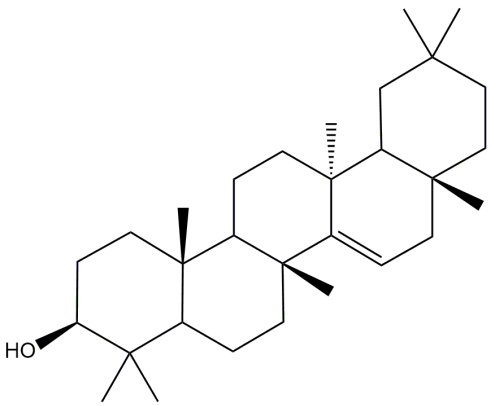
Careaborin



Careyagenolide



Quercetin 3-O-glucopyranoside



Taraxerol

Structures of Important and Characteristic Chemical Constituents of *Careya arborea.*

P. aeroginosa (ATCC 9027), *E. coli* (ATCC 9837), *S. aureus* (ATCC 9886), *Micrococcus luteus* (ATCC 10240) and fungi i.e. *Aspergillus niger* (ATCC 16404), *Candida albicans* (ATCC 10231) (Navya and Anitha, 2018). The fruit extracts were evaluated for antibacterial and antibiofilm activity against multi-drug resistant isolates *S. aureus, E. coli, Salmonella,* and *Shigella* of human pathogens. The isolates of *E. coli, Salmonella,* and *Shigella* were found to be resistant to the extracts while antibacterial and antibiofilm activities were observed against *S. aureus* (Triveni et al., 2022).

Anti-oxidant activity: The ethanol and ethyl acetate extracts of *C. arborea* were reported to have strong anti-oxidant activities due to the presence of high levels of phytochemicals such as phenolics and flavonoids which confirm its traditional claims as a source of potential anti-oxidants (Wadje et al., 2019). The methanol extract of stem bark was also evaluated in various *in-vitro* systems and showed significant free radical scavenging activity (Kumar et al., 2006). The antioxidant activity of 50% hydroalcoholic extract of stem bark and leaves was assessed by total antioxidant capacity (TAC), reducing power, FRAP (Ferric reducing antioxidant power), DPPH (1,1-diphenyl-1,1-picrylhydrazyl), nitric oxide and superoxide radical scavenging assays. Leaves extract showed better activity than the bark in radical scavenging assays and in FRAP assay. The ferric-reducing power of bark and leaves was increased with an increase in the concentration of extracts. This revealed that *C. arborea* possessed significant antioxidant activity (Gupta et al., 2020).

Anti-ulcer activity: The ethanol extract of the stem bark demonstrated anti-ulcer activity against ethanol, pylorus ligation, and cold-resistant stress-induced ulcers. In another study, ethanol extract from the leaf showed significant gastroprotective effects in rats against ethanol, aspirin, cold restraint stress, and pylorus ligation-induced ulcers by decreasing acid volume and simultaneously increasing mucus level on the walls of the stomach (Kumar et al., 2013; Gupta and Rao, 2014). The ethanol extract of stem bark showed anti-ulcer activity against various models such as ethanol-induced, cold restraint stress-induced, and pylorus ligation-induced models (Kumar et al., 2013).

Anti-fertility effects: The phenolic compounds present in the methanol extract of the root of *C.arborea* showed reversible antifertility effects and estrous cycle disturbances (Kalita et al., 2011). The GC-MS analysis of the methanol extract showed the presence of some phenolic compounds-hydroquinone, resorcinol, synergic acid, vanillic acid, gallic acid, 2-methoxydibenzofuran which might be responsible for the anti-fertility activity (Jogen et al.,2011).

Hepatoprotective activity: The effect of the methanol extract of *C. arborea* and silymarin on serum transaminase, alkaline phosphates, bilirubin, uric acid, and total protein were measured in rats induced hepatotoxicity by carbon tetrachloride and it was found that the extract possesses potent hepatoprotective and antioxidant properties (Kumar et al., 2005). The hepatoprotective activity of the methanol extract of bark was evaluated in tumor control animals inoculated with Ehrlich ascites carcinoma (EAC) and it was found to possess potent hepatoprotective activity (Senthilkumar et al., 2008). The flavonoids and alkaloids may be responsible for the hepatoprotective properties of this plant (Wadker et al., 2008). The ethanol extract of bark showed a promising hepatoprotective effect on paracetamol-induced liver damage in rats and, hence proved to be one of the herbal remedies for liver ailment (Islam et al., 2018).

Anti-tumor/ anti-cancer activity: The methanol extract of stem bark showed antitumor activity against dalton lymphoma and HeLa cell lines. The ethanol extract of the leaf demonstrated prominent cytotoxic effects when tested against Vero cell lines and HEp-2 cell lines (Rathod et al., 2013; Senthil kumar et al., 2007). It was associated with apoptosis on DLA cell lines by determination of morphological changes and DNA fragments (Subhadra devi et al., 2010). The anticancer potential of the methanol extract of the bark was evaluated against Dalton'slymphoma ascites (DLA)-induced ascitic and solid tumors and observed a significant reduction in the solid tumor volume induced by DLA cells. *C.arborea* extract possesses significant anticancer activity which may be due to its cytotoxicity and antioxidant properties (Ramesh and Shenoy, 2013). Ethanol extract of the leaves was evaluated for its anticancer activity against human breast cancer, MCF-7 cell lines and demonstrated inhibition against MCF-7 cancer cell viability in a concentration-dependent manner with

very low IC_{50} values which indicates that it might be useful for breast cancer prevention and therapy (Buranrat et al., 2020). The plant leaves exhibited promising anti-proliferative activities against four human cancer cell lines viz., human nasopharynx (KB), human lung (HOP62), human cervix (ME180), and human leukemia (K562) cancerous cell lines which may be due to its free radical scavenging activities and due to the presence of bioactive polyphenols i.e. quercetin, rutin, catechin, gallic acid, and chlorogenic acid (Wadje et al., 2019).

Anti-inflammatory effect: The anti-inflammatory activity of methanol extract of stem bark was evaluated by measuring malondialdehyde (MDA), C-reactive protein (CRP), nitric oxide (NO), myeloperoxidase (MPO), TNF-α, and IL-1β levels in both control and treated groups and observed significant anti-inflammatory activity (Begum et al. 2015). The inhibition of pro-inflammatory cytokines, enzymes, and mediators appears to account for the anti-inflammatory potential of *C. arborea* (Begum et al. 2015). The effect of methanol extract of *C. arborea* was studied on the acute and chronic phases of inflammation in carrageenan, dextran, and mediators (histamine and serotonin) induced paw edema and cotton pellet-induced granuloma and observed maximum inhibition (Kumar et al., 2005). The methanol extract of stem bark of was evaluated for anti-inflammatory activity using a chronic inflammatory model of Complete Freund's Adjuvant (CFA) induced chronic inflammation in rats where Indomethacin was the reference drug. The levels of nitric oxide, myeloperoxidase, gamma-glutamyl transferase, malondialdehyde, and C-reactive protein were significantly downregulated after administration of methanol extract of *C. arborea*. The results revealed that the extract exhibited potent anti-inflammatory effects (Rayhana et al., 2014).

Central nervous system (CNS) activity: The methanol extract of bark was studied for general behavior, exploratory behavior, muscle relaxant activity, and phenobarbitone sodium–induced sleeping time in test animals to investigate central nervous system (CNS) activity and observed CNS depressant activity in Swiss albino mice and Wistar albino rats (Kumar et al., 2008b). The results revealed that the methanol extract of the bark at 100 and 200 mg/kg caused a significant reduction in spontaneous activity and therefore possessed CNS depressant activity (Ramanathan et al., 2008).

Pesticidal activity: The pesticidal activity of methanol and ethanol extracts of *C. arborea* was analyzed and confirmed at a concentration of 50µg/ml against devastating pests such as *Spodoptera litura* and *Helicoverpa armigera* of numerous wild and cultivated plants throughout the world by leaf dip and diet bioassay techniques (Ramya and Roopashree, 2017).

Anti-allergic activity: Anti-allergic activity investigation on methanol extract of leaves and fruits of *C. arborea* showed significant ($p<0.05$) anti-allergic activity when tested using *in-vitro* model (isolated guinea pig ileum preparation and isolated rat ileum preparation) and *in-vivo* mode using passive paw anaphylaxis. The methanol extract of the fruits showed better activity than the methanol extract of the leaves which might be due to the presence of phenolic and flavonoid compounds (Chothani and Patel, 2014).

Anti-coagulant effect: The methanol extract of the bark was tested for its anticoagulant activity and significant activity was observed in comparison to warfarin with a remarkable increase in the activated prothrombin and thrombin levels (Kumar et al., 2010). The methanol extract of bark possessed anticoagulant activity via a significant increase ($p<0.05$) in thromboplastin (aPTT), prothrombin (PT), and thrombin (TT) in comparison to warfarin.

Hypoglycemic effect: A metformin-like compound was reported in the root bark and found to be the active hypoglycemic principle (Kumar et al., 2010). It helps to maintain normal blood sugar levels in humans and animals thereby proved its hypoglycemic effect (Majeed et al., 2007).

Patents and commercial products:

- Composition for improving atopy dermatitis using an extract of *Careya arborea*, Patent No: KR20190095173A
- Composition for improving atopy dermatitis using active compounds isolated from an extract of *Careya arborea*, Patent No: KR20190035248A
- An improved micro HPLC method for identification of metformin hydrochloride in root of *Careya arborea*, Patent No: 540/MUM/2003

- A Method of making *C. abrorea* herbal drug for complex hyper and hypoglycemic activity, Patent no: 543/mum/2003
- Composition for alleviating atopy dermatitis sing extract of *Careya arborea*, Patent No: KR1020190095173
- An improved micro hplc method for identification of metformin hydrochloride in root of *Careya arborea*, Patent no: IN540/MUM/2003

Scope of further R&D: The scope for further research and development (R&D) on *Careya arborea*, or wild guava, is promising and multifaceted. Given its extensive traditional uses and rich phytochemical profile, there are several avenues for exploration. Investigating its bioactive compounds such as lupeol, quercetin, and gallic acid could lead to the development of novel antioxidants and anti-inflammatory agents. Exploring its antibacterial, anti-ulcer, and hepatoprotective properties in more depth could unveil new therapeutic applications. Additionally, further studies into its anti-cancer potential, particularly against different cancer cell lines, could pave the way for new cancer therapies. Moreover, understanding its mechanisms of action in various biological activities and exploring synergistic effects with other medicinal plants could enhance its efficacy and application breadth. Conducting clinical trials to validate its traditional uses and safety profile would be crucial for its integration into mainstream healthcare. Overall, *Careya arborea* presents a robust platform for future R&D endeavors aimed at harnessing its full therapeutic potential and translating traditional knowledge into modern medical solutions.

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Cassine glauca
(Rottb.) Kuntze

Synonyms:
Barringtonia sphaerocarpa C.A. Gardner, *Celastrus glaucus* Vahl, *Elaeodendron dichotomum* Royle, *Elaeodendronglaucum* (Rottb.) Pers, *Elaeodendron oxyodon* Turcz, *Elaeodendron paniculatum* Wight & Arn, *Elaeodendron roxburghii* Wight & Arn, *Euonymus grossus* Wall, *Schrebera albens* Retz

Local/Common/Popular Name(s):
Ceylon tea, ***Hindi:*** Jamarassi, ***Kannada:*** Kannurmara, Mookarki, Mookrike, ***Marathi:*** Mothabhutya, Bhutikes, Alan, Bhutkas, Buscut, Butiyakalas, Jamarasikirmira, Kangune, Pigavi, Tamruj, ***Sanskrit:*** Krishnamokshaka, ***Tamil:*** Kanneermaram, Karuvali, Kannimaram, ***Telugu:*** Nirija, ***Odia:*** Chauli, Mokha, Pisitondora

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Clade	:	Tracheophytes
Order	:	Celastrales
Family	:	Celastraceae
Genus	:	*Cassine*
Species	:	*Cassine glauca*

Plant Description: *Cassine glauca* is a large evergreen tree that grows up to 25m in height. The bark is dark grey/ reddish with thin, smooth, and exfoliating scales. The dark green leaves are simple, opposite or sub-opposite, elliptic, ovate-oblong or obovate, glabrous, shining above and glaucous beneath with measurements 3-16 X 1.5-7.5 cm. The petiole is 0.5-1 cm long and channeled. The inflorescence is an axillary dichotomous cyme. The white or greenish-yellow flowers have a diameter of 5 mm and 4-5 lobed calyx with rounded lobes and membranous margin. The recurved stamens are four in number and are inserted on the margin of the disk with anthers having a bilobed connective. The stamens are shorter than petals with thick and fleshy disks. The 4-celled ovary is adnate to the disc with a very short and persistent style. The single-celled dry, ovoid, green fruit is a drupe with 1-15 cm length and is single-seeded.

Distribution: *C. glauca* is distributed in India in Maharashtra, Tamil Nadu, Chittoor district, West Godavari district, Guntur district, Vishakhapatnam district, Prakasam district and Srikakulam district of Andhra Pradesh, and Puri and Kalahandi district of Odissa (Sankara rao et al., 2019).

Habitat: *C. glauca* is a fast-growing tree found in dry deciduous and evergreen forests from the coastal plains up to 1500 m on the hills and can be planted in the sun or half shade. It is drought-resistant and can grow under severe climatic conditions and different soil types however, the soils need to be free-draining (Flora of Peninsular India, 2019).

Ethnobotanical Significance: *C. glauca* is used in Ayurveda and Siddha medicines. The paste of the bark is taken orally against snakebite and fresh root bark of this plant is used for swelling. The fresh extract of stem bark and leaves is applied to cuts and wounds to cure them (Vijendra et al., 2010). The powdered leaves have a sternutatory action and are used as snuff to relieve headaches and as a fumigatory in hysteria and cooked leaves are eaten for gastritis (Khare, 2007, Mahishi et al., 2005). The stem and leaf juice are dropped into the nose to cure headaches. The roots are

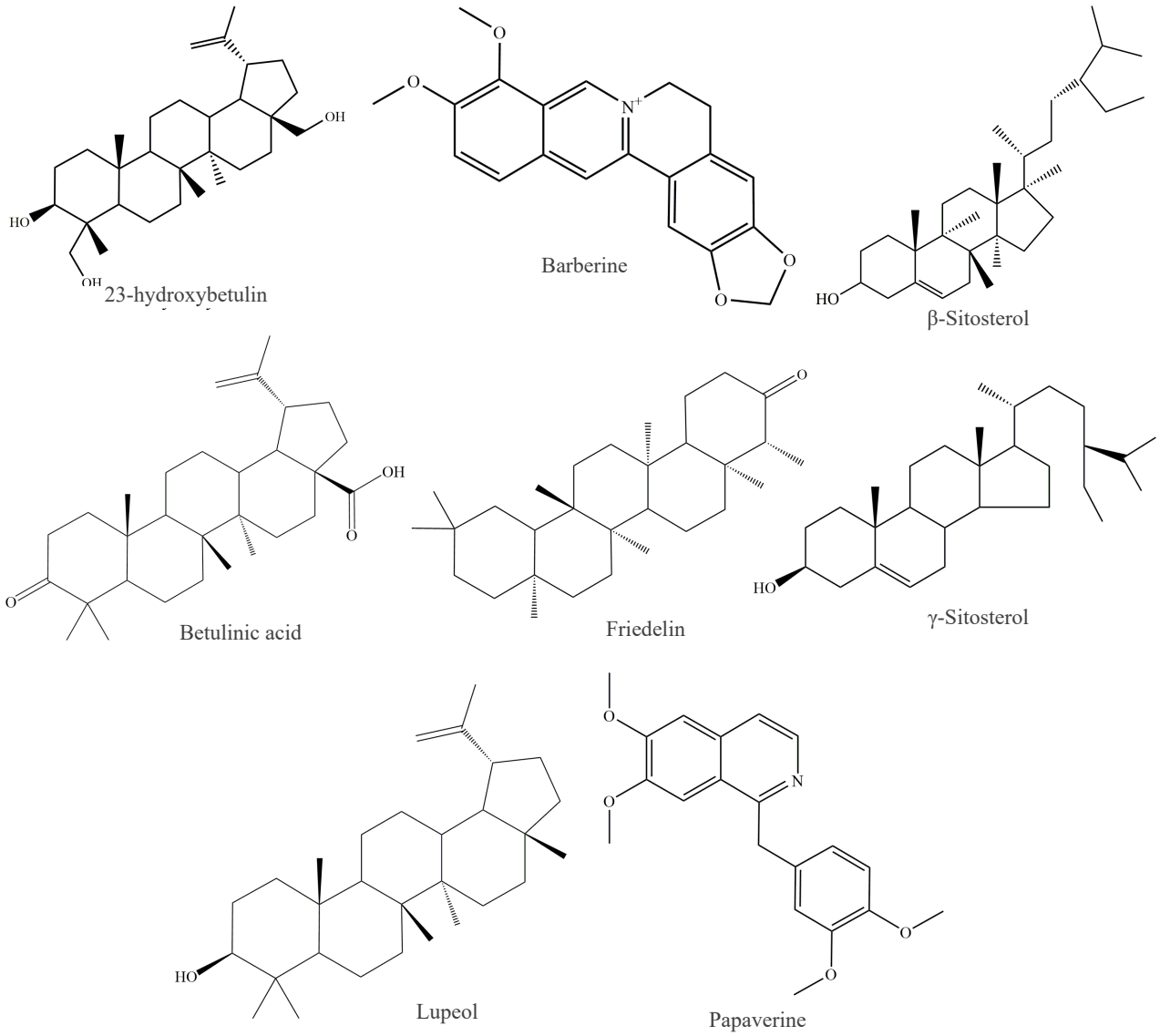
astringent and used to treat dysentery and also as an antidote for snakebites (Quattrocchi, 2012). In a folkloric system of medicine, it is used for the treatment of hysteria, syncope, and normal headache (Kirtikar and Basu, 2005). It is also used in the treatment of cholera, and menstrual disorders and to reduce sterility in women (Singh et al., 2002). The leaves and bark of *C. glauca* are used in folk medicine for the treatment of diabetes mellitus and gonorrhea (Salahuddin et al., 2010; Farswan et al., 2009). Its aerial parts are used as a central nervous system depressant and as a diuretic (Kirtikar and Basu, 1998). The leaves are pounded in sugar and milk is used to cure blennorrhagia and the seeds are known to possess purgative and anti-malarial properties. Roots and leaves of *C. glauca* are used in treating cough with phlegm, swellings, and menstrual disorders (Jagtap et al., 2009). The plant paste is used on skin wounds and cuts (Choudhary et al., 2011) and bark powder is used in treating rheumatism.

Phytochemistry:

Leaves: γ-Sitosterol, β –sitosterol, lupeol, octacosanol, friedelin, betulinic acid, 23-hydroxy betulin, (Hatapakki et al., 2005; Farswan et al., 2009), barberine, aconitine, papaverine, phygostigmine (Malpani and Rajput, 2019).

Seeds: Elaeodendroside A, B, C, D, E, H, I, (Anjaneyulu and Narayanrao, 1980).

Bark: 17β-hydroxy-28-norfriedelan-3-one (elaeodendrol), l7 β- 25-dihydroxy-28-norfriedelan-3-one (elaeodendradiol) (Anjaneyulu and Narayana Rao, 1980; Saraswathy and Thirumurugan, 2018).



Structures of Important and Characteristic Chemical Constituents of *Cassine glauca*

Biological Activities:

Anti-bacterial activity: The ethanol extract of *C. glauca* demonstrated antibacterial activity against *Pseudomonas aeruginosa, Enterococcus faecalis, Escherichia coli,* and *Corynebacterium* species. Additionally, the water extract of *C. glauca* showed antibacterial activity against *P. aeruginosa*, *Salmonella enterica*, and *Salmonella typhimurium* (Moin et al., 2014). The efficacy of whole extract, isolated acidic ingredient, and its newly synthesized analogs of *Cassine glauca* was evaluated for anti-bacterial efficiency against *Streptococcus pyogenes, Nocardia calcarean, Bacillus subtilis,* and *P. aeruginosa*. The isolated acidic ingredient and its newly synthesized analogs showed more significant activity than the whole extract. The results obtained were assessed by comparison with standard ampicilin and the control vancomycin (Malpani and Rajput, 2015). The petroleum ether, ethyl acetate, ethanol, and water extracts from mature leaves of *C.glauca* were evaluated for antibacterial activity. The ethanol extract was active against the tested pathogenic bacteria i.e. *Staphylococcus aureus* ATCC 25923, *Pseudomonas aeruginosa* ATCC 27853, *Enterococcus faecalis* ATCC 29212*, Escherichia coli* ATCC 25922, *Salmonella enterica, S. typhimurium*, *Corynebacterium* sp., and *S. epidermidis.* The antibacterial potential of the plant was compared with positive control (tetracycline) and negative control (dimethylsulfoxide) (Moin et al., 2014)

Anti-oxidant activity: The ethanol extracts of leaves of *Caesalpinia bonduc*, *C. glauca*, and *Cassia absus* were evaluated for antioxidant activity on the basis of the radical scavenging effect of DPPH. The results revealed significant antioxidant activity. The IC_{50} values (mg/mL) were found to be 0.55, 0.65 and 0.75 for *Caesalpinia bonduc*, *Cassine glauca,* and *Cassia absus,* respectively (Malpani and Rajput, 2019).

Anti-diabetic activity: The acetone extract from *C. glauca* leaf caused a significant reduction in the levels of a hepatic enzymes such as aspartate transaminase (AST), alanine transaminase (ALT), creatine kinase (CK) and lactate dehydrogenase (LDH) in STZ-induced diabetic rats and improvement in the blood sugar level and normalization of the liver function specified that it has hepatoprotective potential, along with anti-diabetic activity which contributes a scientific rationale for the use of *C. glauca* leaf as an anti-diabetic agent (Farswan et al., 2009).

Other Biological Activities: Acetone extracts of *C. glauca* exhibited anti-feedant activity against 4th-instar larvae of the noctuid Achaea janata (Deshpande et al., 1993). C. glauca inhibited the H+, K+-ATPase with variable potency, achieving more than 90% inhibition of the growth of *Helicobacter pylori*, a major cause of ulcers, and demonstrated a moderate level of free radical scavenging and reducing power activity (Belagihalli and Dharmesh, 2021). The hydroalcoholic extract of *C. glauca* showed antidepressant and anxiolytic activity in stress-evoked models (Patil et al., 2012). Cultivation of *C.glauca* as a shade tree reduced the attack of stinkbugs *Halyomorphahalys* to nearby rice and horticultural crops (Sasaki *et al*., 2008).

Scope of further R&D: Future research on *Cassine glauca* should focus on detailed phytochemical analysis to isolate and characterize its bioactive compounds using advanced techniques like LC-MS and NMR. Studies to elucidate the mechanisms of its antibacterial, antioxidant, anti-diabetic, and other bioactivities are essential, involving molecular docking, gene expression analysis, and various biological models. Clinical trials are needed to validate its efficacy and safety in humans, adhering to rigorous standards. Development of standardized extracts and formulations, along with stability and bioavailability assessments, is crucial for modern medicinal use. Research into optimal agronomic practices can enhance yield and quality, while sustainable harvesting and conservation strategies are important to prevent over-exploitation. Structural modification of isolated compounds and exploration of synergistic effects with other medicinal plants or conventional drugs can optimize bioactivity and therapeutic outcomes. Addressing these areas will facilitate the integration of *C. glauca* into contemporary therapeutic regimens, providing scientifically validated treatments for various diseases.

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Cinnamomum cecidodaphne Meisn.

Synonyms:
Cinnamomum glaucescens (Nees) Hand. -Mazz., *Laurus glaucescens* Buch. -Ham. ex Nees, *Tetranthera glaucescens* Wall.

Local/Common/Popular Name(s):
Bengali: Malagiri, ***Assamese:*** Gon soroi, ***Nepali:*** Sugandha kokila, ***English:*** Sassafras

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Division	:	Magnoliophyta
Subdivision	:	Spermatophytina
Class	:	Dicotyledonae
Order	:	Laurales
Family	:	Lauraceae
Genus	:	*Cinnamomum*
Species	:	*Cinnamomum cecidodaphnae*

Botanical Description: *Cinnamomum cecidodaphne*, a member of the Lauraceae family, is a lesser-known species closely related to commercially significant cinnamon trees. It is a medium to large evergreen tree, typically reaching heights of 10–25 meters**.** The trunk is straight and cylindrical, covered with smooth to slightly rough bark that releases a characteristic aromatic odor when bruised (Jackson,1994).The leaves are simple, alternate to sub-opposite, and range from elliptic to oblong-lanceolate in shape, tapering to an acute or acuminate tip. They measure 10–20 cm in length and 3–8 cm in width, with a glossy green upper surface and a paler underside. The smooth texture and prominent 3–5 parallel main veins arising from the base are distinctive features of Lauraceae species. When crushed, the leaves emit a cinnamomum-like fragrance. The flowers are small, either bisexual or unisexual, and actinomorphic (Remaetal., 2002). They are arranged in panicles or cymes, borne in the leaf axils or terminally. Pale yellowish to creamy white in color, they typically bloom in spring to early summer, attracting pollinators like bees with their fragrance.The fruit is a drupe, ellipsoid to ovoid in shape, measuring 1–2 cm in length. Immature fruits are green, maturing to a purplish-black color. Each drupe is seated on a small, cup-like receptacle, a distinguishing feature of the genus.The bark is thin, grayish-brown to reddish-brown, and peels off in irregular flakes in older trees. It emits a warm, spicy aroma characteristic of the genus, attributed to its high content of volatile oils.

Distribution: The species is native to Bangladesh, the Eastern Himalayas, India, Laos, Myanmar, Nepal, and Vietnam. In India, it is found in Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Nagaland, and Tripura in the northeastern region; Sikkim and the Darjeeling region of West Bengal in the Eastern Himalayas; and Kerala, Karnataka, and Tamil Nadu in the Western Ghats.

Habitat: *Cinnamomum cecidodaphne* thrives in low land primary evergreen forests at elevations ranging from 500 to 1500 meters. The species is well-adapted to tropical and subtropical regions, particularly in humid, forested areas. It prefers moist evergreen forests but can also be found in mixed forest ecosystems. The tree requires well-drained,

loamy soils enriched with organic matter and flourishes in regions with moderate to heavy rainfall and a warm, humid climate.

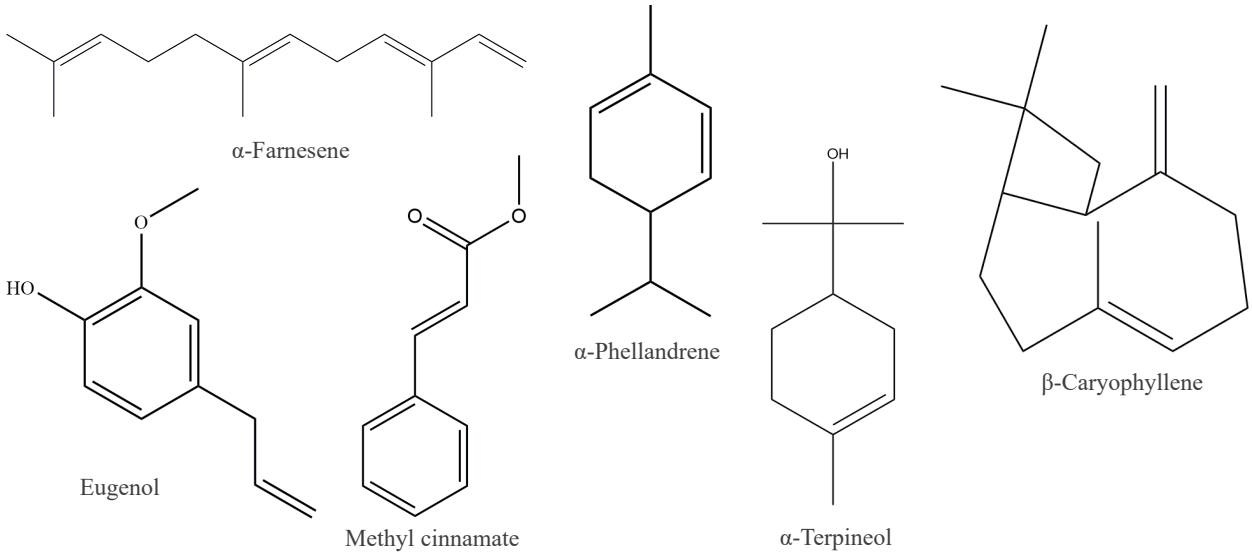
Ethnobotanical Significance: The natives of Nepal use the paste of bark as a remedy for snake bites (Jackson,1994; Remaetal., 2002). Using steam distillation, the dried berries of *C. cecidodaphnae* produce a yellow-colored essential oil with a camphoraceous and spicy aroma, commonly known as sugandha kokila oil. This product can be used as a fragrance in soaps, detergents, cosmetics, perfumes, and industrial fragrances as well as in indigenous medicine as a demulcent and stimulant (Adhikaryetal., 1992).

Phytochemistry:

Leaves: α-Phellandrene, α-farnesene, 1, 8-cineole, α-pinene, linalool, α-phellandrene (Satyal et al., 2013; Prakash et al., 2013; Baruah et al., 2006), terpineol, caryophyllene (Prakash et al., 2013; Baruah et al., 2006), geraniol, terpinene-4-ol (Chinh et al., 2017).

Panicle: 1,8-Cineole, α-pinene, phellandrene, β-caryophyllene, (Z)- methyl isoeugenol, α-farnesene (Baruah et al., 2006).

Fruit: 1,8-cineole, methyl cinnamate, elemicin (Chinh et al., 2017)



Structures of Important and Characteristic Chemical Constituents of *Cinnamomum cecidodaphnae*

Biological Activities:

Allelopathic activity: The allelopathic activity of Nepalese *Cinnamomum* essential oils was analyzed in terms of inhibition of seed germination and seedling growth against a representative dicot (lettuce, *Lactuca sativa*) and a representative monocot (perennial ryegrass, *Lolium perenne*). *Lactuca sativa* seed germination was notably inhibited by *C. camphora* essential oil (IC_{50}=149 µg/mL) as well as its major component, camphor (IC_{50}=239 µg/mL). Although neither *C. tamala* nor *C. glaucescens* appreciably affected the germination of either *L. sativa* or *L. perenne*, the major component of *C. glaucescens* oil, methyl (E)-cinnamate did inhibit *L. perenne* germination (IC_{50}=610 µg/mL). *L. sativa* seedling growth was more sensitive to the *Cinnamomum* essential oils than *L. perenne*. *C. camphora* essential oil significantly inhibited *L. sativa* radicle growth at 250 µg/mL, which can be attributed to its major component, camphor. *C. glaucescens* essential oil and methyl (E)-cinnamate were inhibitory to both *L. sativa* and *L. perenne* at the concentrations tested. *C. tamala* oil inhibited seedling growth of *L. sativa* at 500 µg/mL and *L. perenne* at 1000 µg/mL, likely due to the high concentration of camphor in this essential oil (Satyal et al., 2013)

Cytotoxicity: *C. ceidodaphne* essential oil exhibited *in-vitro* cytotoxic activity against MCF-7 cells, and these activities also correlate with brine shrimp lethality (Anderson et al., 1991; Satyal et al., 2013). Most of the essential oil components tested also

showed cytotoxicity to MCF-7 cells, as well as brine shrimp lethality.

Insecticidal activity: The *Cinnamomum* essential oils were screened for insecticidal activity against mosquito (*Culex pipiens*) and midge (*Chaoborus plumicornis*) larvae, cabbage white butterfly (*Pieris rapae*) larvae, termites (*Reticulitermes virginicus*), fruit flies (*Drosophila melanogaster*), and red imported fire ants (*Solenopsis Invicta×richteri*). All essential oils showed mosquito larvicidal activities comparable with or better than previously reported essential oils (Traboulsi et al., 2002), bay laurel (*Laurus nobilis*) (Traboulsi et al., 2005), amyris (*Amyris balsamifera*) (Zhu et al., 2006), and spearmint (*Mentha spicata*) (Koliopoulos et al., 2010), against *Culex pipiens*. Consistent with the mosquito larvicidal activity, the essential oils and components showed larvicidal activity against *Chaoborus* larvae as well *C. glaucescens* fruit oil was the most active *Cinnamomum* oil against termites with an LC_{50}=34 µg/mL. Several essential oils have shown termiticidal activity (Zhu et.al, 2001; Chang et al.,2001; Cheng et al., 2004; Park et al., 2005; Clausen, 2008; Seo et al.,2009, Prakash et al., 2013), but differences in assay protocols preclude comparisons of bioactivities.

Anti-fungal activity: The essential oil of *C. glaucescens* was evaluated for anti-fungal activity against *Aspergillus flavus* where the essential oil significantly inhibited its growth and aflatoxin production (Prakash et al., 2013).

Nematicidal activity: *C. glaucescens* fruit essential oil exhibited the strongest nematicidal activity with an LC_{50} of 151 µg/mL, followed by *C. camphora* leaf oil (LC_{50} = 574 µg/mL) and *C. tamala* root oil (LC_{50} = 1320 µg/mL). The nematicidal activity of *C. glaucescens* oil on *Caenorhabditis elegans* can be attributed to its major component, methyl (E)-cinnamate (LC_{50}=138 µg/mL), which had previously shown nematicidal activity against the pine wood nematode, *Bursaphelenchus xylophilus* (Kong et al., 2007; Kim et al., 2011 ,Satyal et al., 2013)

Antidiarrheal and Thrombolytic activities: The methanol extract of *C. cecidodaphne* was examined on castor oil induced diarrhea in Swiss albino mice for assessing anti-diarrheal activity and *in-vitro* clot analysis was used for investigation of thrombolytic action of the extract. For analysis of antidiarrheal activity, loperamide was used as standard and streptokinase was used as positive control for assessing thrombolytic test. The extract was found to exhibit significant antidiarrheal activity and thrombolytic activity (Sayeed et al., 2014).

Sedative activity: The methanol extract of bark of *C. cecidodaphne* was evaluated for sedative effect using four methods i.e. open field, hole cross, thiopental induced sleeping time, and EPM test at 200mg/kg and 400mg/kg on Swiss albino mice. The study revealed that the extract possesses significant sedative activity (Karim et al., 2015).

Scope of further R&D: *Cinnamomum cecidodaphnae*, holds significant ethnobotanical value. It is a source of an essential oil derived from its berries. Chemical constituents of the essential oil suggest diverse bioactive potential. Biological screening of the essential oil reveal cytotoxic effects on cancer cells, potent insecticidal activities, and promising antifungal and nematicidal properties of the essential oil. Future research could focus on elucidating pharmacological mechanisms, optimizing extraction techniques, and exploring sustainable cultivation methods. The essential oil's prospects in aroma and cosmetic industries are promising, suggesting potential applications in perfumes, soaps, and cosmetics, highlighting its economic and ecological significance. Further exploration of *C. cecidodaphnae* could unlock novel therapeutic and commercial opportunities, making it a focal point for future interdisciplinary studies and applications

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Citrullus colocynthis (L.) Schrad.

Synonyms:
Colocynthis officinalis Schrad,
Colocynthis vulgaris Schrad,
Citrullus colocynthoides Pangalo,
Citrullus pseudocolocynthis M. Roem.

Local/Common/Popular Name(s):
Desert Gourd, Bitter cucumber, Bitter apple, Tumba.

Vernacular Names:
Hindi: Indrayan, ***Marathi:*** Kadu Vrundavan, ***Sanskrit:*** Indravaaruni, Indra, Indravaaru Gavaakshi, ***Bengali:*** Raakhaalashasa, ***Punjabi:*** Kaud Tumbha, ***Gujarati:*** Indrayana, ***Tamil:*** Petikari, ***Telgu:*** Paaparbudam, ***Arabi:*** Hanjal, ***Arabic:*** handhal, ***English:*** bitter-apple, bitter-cucumber, colocynth, vine-of-Sodom, wild gourd, ***French:*** coloquinte, ***German:*** bitter-melon, koloquinte, ***Portuguese:*** colocintida, ***Spanish:*** alhandal, coloquíntida.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Cucurbitales
Family	:	Cucurbitaceae
Genus	:	*Citrullus*
Species	:	*Citrullus colocynthis*

Botanical Description: *Citrulus colocynthis* is a wild, perennial, herbaceous, non-tough, harsh, and angular vine with lobular tendrils, which is well adapted to arid climatic conditions. The leaves are alternate, rough, and hirsute with upper green and lower pale colored surfaces with long petioles which are 5-10 cm in length and possess 3-7 profound lobes. The leaves are very similar to that of the watermelon plant. The plant has delicate, fleshy and long tap roots (Dhakad et al., 2017). The flowers are yellow and solitary occurring in the axes of leaves borne by yellow-greenish peduncles. Each flower has a sub-campanulated five-lobed corolla and a five-parted calyx. They are monoecious that is the male (stamens) and the female reproductive parts (pistils and ovary) are borne in different flowers on the same plant. The male flower's calyx is shorter than the corolla. They have five stamens out of which, four occur in pairs while the single one has an amonadelphous anther. The female flowers have three staminodes and a three-carpel ovary and can be distinguished from male flowers due to the presence of globular and hairy inferior ovaries in the female flowers. About 75 % bulk of the *C. colocynthis* fruit is found to be of seeds (Hussain et al., 2010) which are about 6 mm in size, brownish, smooth and caramel when ripened. The fruit is smooth and spheric with a 5 -10 cm diameter and exhibits a nutty-flavored and extremely bitter taste which is rich in fat and protein. The calyx englobes the yellow-green fruit which becomes marble (yellow stripes) at maturity. The mesocarp is filled with a soft, dry and spongy white pulp with embedded seeds. Each of the three carpels bears six seeds. Each plant produces 15 to 30 fruits (Schafferman et al., 1998). They are eaten whole or used as oilseed. The flowering occurs from November to July while the fruiting occurs from December to January and all around the year in a few sandy places.

Distribution: *C. colocynthis* is a valuable plant commonly known as Colocynth reported in parched and arid zones of the world. It is native to the Mediterranean and Asian region (Gurudeeban et al., 2010 and Pravin et al., 2013). Geographically, it is distributed in deserts of North Africa, South Europe and the whole of Asia extending up to Egypt. In India, it is found in hot and arid areas (Gurudeeban et al., 2010).

Habitat: *C. colocynthis* is found in plains and dunes (Bhandari, 1990). Though this is found growing in various habitats, it is observed that they mainly prefer the sandy river beds and sandy sea coast. In India, it is distributed near the dunes of Jaisalmer in Rajasthan and in Gandhinagar, Kheda, Ahmedabad, Anand, Vadodara, Panchmahal and Dahod in Gujarat (Source: Regional Center of BSI, Jodhpur).

Ethnobotanical Significance: Most of the tribal areas and rural communities use entire plants of *C. colocynthis* to treat various ailments. The seeds are used to cure bowel complaints, blackness of grey hair (Mohammed et al. 2004), and malaria (Ali et al., 2004). Fruits are used to reduce stomach aches (Singh et al., 1983), dropsy (Nadkarni et al., 1998), in pregnancy (Sharma et al., 2002), hepatitis, (Dafni et al., 2002) and snake poison (Tiwari et al., 2003). Roots are applied in the form of paste to enlarge the abdomen and to cure rheumatism (Kirtikar et al., 1998, Tiwari et al., 2003). The dried pulp of unripe fruit is used medicinally for its drastic purgative and hydragogue cathartic action on the intestinal tract. When the fruit is ripe its pulp dries to form a powder which is used as a bitter medicine and drastic purgative. This powder is so inflammable that the Arabs collect it to use as kindling. The fruit is used to repel moths from wool. Seed, often removed from the poisonous pulp and eaten in Central Sahara regions contains an essential oil. According to Hartwell the plant figures into remedies for cancer, carcinoma, endothelioma, leukemia, corns, tumors of the liver and spleen and even the eye. The pulp or leaves are a folk remedy for cancerous tumors. A decoction of the whole plant made in the juice of fennel is said to help the induration of the liver. Roots may also be used as purgative against ascites, for jaundice, urinary diseases, rheumatism, snake poison, also for relief of inflammation of the breasts and joint pain. The roots of the plant are also used in the treatment of ophthalmia and uterine pains. The fruit and root were rubbed with water and applied to boils and pimples. The fruit was also used in the treatment of ascites, jaundice, cerebral congestion, colic, constipation dropsy, fever, worms and sciatica. Root is also given in cases of abdominal enlargement, cough, asthma, inflammation of the breast, ulcers, urinary diseases and rheumatism. Oil from seeds is used for poisonous bites, bowel complaints, epilepsy and also for blackening hair (Nadkarni et al., 1954, Dey et al., 1980). The fruits are also traditionally used as an abortifacient and to treat constipation, edema, bacterial infections, cancer and diabetes (Jayaraman et al., 2013). In moderate doses, the plant acts as a drastic hydragogue, catalartic and diuretic while in large doses, it acts as an emetic and gastrointestinal irritant and in small doses, it acts as an expectorant and alternative. Physicians use this drug extensively as a drastic purgative in ascites and jaundice in various uterine conditions, especially in amenorrhea. The juice of the fruit mixed with sugar is a household remedy in dropsy (Usman et al., 2003).

Phytochemistry:

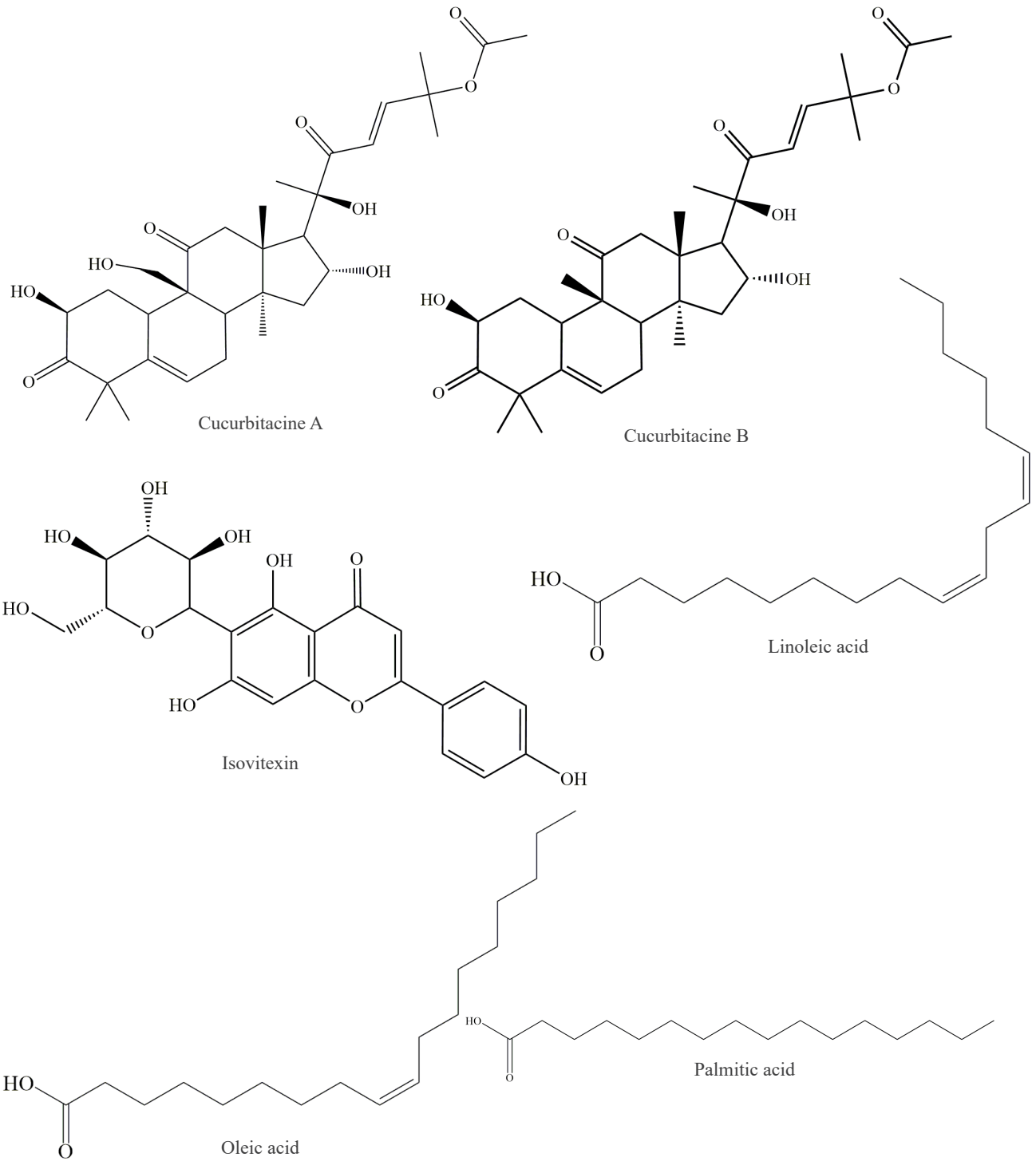
Fruits: 2-O-β-D-glucopyranosyl-16α-20R-dihydroxy-cucurbita-1, 5, 23E, 25(26)-tetraen-3, 11, 22-trione, 2-O-β-D-glucopyranosyl-cucurbitacin B (arvenin I), 2,25-di-O-β-D-glucopyranosyl-cucurbitacin L (Nayab et al., 2006), colocynthosides A, colocynthosides B, cucurbitacin A and B (Yoshikawa et al., 2007), isovitexin, isoorientin-3′-O-methyl ether

Seed oil: Palmitic acid, stearic acid, linoleic acid, oleic acid (Dhakad et al., 2017)

Biological activity:

Anti-inflammatory and analgesic activities: Aqueous extracts from roots, stems, fruits and seeds of *C. colosynthis* at different maturation stages were tested using the acetic acid writhing test in mice for analgesic activity and the carrageenan-induced paw edema assay in rats for anti-inflammatory activity. The results showed that all extracts exhibited analgesic and anti-inflammatory activities at different doses. The most significant results were obtained with immature fruits followed by seeds, while stem and root extracts showed less significant inhibitory activity in the analgesic and anti-inflammatory models (Marzouk et al., 2010; Marzouk., et al.,2011).

Hypolipidemic activity: The hypolipidemic effect of *C. colocynthis* on patients with hyperlipidemia was examined. It was reported that intake of powdered form of seeds (300 mg per day) by non-diabetic hyperlipidemia patients is very beneficial in reducing triglyceride and cholesterol levels (Rahbar et al., 2010).



Structures of Important and Characteristic Chemical Constituents of *Citrulus colocynthis*

Anti-hyperglycemic activity: The effects of aqueous, glycosidic, alkaloidal and saponin extracts from *Citrullus colocynthis* rind on plasma glucose levels were studied in normal rabbits, with saponin extract effects also tested in alloxan-induced diabetic rabbits. Aqueous extract (300 mg/kg) significantly reduced plasma glucose in normal rabbits. Glycosidic and saponin extracts significantly lowered glucose levels with saponin showing pronounced effects. Saponin extract also significantly reduced glucose in diabetic rabbits, suggesting its strong hypoglycemic potential (Abdel-hassan et al., 2000).

Antidiabetic activity: Antidiabetic action of fruits petroleum ether extract of *C. colocynthis* against Streptozotocin initiated hyperglycemic rats was assessed after oral administration of two distinct doses (300 and 500 mg/ kg). The extract enhanced the body weight of diabetic rats in a dose and time-dependent manner. The extract showed antidiabetic action through stimulation of β-cells of islets of Langerhans by releasing more insulin (Jayaraman et al., 2009). The fruit of *C. colocynthis* was analyzed in 2 months clinical trial conducted in 50 type II diabetic patients. Two groups of 25 each under standard antidiabetic therapy received 100 mg *C. colocynthis* fruit capsules or placebos thrice a day, respectively. The results showed a significant decrease in HbA1c and fasting blood glucose levels in *C. colocynthis* treated patients. The antidiabetic potential of *C. colocynthis* was investigated in rats at doses 50 and 100 mg/ kg for 28 days. Haematological and biochemical estimates were done at the end of experiment and histopathological examinations were performed. It was observed that *C. colocynthis* is safe to use as antidiabetic remedy (Atole et al., 2009).

Antibacterial and Anticandidal Activity: *In vitro* antibacterial and anticandidal activity of aqueous and acetone extracts of *C. colocynthis* were assessed against *Escherichia coli*, *Pseudomonas aeruginosa, Staphylococcus aureus*, *Enterococcus faecalis* and *Candida* spp viz: *Candida glabrata, C. albicans, C. parapsilosis* and *C. kreusei*. The most elevated minimum inhibitory concentration (MICs) were obtained from the fruits derived aqueous extracts (MIC 0.20 mg/ml against *Escherichia coli* and *Pseudomonas aeruginosa*, and 0.10 mg/ml against *Candida albicans* and *Candida glabrata*) and the lowest activity obtained from the root extracts (Marzouk et al., 2009). The antibacterial effect of *C. colocynthis* fruits and leaves aqueous and ethanol extracts against a standard novobiocin and isolated strains of *Staphylococcus aureus* (ATCC 25923) were assessed utilizing the disc diffusion method. The ethanol extracts showed significant inhibitory activity against *S. aureus* as compared to aqueous extracts in a dose-dependent manner (Najafi et al., 2010). The aerial parts and ripe deseeded fruits of *C. colocynthis* were investigated for bactericidal activities against drug sensitive standard strain of *Mycobacterium tuberculosis* H37Rv (ATCC 27294), 16 drug resistant strains of *M. tuberculosis* and two *Mycobacterium* strains other than tuberculosis (MOTT) using radiometric BACTEC system. The results revealed that the methanol extract of fruits demonstrated significant antibacterial activity (Mehta et al., 2013). The alkaloid extract of *C. colocynthis* was examined for antimicrobial activity against *Escherichia coli, Staphylococcus aureus, Streptococcus* sp., *Bacillus subtilis* and *Klipsella* sp. using agar disc diffusion method. Maximum antibacterial activity was exhibited against *Streptococcus* sp. (Al-hejjaj et al., 2010).

Antiulcer Activity: Anti-ulcer activity of *C. colocynthis* fruits showed positive results against pylorus ligation-induced ulcers in male Wistar rats. Aqueous and ethanol extracts the fruits administered at doses of 200 mg/kg and 400 mg/ kg were evaluated for pH, gastric volume, free acidity, total acidity, the percentage inhibition of ulceration and ulcer index. Ethanol and aqueous extracts at 400 mg/kg indicated a noteworthy ($P<0.001$) decline in the total acidity, free acidity, and gastric volume. It showed also a significant ($P<0.001$) decrease in ulcer score index and a number of ulcers in the pylorus ligation ulceration model (Reddy et al., 2012).

Antioxidant Activity: The methanol fruit extract of *C. colocynthis* was evaluated for its free-radical scavenging activity. The fruit extract exhibited an 88.0±2.7% scavenging effect on the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical at a concentration of 2500 mg/mL ($P<0.005$), compared to 89.5±1.1%, 83.2±1.1% and 67.5±0.8% for ascorbic acid, BHA and α-tocopherol respectively at 50 mg/mL ($P<0.05$) (Kumar et al., 2008). Additionally, the methanol extract of the seeds showed antioxidant activity with a maximum inhibition of 79.4% and 72.4% using the DPPH and hydrogen peroxide free radical scavenging methods, respectively (Gil et al., 2011).

Antimicrobial activity: The antimicrobial activity of the leaf extract of *C. colocynthis* was determined using the agar disc diffusion technique against sixteen bacteria and six fungal strains. The antimicrobial activity of extract was compared with the standard Gentamicin (10µg/disc) and piperacillin (100µg/ disc). Aqueous extract showed high antibacterial action against *S. aureus* and *E. coli* and less impact against *K. pneumonia* and *Bacillus subtilis*

while methanol extract showed better antibacterial action against *B. subtilis*, *Streptococcus pyogenes*, *Salmonella typhi* (Gurudeeban et al., 2010). The hydroalcoholic extract of *C. colocynthis* fruits were evaluated for antifungal activity against *Aspergillus* sp. and *Candida* sp. using disk diffusion and broth microdilution methods. The study revealed that all tested fungal strains were sensitive to extract. However, high antifungal activity was observed against *A. fumigatus* and *A. niger* and low activity was observed against *C. guilliermondii* and *C. kreusei* (Eidi et al., 2015).

Insecticidal activity: Insecticidal effect of cucurbitacin E glycoside (2-O-β-D-glucopyranosyl cucurbitacin E) isolated from *C. colocynthis* was tested against *Aphis craccivora*. Different extracts of *C. colocynthis* fruits (n-hexane, methylene chloride, chloroform and ethanol) against *A. craccivora* were studied in this experiment. The highest insecticidal effect (LC_{50} 11003 ppm) was shown by the ethanol extract (Torkey et al., 2009).

Larvicidal activity: The plant demonstrates significant toxicity against mosquito larvae (*Culex quinquefasciatus*). The death rate of larvae was observed after 24 hours with the highest mortality reported using petroleum ether as a solvent for the whole plant extract. Additionally, oleic and linoleic acids were found to be effective to a certain extent against fourth instar larvae of *Anopheles stephensi, Aedes aegypti* L. and *C. quinquefasciatus*. (Rahuman et al., 2008 Rahuman and Venkatesan, 2008).

Toxicology: One traditional use of *Citrullus colocynthis* as a hypoglycemic agent for diabetic patients has been reported to cause gastrointestinal disorders in some individuals (Farzaneh et al., 2006). The teratogenicity of *C. colocynthis* fruit pulp extract was studied in rats, revealing a high percentage of resorbed fetuses, smaller size and weight of fetuses and absence of coccygeal vertebrae, metacarpal and metatarsal bones and carpal and tarsal bones. These findings suggest that the fruit pulp extract of *C. colocynthis* may cause teratogenic effects if administered during early pregnancy (Elgerwi et al., 2013).

Patents and Commercial Products

- Method for cultivating *C. colocynthis* plants, Patent No: CN102144491A.
- *Citrulus colocynthis* seed and its cultivation production method, Patent No: CN1399864A.
- Method for determination of fat-acid composition of lipid complex colocynt (Citrullus colocynthis), Patent No: UA69521U.
- Noval bio pesticide compositions and formulation from tumba (*Citrullus colocynthis*) for insect control, Patent No: 201911012592.
- Benzyl alcohol glycoside compound in *Citrulus colocynthis* and preparation method thereof, Patent No: EN108191922.
- Jaisalmeri preserve and candy from fruit of toosh (*Cituilus colocynthis*)., Patent No: IN 1381/del/2008.
- Ethanolic extract of *Citrulus colocynthis* seeds, method to obtain it, pharmaceutical composition that contains it and its use as an antitumor agent, Patent No: ES 2906476a1.
- Method for the determination of amino acid composition of bitter apple (*Citrullus colocynthis*) fruits, Patent No: UA103897u.

Scope of further R&D: *Citrullus colocynthis*, a wild, perennial herbaceous plant, thrives in arid climates and has significant ethnobotanical value and diverse phytochemical properties. The plant is used traditionally to treat various ailments, such as bowel complaints, malaria, stomach aches, dropsy, hepatitis and snake bites and its seeds, fruits and roots have shown potential in treating conditions like cancer, diabetes and bacterial infections. The plant contains notable bioactive compounds like cucurbitacins and linoleic acid, which exhibit anti-inflammatory, hypolipidemic, antidiabetic, antibacterial, antifungal, insecticidal and larvicidal activities. Furthermore, recent studies have highlighted its potential as an antioxidant and anti-ulcer agent. Despite its therapeutic promise, *C. colocynthis* also presents toxicological risks, such as gastrointestinal disorders and teratogenic effects if consumed during early pregnancy. This dual nature underscores the need for extensive research to optimize its medicinal benefits while mitigating adverse effects. Investigating the detailed mechanisms of its bioactive compounds, improving extraction methods and conducting clinical trials are essential for developing safe and effective pharmaceuticals. Additionally, exploring its potential in agricultural applications, such as

natural insecticides, could provide sustainable solutions in pest management. The existing patents indicate significant commercial interest, paving the way for innovative product development. Overall, *C. colocynthis* offers a rich scope for further research and development, promising significant contributions to medicine, agriculture and industry.

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Cupressus torulosa
D.Don ex Lamb.

Synonyms:
Cupressus lusitanica sub sp. *torulosa* (D.Don ex Lamb.) Silba & Brian Chen.

Local/Common/Popular Name(s):
Himalayan cypress or Bhutan cypress, Surai, Raj sallo, Dhupi, Bugla in central Himalayas, Xi zang bai mu in China

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Pinidae
Order	:	Pinales
Family	:	Cupressaceae
Genus	:	*Cupressus*
Species	:	*Cupressus torulosa*

Botanical Description: *Cupressus torulosa* is a monoecious species pollinated by wind and has a broad pyramidal crown (Prodr and Nepal, 1825) with drooping branchlets of around 50 feet in height, and approximately 7.15 m in girth (Malik et al., 2018). It requires an annual rainfall below 300 mm, of which the majority is required in the summer and autumn seasons. *C. torulosa* occurs at an altitude range of 560–3670 m. It can also resist frosts ranging from −1°C to −7°C (Farjon, 2013). The branchlet system of the plant is long and pendulous. It has slender and horizontal branches with pinnate branchlets that are 2–3 in number and whip-like curved (Lohani et al., 2012; Schulz et al., 2005). The solitary, yellow or light brown male cones are 3-6 mm in length and 1.5-2.5 mm wide. The reddish or dark woody female cones are 13-20 mm long and 10-20 mm wide and do not disintegrate after maturity with the clustered cone scales more or less in the center. The young cones are green in color with a coating of blue, green or reddish color with 48-80 seeds per cone and 6-8 seeds per female cone scale (Schulz et al., 2005). The seeds are winged and are 3-5 mm long and 3-5 mm wide with almost 2 equal reddish wings which are 1-2 mm wide and black or bright-dark brown with flattened non-tuberculated and with or without conspicuous hilum. The leaves are somewhat acute with bright or bluish-green color, (Baulatabad et al., 1990). Leaves are uniform in four to many ranked, closely appressed, 1/16 inch long, ovate and obtuse at the tip, convex back and frequently have an unclear glandular depression along the length (Lohani et al., 2012; Prodr and Nepal, 1825). The Bark is 0.5 inch thick, greyish brown, peeling off in long thin strips (Malik et al., 2018; Prodr and Nepal, 1825). The staminate flowers are 3/4 inch long, when open, twelve to sixteen stamens with three to four anthers, and 2–6 globose anther cells (Prodr et al., 1825; Lohani et al., 2012). The pollen grains are monolete type with equatorial view and rhomboidal and polar view as spheroidal. Its P/E ratio (polar to equatorial ratio) is 0.8 and the ornamentation is faveolate, sculpturing is gemmate and pollen fertility is 78% (Khan et al., 2018).

Distribution: *C. torulosa* is indigenous to India. It is widely distributed at an altitude of 1800 to

3300 m throughout India, Nepal, Tibet, Pakistan, and Bhutan (Lohani et al., 2014). Occurrence of the tree in Uttarakhand has been reported in the Pauri, Garhwal regions, and Kullu and Shimla districts of Himachal Pradesh (DD Herbarium, FRI and BSI Records). It is also locally distributed on the Naina Hill slopes in Nanital, in Jaunsar calcareous Moila and Lokhandi cliffs below Karamba peak, in the Shimla catchment area on shale, and in separate places in Chamba, Kullu, and other western and Central Himalayas (Pandit and Ram, 2004).

Habitat *C. torulosa* is found in drier areas, especially on limestone substrates (Lohani et al., 2014; Rajput et al., 2016). The most suitable soil combination for the species is light sandy with medium loamy and heavy clayey soils and it also favors dry or moist soil which is well-drained. The suitable pH is acidic and neutral, can also grow in highly acidic soils but cannot grow in the shade (Pandit and Ram, 2004).

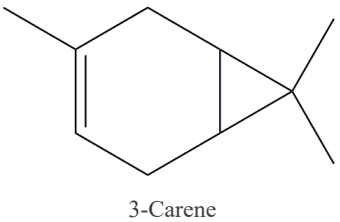
Ethnobotanical Uses: *C. torulosa* is famous for its very durable wood. The timber is even more durable than that of the deodar (Prodr and Nepal, 1825). Wood is so durable that in ancient times Egyptians used it for building cases for mummies (Shaheen et al., 2020). In India, Nepal, and Tibet, its needles are used to protect stored grains from insect infestation (Gupta et al., 2018). Needles' paste/juice with a few drops of *Citrus medica* are applied on blisters and boils (Quattrocchi, 2016). The essential oil of the needles has astringent properties and is used to effectively fight against whooping cough and rheumatism (Sellappan et al., 2007; Lohani et al., 2014) and also helps to shield stored grains from an infestation of insects (Su et al., 2015). *C. torulosa* has an old time of usage in traditional ancient therapies and is used in the Indian System of Medicines as an efficient medicinal plant for various ailments. Oil extracted from wood, especially root wood, is used in the treatment of inflammations and wounds, or as an antiseptic, and is also widely used in cosmetics (FIPI 1996; Barreto et al., 1961). Water extract from cones is used for cleaning the feet and also to reduce extreme perspiration (Singh et al.,1990).

Phytochemistry

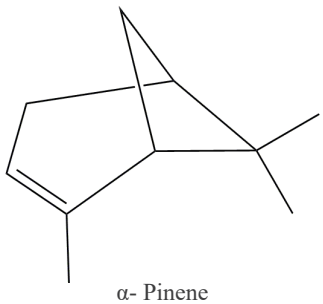
Needles : α-Pinene, sabinene, delta-3-carene, limonene, γ-terpinene, β-myrcene, β-phellandrene, p-cymene, α-thujene, terpinolene, terpinen-4-ol, α-terpinyl acetate, umbellulone, bornyl acetate, α-cedrene, β-cedrene, cis-thujopsene, cuparene, germacrene D, caryophyllene, (+)-aromadendrene, cedrol, α-muurolol and 4-hydroxygermacra-1, 5-diene (Lohani et al., 2014; Malizia et al., 2000; Cool et al., 1998), amentoflavone, cupressuflavone, hinokiflavone, apigenin (Lohani et al., 2014).

Seeds: Linoleic acid, oleic acid, palmitic acid, capric acid, lauric acid, myristic acid, stearic acid, arachidic acid, behenic acid (Baulatabad et al., 1990).

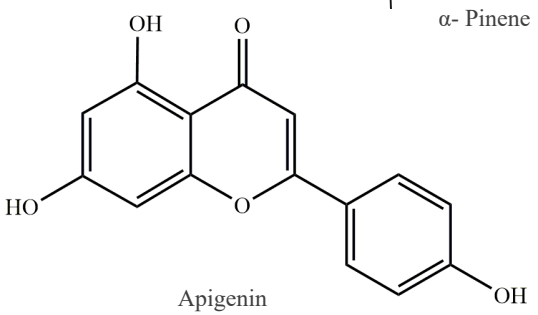
Wood: Carvacrol, carvacrol methyl ether (Barreto et al., 1961), ferruginol, hinokiol, hinokione, manool, torulosal, torulosol, α-thujaplicin, β-thujaplicin (Barreto et al., 1961).



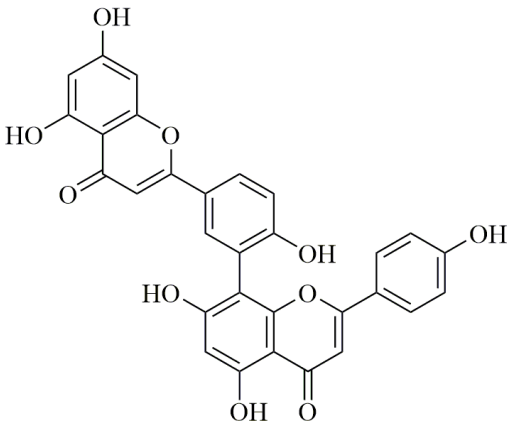
3-Carene



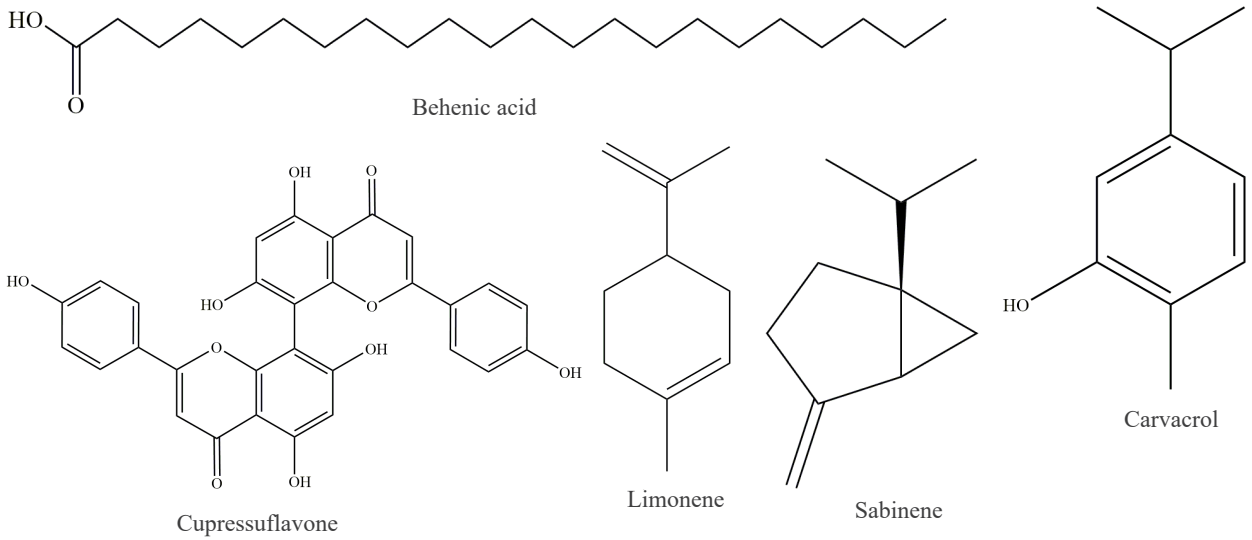
α- Pinene



Apigenin



Amentoflavone



Structures of Important and Characteristic Chemical Constituents of *Cupressus torulosa*

Biological activities:

Antibacterial activity: The antibacterial activity of essential oil and three extracts (chloroform, methanol, and water), isolated from the needles of *C. torulosa* has been screened against 10 different strains of gram-negative and gram-positive bacteria. The method used for testing was the agar well diffusion method. The oil demonstrated significant inhibitory action against *Bacillus subtilis* (21±0.7mm), *Pseudomonas alcaligenes* (13±0.7mm), *Micrococcus luteus* (12±0.4mm), and *Bacillus cereus* (10±0.5mm), and moderate action against *P. aeruginosa* (9±0.42mm), *Alcaligenes denitrificans* (7±0.3mm) and *Staphylococcus aureus* (5±0.2 mm). However, *Escherichia coli, Enterococcus fecalis,* and *Campylobactor coli* remained resilient to the oil. In the case of extracts, the methanol extract exhibited antimicrobial action against *A. denitrificans* (11±0.32), *S. aureus* (9±0.23 mm), *M. luteus* (9±0.3mm), *E. coli* (6±0.23) whereas no inhibitory properties are shown by the water and chloroform extracts. Here chloramphenicol (10µg) was used as a positive control and DMSO was used as a negative control. The oil exhibited better results than extracts. In an another study, the antibacterial activity of methanol, hexane and ethyl acetate extracts of *C. torulosa* needles was investigated against S*treptococcus pyogens, Acinetobacter calcoaceticus, Escherechia coli* and *Staphylococcus aureus.* The methanol extract demonstrated the highest antibacterial activity while hexane extract demonstrated the lowest activity. All four pathogenic bacteria were found susceptible at different concentrations in methanol extracts. In ethyl acetate extract, *S. aureus* and *E. coli* were less susceptible while in hexane extract, *Acinetobacter calcoaceticus* was found to be less susceptible (Padhaya et al., 2019).

Antifungal activity: The disc diffusion method was used to examine the essential oil extracted from *C. torulosa* needles against diverse disease-causing fungal strains, including *Aspergillus niger, A. terreus,* two species of the genus *Candida*, *Microsporum audouinii, M. canis, Penicillium chrysogenum, P. expansum, P. griseofulvum, Trichophyton mentagrophytes,* and *T. rubrum*. *T. mentagrophytes* exhibited the greatest zone of inhibition with a diameter of 16 ± 0.78 mm, along with another fungal strain, *T. rubrum* (16 ± 0.61 mm), whereas the lowest zone of inhibition was observed against *M. audouinii* (12 ± 0.18 mm). Amphotericin B, used as a positive control, exhibited inhibition zones ranging from 4 to 14 mm at a concentration of 10 µg/disc (Bhandari et al., 2015). By the use of the poison food technique, antifungal activity of the oil was examined against three disease-causing fungal strains i.e., *Alternaria alternata*, *Curvularia lunata* and *Bipolaris specifera* where amphotericin B was used as a positive control. Significant antifungal activity of the oil was observed against all three plant pathogenic fungi-*B. specifera* (IC_{50}=0.91%), *A. alternate* (IC_{50}=0.32%), and *C. lunata* (IC_{50}=0.96%) (Gupta et al., 2018).

Larvicidal activity: The larvicidal and repellent characteristics against *Aedes albopictus* were inspected for the essential oils derived from the leaves of eight species of the family *Cupressaceae: C. arizonica, C. benthamii, C. macrocarpa, C. sempervirens, C. torulosa, Chamaecyparis lawsoniana, Juniperus phoenicea,* and *Tetraclinis articulata*. The standard repellent used was 'Deet' at a dosage of 0.2 mg/cm². The most effective was found to be *C. macrocarpa* at a dose of 0.08 mg/cm². *C. torulosa* showed relatively weaker activity, but still adequate, with a mosquito inhibition landing rate of 3.5–6 landings when compared with standard Deet and the untreated control (Surai et al., 2013).

Scope of further R&D: *C. torulosa* presents promising avenues for further research and development across several domains. Botanically distinguished by its broad pyramidal crown and enduring adaptability to harsh climates and altitudes ranging from 560 to 3670 meters, *C. torulosa* holds substantial potential for genetic and ecological studies aimed at enhancing its resilience and growth under varying environmental conditions. Investigating its reproductive biology, including pollination mechanisms and seed dispersal dynamics, could provide insights into optimizing its regeneration and propagation strategies. Ethnobotanical applications highlight the medicinal properties of *C. torulosa*, particularly its durable wood used historically for medicinal preparations and construction. Further exploration into its phytochemical composition, focusing on bioactive compounds identified in needles, seeds, and wood, could lead to the development of novel pharmaceuticals, nutraceuticals, and cosmeceuticals. Additionally, expanding research on the antibacterial and antifungal activities of its essential oils and extracts against a broader spectrum of pathogens, including multi-drug resistant strains, holds promise for therapeutic applications in combating infectious diseases. Moreover, *C. torulosa*'s potential as a source of natural insecticides, demonstrated by its larvicidal and repellent properties against *Aedes albopictus*, and protection of stored grains from infestation of the insects, invites investigations into sustainable pest management strategies. Collaborative interdisciplinary research, integrating botanical, chemical, pharmacological, and ecological perspectives, will be crucial in unlocking the full potential of *C. torulosa*. By leveraging its traditional knowledge and harnessing modern scientific approaches, *C. torulosa* has the potential to contribute significantly to health care, agriculture, and environmental sustainability initiatives.

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Cyperus rotundus L.

Synonyms:
Chlorocyperus rotundus (L.) Palla, *Cyperus olivaris* Targioni Tozzetti, *Cyperus purpuro variegatus* Boeckeler, *Cyperus stoloniferum pallidus* Boeckeler, *Cyperus tetrastachyos* Desf, *Cyperus tuberosus* Roxb, *Pycreus rotundus* (L.) Hayek (Al-Snafi, 2016).

Local/Common/Popular Name(s):
Coco-grass, Java grass, Nutgrass, Purple nut sedge or purple nutsedge, and Red nut sedge.

Vernacular Names:
India: Motha, Mutha; ***Italian:*** Zigoloinfestante; ***Arabic:*** Sa'ed; ***Chinese:*** Suo cao, Xiang fu zi; ***English:*** Coco-grass, Ground-almond, Java-grass, Nut sedge, Nut-grass, Purple nut, Sedge, Purple nut-grass, Red nut sedge; ***French:*** Souchetrond; ***German:*** Knolliges Zypergras; ***Japanese:*** Hamasuge; ***Korean:*** Hyangbuja; ***Portuguese:*** Alho-bravo, Capim-alho, Capim-dandá, Tiririca, Tiririca-vermelha; ***Spanish:*** Castañuela, Cipero, Coquito, Juncia real; ***Swedish:*** Nötag (National Germplasm Resources Laboratory, 2010).

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Poales
Family	:	Cyperaceae
Genus	:	*Cyperus*
Species	:	*Cyperus rotundus*

Botanical Description: *Cyperus rotundus* is a lender, erect, perennial sedge which spreads by means of a fibrous root system with fleshy and scaly, modified leaves-covered rhizomes which become brown and woody with age. On reaching the surface, a rhizome may swell into a small, rounded structure (basal bulb), from which shoots, roots and further rhizomes arise. Tubers are formed by the rhizomes. These tubers can produce new rhizomes or plants and also, act as a reservoir of food in the form of starch. The tubers measure around 1 to 3.5 cm in length and are white and succulent when young, later turning brown and hard. The stem is smooth and erect, reaching a height of 30 to 40 cm, and has a triangular cross-section. The leaves grow from the plant's base and are organized in three groups on the stem. They are long and slender, measuring 20 to 30 cm in length and 0.2 cm in width, with a grooved upper surface and a pointed tip. The flowers of this species are borne in clusters (inflorescences) at the ends of the stems. The inflorescence comprises three to nine stalks of varying lengths, each with a reddish-brown to purple terminal spikelets. Each spikelet is 3.5 cm in length and consists of 10 to 40 flowers, which lack petals, but instead sit within dry, membranous, oval-shaped bracts, known as glumes. The plant produces a dry, single-seeded fruit, which is up to two mm long, brown to black in color with a network of grey lines (Wills, 1987).

Distribution: *C. rotundus* is distributed in Africa (Algeria, Egypt, Libya, Morocco, Tunisia, Western Sahara, Chad, Djibouti, Eritrea, Ethiopia, Somalia, Sudan, Kenya, Tanzania, Uganda, Burundi, Equatorial Guinea, Gabon, Rwanda, Zaire, Benin, Burkina Faso, Cote D'Ivoire, Ghana, Guinea, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo, Angola, Malawi, Mozambique, Zambia, Zimbabwe, Botswana, Namibia), South Africa, Swaziland, Western Indian Ocean (Comoros, Madagascar, Mauritius, Reunion, Seychelles), Western Asia (Afghanistan, Iran, Iraq, Saudi Arabia, Yemen, Palestine, Lebanon, Syria, Turkey), Caucasus (Armenia, Azerbaijan, Russian Federation), Middle Asia: (Kazakhstan, Kyrgyzstan, Turkmenistan, Uzbekistan), Eastern Asia (China, Japan, Korea, Taiwan, India, Nepal;

Pakistan, Sri Lanka, Myanmar; Thailand, Vietnam, Indonesia, Malaysia, Philippines) Europe: (Austria, Switzerland, Albania, Bulgaria, Croatia, Greece, Romania, Serbia, Slovenia, France, Portugal, Spain), Pacific (Marshall Islands, Micronesia, Northern Mariana Islands),North America: (USA, Mexico); and Southern America (Brazil, Bolivia, Colombia, Ecuador, Peru, Argentina) (USDA, 2010).

Habitat: *C. rotundus* is a noxious weed that thrives in tropical and subtropical climates. It mostly grows in shores, wet meadows, ditches, turf, ornamental areas, agricultural fields, moist roadsides, sandy soils, river bottoms, and waste places (Baloch *et al.,* 2021). In India, it is common in open, disturbed habitats to an elevation of about 1800 m.

Ethnobotanical Significance: *C. rotundus* is reported to be used traditionally for the treatment of gastrointestinal spasms, stomach disorders, nausea, vomiting, intestinal parasites, food poisoning, indigestion, and irritation of the bowel. It has also been used for treating fevers, wounds, bruises and carbuncles, malaria, cough, bronchitis, renal and vesical calculi, urinary tenesmus, amenorrhoea, dysmenorrhoea, deficient lactation, loss of memory, insect bites, dysuria, bronchitis, infertility, cervical cancer, and menstrual disorders (Talukdar *et al.,* 2011). The leaves are used by local folks of the Middle East and Southeast Asia to flavor food which is an important component in their daily diet. The seeds are also used as a curry and pickling spices in India and Southeast Asia. Seeds have digestive properties and are used for the cure of minor digestive problems, hemorrhoids, and painful joints (Baloch *et al.,* 2021). According to the Ayurveda, *C. rotundus* rhizomes are considered astringent, diaphoretic, diuretic, analgesic, antispasmodic, aromatic, carminative, antitussive, emmenagogue, litholytic, sedative, stimulant, stomachic, vermifuge, tonic and antibacterial (Sivapalan, 2013).

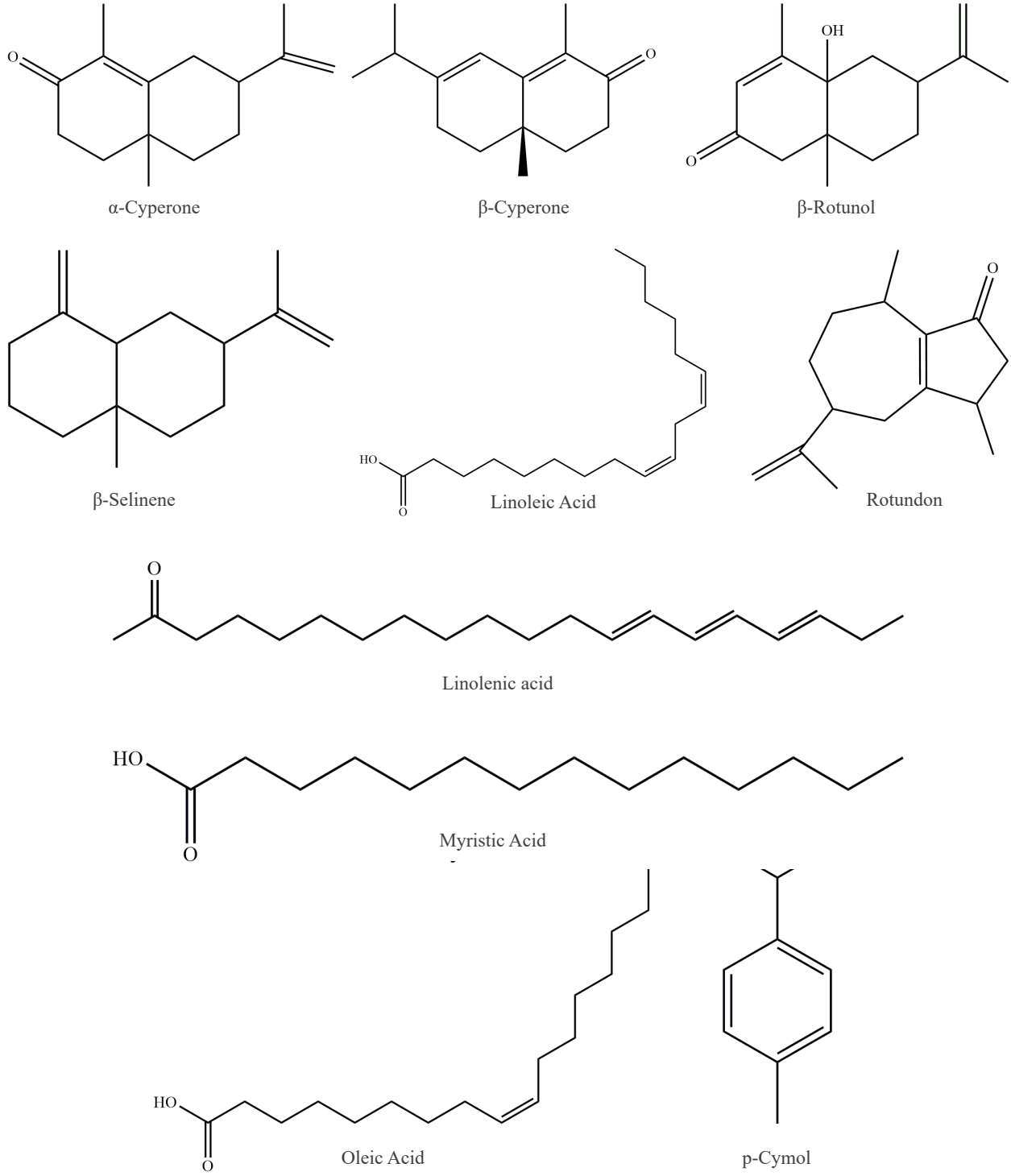
Phytochemistry:

Rhizomes: α-Cyperone, β-cyperone, ρ-cymol, camphene, cyperene, cyperenone, cyperol, cyperolone, β-caryophyllene, cyperotundone, D-copadiene, D-epoxyguaiene, isocyperol, isokobusone, kobusone, limonene, linoleic-acid, linolenic-acid, mustakone, myristic acid, oleanolic acid, oleic acid, β-pinene, patchoulenone, rotundene, rotundenol, rotundone, α-rotunol, β-rotunol, β-selinene, selinatriene, sitosterol, stearic acid, sugeonol, sugetriol, linolenic acid, myristic acid, furochromones, nootkatone, 4α, 5 α, oxidoeudesm-11-en-3α-ol, cyperene-1, α-cyperone and cyperene-2, 1(2)-acetyl-3(5)-styryl-5(3)-methylthiopyrazole (Kamala et al., 2018), (+) oxo-α-ylangene, (+) α-cyperone, trans-pinocarveol, cyperene (Ghannadi et al., 2012)

Tuber: α-Pinene, cyclopentene-3-ethylidene-1-methyl, sabinene, β-pinene, p-cymene, 1-limonene, 1,8-cineole, trans-pinocarveol, terpinen-4- ol, citronellal, 4, 4-dimethyl-tricyclo-(3,2,1) octan-6-one, p-cymen-8-ol, α-terpineol, cis-dihydro carvone, myrtenol, verbenone, 1-β-4,4-trimethyl-bicyclo (3,2) hept-6-en-2- ol, trans-carveol, carvone, carvenone, α-cubebene, dihydro-carvylacetate, α-copaene, isolongifoline, cyperene, trans-caryophyllene, dihydroaromadendrene, aromadendrene-epoxide, 1,6-dimethyl-4-(1-methyl ethyl) naphthlene, α-silenene, cis-calamenene, trans-calamenene, elema-1,3,11 (13)-trien-12-ol, caryophyllene oxide, cis-12-caryophyll-5-en-2-one, caryophylla-2(12),6(13) dien-5-one, cyclohexane, 1,1,2-trimethyl,3,5 bis- 1-methyl ethyl) cyclo-hexenone, longiverbenone, 10-epi-α-cyperon, (+) oxo-α-ylangene, (+) α—cyperone, caryophyllenol, vulgarol A, vellerdiol, aristolone, vulgarol B, ledenoxide, dimethyl-7-isopropenyl-bicyclo-dec-1-en-3-one, longifolinaldehyde, longipynocarvone (El-Gohary, 2004; Bisht et al., 2011).

Biological Activity:

Anti-inflammatory activity: Nootkatone and valencene are the major components present in the rhizomes of *C. rotundus* responsible for anti-inflammatory activity via the heme oxygenase-1 pathway (Seo et al., 2001; Tsoyi et al., 2011). The alcoholic extract of *C. rotundus* was observed to possess significant anti-inflammatory activity against carrageenan-induced edema and formaldehyde-induced arthritis in albino rats (Sundaram et al., 2008). The anti-inflammatory activity of a crude extract of *C. rotundus* at doses of (300 mg/kg and 500 mg/kg) was investigated in rats. Carrageenan caused inflammation in rats, which was compared to saline and aspirin-treated groups. The analgesic and anti-inflammatory effects of *C. rotundus* extracts were investigated in mice using aqueous,



Structures of Important and Characteristic Chemical Constituents of *Cyperus rotundus.*

ethyl acetate, methanol, and TOF-enriched extracts at concentrations of 300, 150, and 50 µg/mL. The examined extracts showed evidence of peripheral analgesic activity by being able to reduce the mouse ear edema caused by xylene and the frequency of stomach contractions caused by acetic acid. No adverse effects were reported in mice at doses up to 300 mg/kg body weight (Soumaya et al., 2013).

Antidiabetic activity: The antidiabetic potential of a specific compound isolated from *C. rotundus*, 15-hydroxy-4-oxo-10-pentadecynoic acid lactone, was observed through insilico studies (Lydia &

Sudarsanam, 2014). Rats with alloxan-induced hyperglycemia were used to assess the anti-diabetic effects of *C. rotundus*. 500 mg/kg of the hydro-ethanolic extract of *C. rotundus* administered orally once a day for seven days in a row substantially decreased blood sugar levels (Raut & Gaikwad, 2006). *C. rotundus* (2.5 ml/kg, orally of 10% of the aqueous decoction of tuber portions) effectively reduced fasting serum glucose levels in rabbits with normoglycemia and diabetes caused by alloxan. The hypoglycemic effects began to manifest within the first week of treatment and tended to increase with continued treatment (Al-Snafi et al., 2013).

Antimalarial activity: Patchoulenone, caryophyllene oxide, 10, 12-peroxycalamenene, and 4, 7-dimethyl-l-tetralone isolated from *C. rotundus* tubers showed antimalarial activities, in the range of EC_{50} 10.4 $x10^{-6}$M, with the novel endoperoxide sesquiterpene, 10, 12-peroxycalamenene, exhibiting the strongest effect at EC_{50} 2.33×10^{-6} M (Thebtaranonth & Thebtaranont, 1995).

Anti-microbial activity: The antimicrobial activity of the essential oil of *C. rotundus* was assessed using the agar disc diffusion method. The diameter of the zones of inhibition was measured and compared with negative controls, as well as with ofloxacin, rifampicin, and amphotericin B used as positive controls for the microbes. The oil was found to be active against the tested gram-positive microorganisms, while it showed no activity against gram-negative microorganisms (El-Gohary, 2004). The petroleum ether, chloroform, ethanol, and water extracts of the rhizomes of *C. rotundus* were investigated against six important pathogenic microbes (*Staphylococcus epidermidis, Bacillus cereus, Pseudomonas aeruginosa, Escherichia coli, Aspergillus niger* and *Candida* sp.). The antibacterial and antifungal activities were assessed by both agar well diffusion and serial dilution methods. The ethanol extract exhibited the highest activity against the tested bacteria while it was found to be ineffective against fungal strains (Sharma & Singh, 2011).

Anti-ulcerogenic activity: The antiulcer activity of *C. rotundus* crude extract was investigated in rats at doses of 300 mg/kg and 500 mg/kg. Rats were given 300 mg/kg of aspirin to cause ulcers. The crude extract significantly reduced the effects of ulcers (Ahmad et al., 2014).

Anti-allergic: The sesquiterpenoids (valencene, nootkatone, and caryophyllene oxide), along with monoterpenoids (β-pinene, 1,8-cineole, limonene and p-cymene) from the rhizomes of *C. rotundus* were studied *in vitro* and *in vivo* for their anti-allergic activities. The studies indicated that the sesquiterpenoids, but not the monoterpenoids, contributed to preventing the allergic reaction in mice (Jin *et al.,* 2011).

Hypotensive activity: *C. rotundus* aqueous extract showed antihypertensive activity in Sprague–Dawley rats (Mansoor *et al.,*2013).

Insecticidal Activity: Alcoholic extract of *C. rotundus* foliage was found to exhibit significant insecticidal activity against *Diabrotica speciosa* in agroecologic system (Maia, 2011).

Repellent activity: The hexane extract of the tuber of *C. rotundus* was tested for repellent activity against mosquito vectors *Anopheles culicifacies, A. stephensi,* and *Culex quinquefasciatus.* The results showed that the extract was effective against the mosquitoes even at low doses. (Vivek & Bhat, 2008)

Larvicidal activity: The ovicidal and larvicidal activity of essential oil obtained from *C. rotundus* was studied on eggs and fourth instar larvae of *Aedes albopictus*. The eggs and larvae were exposed to serial concentrations of oils ranging from 5-150 ppm and observed for 24 h. The results revealed that the oils possessed efficient larvicidal activity (Vivek & Bhat, 2008).

Toxicology: The acute and subacute toxicity of the ethanol extract of *C. rotundus* was studied in rats. 5000 mg/kg of the extract administered orally once did not result in behavioral alterations, death, or differences in the physical appearance of internal organs. For subacute toxicity, all rats were given 1000 mg/kg of the ethanol extract orally over the course of 14 days. When compared to the internal organs of the control group, the findings of the gross and pathological examinations revealed that they were in normal appearance (Thanabhorn et al., 2005). Mice and rats were used in biochemical and toxicology effects of a crude ethanol extract of *C. rotundus*. The dosage of the extract were 10, 100, and 1000 mg/kg. At these levels, none of the groups showed any signs of toxicity. However, motor activity was only modestly decreased at the dose level of 1000 mg/kg. Additionally, the effects

of the *C. rotundus* extract on various biochemical variables (glucose, lipid profile, cardiac enzymes, liver enzymes, and kidney function test) were examined. Despite a non-significant rise in serum bilirubin, gamma-GT, and SGPT, liver enzymes were confirmed to be normal. Additionally, non-significant harmful alterations were seen in hematological investigations. The drug's safety and lack of toxicity were also confirmed by a histopathological study (Ahmad et al., 2013).

Patents:

- Sesquiterpenoid-based compounds, extracts of *Cyperus rotundus* comprising the same, and use thereof, Patent No: US9795649B2
- A composition for preventing or treating female menopausal diseases, comprising sesquiterpenoids isolated from extracts of *Cyperus rotundus,* Patent No: KR101485705B1
- *Chinese angelica, Folium artemisiaeargyi,* and *Cyperus rotundus* sanitary towel, Patent No: CN211863123U
- Herbicide composition for preventing and treating *Cyperus rotundus* in alfalfa field and application thereof, Patent No: CN113115784A
- Medicine applying device specially for *Cyperus rotundus,* Patent No: CN210642140U
- Pharmaceutical composition for treating atopic dermatitis comprising fraction of *Cyperus rotundus* extract, patent no: kr101789446b1
- A composition comprising Cyperus rotundus methanol extract for preventing or treating Sepsis, Patent No: KR101188581B1
- Application of *Cyperus rotundus* L in purifying heavy metal polluted soil, Patent No: CN115921508A
- The extraction method of *Cyperus rotundus* extract and toothpaste and mouthwash containing *Cyperus rotundus* extract, Patent No: CN106377481A
- Method for preparing *Cyperus rotundus* essence, Patent No: CN101619268A
- Use of *Cyperus rotundus* as a base for topical or oral medicines, Patent No: BRPI1100537A2
- A topical composition comprising the extract of *Cyperus rotundus* as an active ingredient for preventing and treating inflammatory disease, Patent No: KR20130062112A
- Method for restoring Cr-polluted soil by utilizing *Cyperus rotundus* L., Patent No: CN104607444A
- Composition comprising scirpusin a and b isolated from extracts of *Cyperus rotundus* for preventing or treating neurodegenerative disease and stress disease, Patent No: KR101862032B1
- Obtaining dry extract, tincture or oil of *Cyperus rotundus*, popularly known as; tyrant, junca or goat's beard, Patent No: BRPI1000742A2
- Construction method of *Cyperus rotundus* medicinal material fingerprint spectrum and detection method thereof, Patent No: CN104777255A
- N-alpha, alpha-di:methylbenzylpivalyl-amide herbicide - active against *Cyperus rotundus* and *esculentus* e.g. in rice crops and against a wide range of weeds, Patent No: FR2471368A1
- Material preprocessing device is used in *Cyperus rotundus* preparation, Patent No: CN211488566U
- Hui traditional Chinese medicine *Cyperus rotundus* stomach cancer elimination particles and preparation method thereof, Patent No: CN106668500A
- Composition comprising an extract of *Cyperus rotundus* for preventing and treating hyperlipidemia or artherosclerosis, Patent No: KR20130127089A
- Health functional composition for skin anti-aging extracted from rhizomes of *Cyperus rotundus,* Patent No: KR101689156B1
- Cosmetic composition comprising an extract of a mixture comprising baked *Glycyrrhiza uralensisfisch, Cyperus rotundus* l., and *Curcuma longa* l., Patent No: KR102477053B1
- A tea using *Cyperus rotundus* and method thereof, Patent No: KR20130102181A
- Composition comprising *Cyperus rotundus* for preventing or treating neurodegenerative disease and menopausal brain disorder, Patent No: KR101142838B1
- 3,3,3, trifluoro-n-4-fluorophenyl)-bicyclo (4.1.0) heptane with immunity boosting properties isolated from *Cyperus rotundus,* Patent No: 202241009485

- Special medicine applicator for *Cyperus rotundus,* Patent No: CN112136797
- *Cyperus rotundus* essential oil anti-allergy cream and preparation process thereof, Patent No: CN111920763
- *Schisandra chinensis-Cyperus rotundus* powder, Patent No: CN108392606
- Method for restoring polluted soil by utilizing *Cyperus rotundus* l., Patent No: CN104607444
- Cosmetic or pharmaceutical, particularly dermatological composition, intended to enhance the pigmentation of the skin or hair, containing a *Cyperus* extract and production process, Patent No: WO1992020322
- Application of *Cyperus rotundus* extract in reducing skin inflammatory response caused by keratinocyte irradiation ultraviolet light and promoting skin keratin metabolism, Patent No: CN110179903
- Fructus aurantii, *Cyperus rotundus* pill, Patent No: CN106138581
- External beautifying powder containing lily, poria cocos, dioscorea opposite, and *Cyperus rotundus* and preparation method thereof, Patent No: CN108245612
- Extracts of *Cyperus rotundus* comprising piceatannol, scirpusin a, and scirpusin b useful for the treatment of obesity and hypercholesterolemia, Patent No: CA2979195
- External use skin composition containing a *Cyperus rotundus* extract for preventing and treating inflammatory diseases, Patent No: KR1020130062112
- Composition for alleviating skin troubles containing perilla oil extract and *Cyperus rotundus* extract, Patent No: KR102371272

Scope of further R&D: *Cyperus rotundus,* a perennial sedge found across diverse regions globally, offers a rich reservoir of bioactive compounds with extensive traditional uses and promising biomedical applications. The plant's intricate botanical structure, characterized by fibrous rhizomes and slender stems bearing clustered flowers, highlights its adaptability to various habitats from wet meadows to agricultural fields. Phytochemical investigations have identified a plethora of compounds, including bioactive sesquiterpenes like patchoulenone and caryophyllene oxide. Further R&D could focus on exploring synergistic interactions among these compounds, conducting comprehensive toxicological assessments, developing standardized formulations for enhanced efficacy, and exploring its potential in environmental and agricultural applications such as phytoremediation and natural pest control. Clinical trials to validate its therapeutic benefits and patent development for innovative uses would further propel its integration into pharmaceuticals, agriculture, and cosmetic industries.

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Dysoxylum malabaricum
Bedd. ex C.DC.

Synonyms:
Alliaria malabarica (Bedd. ex C. DC.) Kuntze, *Dysoxylum glandulosum* Talbot

Local/Common/Popular Name(s):
White cedar

Vernacular Names:
Kannada: Bile agilu, Bile devadaaru, ***Malayalam:*** Vellagil, Akil, Kana mullu, Purippa, ***Tamil:*** Vellaiyagil, Agil, ***Sanskrit:*** Agaru

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Sapindales
Family	:	Meliaceae
Genus	:	*Dysoxylum*
Species	:	*Dysoxylum malabaricum*

Botanical Description: *Dysoxylum malabaricum* is a tree, which can reach a height up to 35 m with the bark being 5-8 mm in thickness. The greyish-yellow aromatic bark is rough and verrucose with warty lenticels and is fissured with the dead and corky outer bark. The leaves are imparipinnate, alternate, and estipulate with 7-11 leaflets arranged either in opposite, sub-opposite, or alternate arrangement with the measurements being 9-23 x 3-5 cm and are elliptic-oblong, ovate-oblong, or lanceolate with acuminate apex and oblique or acute base having entire margin. The leaves are puberulous when young, become glabrous at maturity, and are coriaceous. The rachis is 17-28 cm long, stout, angular, pubescent, and swollen at the base. The lateral nerves are 6-20 pairs, parallel, ascending, prominent, intercostae reticulate, obscure with prominent secondary laterals. The large corky lenticels in the bark exfoliate with large rectangular scales which are blaze yellow and white. The young branchlets are angular and minutely pubescent. The bisexual, greenish-yellow, and fragrant flowers occur in panicled racemes inflorescence and are shorter than leaves with a length of about 5-6 mm. The calyx is 4 lobed with lobes more or less obtuse. The petals are 4 in number and are linear-oblong, subacute, imbricate, and pubescent outside. The staminal tube is urceolate and more or less 4-angled with 8 deep emarginate crenatures and 8 anthers which are entire and disc cup shaped enclosing the ovary. The ovary is superior, 4-lobed, densely pubescent, 4-celled with 2 ovules in each cell and tapers into style with capitate stigma. The bright yellow fruit is a capsule that is 5-7.5 cm long, pyriform, and verrucose with 4 longitudinal furrows having reddish-brown, bluntly trigonous seeds which are 3-4 in number (Sasidharan, 2004).

Habitat: The tree is found in the evergreen and semi-evergreen forests at an altitude of 600 to 1300 m.

Distribution: In India, the tree is endemic to the southern parts of Western Ghats. In Karnataka, it is occasionally found in Coorg, Mysuru, Shimoga, Uttara Kannada, and Chikkamagalur districts. It is commonly found in Kerala and Tamil Nadu but is less common in Coimbatore and the Nilgiris districts of Tamil Nadu.

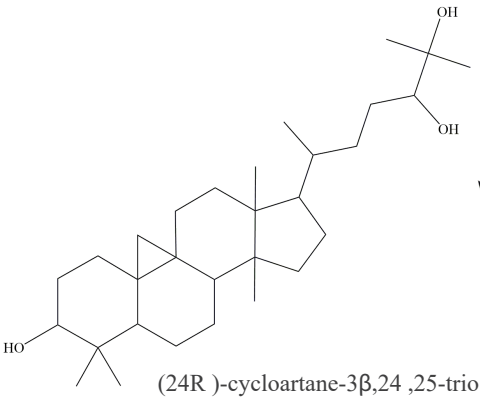
Ethnobotanical Significance: In Siddha, this plant is known as Agil and used as a substitute for *Aquilaria malaccensis*. The fruits and wood are used in traditional medicine (Bodare et al., 2013). The wood oil is used in treating ear and eye diseases. It is used in the treatment of osteomyelitis, abscess, many skin ailments, and also in cancer. A decoction of the wood is useful in the treatment of arthritis, anorexia, cardiac debility, expelling intestinal worms, inflammation, leprosy and rheumatism (Kumar, 2009)

Phytochemistry:

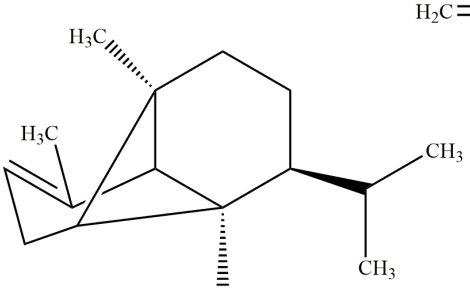
Leaves: Ergosta-5,24(24′)-diene-3β, 4β, 20*S*-triol, (24*R*)-cycloartane-3*β*, 24,25-triol, ergosta-5,24 (24′)-diene-3β, 7α-diol (Govindachari et al., 1997), 21*R*, 23*R*-epoxy-21α-ethoxy-24*S*,25-dihydroxyapotirucall-7-en-3-one, 24-*R*-acetoxy-3-β,25-dihydroxycycloartane, lupeone, lupeol, β-sitosterol, dipterocarpol, cycloart-25-ene-3β, 24-diol, 24*R*, 25-dihydroxy cycloartan-3-one, 3β, 24*R*, 25-trihydroxy cycloartane, beddomeilactone (Hisham et al., 2001).

Bark: Cabraleone (20*S*, 24*S*-eopxy-25-hydroxydammaran-3-one), cabraleadiol (20*S*, 24*S*-epoxydammarane-3α, 25-diol) and shoreic acid (20*S*, 24*S*-epoxy-25-hydroxy-3, 4-secodammar-4(28) -en-3-oicacid) (Hisham et al., 1996).

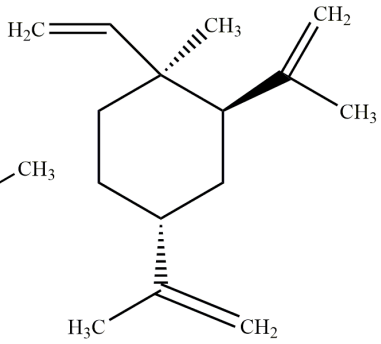
Wood: α-Muurolene, T-muurolol, δ-cadinene, hexahydroxy naphthalene, azulene [1,4 dimethyl-7-(1-methyl ethyl)], 1,4-cyclohexadiene, viridifloral, T.cadinol, α-elemene, α- copaene (Mohan et al., 2010).



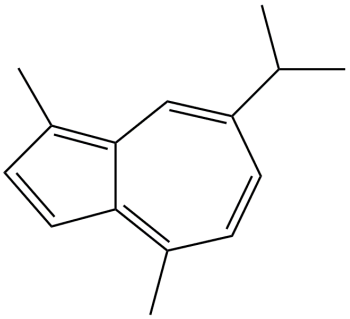
(24R)-cycloartane-3β,24 ,25-trio I



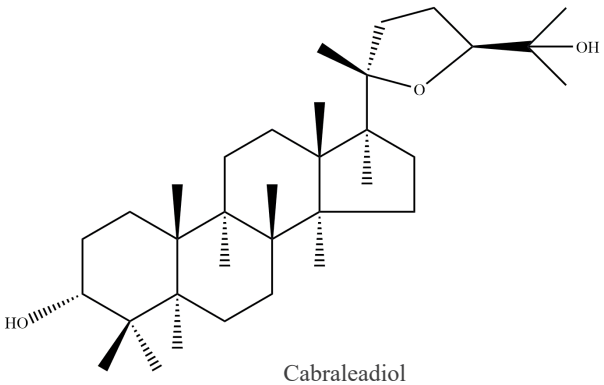
α-Copaene



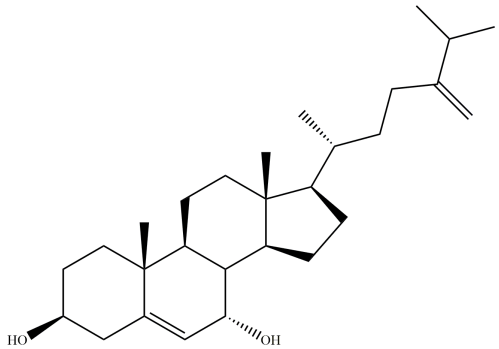
α-Elemene



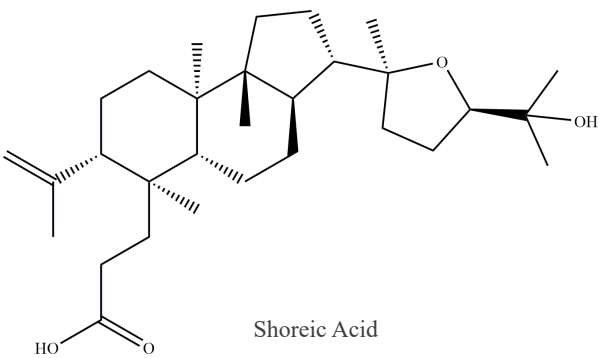
Azulene [1,4 dimethyl-7-(1-methylethyl)]



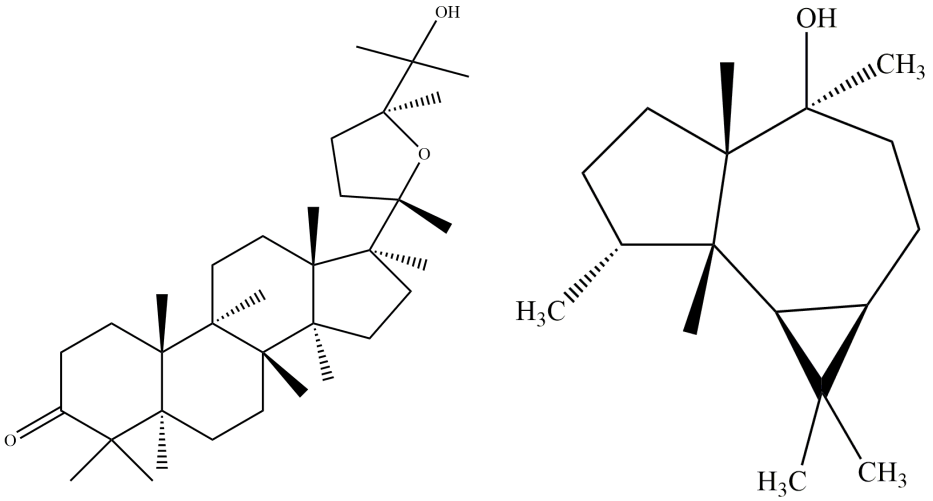
Cabraleadiol



Ergosta-5, 24 (24') diene-3β, 7β-diol



Shoreic Acid



Cabraleone Viridifloral

Structures of Important and Characteristic Chemical Constituents of *Dysoxylum malabaricum*

Biological Activities:

Larvicidal activity: Methanol extracts of leaves were tested against mature and immature *Anopheles stephensi* Liston (Diptera) mosquitoes under laboratory conditions. The extract showed strong larvicidal, pupicidal, adulticidal, and anti-ovipositional activity. Secondary metabolites, triterpenes 3β, 24, 25-trihydroxy cycloartane, and beddomeilactone showed strong larvicidal, pupicidal, and adulticidal activity. The highest concentration tested (10 ppm) of both compounds resulted in more than 90% mortality and oviposition deterrence. (Nathan et al., 2008).

Antifungal activity: The ethyl acetate extract from the wood was tested against the plant pathogen, *Fusariu moxysporum* Schlecht. The extract was active at a 0.5% concentration, showing 15.0% inhibition, while at a 2.0% concentration, the inhibition increased to 40%. (Mohan et al., 2011).

Anti-malarial activity: Bodare et al. (2013) reported that the compounds in the tree are effective against malaria mosquitoes. The methanol extract of the leaf was found to significantly control the population of *Anopheles stephensi* (Nathan et al., 2006). Similarly, the ethyl acetate extract of the leaf was also reported to significantly control the population of *A. stephensi* (Nathan et al., 2008; Basker et al., 2016).

Scope of further R&D: *Dysoxylum malabaricum*, a tree native to the evergreen and semi-evergreen forests of the Western Ghats in India, offers promising avenues for further research and development due to its significant ethnobotanical and pharmacological potential. The plant, known for its height of up to 35 meters and distinctive greyish-yellow aromatic bark, is traditionally used in Siddha medicine for treating a range of ailments, including ear and eye diseases, osteomyelitis, skin conditions, cancer, arthritis, anorexia, cardiac debility, intestinal worms, inflammation, leprosy, and rheumatism. Phytochemical studies have identified a variety of bioactive compounds in its leaves, bark, and wood, such as triterpenes, sterols, and various sesquiterpenes. These compounds have demonstrated notable biological activities, including larvicidal, pupicidal, adulticidal, anti-ovipositional, and antifungal effects. Specifically, the methanol extract of the leaves and ethyl acetate extract of the wood have shown significant efficacy against Anopheles stephensi mosquitoes and Fusarium oxysporum, respectively.

Given these findings, further research could explore the isolation and detailed mechanism of action of these bioactive compounds, the development of novel mosquito control agents, and the potential for antifungal treatments. Additionally, studying the ecological impact and sustainable harvesting methods for *D. malabaricum* will be essential to preserve this valuable species while harnessing its medicinal properties. Moreover, there is a compelling need for a more thorough chemical examination of

the plant in view of its traditional uses in the Unani system of medicine. This could lead to the discovery of new therapeutic agents and formulations, thereby expanding the medicinal utility of *D. malabaricum*. Exploring its potential within the Unani medicinal framework could provide insights into additional applications and benefits, enhancing its role in integrative and traditional medicine practices.

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Garcinia morella
(Gaertn.) Desr.

Synonyms:
Cambogia gutta L.,
Garcinia cambogioides (Murr.) Royle,
Garcinia gutta Wight, *Garcinia elliptica* Wall.,
Hebradendron cambogioides Graham,
Mangostana morella Gaerm,
Stalagmitis cambogioides Murr.

Local/Common/Popular Name(s):
Indian Gamboge tree, Mysore Gamboge tree

Vernacular Names:
Assamese: Kuji thekera, ***Bodo:*** Thaika,
Bengali: Tamal, ***Hindi:*** Tamal, Gola ghamba,
Tamil: Iravasinni, Makki, Solaipuli,
Malayalam: Daramba, Chigiri, Iravi
Telegu: Pasupavarne, Revalchinni,
Marathi: Tamal, Revalchinni (Indian Biodiversity portal, 2008)

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Magnoliopsida /Dicotyledons
Order	:	Malpighiales
Family	:	Clusiaceae
Genus	:	*Garcinia*
Species	:	*Garcinia morella*

Plant Description: *Garcinia morella* is an evergreen tree which may grow up to 20 m in length. The diameter of the trunk is 50 cm but is generally smaller and smooth. The inner bark is about 1 cm thick, blaze white to pale yellow in colour containing brilliant yellow sticky latex. The leaves are simple, entire, decussate, coriaceous and arranged opposite to each other. The petiole is about 2 cm in length and has a conspicuous and glabrous foveola with prominent margins sheathed at the base. The lamina is glabrous and elliptic with tapered base, attenuate and generally acuminate at apex, coriaceous or subcoriaceous shape varying from obovate to oblance with measurements 9-24 cm X 5-10 cm. The lower surface of the leaf has around 7-8 parallel, slender and prominent pair of lateral veins measuring about 8-14 mm in length. The flowers of the plant are dioecious, subsessile, axillary and solitary in case of female or 2-3 flowers clustered together in case of male in fascicles. The sepals are about 5 mm in length. There are 4 elliptical and fleshy white to pink coloured petals about 5-8 mm in length. The stamens in male flowers occur in monadelphous central column with free red anthers while the female flowers possess sessile peltate stigma which is irregularly lobed. The base of the ovary is surrounded by about 15 free staminodes which connate at the base. The ovary is superior, globose, smooth, greenish, 4-celled with one ovule in each cell. The fruit of the plant is spherical or subglobose berry, yellow or light pink in colour with diameter up to 3.5 cm. The base of the fruit is surrounded by persistent sepals and apex is crowned by flat tuberculate smooth and yellowish stigma. The exocarp is thin, pulp edible fruit, acid-sweet in taste and has 2-4 dark brown, laterally compressed, testa-muriculate, kidney shaped seeds (Hooker, 1890; Sullivan et al., 1972). The seeds germinate quite slowly and often take 6 or more months even if sown fresh. The flowering and fruiting in the plant occurs from November-July.

Habitat: *G. morella* grows in moist climate (Herbpathy, 2020). The lack of knowledge and habitat destruction is causing genetic erosion of the species (Cheek, 2004) and has been declared vulnerable according to ENVIS Centre on Medicinal Plants.

Distribution: *G. morella* is native species to Sri Lanka and India and occurs throughout northern part of South-East Asia along with Bhutan hills and Sylhet, the Indo-Himalayan region of China, and the Philippines. In India, it is found in Western Ghats and Northeast India (Parthasarathy et al., 2011). The plant is found in Lakhimpur, Darrang (Mangaldoi), Sivasagar, Nowgang, Dibrugarh, Kamrup, Barak Line Reserve, Silchar (Assam), Bhalukpung (Arunachal Pradesh), Khasi and Jaintia Hills (Meghalaya) and Nagaland. It is also found in the vicinity of Mikir hills (Karbi Anglong) in north-eastern part of India.

Ethnobotanical Significance: Gamboge, a gum-resin obtained from *G. morella* is used as a yellow dye, as an ointment, an illuminate and in varnishes, and for colouring foods, etc. The seed yields fatty oil which can be used for illuminating purposes and as a substitute for ghee (Facciola, 1998). The ripe acid fruits are good for treating dysentery and are eaten either raw or dried. The oil and juice of fruit is used for treatment of fever, jaundice, diabetes, and urinary problems (Dutta, 1985). The Bodo tribe of Assam cooks the unripe fruit with fish, and chutney is made by boiling the fruit. (*G. morella* Wikipedia, 2001). In Assam, the dried and preserved slices of fruit are added to black-green pulses to make a slightly acidic curry. The dried fruit slices are used as a traditional remedy for dysentery (Patiri and Borah, 2007). In Ayurveda, the fruits are used in the treatment of dysentery, and gastritis, and have been reported to possess anti-inflammatory properties (Kankushta, 2015). In Malnad, Tirtahalli, and Chikkamagalore regions of Karnataka, *G. morella* is widely used in preparation of a fish recipe named 'Odduli' which is prepared by boiling the fruit to obtain a thick black liquid which can be stored for years without any preservatives.

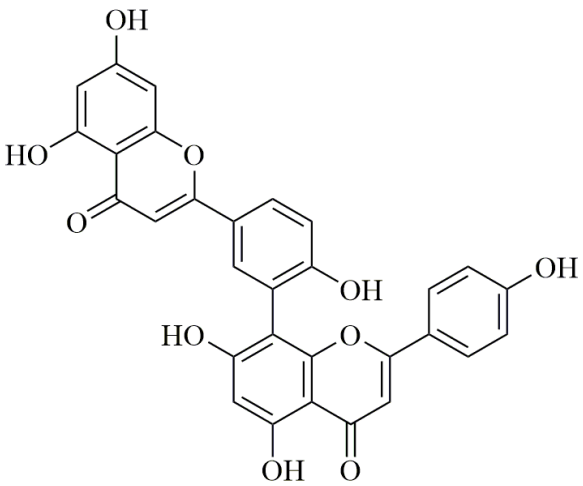
Phytochemistry:

Gum resin: Phenol 2, 4-bis (1, 1-dimethyl ethyl) -6-methyl, hexadecanoic acid (Murthy et al., 2017), morello flavone, gambogic acid, and guttiferic acid (Choudhury et al., 2016) isolmorellic acid, isomorellin, morellic acid (Karanjgaonkar et al., 1966).

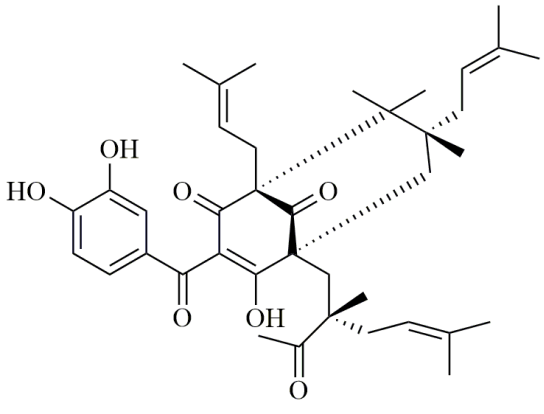
Seed: Morellin, oleic acid, stearic acid, myristic acid, arachidonic acid, palmitic acid, and linolenic acid, desoxymorellin, dihydroisomorellin, 5 morellinol, moreollin (Adawadkar et al., 1976).

Leaves: Hydroxycitric acid, garcinia acid, protocatechuic acid, caffeic acid, ferulic acid, vanillic acid, epicatechin, isoorientin, orientin, isovitexin, vitexin, kaempferol-3-O-rutinoside, luteolin, quercetin, apigenin, kaempferol, garcinia biflavonoid-2, garcinia biflavonoid-1, garcinia biflavonoid-1a, amentoflavone, mangostin, gambogic acid, ursolic acid, betulinic acid, garcinol (Pandey et al., 2015), citric acid (Bheemaiah and Kushalappa, 2019) allo-aromadendrene, aromadendrene, ascaridole, caryophyllene oxide, germacrene B, globulol, myrcene, selina-3,7(11) diene, spathulenol, α-copaene, α-humulene, β-caryophyllene, β-copaene, β-gurjunene, δ-amorphene, and δ-elemene.

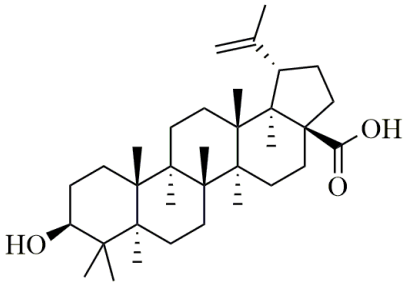
Fruit: Garcinol (Choudhury, 2017)



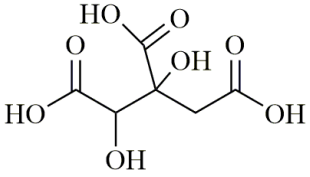
Amentoflavone



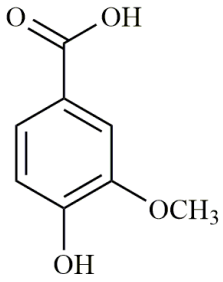
Garcinol



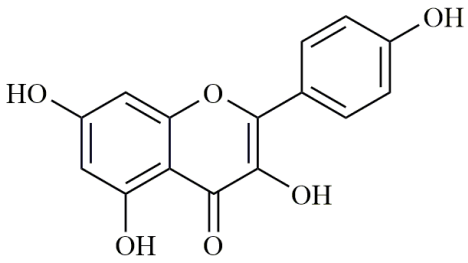
Betulinic acid



Hydroxycitric acid



Vanillic acid



Kaempferol

Structures of Important and Characteristic Chemical Constituents of *Garcinia morella.*

Biological Activities:

Anti-oxidant activity: The extracts of pulp of *G. morella* revealed the presence of polyphenols which exhibit antifungal and antioxidant effects on the body (Dey et al., 2017). The anticancer and antioxidant activity of *G. morella* fruit was evaluated and its ability to enhance the longevity of DLA-induced mice and restoration of their haematological and biochemical parameters was reported to be significant (Choudhury et al., 2016).

Anti-microbial activity: The extracts of pulp of *G. morella* revealed the presence of polyphenols which exhibit antifungal and antioxidant effects on the body (Dey et al., 2017). The seed oil of *G. morella* showed antibacterial activity against *Staphylococcus aureus* and *Pseudomonas aeruginosa* (Payamalle et al., 2016). Morellin and neomorellin isolated from *G. morella* have been used as antiprotozoal and anti-bacterial agents. The morello flavone isolated from the heartwood of *G. morella* has recently been reported to be a proteasome inhibitor (Sengupta et al., 2019).

Anti-cancer activity: Gambogic acid (GBA) inhibited the growth of cultured human hepatoma SMMC-7721 cells, possibly by inhibiting telomerase activity (Guo et al., 2004). Inhibition of the growth of SPA-A_1 cells and its tumor xenografts by GBA has also been reported. After treatment with GBA for a period of time, both the telomerase activity and the expression of hTERT mRNA in the tumour cells were significantly inhibited (Sengupta et al., 2019). The anticancer and antioxidant activity of *G. morella* fruit was evaluated and its ability to enhance the longevity of DLA-induced mice and restoration of their haematological and biochemical parameters was reported to be significant (Choudhury et al., 2016).

Patents:

- Purification of cell-dissolving compound gmd 1630 from the resin of garcinia morella desv., Patent No: JPH03176424A
- Process of purifying a cytolytic toxin from plant garcinia morella desv. (g.m.d.) resin for anticancer study., Patent No: EP0428815
- A process for the encapsulation of garcinia extract, Patent No. WO2004084654A1
- An athermal process for the concentration of garcinia extract., Patent No: WO2005070863A1
- A composition comprising garcinia extracts, and uses thereof, Patent No: 201641010905

Scope of further R&D: *G. morella* is an evergreen tree belonging to the family to Clusiaceae. The plant contains several phytochemicals

or bioactive constituents such as flavonoids, xanthones, phenolic acids, terpenoids, etc. which exhibit different pharmacological and medicinal properties and can be exploited further through scientific research studies to develop treatments and preventive measures against several human diseases and disorders. The phytochemical analysis of fruits, bark, and leaves of *G. morella* revealed that the phytochemicals present in these parts can help in controlling the production of free radicals which may be helpful in the prevention of cancer and therefore may be utilized in the production of an efficient anti-cancer and anti-angiogenic drug. Moreover, the scientific analysis using modern research techniques and technologies might further lead to the determination of several existing as well as novel phytochemicals in *G. morella* exhibiting specific pharmacological activity which can be utilized for different purposes. Future studies could also focus on developing and implementing sustainable harvesting practices to conserve this valuable species amidst habitat pressures.

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Gardenia gummifera L.f.

Synonyms:
Gardenia arborea Roxb.,
Gardenia inermis F.Dietr.,
Genipa arborea (Roxb.) Baill.,
Genipa gummifera (L.f.) Baill.

Local/Common/Popular Name(s):
Dikamali or Cumbigum.

Vernacular Names:
Sanskrit & Hindi: Hingpatri, ***Oriya:*** Gurudu, ***English:*** Cambi gum tree, ***Gujrati:*** Kamarri, ***Telugu:*** Manchibikki, ***Tamil:*** Tella manga, ***Kanada:*** Cittubikke

TAXONOMIC CLASSIFICATION (IUCN)

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Gentianales
Family	:	Rubiaceae
Genus	:	*Gardenia*
Species	:	*Gardenia gummifera*

Botanical Description: *Gardenia gummifera* is a small tree or shrub that can grow up to 3 m tall. The leaves are oblong-obovate with measurements 2.5-6.5 x 1-3cm and acute at the base with entire margin acute-obtuse at the apex and main nerves occur in 10-18 pairs. The yellowish-white or white flowers are axillary and are solitary. The berry is oblong or ellipsoid with a length of up to 2-4 cm (Flora of Andhra Pradesh). The edible fruit is ovoid with fleshy mesocarp and has measurements up to 2 to 4 cm. (Fig.1). The plant flowers every year during the onset of monsoon. However, sporadic flowering occurs during other months of the year. The flowering in the plant occurs from June to July while the fruiting occurs from August to October (Kotwal, 2014).

Distribution: *G. gummifera* is found in different states of India namely Uttar Pradesh, Tamil Nadu, Karnataka, Kerala, Maharashtra, Bihar and Andhra Pradesh. In Telangana, *G. gummifera* has been reported in dry deciduous forests of Nizamabad, Kamareddy, Adilabad, and Warangal (Flora of Andhra Pradesh) while in Odisha, it is found in Gajapati, Kandhamal, Koraput Sambalpur, Mayurbhanj and Nayagarh areas (Mahapatra and Pratap, 2012). It is also reported in Prakasham, Visakhapatnam, Srikakulam, East Godavari, West Godavari, Kurnool, Kadapa, Chittoor areas of Andhra Pradesh (Flora of Andhra Pradesh, Kanneboyena, et al., 2015).

Habitat: *G. gummifera* is found in tropical and subtropical regions of the world. It is an attractive shrub with white bark that grows in rocky areas in slightly undulating terrain (Fig.2) and occurs in specific habitats having well-drained shallow soil with exposed rocks at places usually on plateaus, which are not too dry. The Plant grows only in natural forest and is not cultivated (Kotwal, 2014), and is categorized as the least concern species by IUCN.

Ethnobotanical Significance: The resin of *G. gummifera* has great medicinal value and is used for several medicinal purposes for both external and internal applications (Wealth of India, 1956; Firdoous et al., 2010). It is given to children to treat nervous disorders and diarrhea due to dentition and rubbed on gums to relieve irritation (Prasad et al., 2007; Tambekar and Khante, 2010; Wealth of India, 1956). A decoction of resin is used in fevers.

In dyspepsia along with flatulence, the resin is used frequently (Wealth of India, 1956). Among the tribals, the gum is crushed in water to treat worms, vomiting, and hysteria. The gum is also used to treat foul ulcers, wounds, and obesity (Sumy et al. 2000; Parrotta 2001). A composition called, Unmadnashak Ghrita (UG) which is known for its sedative and anticonvulsant activities is a "panchagavya" in Ayurveda for the treatment of mania, epilepsy, and other disorders of the central nervous system (Achliya et al. 2004). It is also useful for the excretion of intestinal parasitic worms when given orally with local cow urine in the composition, 1 g of gum and 6 g of cumin along with 20 g of cow urine excretes the worms (Kotwal, 2014). The gum is used to treat stomach ailments in humans. The process of preparation is the same as for asafetida, except that the mixture is boiled for 25 to 30 min (CSIR, 1986). *G. gummifera* gum is antiseptic, carminative, expectorant, sore, spasm, stimulant, vermifuge, and repellant (Kotwal, 2014). Fruits of *G. gummifera* have been used by ethnic people of Andhra Pradesh due to their anti-spasmodic properties (Kanneboyena et al., 2015). The traditional practitioners of Pocharam Wildlife Sanctuary, Telangana have used *G. gummifera* gum resin in the treatment of snakebite (Saidulu et al., 2015). *G. gummifera* root has also been used in the treatment of female reproductive disorders by traditional practitioners of Uttara Kannada district in Karnataka (Hegde et al., 2007). Fruits are also edible and are mainly collected as livestock feed but are also consumed by tribal as hunger food in Odisha (Mahapatra and Pratap, 2012).

Phytochemistry

Gum-resin: Gardenin (Mathuram et al., 1998), acerosine (Gupta et al., 1975), apigenin (Gupta et al.,1975), 3',4'-dihydroxywogonin (Chhabra et al., 1976), 3',4'-dimethoxywogonin (Gupta et al.,1975; Chhabra et al., 1976), gardenin B (Krishnamurti et al., 1972; Gupta et al.,1975), gardenin E (Gupta et al.,1975), 4'-hydroxywogonin (Gupta et al.,1975), nevadensin (Krishnamurti et al., 1972; Gupta et al.,1975), 5,7, 3',4'-tetrahydroxy-6,8-dimethoxylfavone (Chhabra et al., 1977), 5,7,3',5'-tetrahydroxy-8,4'-dimethoxyflavone (Chhabra et al., 1977), 5,7,4'-Trihydroxy-6,8-dimethoxyflavone (Gupta et al.,1975), 3',4'.5'-trihydroxywogonin (Chhabra et al., 1976; Krishnamurti et al., 1972; Gupta et al.,1975), gardenin-A (5-hydroxy-6,7,8,3',4',5-hexamethoxy flavone) (Chauhan et al. 2001; Sadishkumar et al. 2003; Gunasekaran et al. 2005), hypolaetin-8,3,4-tri-O-methyl ether (Krishnamurti et al., 1972), 25-hydroxycycloart-23-en-3-one (Sreekanth et al., 2013), gardendiol, 19-β-hydroxyerythrodiol, oleanonic aldehyde, beta-sitosterol (Parmar et al., 2000)

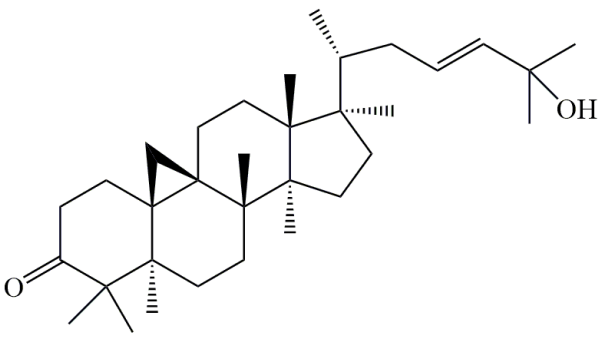
Leaf: Hypolaetin-8,3,4-tri-O-methyl ether (Krishnamurti et al., 1972)

Stem bark: 5, 7, 3, 5-tetrahydroxy-8,4-demethoxy flavone (Reddy et al., 1977)

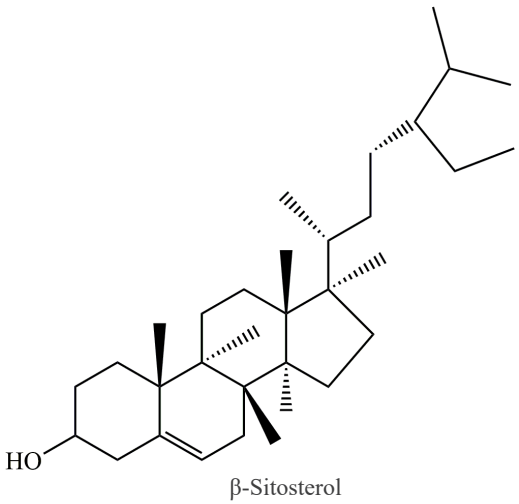
Fruits: 2,3-Dihydro-3,5-dihydroxy-6-methyl-4 H-pyran-4-one, 2-furan 5-hydroxymethyl furfural and quinic acid (Kumar et al., 1979.)

Leaf: Lycopene, anthocyanin, leucoanthocyanin (Kamble and Jadhao, 2018).

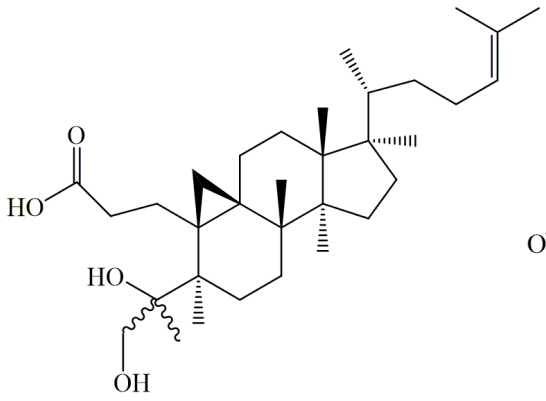
Root: Erythrodiol, lupeol, epicatechin, β-sitosterol, asiatic acid, myricetin, oleanolic aldehyde, vernolic acid, chlorogenic acid, and caffeoyl quinic acid (Prabha et al., 2014).



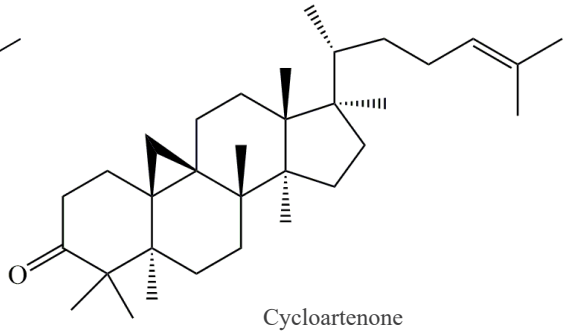
25-hydroxycycloart-23-en-3-one



β-Sitosterol

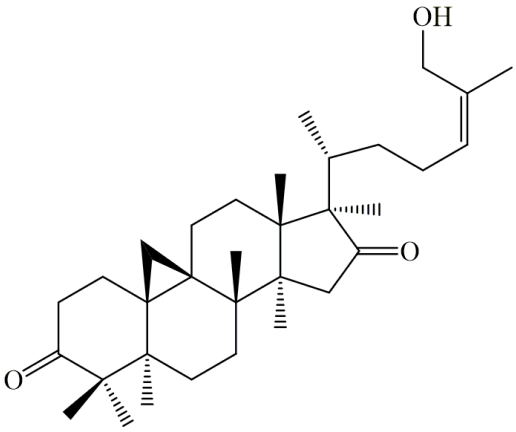


Gummiferartane 1

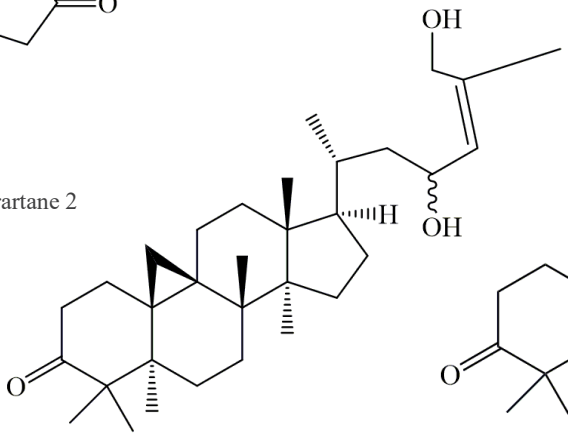


Cycloartenone

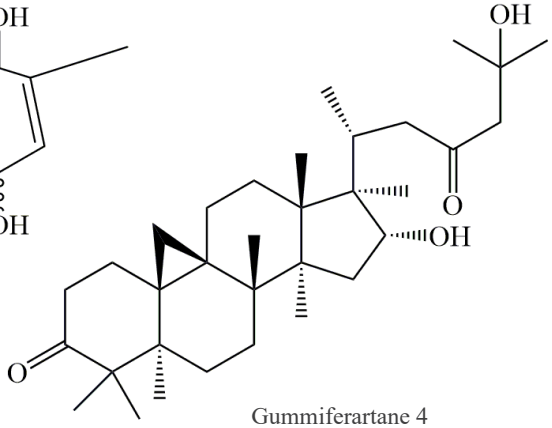
Dikamaliartane-A



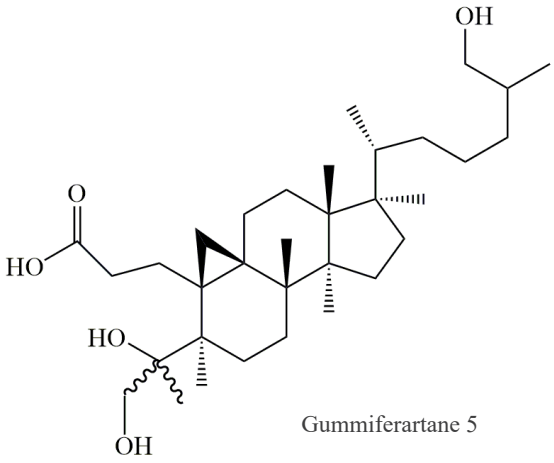
Gummiferartane 2



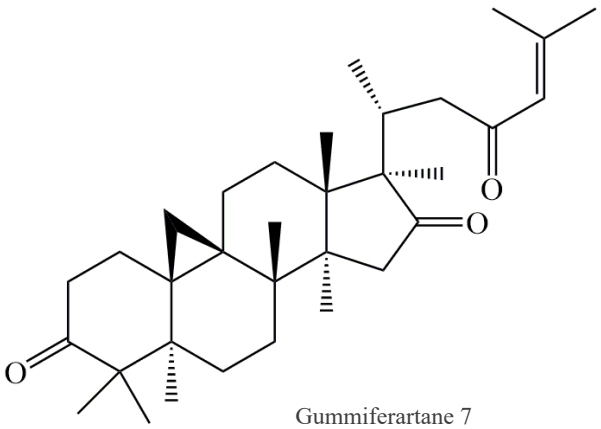
Gummiferartane 3



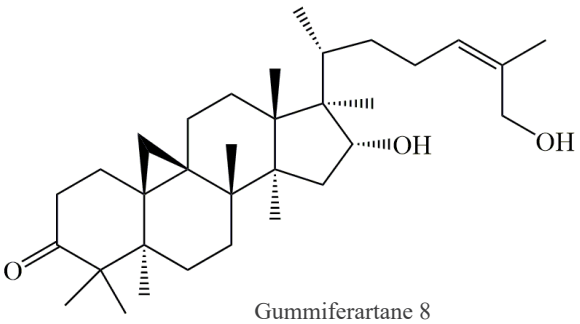
Gummiferartane 4



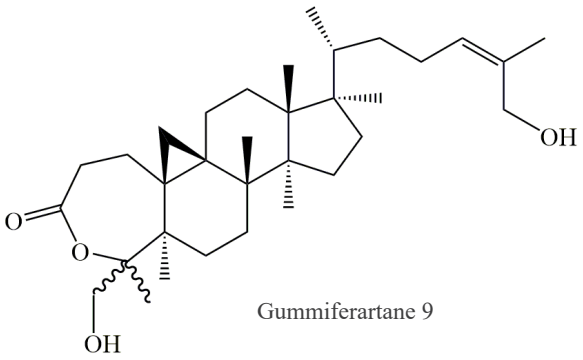
Gummiferartane 5



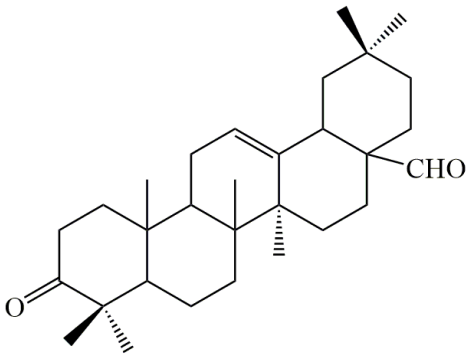
Gummiferartane 7



Gummiferartane 8



Gummiferartane 9



Oleanonic aldehyde

Structures of Important and Characteristic Chemical Constituents of *Gardenia gummifera.*

(Most of the constituents shown here are not mentioned under'Phytochemistry' section.

Biological Activities:

Anti-cancer activity: The anticancer activity of methanol extract of *G.gummifera* resin was tested in various cancer cell lines such as human non-small cell lung carcinoma (H1975), prostatecarcinoma (PC-3 and DU145), colorectal carcinoma (HCT116), and malignant melanoma (A375). The in-vitro cytotoxicity assay revealed that *G. gummifera* extract had the strongest cytotoxicity with IC_{50} of 28.61µg/ml in DU145 cells, 23.03µg/ml in PC-3 cells, 11.71µg/ml in H1975 cells, 11.67 µg/ml in HCT116 cells and 7.81 µg/ml in A375 cells. Thus, methanol extract of *G. gummifera* showed a cytotoxic effect which could be used in potential herbal formulations as an alternative to chemotherapeutic drug due to less toxicity to normal cells (Gopalakrishna et al., 2014a). A polyherbal formulation (PHF) containing a mixture of *Rhus succedanea* (stem), *Rheum emodi* (resin), and *Gardenia gummifera* (resin) extracts, has been developed and tested on human prostate (PC-3) and colorectal (HCT116) carcinoma cells (Gopalakrishna et al., 2014b). PHF significantly exhibited anti- proliferation of PC-3 and HCT116 cells in comparison to the individual extracts with an IC_{50} value of 0.37 µg/ml and 0.37µg/ml, respectively. Hence, this PHF has the potential to be developed as a therapeutic agent against prostate and colon cancer cells (Gopalakrishna et al., 2014b). The ethanol extract of the leaves of *G. gummifera* was also found to exhibit anti-cancer activity against MCF-7 cell lines and has Cytotoxic Concentration 50 value (CTC value) of 200.00µg/ml (Vindhya and Leelavathi, 2015).

Anti-oxidant property: Dikamali resin obtained from *G.gummifera* possess antioxidant property as has been confirmed by the TLC method (β-carotene-linoleate method). The LD_{50} was found to be 2227 mg/kg by Karber's arithmetic method (Sridhar et al., 2003). The leaf and fruit extracts also exhibit antioxidant property which was assessed using ABTS method while DPPH scavenging activity showed that methanol extract of *G. gummifera* exhibits significant free radical-

scavenging capabilities (Kekuda et al., 2017). The hepatoprotective and antioxidant activity of methanol extract of the whole plant of *G.gummifera* was evaluated against paracetamol-induced liver damage in rats. The results of this study strongly indicated that methanol extract and n-butanol fraction have potent hepatoprotective activity against paracetamol-induced liver damage (Sabbani et al., 2016). It has also been reported that ethanol extract of the leaves of *G. gummifera* had higher antioxidant activity due to the presence of higher phenolic content (Vindhya and Leelavathi, 2015). The leaf and fruit methanol extracts of *G. gummifera* scavenged DPPH radical dose-dependently with an IC_{50} value of 49.01µg/ml and 2.53µg/ml, respectively whereas scavenging of ABTS with IC_{50} value for leaf and fruit extract was 2.58µg/ml and 2.31µg/ml, respectively (Kekuda et al., 2017). *G. gummifera* methanol fruit extract showed significant antioxidant activity in DPPH and Nitric oxide radical scavenging with IC_{50}value of 131.11 and 175.95 µg/ml, respectively (Kumar et al., 1979). The fruit methanol extract also showed significant *in vivo* hepatoprotective activity. They performed molecular docking of GC-MS profiled phytocompounds with the target protein TGF-β1and PPARα which confirmed the therapeutic effect with good hydrogen bonding and hydrophobic interaction therefore, proving the traditional medicinal claim of the plant *G. gummifera* possessing the hepatoprotective drug (Kumar et al., 1979).

Antihyperlipidemic activity: The ethanol extract of twigs and gums of *G. gummifera* was showed significant antihyperlipidemic activity in Poloxamer-407 model at a dose 250mg/kg. (Pal et al., 2015). The methanol root extract of *G. gummifera* has a dose-dependent (125mg/kg and 250mg/kg) anti-atherogenic effect against high-fat diet-induced atherosclerosis (Prabha et al., 2013). The methanol root extract of *G. gummifera* also has highly potent cardioprotective and antioxidant activity based on the serum biochemical parameters, level of cardiac lipid peroxides, tissue antioxidants, TTC assay, and histopathological studies (Prabha et al., 2014).

Anti-microbial activity: The ethanol and chloroform extracts of *G.gummifera* twigs were examined for antibacterial activity against *Escherichia coli, Pseudomonas aeruginosa, Bacillus substilis,* and *Staphyllus aureus* using agar well diffusion method. Chloroform extract exhibited significant antibacterial activity than that of the ethanol extract against all bacteria (Garge et al., 2016).

Larvicidal activity: The leaf and fruit extracts of *G. gummifera* exhibited dose-dependent insecticidal activity in terms of larvicidal and pupicidal effects against larvae and pupae *Aedes aegypti* (Kekuda et al., 2017). The ethanol extract (40%) of *G. gummifera* was found to be moderately active with LC_{50} of 3.52 mg/ml and LC_{90} of 10.26 mg/ml against mosquito *Culex quinquefasciatus* (Suryadeva et al.,2002).

Diuretic activity: The ethanol extract of aerial parts of *G.gummifera* has been reported to show potential diuretic and natriuretic properties. (Fathima, 2017)

Anti-atherogenic activity: The methanol extract of *G. gummifera* root was evaluated against high fat diet induced atherosclerosis in male Wistar rats. The anti-atherogenic activity was assessed by quantifying the serum levels of cardiac marker enzymes (LDH, AST, ALT, and CPK), the concentration of serum total cholesterol (TC), triglyceride (TG), low-density lipoprotein (LDL) cholesterol, high-density lipoprotein (HDL) cholesterol, very low-density lipoprotein (VLDL) cholesterol, and phospholipids. The antioxidants such as catalase (CAT), glutathione peroxidase (GP_x), glutathione reductase (GR), glutathione-S-transferase (GST), and reduced glutathione (GSH) were also analyzed in heart tissue. The levels of lipid peroxidation, malondialdehyde (MDA), and histopathological analysis of heart tissue supported the dose-dependent anti-atherogenic effects of the extract. The extract significantly ($p \leq 0.05$) prevented the aforementioned parameters from dropping below normal levels. The extract was demonstrated to exhibit a dose dependent anti-atherogenic effect against high fat diet induced atherosclerosis. (Prabha et al., 2013)

Cardioprotective effect: The methanol extract of *G. gummifera* root was evaluated for its cardioprotective effect against isoproterenol (ISO)-induced myocardial infarction (MI) in rats. Myocardial damage was assessed by measuring the serum levels of cardiac marker enzymes (LDH, AST, ALT, CK-MB), serum iron, iron binding capacity, uric acid, and ceruloplasmin. In myocardial infarcted rats, levels of antioxidants such as catalase,

glutathione peroxidase, glutathione reductase, glutathione-S-transferase, and reduced glutathione were altered. The results revealed that the methanol extract provides dose-dependent cardioprotection against isoproterenol-induced myocardial infarction (Prabha et al., 2014).

Anti-bacterial activity: The ethanol extracts obtained from the stem bark and leaf of *G. gummifera* were evaluated for anti-bacterial activity against human pathogens viz, *Staphylococcus aureus, Streptococcus pneumoniae, Vibrio cholera, Pseudomonas aeruginosa, Salmonella typhi* and *Klebsiella pneumonia* using the agar well diffusion method. Both extracts demonstrated significant antibacterial activity against *S. typhi* and *S. aureus* (Kumar et al., 2017).

Anti-inflammatory activity: The fruit methanol extract and stem bark ethanol extract of *G. gummifera* were evaluated for anti-inflammatory activity. The denaturation of protein, human red blood cell membrane stabilization, and proteinase inhibitory action were analyzed for inflammatory action. The results revealed that the extracts exhibited significant anti-inflammatory activity (Kumar et al., 2021).

Wound healing activity: The fruit methanol extract and stem bark ethanol extract of *G. gummifera* were evaluated for wound healing activity. The wound contraction and epithelialization periods were measured by the excision model and tensile strength was assessed from the incision model. The extracts treated wounds exhibited effective healing capability as validated by increased wound contraction less epithelialization period and higher tensile strength (Kumar et al., 2021)

Anti-diabetic activity: The antidiabetic activity of leaf methanol extract of *G. gummifera* was investigated in normal and alloxan-induced diabetic rats treated with the extract in 200 and 400 mg/kg doses where glibenclamide was used as a reference. The extract was found to exhibit significant anti-diabetic activity (Kannan and Kumar, 2020)

Scope of further R&D: *Gardenia gummifera* is a small tree or shrub with significant ethnobotanical value and a wide range of medicinal applications, making it a promising candidate for further research and development. However, there is conflict of the source of commercial Dikamali gum as it contains both the *G. lucida* (*G resinifera*) and *G. gummifera* exudates. The literature survey revealed that commercial Dikamali gum mainly contained *G. lucida* exudates and thus chemical composition studies before 2010 are belongs to *G. lucida* and not *G. gummifera.* This part should be studied to ensure the quality and identity of the gum resin. Extensive phytochemical analysis has identified numerous bioactive compounds, including gardenin, acerosine, apigenin, and beta-sitosterol, suggesting potential for discovering more through advanced techniques like UPLC-QTOF-MS. Pharmacological studies have shown the plant's efficacy in anti-cancer, antioxidant, cardioprotective, antimicrobial, anti-inflammatory, wound healing, and anti-diabetic activities, warranting further research to isolate and characterize these active constituents and understand their mechanisms. Translating these findings into therapeutic applications through clinical trials is essential. Sustainable harvesting methods and conservation strategies are crucial for ensuring long-term availability, given the plant's occurrence in natural forests and non-cultivated status. Research into domestication and suitable propagation practices can facilitate large-scale production, enhancing its use in pharmaceutical and nutraceutical industries. Collaborative efforts with industries can lead to the development of commercial products, such as herbal medicines and dietary supplements.

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Holarrhena antidysenterica Wall.

Synonyms:
Holarrhena pubescens,
Holarrhena febrifuga

Local/Common/Popular Name(s):
Kurchi, Tellicherry bark

Vernacular Names:
Bengali: Kurchi, Kureya,
Marathi: Pandhra, Kura,
English: Kurchi, Conessi or Tellicherry Bark,
French: Ecoore-De Codagapala,
Gujarati: Indrajavanu,
Hindi: Karchi, Kura,
Punjabi: Kewar, Kura,
Sanskrit: Kutaja, Kalinga, Vatsika, Girimallika,
Tamil: Kashappu, Vetpalarishi, Veppalai,
Telugu: Kaka, Kodise.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Division	:	Magnoliophyta
Order	:	Gentianales
Family	:	Apocynaceae
Genus	:	*Holarrhena*
Species	:	*Holarrhena antidysenterica*

Botanical Description: *Holarrhena antidysenterica* is a short tree with a height of upto 30 to 40 feet producing milky white, thick, and less profuse latex. Its leaves are ovate, simple, large, smoother hairy, and arranged opposite to each other with measurements 15-30 cm × 4-12cm with obtuse, generally rounded or acute base. The leaf nerves occur in 10 to 14 pairs and are opposite and sessile with petioles of length of about 1.5cm and cymes are 3 to 6 cm in diameter. The long coma-shaped or boat-shaped seeds are 1-2cm long, linear or oblong, and are light brown to brownish in color exhibiting epigeal germination. Hairs are present at the apex of the seeds which are short-lived. The stem bark of the plant is smooth or rough, pale brown to greyish brown in color which peels off in irregular patches and is bitter in taste while the root bark is a reddish-brown in colour. The small-sized flowers are white in colour and arranged in a cluster which appears as a flattened top. The disc-shaped petals overlay on the right side and the corolla is 3-4 times longer than the calyx where the anthers are present inside the corolla tube. The fruits have small but long follicles with white spots on the surface. The dried fruits when busted release numerous flat seeds with brown hairs. The flowering in the plant occurs from April to July and fruiting occurs from August to October (Jamadagni et al.,2017; Ganapathy et al., 2011).

Distribution: The plant is abundant in India, especially in the Himalayan ranges, and is also found in tropical and subtropical regions of Asia and Africa (Singh et al., 983).

Ethnobotanical Significance: *H. antidysenterica*, commonly known as Kutaj, and its seeds, also known as Indrajava have traditional and folklore values in India. In Odisha, people offer leaves of this plant along with rice during the festival of 'Nabanna'. The bark of the plant is used in the Mirzapur and Varanasi districts of Uttar Pradesh for gastric problems (Singh et al., 1983) as well as by the Asur and Santhal communities of the Netarhat plateau of Bihar (Gupta et al., 1981). The tribes of the Nallamala district of Andhra Pradesh use the stem bark of the plant for skin diseases (Ram et al., 2001). The Bodo tribe of Assam also uses this plant as traditional medicine (Baruah et al., 1984). In

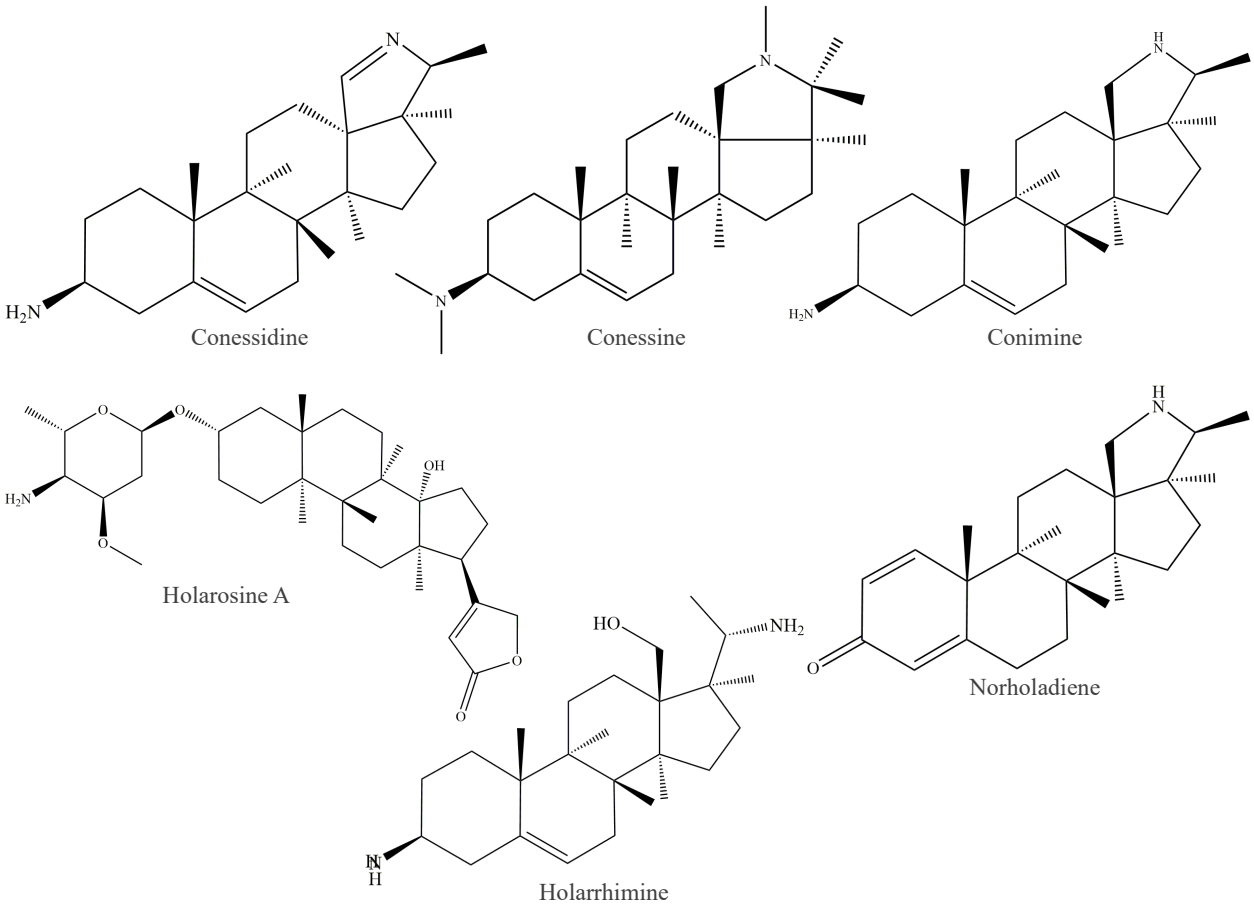
Ayurveda, this plant is used in classical formulations, namely, Kutajarishta, Kutajavleha, Kutajghan vati, Mahamanjishtadi Kashayam, Stanyashodhana Kashaya, and Patoladi Choornam. It is classically known for curing Pravahika (amoebiasis), Atisara (diarrhea), Jwaratisara (secondary diarrhea), Asra (blood or blood-related disorders), Kustha (skin disorder), and Trina (thirst) (Jamadagni et al., 2017).

Phytochemistry:

Stem bark: (20)-N-Methylholarrhimine, (3)-N-methylholarrhimine, 3α-aminoconan-5-ene, 7α-hydroxyconessine, conamine, conessidine, conkurchine, conkurchinine, Di-hydro-isoconessimine, holacetine, holacine, holadiene, holadysenterine, holadysone, holafrine, holarrhenine, holarrhessimine, holarrhidine, holarrhimine/kurchicine, holarrhine, holarrifine, holonamine, kurchamide, kurchamine, kurchenine, kurchessine, kurcholessine, lettocine, norholadiene, pubadysone, pubamide, pubescimine, pubescine, puboestrene, regholarrhenine A, regholarrhenine B, regholarrhenine C, regholarrhenine D, regholarrhenine E, regholarrhenine F, trimethylconkurchine, 20-aminoconanines, 3-aminoconanines, 3, 20-diaminopregnanes, 3-aminopregnans, conanines, conarrhimine, conessimine/isoconessimine, conessine, isoconessine (Ali et al., 2011; Alauddin et al., 1962; Kumar et al., 2007; Sinha et al., 2013; Bhattacharjee et al., 2017; Siddiqui et al., 2001; Yang et al., 2012).

Leaves: Holarosine A, holarosine B, holarricine, holantosine-A, holantosine-B, holantosine-C, holantosine-D, holantosine-E, holantosine-F, 21 kurchiphyllamine, kurchaline, 31 kurchiphylline (Bhattacharjee et al., 2017).

Seeds: Antidysentericine, (Kumar et al., 2000, Kumar et al., 2007), conimine (Keshri et al., 2012), 20-aminoconanines, 3-aminoconanines, 3, 20-diaminopregnanes, 3-aminopregnans, conanines, conarrhimine, conessimine/isoconessimine, conessine, isoconessine (Yang et al., 2012).



Structures of Important and Characteristic Chemical Constituents of *Holarrhena antidysenterica*

Biological activities:

Anti-amnesic activity: Ethanol extract of seeds of the plant was administered for 28 days to the independent groups of STZ and moderately diminished the level of AChE when compared to the diseased group and blocked the elevation in MDA levels and GSH reduction in a dose-dependent manner. Cholinergic dysfunction was also resolved by acetylcholinesterase activity. Decreased levels of AChE, prevented levels of MDA and glutathione demonstrated the anti-amnesic property of *H. antidysenterica* (Mrinal et al., 2016).

Anti-dementia activity: The aqueous and methanol extracts of powdered bark of *H. antidysenterica* were assessed for potential in the treatment of dementia. The methanol extract was administered at doses 100, 150, and 200 mg/kg to mice for 14 days in which scopolamine and lipopolysaccharide were used to induce memory impairment. The brain acetylcholinesterase (AChE) activity, glutathione (GSH) and thiobarbituric acid reactive substances (TBARS) levels were assessed. It was found that the methanol extract significantly increased the learning and memory of mice with a slight decrease in TBARS and AchE activity and increased GSH content (Kaur et al., 2020).

Neuroprotective activity: Treatment with methanol extract of *H. antidysenterica* (MEHA) moderately prevented bodyweight reduction, rise in blood glucose, and moderate depletion in plasma cholesterol when compared to the diabetic control group. HbA1C level was studied as a key indicator of advanced glycation end products, and in the present study treatment with MEHA inhibited this raised level of HbA1c. MEHA-treated rats demonstrated development in locomotion when compared to their non-treated group indicating the avoidance of diabetic neuropathy (Bansal et al., 2016).

Anti-diabetic activity: Ethanolic extract of plant moderately decreased plasma glucose levels 30 mins after administration to rats that have normal glucose levels. The total cholesterol, triglyceride, AST, ALT, urea, serum creatinine, and blood glucose levels were decreased by both ethanolic and methanolic extracts of the plant (Sharma et al., 2004; Mana et al., 2010; Kazi et al., 2010; Berg et al., 2001; Ali et al., 2009; Ali et al., 2011; Karunakar and Jaisal, 2014). Due to insulin recovery, the significant recovery of these biosensors was observed post-administration of the aqueous extract of the plant. The antidiabetic activity of *H. antidysenterica* seed extract was assessed in streptozotocin-induced diabetic rats. The diabetic rats were treated with glibenclamide, methanol extract, petroleum ether extract, and aqueous extract for 18 days. The fasting plasma glucose level, body weight, fasting serum glucose level, serum cholesterol, serum triglyceride, total protein, blood urea, urine glucose, and liver glycogen levels were determined. The seed extracts were found to possess antidiabetic activity (Sheikh et al., 2013).

Anti-bacterial activity: The effects of alkaloids from *H. antidysenterica* (AHA) on enteropathogenic *Escherichia coli* (EPEC) adhesion to epithelial cells. AHA reduced cytotoxicity, bacterial adherence, and apoptotic changes in infected cells, and suppressed type III secretory proteins (EspD). These findings suggest AHA's potential in treating EPEC-mediated diarrhea (Kavitha et al., 2009). *In vitro* studies showed that aqueous and ethanolic extracts of *H.antidysenterica* bark had significant effects on earthworms. Ethanolic seed extracts demonstrated concentration-dependent resistance against EPEC (Enteropathogenic Escherichia coli), known for antibiotic resistance (Pal et al., 2009). In another study, petroleum ether bark extract inhibited *E. coli* at a minimum inhibitory concentration (MIC) of 50 mg/ml, while methanol and chloroform extracts required higher concentrations (Patel et al., 2008).

Anti-hemorrhoidal activity: Shonitarsha (bleeding piles) is a painful chronic disease often requiring surgery, with frequent recurrences. The main symptom is rectal bleeding during defecation. Kutaja (*H. antidysenterica*) is an Ayurvedic remedy used for atisara, pravahika, and arsha, especially Shonitarsha. Patients were given 4g of stem bark powder twice daily for two weeks, significantly stopping bleeding (Pal et al., 2009).

Analgesic activity and Anti-inflammatory activity: Carrageenan-induced rat paw edema was inhibited by the methanol leaf extract of *H. antidysenterica*. Furthermore, it also suppressed the writhing response in a dose-dependent manner induced by acetic acid and demonstrated analgesic efficacy by improving tail-flick latency (Ganapathy et al., 2011). The ethanol extract showed an analgesic

effect by suppressing the writhing response in albino mice (Shwetha et al., 2014). *H. antidysenterica* treatment also prevented a rupture of goblet cells, inflammatory cellular infiltration, and inflammation in the mucosal layer (Siddiqui et al., 2001). Methanol, petroleum ether, chloroform, dichloromethane, and aqueous extracts of *H. antidysenteric*a stem were evaluated for analgesic and central nervous system depressant effects on the Swiss Albino Mice model. The analgesic activity was evaluated by acetic acid-induced writhing and hot plate methods at 50 and 100 mg/kg doses and the CNS-depressant effect was evaluated by using open field, hole cross, and head deep tests at 100 and 200 mg/kg doses. The extracts were reported to exhibit significant analgesic and CNS depressant effects in a dose-dependent manner with the chloroform extract demonstrating the highest activity (Haque et al., 2017). The methanol extract of the leaves was evaluated for analgesic activity at 100, 200, and 300 mg/kg doses using tail immersion and hot plate assays. Significant analgesic activity was reported through both methods and it was therefore concluded that the extract exhibited analgesic potential (Nahar et al., 2017).

Anti-malarial property: Conessine extracted from the stem bark of the plant exhibited effective anti-plasmodial properties, with the reproducible inhibitory concentration of 1.3µg/ml validated by *in-vitro* experiments and 88.95% suppression of parasitemia when administered at 10 mg/kg validated by *in-vivo* experiments. The bark extract exhibited significant results in *in-vitro* studies and exhibited anti-malarial property against *Plasmodium falciparum* and *P.berghei* (Verma et al., 2011).

Anti-diarrhoeal activity: Ethanol extract of the seeds exhibited an increase in the density of dry feces and suppression in defecation drops in the rats having castor oil and *E. coli*-induced diarrhea (Ganapathy et al., 2011). Aqueous extract and ethanol extracts of bark were found to resist enteroinvasive *E. coli* (EIEC), *Salmonella enteritidis, Shigella boydii*, and *Shigella flexneri* (Sharma et al., 2004). In addition, the ethanol extract of the bark was examined for antidiarrheal effects in castor oil-induced diarrheal Wistar albino rats. The antidiarrheal activity was determined using 100 and 200 mg/kg of plant extract administered orally and the percentage inhibition of defecation, change in fecal consistency, and body weight was recorded. The bioactivity was compared with the standard drug Loperamide at 5 mg/kg body weight. The results revealed that the extract at dose of 200 mg/kg significantly reduced the mean volume of intestinal fluid in comparison to the control (Malik et al., 2023).

Anti-mutagenic and Anti-hypertensive activity: The methanol extract of the bark was found to exhibit anti-mutagenic activity in mutagenicity-induced strains of *Salmonella typhimurium* (Lin et al., 1999). Inhibition of angiotensin-converting enzyme (ACE) was observed following the administration of an ethanol extract of the seed (Sinha et al., 2013). For antihypertensive activity, endophytes from the fungal extract of *H. antidysenterica* were dissolved in 20% methanol, resulting in 60% ACE inhibition (Aqil et al., 2008).

Antioxidant activity: A methanol extract of the leaves of *H. antidysenterica* was found to exhibit antioxidant properties, scavenging superoxide and hydroxyl ions with limited ability to convert ferric ions to ferrous ions (Jamadagni et al., 2017). The ethyl acetate fraction of the aqueous methanol extract of the seed inhibited deoxyribose degradation by hydroxyl ions, the deterioration of H_2O_2, nitrite formation, and lipid peroxidation (Ali et al., 2011). Aqueous and ethanol extracts of the seeds were analyzed for antioxidant activity using the DPPH method, with ethanolic extract showing higher antioxidant activity compared to aqueous extract (Ray et al., 2014).

Diuretic activity: Excess urine output was recognized in Wistar rats after the application of aqueous extracts of the seeds of *H. antidysenterica* at doses varied from 30 to 100 mg/kg. A considerable rise in the volume of sodium and potassium ions released through urine was observed (Khan et al., 2012).

Anti-amoebic activity: Amoebiasis, common in tropical regions with poor hygiene, is caused by *Entamoeba histolytica* through contaminated food and water. A study was conducted to reduce its prevalence using herbal medicines. In a randomized clinical trial with 202 patients, Amoebin Cap (containing *Phyllanthus emblica, Aegle marmelos, Holarrhena antidysenterica, and Myrtus communis*) showed significant improvement compared to

positive control Entamizole DS and Endemali. Statistical analyses confirmed the effectiveness of Amoebin Cap over other treatments (Shahabuddin et al., 2006).

Anti-methicillin-resistant Staphylococcus aureus (MRSA) activity: Ethanolic extracts of *Acorus calamus* (rhizome), *Hemidesmus indicus* (stem), *Holarrhena antidysenterica* (bark), and *Plumbago zeylanica* (root) exhibited anti-MRSA activity with inhibition zone sizes ranging from 11 to 44 mm and MIC values from 0.32 to 3.25 mg/mL. Ethyl acetate, acetone, and methanol fractions also showed antibacterial effects. P. zeylanica (ethyl acetate fraction) displayed the highest potency, followed by acetone fractions of *H. indicus, A. calamus* and *H. antidysenterica.* Time kill assays demonstrated concentration-dependent MRSA killing within 9-12 hours. Synergistic interactions were observed between these plant extracts and antibiotics like tetracycline, chloramphenicol, ciprofloxacin, cefuroxime, and ceftidizime, supporting their traditional uses against infectious diseases. Phytochemical analysis identified flavonoids and phenols as major active compounds, warranting further investigation into their mechanisms and interactions with antibiotics (Farrukh et al., 2006).

Anti-convulsant activity: The anticonvulsant activity of ethanol extract obtained from the seeds of *H. antidysenterica* was examined in Swiss albino mice using MES, PTZ, and BC tests. The extract significantly reduced MES-induced seizure duration and protected mice from PTZ-induced tonic seizures at doses of 250 and 500 mg/kg (Debnath et al., 2011).

Wound healing activity: The ethanol extract of *H. antidysenterica* leaves was evaluated for its wound healing activity in rats using an excision wound model. Wound closure rate was assessed, with 5% w/w povidone-iodine ointment used as the reference standard for comparison. The results demonstrated that the extract accelerated wound healing compared to the standard (Khayum et al., 2016).

Cytotoxic activity: The cytotoxic potential of *H.antidysenterica* leaf extracts (95% ethanolic, 50% ethanolic and hot water) was assessed against fourteen human cancer cell lines: A-549 (lung), COLO-205 (colon), DU-145 (prostate), HeLa (cervix), HEP-2 (liver), IMR-32 (neuroblastoma), KB (oral), MCF-7 (breast), NCI-H23 (lung), OVCAR-5 (ovary), SiHa (cervix), SK-N-MC (neuroblastoma), SW-620 (colon), and ZR-75-1 (breast) using SRB assay at 100 µg/ml concentration. The 95% ethanolic extract displayed significant anti-proliferative effects (73-92%) against eight cell lines, while the 50% ethanolic extract showed cytotoxic activity (70-94%) against seven cell lines. However, the hot water extract exhibited no activity. The chloroform-soluble fraction of the 95% ethanolic extract demonstrated notable cytotoxicity (71-99%) against A-549 (lung), HT-29 (colon), SK-N-MC (neuroblastoma), HEP-2 (liver), COLO-205 (colon), NIH-OVCAR-3 (ovary), and OVCAR-5 (ovary) cell lines, exceeding the effectiveness of standard anticancer drugs (Sharma et al., 2014).

Toxicology: Evaluations of the acute oral toxicity of aqueous, ethanolic, hydro-alcoholic extracts of the seeds of *H. antidysenterica* showed that all the extracts were safe up to 2000 mg/kg body weight in rats (Pathak et al., 2015; Sheikh et al., 2016). Similarly, the ethanol extract of the leaves was found safe up to a single oral dose of 2000 mg/kg in rats (Hegde et al., 2014), and up to 3000 mg/kg body weight in other studies (Kumar et al., 2015; Keshri et al., 2012). Subchronic toxicity studies using the ethanol extract complexed with polyvinylpyrrolidone at doses equivalent to 270 and 530 mg/kg body weight per day (which are 10 and 20 times less than human equivalent doses) revealed hepatotoxic effects in rats after three months (Permpipat et al., 2012; Singh et al., 2018). Therefore, caution is advised against overdosing and prolonged usage to mitigate potential hepatotoxic risks.

Patent and Commercial Products (if any):

- Method for preparing effective monomer of total alkaloid extract of *H. antidysenterica* and application thereof, Patent No.: CN102153614B
- Method of preparing high-content conessine extract from *Holarrhena antidysenterica* bark and the resulting extract, Patent No.: 202011007972
- *Holarrhena antidysenterica* containing chinese herbal medicine feed additive as well as preparation method and application thereof, patent no: cn112674207
- Formula particle of *Holarrhena antidysenterica* and preparation method and detection method of formula particle, Patent No.: CN110051713

- Method for preparing effective monomer of total alkaloid extract of *Holarrhena antidysenterica* and application thereof, Patent No.: CN102153614

Scope of further R&D: *Holarrhena antidysenterica*, widely distributed across India's Himalayan ranges and tropical regions of Asia and Africa, bears substantial ethnobotanical significance as Kutaj, revered in traditional practices for treating ailments such as gastric issues and skin disorders. Its pharmacological potential is underscored by a rich phytochemical profile, including alkaloids like conessine and holarrhimine. Research has unveiled a spectrum of biological activities spanning anti-amnesic, anti-diabetic, antibacterial, anti-inflammatory, and wound healing properties among others. While studies affirm the safety of its extracts up to specified doses, ongoing research avenues include isolation of bioactive compounds, mechanistic explorations, formulation development, clinical validation, and safety assessments. *H. antidysenterica*'s diverse therapeutic capabilities highlight its potential for pharmaceutical applications and merit further exploration to unlock its full medicinal and commercial promise.

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Juniperus indica Bertol.

Synonyms:
Juniperus wallichiana Hook. f. & Thomson ex Parl., *Juniperus wallichiana* Hook. f. & Thomson ex E. Brandis, *Sabina indica* (Bertol.) L.K.Fu & Y.F.Yu, *Sabina wallichiana* (Hook.f. & Thomson ex E.Brandis) W.C.Cheng & L.K.Fu

Local/Common/Popular Name(s):
Data is not available

Vernacular Names:
English: Black Juniper, Wallich's Juniper,
Chinese: Dian Zang Fang Zhi Bai (Farjon, 2013).

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Pinidae
Order	:	Pinales
Family	:	Cupressaceae
Genus	:	*Juniperus*
Species	:	*Juniperus indica*

Botanical Description: *Juniperus indica* Bertol is an erect or procumbent tree reaching a height of about 20 m and possesses a hard trunk with densely arranged branchlets. The leaves are both scale-like and needle-like. The needle-like leaves are usually present on young branches with acuminate apex while the scale-like leaves are decussate and linear with obtuse apex. The single-seeded fruit is a fleshy berry and is brown in color which later turns shining blue (Gyawali et al., 2012).

Distribution: *J. indica* is distributed in temperate and cold regions of the northern hemisphere (Anonymous, 1959; Hooker, 1999). It is distributed in temperate Himalayas from Kashmir to Bhutan and western Tibet. It is native to Bhutan, China (Sichuan, Tibet [or Xizang], Yunnan), India (Himachal Pradesh, Sikkim, Uttarakhand) (Lohani et al., 2010), Nepal, and Pakistan (Farjon, 2013). The plant grows in rocky areas such as inland cliffs, mountain peaks, forests**,** grassland, and shrubland (Farjon, 2013). It grows in areas from upper montane coniferous forest and woodland in pure stands or with *Abies, Pinus, Cupressus torulosa* or in *Betula utilis* sub-alpine woodland to alpine heath and grassland and into the bare moraines and scree of the niveous zone. The altitudinal range for the growth of *J. indica* is from 3,600 m to 4,800 m. As an understorey shrub or tree in the coniferous forest, it is often accompanied by *J. squamata, Rhododendron*, *Rosa,* and *Cotoneaster* spp.. Above the tree line, it can form juniper-rhododendron thickets, grow in *Kobresia-Stipa* turf with dwarfed alpine shrubs (e.g.*Rhododendron, Salix*, *Juniperus squamata*), or occur scattered on moraines and consolidated scree slopes of granite or gneiss or other metamorphic acidic rock, at the highest altitudes exclusively on S-facing slopes. The appropriate climate for the growth of plants is high montane to alpine with a pronounced monsoon phase delivering heavy precipitation (much as snow) from May to October (Farjon, 2013).

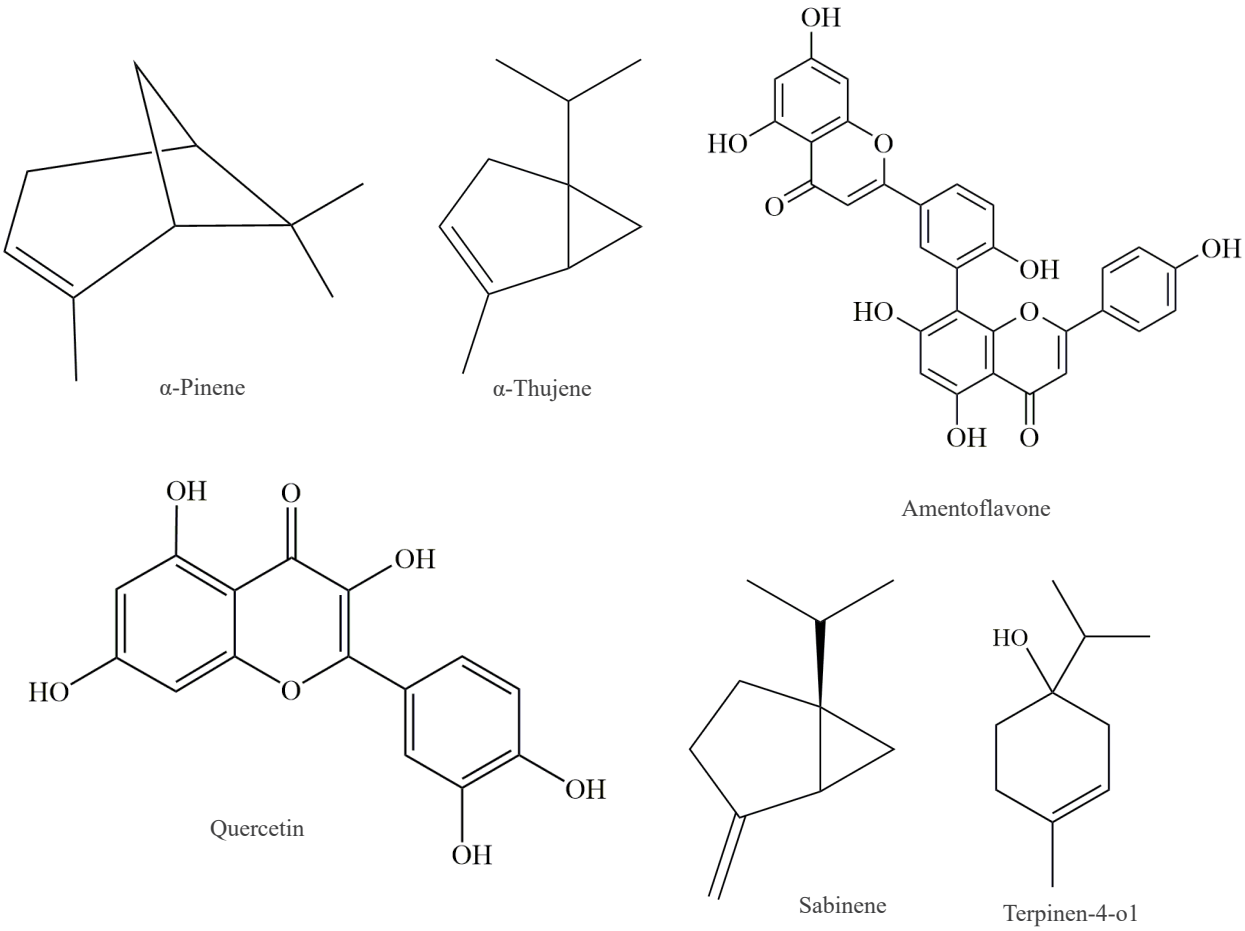
Ethnobotanical Significance: In the Himalayas, where Black Juniper is common and widespread, its wood is used as fuel, and branches and foliage are burnt as incense in Buddhist temples (Farjon, 2013). The fruits, leaves, stems, and bark are employed in traditional medicinal practices to treat

a variety of ailments, including cough and cold, tonsillitis, headache, malarial fever, neck pain, and high blood pressure. Additionally, it is used for chest pains, lung diseases, bronchitis, and for treating animals suffering from respiratory diseases, insect infestations, scabies, and wounds (Gyawali et al., 2012)

Phytochemistry:

Leaves: Quercetin, pyrogallol, tricyclene, α-thujene, α-pinene, camphene, myrcene, 1, 8-cineole, α-thujone, terpinen-4-ol, α-terpineol, sabinene, terpinen-4-ol, β-pinene, δ-2-carene, α-phellandrene, δ-3-carene, α-terpinene, p-cymene (Lohani et al., 2010), amentoflavone (Adams et al.,1998; Adams et al., 1996).

Berries: Tricyclene, α-thujene, α-pinene, camphene, myrcene, 1, 8-cineole, α-thujone, terpinen-4-ol, α-terpineol, sabinene, β-pinene, δ-2-carene, α-phellandrene, δ-3-carene, α-terpinene, p-cymene (Lohani et al., 2010)



Structures of Important and Characteristic Chemical Constituents of *Juniperus indica*.

Biological Activities:

Antibacterial Activity: Three extracts from the branches and twigs of *J. indica*–petroleum ether, ethyl acetate, and methanol–were evaluated for their antibacterial activity against the human pathogenic bacterial strains *Staphylococcus aureus*, *Escherichia coli*, and *Klebsiella pneumoniae*. At a maximum concentration of 8%, all extracts exhibited activity against the bacterial strains, with *S. aureus* showing relatively higher resistance. The highest bacterial mortality was observed at a concentration of 1000 ppm, while the lowest was at 10 ppm. The petroleum ether extract was the most effective, followed by the ethyl acetate extract, with the methanol extract being the least active (Gyawali et al., 2012).

Antimicrobial activity: The essential oils obtained from *J. indica* collected from four regions of North-Western Himalaya of Uttarakhand (India) were assessed for antimicrobial activity against six microorganisms, *Staphylococcus aureus*, methicillin-resistant *S. aureus, Escherichia coli, Pseudomonas aeruginosa, Candida albicans,* and *Aspergillus fumigatus* using broth dilution method. It was reported that the essential oil from the Gomukh region exhibited strong antimicrobial activity against the microbes except *P. aeruginosa* (Zafar et al., 2013).

Toxicology: The petroleum ether, ethyl acetate, and methanol extracts of *J. indica* were evaluated for their lethality to brine shrimp larvae (*Artemia salina* Leach). The reported cytotoxic activity was minimal, suggesting that the extracts could be used in high doses or concentrations without any significant toxic effects (Gyawali et al., 2012).

Scope of further R&D: *J. indica* is an evergreen coniferous tree belonging to the family Cupressaceae. It is widely used in traditional medical systems to treat various ailments. An extensive literature survey revealed that insufficient photochemical examination and pharmacological studies have been conducted. Therefore it is important to investigate the novel phytochemicals in *J. indica*, particularly in the essential oils by using modern scientific studies. These studies could lead to the development of value-added products for the fragrance, cosmetics, and pharmaceutical industries. Further research is needed to investigate its potential medicinal properties and it may help in developing new pharmaceuticals or herbal remedies.

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Juniperus polycarpos
K.Koch

Synonyms:
Juniperus excelsa subsp. *polycarpos* (K. Koch) Takht.,
Juniperus excelsa var. *polycarpos* (K. Koch) Silba,
Juniperus pingii subsp. *polycarpos* (K. Koch) Takht.,
Juniperus polycarpos var. *pendula* Mulk.,
Sabina polycarpos Antoine

Local/Common/Popular Name(s):
Persian juniper

Vernacular Names:
Hindi: Bhutal, Dhup, Guggul, Shupa, Shupe, Shur,
Persian: Ors

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Pinidae
Order	:	Pinales
Family	:	Cupressaceae
Genus	:	*Juniperus*
Species	:	*Juniperus polycarpos*

Botanical Description: *Juniperus polycarpos* is a dioecious tree with a height of about 6–7 m or a low shrub with a dense head. The scaly bark of the tree is reddish-grey and has short, firm, rather stout, and leafy branchlets. The leaves on the branches are ovate or deltoid and long-pointed on branchlets that are obtuse, rhombic, or ovate-rhombic, acute to sub-obtuse and slightly keeled on the back with an ovate-inflated gland. The pruinose, globose, and large berries are short-stalked and occur either solitary or in groups which are brownish-lilac in color when unripe and turn blackish-blue in color on ripening with 4 or 5 seeds. The brownish seeds are ovate-oval and ribbed (Taylor, 2010).

Distribution: *J. polycarpos* is distributed in the Himalayan region across Pakistan and India at an altitude range of 2400-4300 m. This variety is distributed from the Western Himalayas to the Caucasus. In India, it has been recorded in Jammu & Kashmir, Himachal Pradesh and Uttarakhand. In Himachal Pradesh, it is found at an altitude of 3000-4200 m and is mainly distributed in Manimahesh in Chamba, Kullu, Churdhar in Sirmour, Chhota, and Bara Bhanghal in Kangra, Kinnaur, and Pattan valley in the Lahaul-Spiti districts. In Jammu and Kashmir, it is found in Skiu Village near Monastery Ladakh, and Uttarakhand, it is found on the way to Nelong 3000m (Uttarkashi district). (Data collected from BSI, Dehradun and DD Herbarium, FRI, Dehradun).

Ethnobotanical Significance: The plant has several traditional uses. The extracted material of the plant is applied in the remedy of infections, fungus, contagious diseases such as cold, bronchitis, hemorrhoids, gynecological diseases, and wounds, tumor, and blood glucose (Akkol et al., 2009; Orhan et al., 2011; Toshio Muranaka et al.,1998). The boiled fruit extract of this plant has been used widely in the treatment of gastrointestinal disorders, and common colds, as an expectorant in cough, to treat calcinosis in joints, and as a diuretic to pass a kidney stone, against urinary inflammations, hemorrhoids, and as hypoglycemic agent (Erdem Yeşilada et al., 1993; Honda et al., 1996; Sezik et al., 1992; Yeşilada et al., 1995). Also, the resin was used for wound healing (Yeşilada et al., 1993) and the tar was applied externally against parasitic infections (Sezik et al., 1997). The seed decoction is used as

a folk medicine for kidney diseases and as a diuretic and abortive in Uzbekistan (Rasht, 2009). The plant is also used as an antibiotic for animals and as fly-repellent (Dorjey and Maurya, 2021). The local people of Ladakh generate mesmerizing aromatic smoke from the leaves and twigs of *J. polycarpos.* They discovered an incensing technique in which raw coal or dried dung cakes were placed in a typical earthern bowl called 'phokspor' specially designed for this purpose (Dorjey and Maurya, 2021).

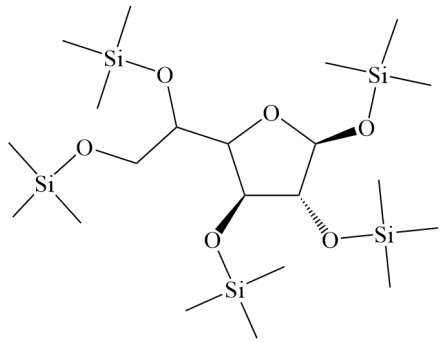
Phytochemistry:

Leaf oil: α-Pinene, β-pinene, thujene, sabinene, terpinene-4-ol, α-terpineol, borneol, geraniol, α-cadinene, β-cadinene, β-caryophyllene, δ3-carene, α-phellandrene, β-myrcene, limonene, P-cymene, germacrene, linalool (Taylor, 2010).

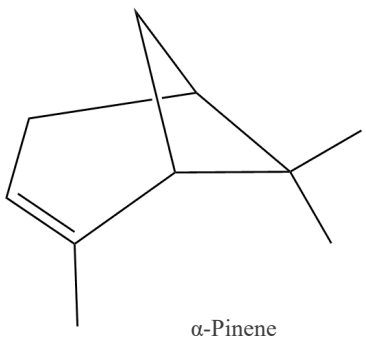
Fruit oil: α-Pinene, cedrol, myrcene, germacrene B, β-pinene

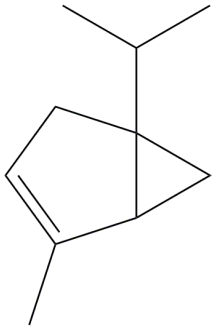
Wood: Pimaric acid, α-D-glucopyranoside, 1,3,4,6-tetrakis-O-(TMS)-β-D-fructofuranosyl 2,3,4,6-tetrakis-O-(TMS), triflouromethyl-bis-(TMS) methyl ketone, cedrol (Hosseinihashemi et al., 2017), β-D-galactopyranose,1,2,3,4,6-pentakis-O-(TMS), D- glucose, 2,3,4,5,6-pentakis-O-(trimethylsilyl) (Dadpour and Hosseinihashemi, 2017)

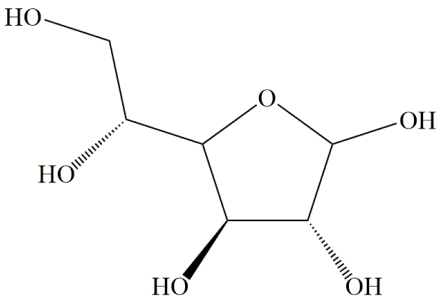
Bark: β-D-Glucofuranose,1,2,3,5,6-pentakis -O-(trimethylsilyl), pimaric acid, D-mannopyranose, 2,3,4,6-pentakis-O-(trimethylsilyl), D-fructose, 1,3,4,5,6-pentakis-O-(trimethylsilyl) (Dadpour and Hosseinihashemi, 2017).



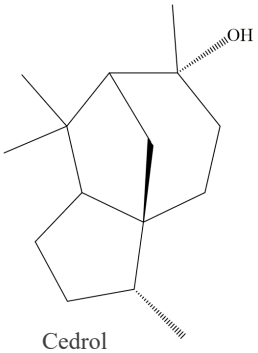
1,2,3,5,6-pentakis-O-(trimethylsilyl)


α-Pinene

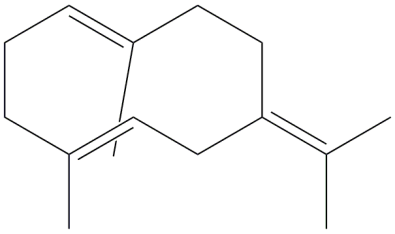

α-Thujene

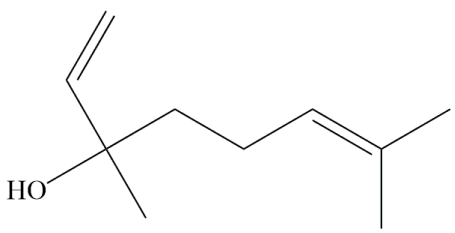


β-d-glucofuranose

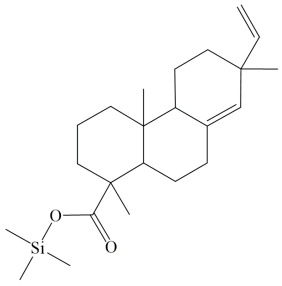


Cedrol

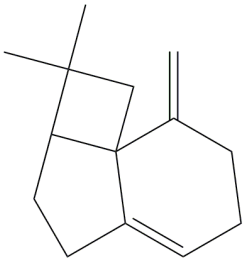

Germacrene B



Linalool



Pimaric acid trimethylsilyl


trans-caryophyllene

Structures of Important and Characteristic Chemical Constituents of *Juniperus Polycarpos*

Biological Activities:

Antimicrobial activity:

The antimicrobial activity of the essential oils obtained from the fruits and the leaves of the plant was determined using five strains of microorganisms from the Persian Type Culture Collection (PTCC). The following microbial strains were used: *Bacillus subtilis* (PTCC 1023), *Candida albicans* (PTCC 5027), *Escherichia coli* (PTCC 1038), *Pseudomonas aeroginosa* (PTCC 1074), and *Staphylococcus aureus* (PTCC 1112). Minimum inhibitory concentrations (MICs) were determined using the agar dilution method. Also, each strain was tested against the positive controls (gentamycin for bacteria and clotrimazole for fungus). The comparison of the MIC values showed all the tested essential oils either have weak antimicrobial activity against *Candida albicans* and *Staphylococcus aureus* at almost similar concentrations or showed no antimicrobial activity against the other tested microorganisms (Taylor et al., 2014). The antifungal activity of the essential oil of the leaves was assessed against phytopathogenic fungi, *Alternaria alternata*, *Colletotrichum trichellum, Curvularia fallax, Cytospora sacchari, Fusarium oxysporum* and *Macrophomina phaseolina* using disk diffusion and agar dilution assays. The extract demonstrated high antifungal activity against the fungi. The most susceptible fungi were *C. trichellum* in the agar dilution method and *M. phaseolina* and *C. fallax* in the disk diffusion method (Mehdizadeh et al., 2020).

Herbicidal activity: The essential oil from *J. polycarpos* exhibited high phytotoxicity against three weeds namely *Portulaca oleracea*, *Amaranthus retroflexus*, and *Datura stramonium* (Mehdizadeh et al., 2020).

Anti-oxidant activity: The acetone extract obtained from the wood of *Juniperus excelsa* ssp. *polycarpos* was evaluated for antioxidant activity using the DPPH method. The results were compared to those of ascorbic acid and butylated hydroxytoluene. The extract demonstrated significant antioxidant activity (Hosseinihashemi et al., 2017).

Scope of further R&D: *J. polycarpos* is an evergreen coniferous tree or shrub belonging to the family Cupressaceae. It has been utilized in traditional medicine for treating a range of ailments. Previous research has unveiled its rich reservoir of bioactive compounds and its potential for diverse pharmacological applications. Consequently, there is a pressing need for further exploration into its phytochemical composition and potential medicinal properties, as this could pave the way for the development of innovative pharmaceuticals. Notably, the essential oils derived from *J. polycarpos* offer significant commercial potential, and their study could lead to the creation of various value-added products.

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Litsea cubeba
(Lour.) Pers.

Synonyms:
Litsea citrata Blume,
Tetranthera polyantha Wall,
Laurus cubeba Lour.

Local/Common/Popular Name(s):
Mountain pepper, May Chang, Chinese pepper, Mezankori (Assamese), Dieng-si-ing (Khasi), Zeng-jir (Garo), Siltimber (Hindi)

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Laurales
Family	:	Lauraceae
Genus	:	*Litsea*
Species	:	*Litsea cubeba*

Botanical Description: *Litsea cubeba* is an evergreen tree that can reach a height of about 5–12 m and has a delightful fragrance of oranges. The short bole is straight with abundant branching above. The bark is green and warty with hairless or silky velvet-hairy branchlets. The leaves are alternately arranged on hairless, slender petioles of length about 0.5-0.9 inch. The leaves are lanceolate or narrow ovate-lanceolate, oblong or elliptic with measurements 8-15 x 2-4 cm, and are hairless on both surfaces or glaucous beneath. The lateral nerves occur in 10-13 pairs with wedge-shaped bases with tapering or pointed tips and the midrib being purplish below. The flowers are found in 4-6 flowered capitates either solitary or in corymbs with 4 bracts and are ovate, membranous, glabrous, ciliate at the edges with a slender peduncle of length about 10-15 mm. The flowering occurs prior to the growth of leaves or along with the growth of leaves. The flower-cluster-stalk is about 2-10 mm long and is either reflexed or straight and is hairless or possesses silky velvet hairs. The male flowers have 6 membranous sepals which are broadly ovate. The fertile stamens are 9-10 in number with hairy filaments and quadrate anthers. The nearly spherical fruits are about 5-6 mm in diameter and attain pepper-like black color at maturity (Balakrishnan, 1983; Deb, 1981; Flora of China, 1994; Hooker, 1890; Kanjilal, 1934). The flowering occurs from November to February and the fruiting occurs from June to July.

Distribution: *L. cubeba* is native to China, Indonesia, and other areas of Southeast Asia and is mainly distributed in Myanmar, Thailand, Laos, Indo-China, Indo-Malaya, Taiwan, China, Japan, Malaysia, Vietnam, and Java. In India, it is found in Eastern Himalayas from Sikkim to Mishmi at an altitude of 1550 to 2750 m (Hooker, 1890) and from Nepal to Bhutan border at an altitude of 300-3200 m (Flora of China, 1994). In northeast India, the plant is fairly common in Meghalaya usually in secondary forests and forest borders at lower elevations at 500-1500m (Balakrishnan, 1983), and is also found in Assam (foothills of Nagaland), Naga Hills, and Manipur at a height up to 1550-1850 m. (Hooker, 1890). The plant grows in sunny slopes, thickets, sparse forests, roadsides, and watersides (Chakraborty et al., 2018) and is commonly found in moist and

shady grasslands. It is a fast-growing pioneer species that is usually gregarious in open areas and is found along the edge of tropical rainforests and both lower and upper montane forests (Pakkad et al., 2022).

Ethnobotanical Significance: The roots, branchlets, leaves, and fruits of *L. cubeba* are used in traditional medicine to treat various internal health issues, including swelling and pain. This plant is significant in traditional Chinese medicine and is also used as a spice (Yang et al., 2010). The fresh green fruit is commonly used in salads, chutneys, and pickles (Mao, 1993). Additionally, it serves as a secondary food source for the Muga silkworm (Yadav et al., 1990). The tree's bark, which has a scent similar to 'Odomos,' is used as a mosquito repellent and in treating inflammatory conditions (Lin et al., 2004; Kamle et al., 2019). The Dayak Kenyah people of East Kalimantan use the fruits and bark as both oral and topical medicine for babies and adults. In Darjeeling, the fruit is used to manage diabetes, likely due to its antioxidant properties (Chakraborty et al., 2018). *L. cubeba* is also applied as a tonic for fever, stomachache, chest pain, and as an antidote for drunkenness. The leaves are used to treat skin diseases (Mao et al., 1993; Xie et al., 1996). In Sikkim, the Darjeeling Himalayan tribe uses *Litsea* as an antidiabetic plant (Chhetri et al., 2005).

Phytochemistry:

Fruits: Essential oil **(**Neral, geranial, D-limonene, sabinene, methyl heptanone, citronellal, citronellol, α-pinene, (Z)-iso citral, linalool, (E)- iso citral) (de Groot & Schmidt, 2016; Saikia et al., 2013; Ho et al., 2010; Trisonthi et al., 2014)

Seed: Lauric acid, capric acid, myristic acid.

Bark: Laurotetanine, methyl laurotetanine, dibenzopyrrocolin, litebamine, isoquinoline (Feng et al., 2009, Huang et al., 2008, Lee et al., 1996, Peng et al., 2018).

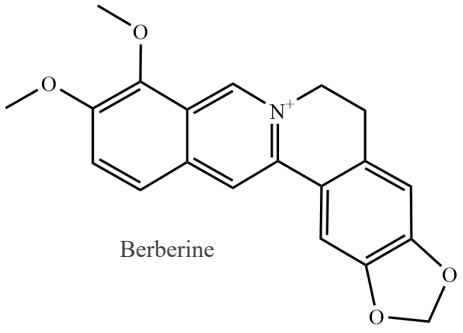
Stem: Essential oil **(c**itronellol, citronellal) (Saikia et al., 2013)

Flowers: Essential oil **(s**abinene, citronellal, β-phellandrene, α-pinene, β-pinene) (Saikia et al., 2013)

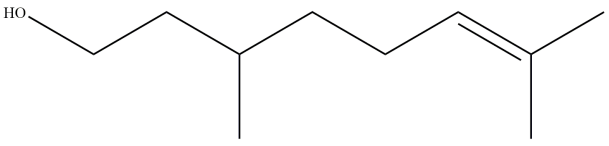
Branch: β-sitostenone, β-sitosterol, 2,5-dimethoxy-*p*-benzoquinone, 2,6-dimethoxy-p-benzoquinone, N-transferuloyl-3-methyldopamine, N-trans-feruloyl tyramine, N-trans-*p*-coumaroyltyramine, daucosterol, and 1,2-dihydro-6,8-dimethoxy-7-1-(3,5-dimethoxy-4-hydroxyphenyl)-N1,N2-bis-[2-(4-hydroxyphenyl) ethyl]-2,3-naphthalene dicarboxamide. (Chen et al., 2013; Wang et al., 2017)

Root: 9-Fluorenone, 1-ethoxy-3,7-dihydroxy-4,6-dimethoxy-9-fluorenone, pinoresinol, syringaresinol, 9,9′-*O*-di-(*E*)-feruloyl-meso-5,5′-dimethoxysecoisolariciresinol, lyoniresinol (Lin et al., 2016); (+)-norboldine, (+)-boldine, (+)-reticuline, (+)-laurotetanine, (+)-isoboldine, (+)-N-methyl-laurotetanine, berberine (Zhang et al., 2014)

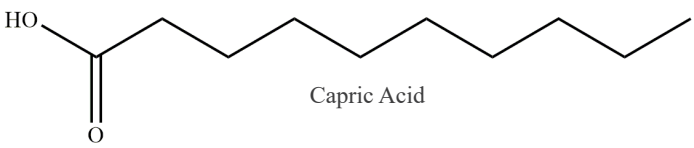
Stem: (+)-norboldine, (+)-boldine, (+)-reticuline, (+)-laurotetanine, (+)-isoboldine, (+)-N-methyl-laurotetanine, berberine (Zhang et al., 2014).



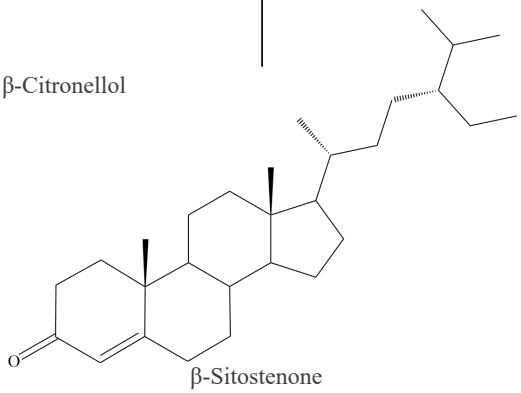
Berberine



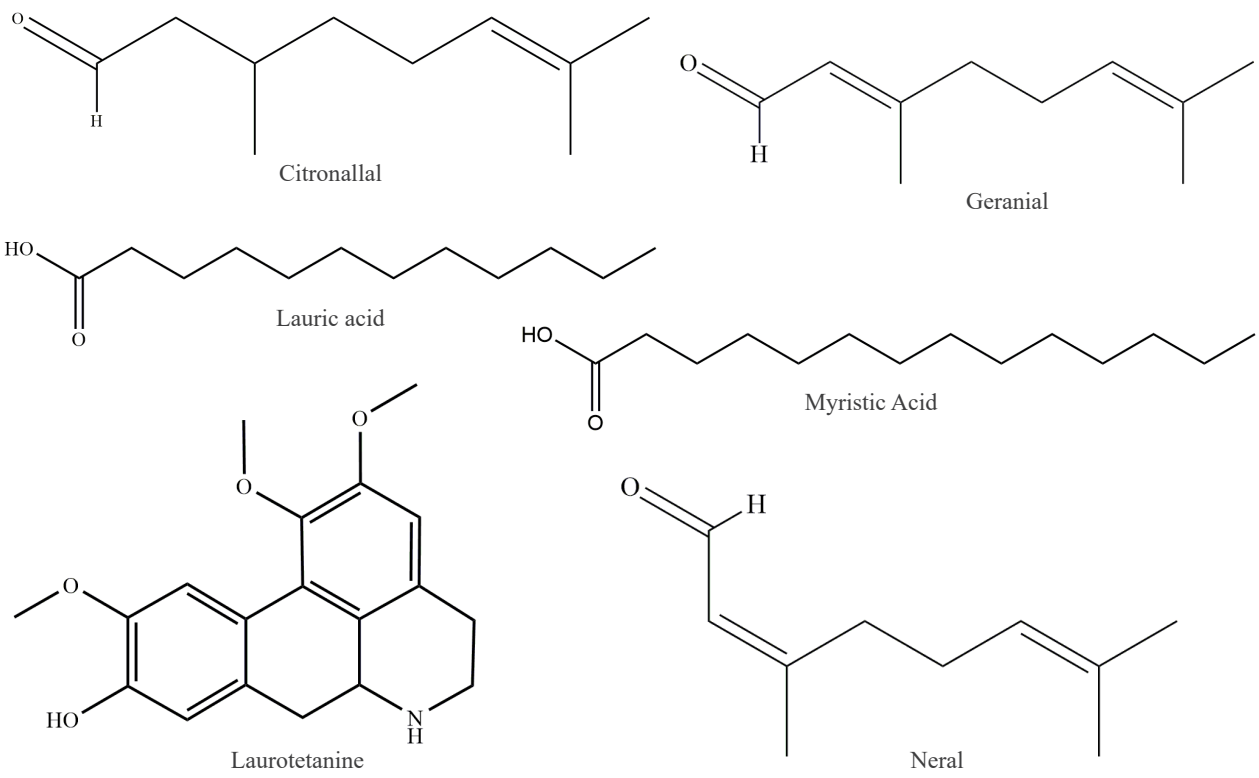
β-Citronellol



Capric Acid



β-Sitostenone



Structures of Important and Characteristic Chemical Constituents of *Litsea cubeba*

Biological Activities:

Anti-inflammatory activity: The essential oil of *L. cubeba* is reported to possess anti-inflammatory activity (Guo et al., 2015).

Anti-microbial activity: *L. cubeba* essential oil exhibited strong antibacterial activity against *Acinetobacter baumannii*, as demonstrated through serial dilution and growth curve methods. Additionally, Hu et al. (2019) evaluated the essential oil's effectiveness against methicillin-resistant *Staphylococcus aureus* (MRSA), revealing that it disrupts bacterial cell membranes and inhibits the hexose monophosphate pathway, leading to bacterial inhibition. The essential oil of *L. cubeba* has demonstrated antifungal properties against several fungal pathogens including *Alternaria alternata, Aspergillus niger, Candida albicans, Fusarium spp, and Helminthosporium* spp. *L. cubeba* oil is an excellent tonic for the skin and helps balance sebum levels on the skin surface and remove acne. The oil is also used to treat gout and fungal infections (Staff et al., 2018; Deka et al., 2018). The mold growth control on bamboo food packaging through *L.cubeba* is observed (Suhem et al., 2015 and Xia et al., 2020) The antimicrobial impact of essential oil from Taiwan was reported (Liu et al.,2012; Hao et al., 2021).

Anti-arthritic activity: The ethanol and aqueous root extract of *L. cubeba* was investigated for its potential in the treatment of rheumatoid arthritis using Freund's complete adjuvant (CFA) induced arthritis in a rat model. The extract significantly suppressed paw swelling and the arthritic score increased the loss in body weight and decreased the index of the thymus. The overproduction of TNF-α, IL-1β, and IL-6 was significantly attenuated in the serum of all *L. cubeba* oil-treated rats while IL-10 was increased at doses of 50 mg/kg of extract (Lin et al., 2013).

Anti-oxidant activity: The antioxidant activity of fruits of *L. cubeba* was investigated using different solvent extracts. The methanol extract was found to exhibit significant antioxidant activity. The HPLC analysis of the extract revealed the presence of various phenolic acids and flavonoids. Notable compounds include caffeic acid (145.96 µg/100

mg DE), syringic acid (125.85 µg/100 mg DE), ferulic acid (155.89 µg/100 mg DE), apigenin (28.43 µg/100 mg DE), and kaempferol (53.41 µg/100 mg DE) (Seal et al., 2020)

Insecticidal activity: The n-hexane, ethyl acetate, chloroform, and water extracts of the fruit of *L. cucbeba* were investigated for insecticidal activity against *Sitophilus zeamais*. The chloroform extract was found to exhibit the strongest repellent, contact, and fumigant activities against *S. zeamais* (Zhang et al., 2017).

Acaricidal activity: The essential oils of *L. cubeba* fruits and *Mentha arvensis* leaves were evaluated for acaricidal activity against *Dermatophagoides farina, D. pteronyssinus,* and *Tyrophagus putrescentiae* using a fumigant bioassay. The results revealed that both *L. cubeba* and *M. arvensis* exhibit significant acaricidal activity (Jeon and Lee, 2016).

Toxicology: The essential oil of fruits of *L. cubeba* was found to possess strong contact toxicity against *Lasioderma serricorne* adults and *Liposcelis bostrychophila*. (Yang et al., 2014; Luo et al., 2005).

Patent and Commercial Products (if any)

- *Litsea cubeba* oil microcapsule and preparation method thereof, Patent No: CN103548995B
- Preparation method of *Litsea cubeba* essential oil nanoemulsion and application of L*itsea cubeba* essential oil nanoemulsion in fresh keeping of salmon, Patent No: CN111280240A
- *Litsea cubeba* essential oil nanoemulsion, Patent No: CN111194767A
- *Litsea cubeba* essence oil clathrate and preparation method thereof, Patent No: CN102925290A
- *Litsea cubeba* oil distillation separation equipment and technology, Patent No: CN106350230A
- A kind of *Litsea cubeba* oil microemulsion and preparation method thereof, Patent No: CN109908779A
- *Litsea cubeba* oil mildew and moth proof slow release microcapsule and preparation method, Patent No: CN102715154B
- Skin care ointment containing *Litsea cubeba* oil and preparation method thereof, Patent No: CN112972331B
- A kind of *Litsea cubeba* oil and the preparation method and application thereof, Patent No: CN108624406A
- Preparation process of *Litsea cubeba* tea, Patent No: CN111587943A
- *Litsea cubeba* extracting solution and preparation method and application thereof, Patent No: CN110313402B
- Cultivation method for artificially promoting natural renewal of *Litsea cubeba*, Patent No: CN112205228B
- A kind of application of L*itsea cubeba* oil on control capsicum epidemic disease, Patent No: CN107232238B
- Method for extracting citronellal from L*itsea cubeba* head oil, Patent No: CN108383702B
- Extraction method of *Litsea cubeba* oil, Patent No: CN104694248A
- *Litsea cubeba* essential oil-hydroxypropyl-beta-cyclodextrin inclusion compound and preparation method and application thereof, Patent No: CN113068720A
- Method for remarkably improving rooting rate of *Litsea cubeba* cluster buds, Patent No: CN110731269B
- *Litsea cubeba* spicy and hot sauce and production method thereof, Patent No: CN104996979A
- *Litsea cubeba* oil extraction element, Patent No: CN215975715U
- A kind of preparation method of the *Litsea cubeba* oil embedded object with antioxidant activity, Patent No: CN108913360A
- Preparation method of *Litsea cubeba* essential oil with antibacterial activity, Patent No: CN108676622B
- Method for improving germination rate of *Litsea cubeba* seeds, Patent No: CN110933969A
- *Litsea cubeba* oil microcapsule suspension and preparation method thereof, Patent No: CN102487941A
- High-yield cultivation method for *Litsea cubeba*, Patent No: CN113079914A
- *Litsea cubeba* oil extracting method, Patent No: CN108384640A
- A kind of method that rapid flash extracts *Litsea cubeba* oil, Patent No: CN109628227A
- Method for improving germination rate and germination rate stability of *Litsea cubeba* seeds, Patent No: CN109511309B

- method for preparing *Litsea cubeba* oil, Patent No: CN110734806A
- Method for extracting *Litsea cubeba* oil and citral, Patent No: CN104450197A
- Gynaecology and obstetrics's obstetrics is with *Litsea cubeba* trunk cutting equipment, Patent No: CN108466298B
- SNP (Single nucleotide polymorphism) marker for identifying the sex of *Litsea cubeba* and screening method of SNP marker, Patent No: CN106987652B
- *Litsea cubeba* ointment with anti-inflammatory and itching relieving effects and preparation method thereof, Patent No: CN112999264A
- Method for preparing citranitrile by using *Litsea cubeba* essential oil, Patent No: CN113801036A
- A kind of healthcare *Litsea cubeba* essential oil foot bath liquid and preparation method thereof, Patent No: CN103520280B
- Application of beta-cyclodextrin and derivatives thereof in purification of *Litsea cubeba* oil, Patent No: CN105481668A
- Method for deironing and purifying oil of *Litsea cubeba*, Patent No: CN103031202B
- *Litsea cubeba* oil-based preservative and fresh-keeping composition, Patent No: CN107258895B
- Processing method of *Litsea cubeba* oil, Patent No: CN104120036A
- Method for preparing drug for preventing and treating freshwater fish disease from *Litsea cubeba* essential oil and dithiocyano-methane, Patent No: CN103109875B
- A *Litsea cubeba* condiment and a production method thereof, Patent No: CN104996956A
- The application of *Litsea cubeba* oil in sun-proof articles and a kind of sunscreen composition, Patent No: CN103622880B
- Bagged *Litsea cubeba* tea and preparation method thereof, Patent No: CN103315089A
- Process and device for extracting citral from *Litsea cubeba* oil, Patent No: CN102211986A
- A method of addition Extracted From Oil-tea-cake extract-Fructus Perillae quintessence oil-Litsea cubeba oil microcapsule prepares antimicrobial preservative film, Patent No: CN109439008A
- Method for extracting limonene from *Litsea cubeba*, Patent No: CN105237323A
- *Litsea cubeba* pers asexual quick propagation and seedling breeding method, Patent No: CN102227976B
- Backpack *Litsea cubeba* picking device, Patent No: CN110731170A
- Method for preparing biological aviation fuel by using *Litsea cubeba* kernel oil, Patent No: CN102719317B
- Medicinal and edible plant *Litsea cubeba* essential oil extraction device, Patent No: CN216764826U
- The method of long carbon chain triglycerides in a kind of preparation of *Litsea cubeba* kernel oil tea oil, Patent No: CN109439699A
- Method for extracting methyl heptenone from *Litsea cubeba*, Patent No: CN104478680A
- Sunscreen composition composed of *Litsea cubeba* oil and resveratrol, Patent No: CN111743822A
- Process method for extracting *Litsea cubeba* oil by using supercritical CO2, Patent No: CN103194311A
- Detoxification and rapid propagation method for *Litsea cubeba*, Patent No: CN108967199B
- Extraction method and formula of *Litsea cubeba* compound essential oil, Patent No: CN102199489B
- Split charging device for *Litsea cubeba* oil, Patent No: CN209835595U
- Natural plant *Litsea cubeba* fragrant degerming agent, Patent No: CN102451484A
- Method for preparing citral by using *Litsea cubeba* oil as raw material, Patent No: CN109796320B
- Method for enhancing germination rate of *Litsea cubeba* seeds, Patent No: CN102696301B
- Method for purifying *Litsea cubeba* aromatic oil by molecular distilling technology, Patent No: CN103232331A
- *Litsea cubeba* pickling method, Patent No: cn103169048
- Processing method of health-caring frutus *Litsea cubeba* tea, Patent No: CN106954709
- Method for evidently increasing *Litsea cubeba* cluster bud rooting rate, Patent No: CN110731269

- *Litsea cubeba* pomace feed and preparation method thereof, Patent No: CN107373084
- Processing method for edible *Litsea cubeba* oil, Patent No: CN107361160
- Fructus *Litsea cubeba* tea and manufacturing method thereof, Patent No: CN106212768
- Technology for tea leaf scenting through *Litsea cubeba* and application of technology, Patent No: CN106962540
- *Litsea cubeba* cutting propagation method, Patent No: CN108738779
- Rooting medium and culture method for tissue culture seedlings of *Litsea cubeba*, Patent No: CN107223565
- Application of *Litsea cubeba* essential oil in controlling pepper phytophthora blight, Patent No: CN 107232238
- Method for cultivation of test-tube seedlings of *Litsea cubeba*, Patent No: CN 103535172
- *Litsea cubeba* essential oil sustained-release preparation and application thereof in agricultural product airing and night storage, Patent No: CN 111713552
- Preparation method of *Litsea cubeba* compound oil, Patent No: CN 112205483
- Method for preserving Litsea cubeba, Patent No: CN 102578225
- Novel *Litsea cubeba* distillation kettle, Patent No: CN 113512468
- Native *Litsea cubeba* seed granular active carbon as well as preparation method and application thereof, Patent No: CN 107866200
- *Litsea cubeba* powder grease and preparation method thereof, Patent No: CN 112471484
- Humic acid and *Litsea cubeba* compound and preparation process thereof, Patent No: CN113813304
- Dry *Litsea cubeba* flower tea and preparation method thereof, Patent No: CN 104719572
- Method for recycling polystyrene by dissolving waste polystyrene foam with *Litsea cubeba* oil emulsion, Patent No: CN 113480777
- *Litsea cubeba* jelly and preparation method thereof, Patent No: CN 112220016
- *Litsea cubeba* oil ointment with anti-inflammatory and antipruritic effects and preparation method of *Litsea cubeba* oil ointment, Patent No: CN 112999264
- Making method for *Litsea cubeba* bean milk, Patent No: CN 106106765
- *Litsea cubeba* traditional chinese medicine health-care hammer and manufacturing method thereof, Patent No: CN 112274422
- *Litsea cubeba* oil mildew and moth proof slow release microcapsule and preparation method, Patent No: CN 102715154
- Cleaning device used after *Litsea cubeba* steaming, Patent No: CN 213223541
- Cultivation method for artificially promoting natural renewal of *Litsea cubeba*, Patent No: CN 112205228
- Brewing method of *Litsea cubeba* wine, Patent No: CN 108913463
- Process for blending camellia oil, sesame oil, and *Litsea cubeba* oil, Patent No: CN 111972508
- Fresh *Litsea cubeba* fruit storage device, Patent No: CN 2214453574
- *Litsea cubeba* fruit branch high-throughput separation and collection device, Patent No: CN 215507830
- Preparation method of *Litsea cubeba* mesophyll cell protoplast, Patent No: CN110358722
- *Litsea cubeba* tissue culture seedling micro-cuttage method, Patent No: CN 107980466
- Application of *Litsea cubeba* oil to inhibition of phytophthora infestans, Patent No: CN 107019003
- Preparation method of *Litsea cubeba* oil for food flavor improvement, Patent No: CN: 113881489

Scope of further R&D: *L. cubeba* is an evergreen tree belonging to the family Lauraceae. It is an important medicinal plant and is widely used in traditional medicinal systems to cure various ailments. Therefore, it is important to investigate novel chemical compounds by using advanced techniques, which can have applications in the cosmetic, pharmaceutical, and food industries. Research could focus on the potential health benefits such as its antimicrobial, anti-inflammatory, and analgesic properties. *L. cubeba* essential oil has a pleasant citrusy aroma and potential skin benefits. Thus, it can be explored in the formulation of cosmetics and personal care products. Traditionally, *L. cubeba* is used as a flavoring

agent in some cuisines. Therefore, research can explore its culinary applications and its potential as a natural food preservative. Further research is needed to understand the safety and potential toxicity of *L. cubeba* and its essential oil, mainly in high concentrations or prolonged use.

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Mallotus nudiflorus
(L.) Kulju &Welzen

Synonyms:
Trewia nudiflora Linn., *Trewia integerrima* Stokes, *Trewia macrophylla* Roth, *Trewia macrostachya* Klotzsch, *Mallotus cardiophyllus* Merr.

Local/Common/Popular Name(s):
Gutel, False white teak, River Portia

Vernacular Names:
Sanskrit: Shriparni, Tumri, Pindaara; ***Hindi:*** Bhillaura, Gori Gambhara, Pindar, Pindalu; ***Manipuri:*** Wangphop; ***Tamil:*** Arruppuvarachu, Aattharasu; ***Malayalam:*** Niirkkatamp, Pamparakkumpil; ***Telugu:*** Eruponuku; ***Kannada:*** Kaadugumbala; ***Bengali:*** Kaadukamchi, Pitali; ***Oriya:*** Pithaliya; ***Urdu:*** Pindara; ***Assamese:*** Bhel-kor, Kenlo; ***Khasi:*** Dieng Soh Lyndot; ***Garu:*** Arurong, Jongchia; ***Nepali:*** Gurel; ***Kachari:*** Panipitha; Tripura: Merua.

TAXONOMIC CLASSIFICATION

Kingdom	: Plantae
Phylum	: Streptophyta
Class	: Equisetopsida
Subclass	: Magnoliidae
Order	: Malpighiales
Family	: Euphorbiaceae
Genus	: *Mallotus*
Species	: *Mallotus nudiflorus*

Botanical Description: *Mallotus nudiflorus* (Fig.1) is a medium-sized deciduous tree that grows up to 20 meters in height. The bark is smooth and greyish-brown, with a creamy yellow blaze and light pinkish inner bark. Younger bark is tomentose. Leaves are simple, opposite, and decussate, with interpetiolar stipules measuring 2-3 mm. The petiole is slender, glabrous, and varies in length from 3 to 12 cm. The leaves are broadly ovate-cordate or deltoid, measuring 6-20 cm by 9-15 cm, with a cordate or subcordate base and an acuminate apex. Leaf margins are entire, glabrous above, and glaucous beneath, with 4-6 pairs of lateral nerves arranged in a scalariform pattern. The flowers of *M. nudiflorus* are dioecious and unisexual, with a greenish-yellow color. Male flowers are small, measuring 3-5 mm, and are clustered on long racemes (10-20 cm). They have pubescent, ovate-lanceolate bracts about 3 mm wide. The pedicels are 4-5 mm long, and the tepals are globose, splitting into 3-4 broad, concave segments (4-7 mm long). The numerous stamens, each with 1.5-3 mm filaments and 1 mm oblong, hairy anthers, are clustered on a convex receptacle. The female flowers are 5-9 mm long and occur in groups of 4-5 on axillary racemes, with pedicels 5-10 mm long. They have 3-5 broadly ovate tepals, densely tomentose beneath, and 4-5 mm in length. The yellow styles (2-5) are papillose and connate below, measuring 1.5-5 cm. The ovary is superior, globose, woolly, and 3-4-loculed with one ovule per cell. The seeds are black, smooth, and ovoid with fleshy albumen. Flowering occurs from January to March, and fruiting from July to August (Deb, 1981; Hooker, 1890; Kanjilal et al., 1934).

Distribution: *M. nudiflorus* is distributed across India, Sri Lanka, Myanmar, Indo-China, southern China, Thailand, Peninsular Malaysia, Sumatra, Java, Borneo, and the Philippines (Matthew, 1983). In India, it is found in the southern regions of Kumaon, northeastern India (Balakrishnan et al., 2013a), and northeastern Uttar Pradesh (Balmukund et al., 2016). In Northeast India, it is widespread in Meghalaya (Re-bhoi district), Assam (Nawgaon, Sivasagar, Golaghat, Jorhat, Dibrugarh, Lakhimpur, Dhemaji, Majuli), and Arunachal Pradesh (Namsai, Papum Pare, Lohit).

Ethnobotanical significance: The roots of *M. nudiflorus* are used in traditional medicine to treat stomachaches, flatulence, gout, rheumatism,

malignancy, leukemia, and hepato-biliary affections. The seeds yield oil that is beneficial in treating rheumatism (Rathore et al., 2007; Samad, 1966). The leaves are used for wound healing (Rastogi et al., 2004), and a decoction of the shoots and leaves is employed to relieve swelling and treat flatulence, excessive bile, and sputum (Nadkarni et al., 2002). The Halam community of Tripura, Northeast India, uses the tree as fuelwood.

Phytochemistry:

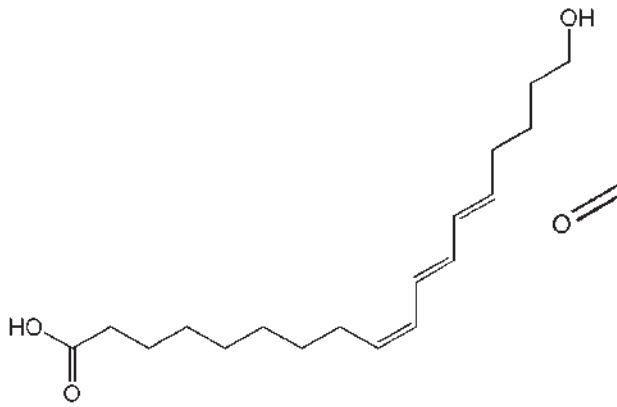
Bark: β-sitosterol; trewiasin; stigmast-4-en-6-beta-ol-3-one; stigmast-4-en-6-alpha-ol-3-one; 7-β-hydroxy sitosterol; 7-α-hydroxy sitosterol; schleicheol; taraxerone; abbeokutone; β-hydroxypropiovanillone; o-vanillyl alcohol; glycerol monopalmitate; trewianin; trewioside; scopoletin; indole-3-carboxylic acid; (+)-dihydrodehydrodiconiferyl alcohol 4-O-β-(6''-O-galloyl)-glucopyranoside; 4,4'-O-dimethyl ellagic acid 3-(2''-O-acetyl)-α-rhamnopyranoside; ethyl O-β-(6'-galloyl)-glucopyranoside (Balakrishnan et al., 2013b; Feng et al., 2005; Wu et al., 2008, 2009; Kang et al., 2008; Shilpi et al., 2010).

Fruit: 17-hydroxy-ent-atisan-19-oic acid; 17-hydroxy-ent-atisan-19-oic acid methyl ester; 16α,17-dihydroxy-ent-atisan-19-al; gallic acid; ethyl gallate; protocatechuic acid; 3,4,4′-tri-O-methylellagic acid; α-tocopherol; trans-cinnamic acid; taraxerone (Du et al., 2004); 3β,17-dihydroxy cleistantha-12, 15-dien-2-one (Du and Shen, 2006).

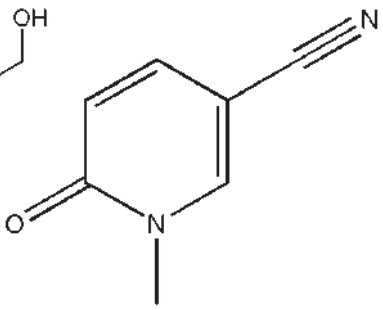
Seeds: Ricinidine; trewiasine; treflorine; trenudine; N-methyltrenudone; α-eleostearic acid; oleic acid; linoleic acid; arachidic acid; palmitic acid; stearic acid; eicosenoic acid; conjugated trienoic acid; conjugated tetraienoic acid; kamlolenic acid; triacylglycerol estolides (Smith et al., 2013; Madrigal & Smith, 1982) 9'-methyl americanol A; 9'-methyl isoamericanol A; 9'-ethyl americanol A; 9'-butyl americanol A; americanin (Li, et al., 2004).

Leaves: Nudiflorine (Mukherjee et al., 1966).

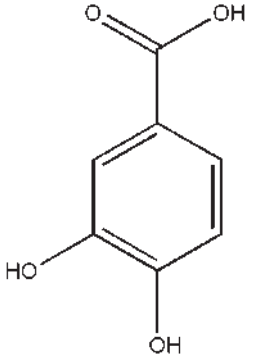
Stems: Cyclo(L-Pro-L-Leu); cyclo(D-trans-Hyp-D-Leu); cyclo(D-Pro-L-Phe); cyclo(D-cis-Hyp-L-Phe) (Xiang et al., 2020).



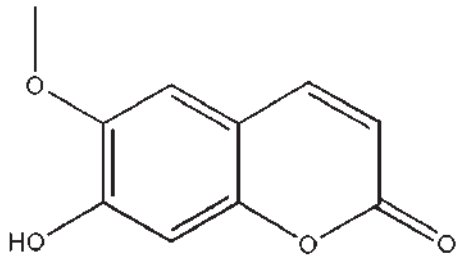
Kamlolenic acid



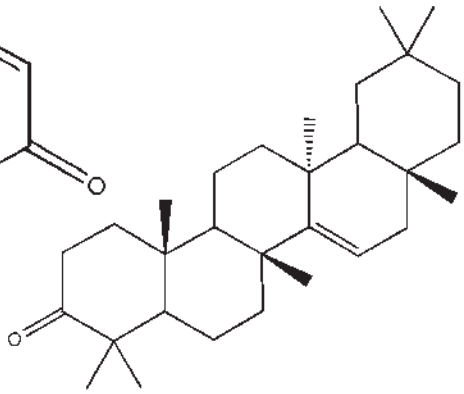
Nudiflorine



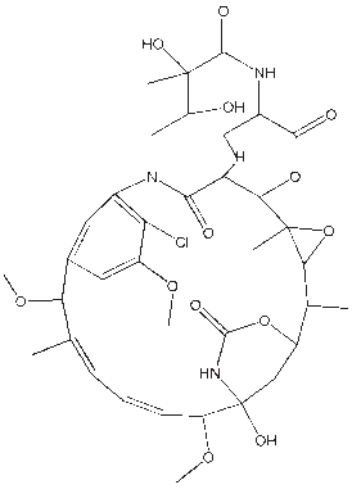
Protocatechuic acid



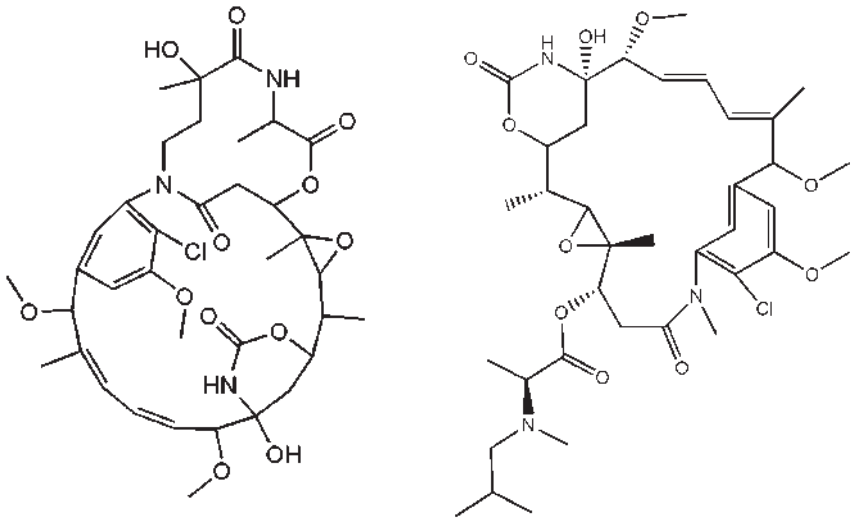
Scopoletin



Taraxerone



Trenudine



Treflorine Trewiasin

Structures of Important and Characteristic Chemical Constituents of *Mallotus nudiflorus*

Biological Activities:

Anti-microbial activity: The seed oil is noted for its antimicrobial properties, particularly against *Mycobacterium tuberculosis* (Guo-Hong et al., 2004). The methanol extract of the fruit demonstrates significant antibacterial efficacy, with notable activity against twelve pathogenic bacteria, including both gram-positive (*Staphylococcus gallinarum*, *S. sciuri*, *Streptococcus iniae*, and *S. constellatus*) and gram-negative strains (*Xanthomonas axonopodies*, *X. campestris*, *Edwardsiella anguillarum*, *Siccibacter colletis*, *Aeromonas cavernicola*, *A. diversa*, *Vibrio rotiferianus*, and *Enterobacter xiangfangensis*) (Chaity et al., 2020). Additionally, ethanolic extracts from the leaves, fruits, twigs, and seeds show varied antibacterial activity. Specifically, the leaf extract is highly effective against *Shigella dysenteriae* and moderately effective against *Pseudomonas aeruginosa*, while the fruit extract shows high activity against *Shigella boydii* and the twig extract against *Pseudomonas aeruginosa*. The seed extract has moderate antibacterial activity (Begum, 2016).

Insecticidal activity: Nudiflorine from the *M. nudiflorus* leaves has shown insecticidal activity (Begum, 2016).

Larvicidal activity: The leaf extracts of *M. nudiflorus* were found to be particularly toxic to *Culex quinquefasciatus* mosquito larvae in a dose-dependent manner, outperforming other tested plant extracts (Siam et al., 2021).

Anti-cancer activity: The plant also has notable anti-cancer activity; Trewiasine isolated from *M. nudiflorus* exhibits significant cytotoxicity in various human cancer cell lines (Begum, 2016). Phytoconstituents such as Treflorine, Trenudine, and N-Methyltrenudone are recognized as chemotherapeutic agents (Powell & Smith, 1983). Furthermore, ethanolic extracts of the leaves have shown anti-tumor activity against crown gall tumors on potato discs, KB cell culture, and P388 leukemia in mice (Powell et al., 1982).

Cytotoxic activity: The cytotoxicity of ethanolic extracts of leaves, fruits, twigs, and seeds was confirmed using the brine shrimp lethality bioassay, where the leaf, twig, and fruit extracts demonstrated significant cytotoxic effects (Begum, 2016).

Anti-ulcerogenic activity: The ethanolic extracts of *M. nudiflorus* leaves have demonstrated anti-ulcerogenic properties. These extracts were found to be effective against indomethacin-induced gastric ulcers (Rajalakshmi et al., 2012) and showed protective effects in cold-resistant stress-induced ulcer models (Wu et al., 2009).

Cerebroprotective activity: The ethanolic extracts of *M. nudiflorus* leaves have shown cerebroprotective effects in rats against global ischemia (Praveen et al., 2012).

Anti-oxidant activity: Antioxidant activity was observed in various plant parts, including stem bark, which contained (+)-dihydrodehydrodiconiferyl

alcohol 4-O-β-(6''-O-galloyl)-glucopyranoside. This compound exhibited significant antioxidant potential in a DPPH free radical scavenging assay (Kang et al., 2008; Niranjan et al., 2015). Further, ethanolic extracts of leaves, fruits, twigs, and seeds were tested for antioxidant activity using DPPH spectrophotometry, with the twig extract showing the highest activity (Begum, 2016).

Patent:

- Chemotherapeutically active maytansinoids from *Trewia nudiflora*, patent No. US4313946A
- Chemotherapeutically active maytansinoids: treflorine, trenudine, and N-methyltrenudone, patent No. US4418064A

Scope of Further R&D: *M. nudiflorus* is recognized as an important therapeutic agent with various medicinal properties. The fruit pulp is edible and contains significant levels of crude protein (1.41%), carbohydrates (15.84%), calcium (0.03%), and iron (1.80%). Current research highlights the potential of its fatty oil from the fruits and the anti-ulcerogenic properties of its leaves for pharmaceutical use. Future research should prioritize a comprehensive exploration of its chemical composition, with an emphasis on identifying and isolating bioactive compounds. Additionally, its pharmacological activities, traditional medicinal uses, and broader applications in the pharmaceutical industry need further investigation to fully assess its therapeutic potential.

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Mallotus philippensis
(Lam.) Müll.Arg.

Synonyms:
Aconceveibum trinerve Miq., *Croton coccineus* Vahl, nom. illeg., *Croton distans* Benth., nom. nud., *Croton montanus* Willd., *Croton philippensis* Lam., *Croton punctatus* Retz., nom. illeg., *Echinus philippensis* (Lam.) Baill., *Macaranga stricta* (Rchb. f. & Zoll.) Müll. Arg., *Mallotus bicarpellatus* T. Kuros., *Mallotus philippensis tomentosus* Gamble, *Mallotus philippensis* var. *microphyllus* Müll.Arg., *Mallotus philippensis* var. *Reticulatus* (Dunn) F. P. Metcalf, *Mallotus reticulatus* Dunn. Mappastricta Rchb f. & Zoll., *Rottlera affinis* Hassk., *Rottlera aurantiaca* Hook. & Arn., *Rottlera philippensis* (Lam.) Scheff., *Rottlera tinctoria* Roxb., *Rottlera tinctoria* var. *monstruosa* Ham. ex Dillwyn, *Tanarius strictus* (Rchb.f. & Zoll.) Kuntz.

Local/Common/Popular Name(s):
Kamala Tree, Sinduri

Vernacular Names:
Kamala, Sindur, Rohini, Kambhal, Kamala, Kamalagundi, Kapilo, Kampill, Kunkumadamara, Sinduri, Manjana, Kuramatakku, Kampipala, Ponnagam, Shindur, Shendri, Kapila, Kumila, Kamal, Kambal, Kamela, Kapli, Kungumam, Kurangumanjanatti, Manjanai, Kunkumam, Kunkuma, Chendrasinduri, Vassuntagunda, Sundari, Vasanta, Kumkumam, Kinbil, Gangai, Puddum, Lochan, Bosontogundi, Kumala, Sundragund, Kanbela, Rora

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Malpighiales
Family	:	Euphorbiaceae
Genus	:	*Mallotus*
Species	:	*Mallotus philippensis*

Botanical Description: *Mallotus philippensis* is a monoecious, small to medium-sized tree which can reach up to a height of 25 m and has a bole up to 50 cm in diameter. The reddish-brown branchlets are glandular. The leaves are alternate and simple, more or less leathery, ovate to lanceolate, and cuneate to rounded with two glands at the base. The leaves are mostly acute or acuminate at apex, conspicuously 3-nerved, hairy and reddish glandular beneath, petiole of length 1-4 cm, puberulous and reddish-brown in color. The male flowers occur in terminal and axillary positions and are 2–10 cm long, with solitary or fascicled paniculate spikes with each flower having numerous small stamens. The female flowers have spikes or slender racemes with each flower having a stellate hairy, 3-celled ovary with 3 papillose stigmas. The fruit is a depressed-globose3-lobed capsule of measurements 5 x 7 x 10 mm and stellate and puberulous with abundant orange or reddish glandular granules and is 3-seeded**.** The seeds are sub-globose and black in color and 4 mm in diameter (Orwa, et al., 2009). The plant has additional floral nectaries which attract ants. The flowers mature from March to April while the fruits mature in July-August.

Distribution: *M. philippensis* has widespread natural distribution ranging from the western Himalayas, through India, and Sri Lanka, to southern China, and throughout Malaysia to Australia. The plant grows in both forests and open scrub land and is generally found mixed with other plant species while it is found to be gregarious sometimes. It is common in evergreen forests, especially in secondary forests, and sometimes even dominant in the undergrowth. The tree withstands considerable shade and is frost-hardy and resistant to drought. It mostly grows at an altitude of 0–1600 m and at a mean annual temperature of 16–28^{0}C with a mean annual rainfall of 800–2000 mm and grows mostly in a wide range of soil types, including infertile soils, limestone, acid, and rocky land.

Ethnobotanical Significance: According to Ayurveda, the leaves of *Mallotus philippensis* are bitter in taste and are used for their cooling effect and as an appetizer. Various parts of the plant, including the glands and hairs from the capsules or

fruits, have multiple medicinal uses. These parts are employed as purgatives, anthelmintics, vulneraries, detergents, maturants, carminatives, and alexiterics. They are beneficial in treating bronchitis, abdominal diseases, and spleen enlargement. When taken with milk or yogurt, they are particularly effective in expelling tapeworms (Usmanghani et al., 1997). The plant's powder and other parts are also applied externally to promote the healing of ulcers and wounds and are used to treat parasitic skin conditions like scabies, ringworm, and herpes. Historically, *M. philippensis* was used in India for dyeing silk and wool (Ramakrishna, 2010). In the Unani system of medicine, the plant's hairs and glands are used to treat scabies, ringworm, and other skin diseases, as well as to alleviate intestinal pain, jaundice, and piles as part of the Arshina ointment (Kirtikar and Basu, 1935). The fruits are used to produce dyes and insect repellents, while the kernels are effective against helminths, rheumatism, and snake bites. The red powder on the fruits, when mixed with oil, serves as a remedy for ulcers (Nadkarni, 1976; Ramakrishna, 2010). Additionally, a decoction of the bark is used to relieve abdominal pain. In the Chota Nagpur region, the well-ground root of the plant is applied to painful areas in cases of articular rheumatism. In Katha, Burma, the seeds are ground into a paste and applied to wounds and cuts (Chopra et al., 1956)

Phytochemistry:

Seeds: Corotoxigenin L-rhamnoside, coroglaucigenin L-rhamnoside (Bandopadhyay et al., 1972), coroglaucigenin, corotoxigenin (Roberts et al., 1963); Kamlolenic acid (Gupta et al., 1953)

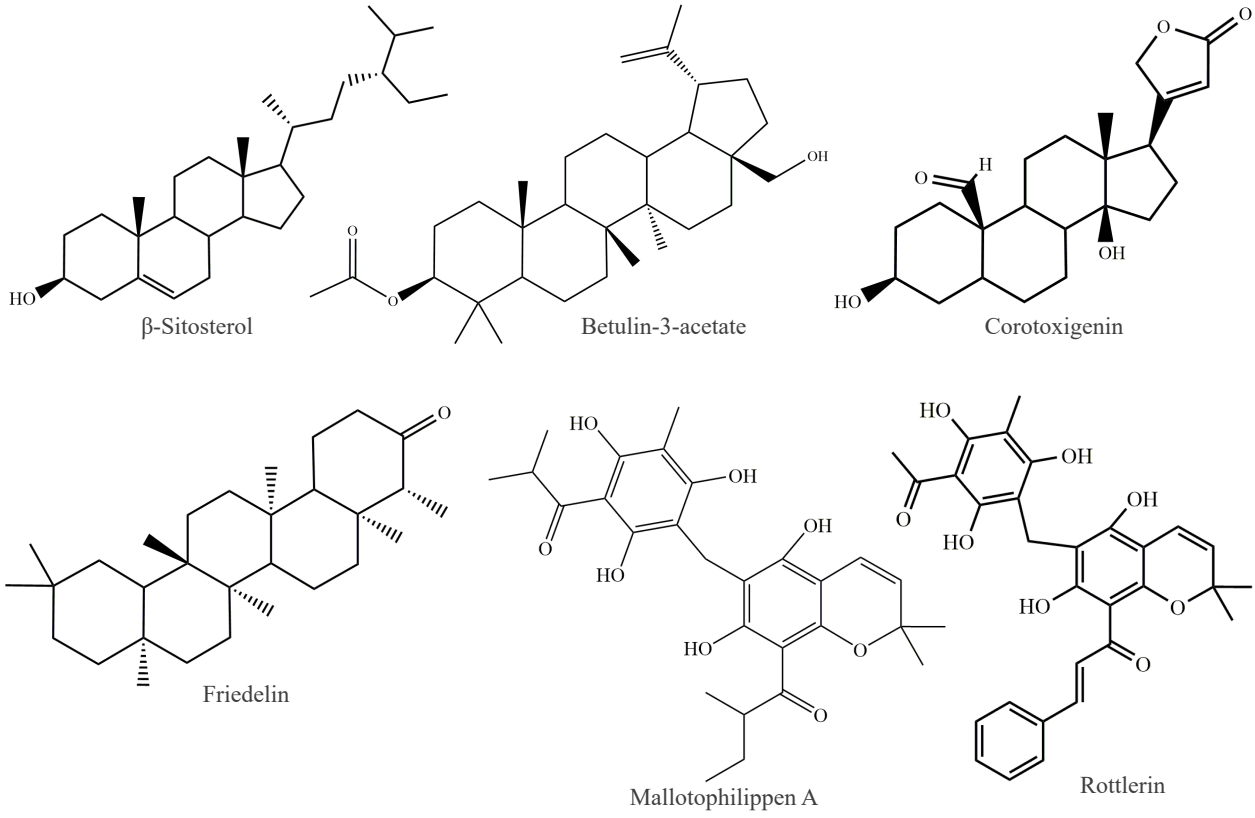
Heartwood: Betulin-3-acetate, lupeol acetate. lupeol, β-sitosterol, bergenin (Bandopadhyay et al., 1972).

Stem bark: Friedelin, 3-hydroxy-D:A-friedoolean-3-en-2-one, 2β-hydroxy-D:A-friedoolean-3-one, 3α-hydroxy-D:A-friedoolean-2-one, lupeol, betulin (Tanaka et al., 2008; Furusawa, et al., 2005)

Bark: Acetyl aleuritolic acid, α-amyrin,β-sitosterol, bergenin (Bandopadhyay et al., 1972)

Leaves: Bergenin (Bandopadhyay *et al.,* 1972).

Fruits: Mallotophilippens C, D, and E (Nguyen etal., 2010), rottlerin (Manhas et al., 2021), and isorottlerin (Tiwari and Mishra, 2010).



Structures of Important and Characteristic Chemical Constituents of *Mallotus philippensis*

Biological Activities:

Antifilarial Activity: The effects of aqueous and alcoholic leaf extracts of *M. philippensis* were investigated on the spontaneous movements of whole worms and nerve-muscle (n.m.) preparations of *Setaria cervi*, as well as on the survival of microfilariae in vitro. Both extracts inhibited the spontaneous motility of whole worms and n.m. preparations, initially stimulating followed by a decrease in amplitude, while contraction tone and rate remained largely unaffected. The aqueous extract at higher concentrations caused an immediate reduction in tone. The concentration needed to inhibit n.m. preparation movements was 1/5th for the aqueous and 1/11th for the alcoholic extract compared to that for the whole worm, indicating a permeability barrier. The aqueous extract blocked acetylcholine's stimulatory effect on worm movements. The LC_{50} and LC_{90} values for the aqueous extract were 18 and 20 ng/mL, respectively, while for the alcoholic extract they were 12 and 15 ng/mL (Singh et al., 1997)

Antifertility activity: The seed extract of *M. philippensis* shows adverse effects on various reproductive parameters in female rats. The study indicates that the extract lowers serum levels of FSH and LH, likely by impacting the hypothalamic/pituitary axis. This reduction may impair follicular development, the quality of ovulated eggs, corpus luteum formation, the estrus cycle, and pregnancy maintenance in rats (Thakur et al., 2005). The antifertility effect is attributed to rottlerin, a phloroglucinol derivative (Gujral et al., 1960).

Antiurolithiatic activity: The alcoholic leaf extract of *M. philippensis* was evaluated for antiurolithiatic activity in Wistar rats with ethylene glycol-induced urolithiasis, using Cystone as the standard. The extract effectively reduced and inhibited the growth of urinary stones, as evidenced by changes in biochemical parameters such as phosphorus and calcium levels in urine (Patel et al., 2020).

Antimicrobial activity: Crude extracts of *Mallotus philippensis* demonstrate significant antimicrobial activity, supporting its traditional use as a broad-spectrum antimicrobial agent (Kumar et al., 2006). The stem bark and its chloroform and methanol extracts effectively inhibit pathogenic bacteria, showing notable zones of inhibition compared to standard drugs. However, the hexane extract did not exhibit significant activity (Moorthy et al., 2007). Glandular hairs of the fruit show significant antibacterial activity against human pathogenic bacteria, with MIC values ranging from 15-20 mg/mL, though they do not inhibit *Candida* species (Gangwar et al., 2011; Zaidi et al., 2009). The ethanol crude extract has been tested against clinical and ATCC strains, including *Bacillus subtilis*, *Escherichia coli*, *Staphylococcus aureus*, *Salmonella*, *epidermites*, *E. faecalis*, and *Pseudomonas aeruginosa*, and exhibited inhibition across all tested bacterial strains (Bilal et al., 2022). Additionally, acetone and methanol fruit extracts were tested against *E. coli*, *Yersinia pestis*, *P. aeruginosa*, and *S.aureus* using the agar-well diffusion method, showing significant activity against *S. aureus* (Rana et al., 2016). The aqueous extract of *M.philippensis* was also evaluated for antimicrobial activity against pathogenic bacteria in pus samples from subjects with Dushtavrana, revealing inhibition against *S. spp.*, *Pseudomonas spp.*, and *E. coli* (Devaraj et al., 2023).

Anti-diabetic activity: The hydroethanolic bark extract of *M. philippinensis* was evaluated for anti-diabetic activity. The extract showed a significant increase in levels of body weight, and insulin and a significant decrease in blood glucose and glycosylated haemoglobin when administered orally for 30 days to streptozotocin-induced diabetic rats at doses of 200 and 400 mg/kg body weight (Nandhini and Doss, 2013).

Anti-inflammatory and Immunoregulatory Activity: Chalcone derivatives from the fruits of *M. philippensis*, including mallotophilippens C, D, and E, were found to inhibit nitric oxide (NO) production and the expression of inducible NO synthase (iNOS) in the RAW 264.7 murine macrophage-like cell line activated by lipopolysaccharide (LPS) and recombinant mouse interferon-gamma (IFN-gamma). Further research indicates that these chalcones also downregulate the expression of cyclooxygenase-2 (COX-2), interleukin-6 (IL-6), and interleukin-1β (IL-1β) genes, demonstrating significant anti-inflammatory and immunoregulatory effects (Daikonya et al., 2004). Additionally, the anti-inflammatory activity of *M. philippensis* fruit hair extracts was assessed using carrageenan and turpentine oil-induced paw edema and granuloma

pouch tests in rats. The extract was effective in reducing inflammation (Gangwar et al., 2016).

Antioxidant activity: Various fractions of the bark and fruit of *Mallotus philippensis* were evaluated for total antioxidant activity (TAA) and antiradical activity against DPPH using a Sephadex LH-20 column with ethanol and acetone-water as the mobile phases. Among the extracts, the bark fraction exhibited the strongest antiradical activity with a TAA value of 5.27 mmol Trolox equivalent per gram and significant reducing power. The phenolic fraction showed a TAA ranging from 0.58 mmol Trolox equivalent per gram (fraction I) to 6.82 mmol Trolox per gram (fraction IV), with fraction IV demonstrating the highest antiradical activity against DPPH and reducing power. Other extracts had TAA values ranging from 0.05 to 1.79 mmol Trolox equivalent per gram (Arfan et al., 2009). Additionally, another study assessed the antioxidant activity of the ethanolic crude extract of the plant using the DPPH method, revealing significant antioxidant activity (Bilal et al., 2022).

Protein kinase inhibition activity: Rottlerin, a compound isolated from *Mallotus philippensis*, exhibits specific inhibition of Protein Kinase C (PKC). The inhibition of PKC by rottlerin is attributed to strong competition with ATP. Rottlerin effectively suppresses CaM-kinase III as well as PKC δ among various protein kinases tested. The novel inhibition properties and improved selectivity for distinct PKC isoenzymes suggest a unique chemical structure for rottlerin (Gschwendt et al., 1994). Additionally, rottlerin is highly effective in blocking other kinases, including Akt/PKB and p38 MAPK (Kang et al., 2004).

Immunomodulatory Activity: Rottlerin also inhibits human T cell responses (Springael et al., 2007).

Anti-inflammatory activity: Rottlerin has been reported to reduce MUC5AC expression in human epithelial cells (Choi et al., 2011), abrogate reactive oxygen species (ROS) production in hepatic stellate cells (Guimarães et al., 2010), and prevent histamine-induced H1-receptor gene expression in HeLa cells (Mizuguchi et al., 2011).

Hepatoprotective Activity: The methanol extract of *M. philippensis* leaves significantly decreases the CCl_4-induced elevation in biochemical parameters, including SGOT, SGPT, SALP, direct bilirubin, total bilirubin, and MDA, when administered at doses of 100-200 mg/kg. It also reverses functional and antioxidant parameters, suggesting that the leaf extract is effective in improving hepatocyte function. Histopathological studies further support the hepatoprotective activity of *M. philippensis* (Ramakrishna et al., 2011).

Antitumor activity: Four known friedelane-type triterpenoids, friedelin, 3-hydroxy-D,A-friedoolean-3-en-2-one, 2β-hydroxy-D,A-friedoolean-3-one, and 3α-hydroxy-D,A-friedoolean-2-one, and two known lupane type triterpenoids, lupeol and betulin, were isolated from the stem bark of *M. philippensis* and tested for their inhibitory effects on Epstein-Barr virus early antigen (EBV-EA) activation induced by 12-O-tetradecanoylphorbol 13-acetate (TPA). Compounds 2 (IC_{50} = 292 µM) and 4 (IC_{50} = 288 µM) exhibited stronger inhibitory effects compared to the other tested compounds and the positive control, curcumin (IC_{50} = 343 µM). Additionally, compound 3α-hydroxy-D:A-friedoolean-2-one strongly inhibited mouse skin tumor promotion in an in vivo two-stage carcinogenesis model (Tanaka et al., 2008)

Wound healing activity : The bark extract of *M. philippensis* was tested in vitro for wound healing activity by evaluating the proliferation and migration of MSCs (mesenchymal stem cells). The proliferation and migration of KUM6 cells were enhanced at concentrations ranging from 0.16 to 4 µg/mL. The extract also upregulated MSC activity by promoting the secretion of various cytokines, which facilitate the migration of cells from the bone marrow to the wounded site and contribute to the remodeling of damaged tissues (Furumoto, 2014).

Anti-leukemic activity: Root extracts of *M. philippensis* were evaluated for anti-leukemic potential by examining their effects on human promyelocytic leukemia HL-60 cell proliferation, cell cycle regulators, and apoptosis. The study found that the hexane fraction of the root extract exhibited significant anti-leukemic activity in HL-60 cells. Polyphenols were identified as the primary compounds responsible for inhibiting cell proliferation and inducing apoptosis (Khan et al., 2013).

Toxicology: No data are reported.

Commercial Products: The bark extract of *M. philippensis* is one of the ingredients of cosmetic

products such as face masks (*https://incidecoder.com/ingredients/mallotus-philippinensis-bark-extract*)

Patents:

- Process for producing *M. philippensis* colorant composition and the composition, Patent No: KR20070015541A
- A kind of method of White back leaf Mallotus Root seed endosperm vigor after raising Cord blood, Patent No: CN107155445A
- A kind of method that White back leaf Mallotus Root seed is sprouted after promotion Cord blood, Patent No: CN107409529A
- A kind of method for promoting White back leaf Mallotus Root seed to sprout, Patent No: CN107155444A

Scope of further Research and development: Future research on *Mallotus philippensis* should comprehensively explore its potential across various domains. This includes expanding phytochemical profiling and elucidating structure-activity relationships of its bioactive compounds. Understanding the mechanisms behind its biological activities such as anti-leukemic, wound healing, and anti-diabetic effects will be crucial, alongside conducting preclinical and clinical trials to establish safety and efficacy. Additionally, there should be a focus on optimizing traditional dye extraction methods, enhancing colorfastness, and assessing environmental impacts. Integrating sustainable practices and developing commercial formulations, while ensuring safety and efficacy, will enhance its value both as a medicinal plant and as a source of natural dyes in the textile industry. Combining traditional knowledge with modern techniques can maximize the plant's utility and commercial potential.

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Mimusops elengi L.

Synonyms:
Mimusops javensis Burck, *Mimusops latericia* Elmer, *Mimusops lucida* Poir, *Mimusops parvifolia* R. Br. *Mimusops timorensis* Burck.

Local/Common/Popular Name(s):
Spanish cherry, Medlar, Asian Bullet wood, Bakul Tree, Maulsari.

Vernacular Names:
Assamese: Bokul, Bakul, ***Bengali:*** Bakul, ***English:*** Bullet wood, Spanish Cherry, Bakul Tree, West India Medlar, Asian Bullet wood, ***Gujarati:*** Barsoli, ***Hindi:*** Malsari, Maulsari, ***Punjabi:*** Maulsari, Maulsiri, ***Kannada:*** Pokkalathu, Ranial, ***Malayalam:*** llanni, Elenji, Elanchi, Elangi, Mukura, Bakura, ***Manipuri:*** Bokul Lei, ***Marathi:*** Bakuli, ***Tamil:*** Magadam, Magizham, ***Telugu:*** Pagada, Vakulamu, ***Sanskrit:*** Anangaka, Bakula, Chirapushpa, Dhanvi, Gudhpushpa, Kantha, Karuka, Kesha, Madhupushpa, Mukula, Padyamoda, Sharadika, Sindhugandha, Simhakeshaa, Sthirmukhgandha, Surabhi, Tailanga, Varalahdha, Visharada

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Ericales
Family	:	Sapotaceae
Genus	:	*Mimusops*
Species	:	*Mimusops elengi*

Botanical Description: *Mimusops elengi* (Fig.1) is a large glabrous, medium-sized, evergreen tropical tree growing up to 12-15 m in height with a compact leafy head and short erect trunk with scaly, smooth gray colored bark. The measurements of the leaves are 6.3-10 X 3.2-5 cm and the leaves are elliptic, shortly acuminate, glabrous and base acute or rounded. The petioles are about 1.3-2.5 cm long and the calyx is about 1 cm long with 8 stamens opposite to the inner circle of lobes. The ovary is silky-pubescent. The ovoid fruit is a berry that is about 2.5 cm long and is yellow in color when ripe with a solitary, compressed, shining brown seed (Kirtikar et al., 2001). It has a dense, rounded, spreading crown and short bole up to 100 cm in diameter. The flowers are very small about 1.2 cm wide, creamy-white, star-shaped and borne in small clusters on the leaf axils. They are bisexual with 8 white petals, each with two side lobes joined into a star-like corolla with 24 points and they fall off as a ring. There are 8 fertile stamens, alternating with 8 staminodes. The flowers open at twilight and gradually become very fragrant through the night, until the next morning when they are shed. The star-shaped, cream and hairy flowers form into clusters in the leaf axils. The flowers are pollinated by wind as the plant does not self-pollinate. The fruits are orange-red when ripe and oval. The wood is very hard, heavy and highly durable. It is resistant to the attack of marine borer and dry-wood termites. The flowering occurs in April while the fruiting occurs in June.

Distribution: *Mimusops elengi* is native to India, Sri Lanka, the Andaman Islands, Myanmar and Indo-China and is widely planted as an ornamental tree across the tropics including Africa. In India, it is found in evergreen forests and is commonly grown as an avenue tree. In Rajasthan it occurs in Udaipur, Banswara-Anand Sagar Forest block in South Rajasthan, Punchkund Forest in Ajmer and the Tehla area in Alwar's Tiger Reserve. In Gujarat, it is distributed in South Gujarat (including Surat, Bharuch, Dang, Navsari, Valsad, Narmada and Tapi) and Bhavnagar (Soygarh). The plant can thrive in full shade, semi-shade or no shade, prefers moist soil and can withstand drought and

strong winds, although it is not suitable for maritime exposure (Kadam, et al., 2012).

Ethnobotanical Significance: *M. elengi* holds significant ethnobotanical value particularly in Hinduism where it is considered a sacred plant. Its fragrant flowers are celebrated in ancient texts such as the Puranas and have been placed among the flowers of the Hindu paradise (Mitra et al., 1981; Anonymous, 1956). Native to India, *M. elengi* has a long history of medicinal use with various parts of the plant leaves, roots, fruits, seeds, bark and flowers employed to treat a wide range of disorders (Deepak et al., 2005). Traditionally, a hot aqueous extract of dried flowers is given orally to treat blood disorders and is also used as an astringent, diuretic and antipyretic. The ripe fruits are used to aid childbirth and occasionally as an abortifacient (Bharat et al., 2007; Ravindra et al., 2010). The dried fruit extract is believed to benefit dental health while a hot water extract of seeds is used to treat loose teeth and menorrhagia (Bharat, 2007). The bark known for its astringent and bitter properties is used to treat diarrhea, dysentery and gum inflammation (Sharma, 2005; Nadkarni, 1976) and is also applied in cases of gonorrhea, snakebites, fevers, wounds and skin conditions such as scabies and eczema (Kirtikar and Basu, 1987). The bark is often combined with tamarind bark (*Tamarindus indica*) for use as a lotion (Warrier et al. 1994). Leaves are used to treat headaches, toothaches, wounds and sore eyes and are smoked to cure infections of the nose and mouth (Jain and DeFilipps 1991). The flowers have been used to treat diarrhea, young fruits for sprue and pounded seeds to alleviate obstinate constipation (Sigh and Pandey 1998; Chopra et al., 1956).

Phytochemistry:

Bark: β-Amyrin, brassic acid, gallic acid esters, farnan-2-one-3 β-ol, farnan-3-one, olean-18-en-2-one-3-ol, lup-20 (29)-en-3β-ol, 3-β-hydroxy-lup-20(29)-ene-23, 28-dioicacid, β-amyrin, lupeol (Akhtar et al., 2009; Akhtar et al., 2010; Jahan et al.,1995; Jahann et al., 2001), taraxerone, taraxerol, betulinic acid, spinasterol, urosolic acid, fatty acid esters of α-spinasterol (Mishra et al., 1909). α-cadinol, taumuurolol, hexadecanoic acid, octa decadienoic acid (Ruikar et al., 2012).

Seed: Capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachidic acid, oleic acid, linoleic acid (Kirtikar et al., 1999; Chopra et al., 2000; Lalitha et al., 2011; Manjeshwar et al., 2011), mimusopin 1 and mimusopin 2 (Sahu et al., 1995), quercitol, ursolic acid, dihydro quercetine, quercetin, β-sitosterol-D-glucoside, α-spinasterol (Mishra et al., 1967), mimusin, mi-saponin A, 16 α-hydroxyl mi-saponin A (Sahu et al.,1997; Sahu et al., 1996).

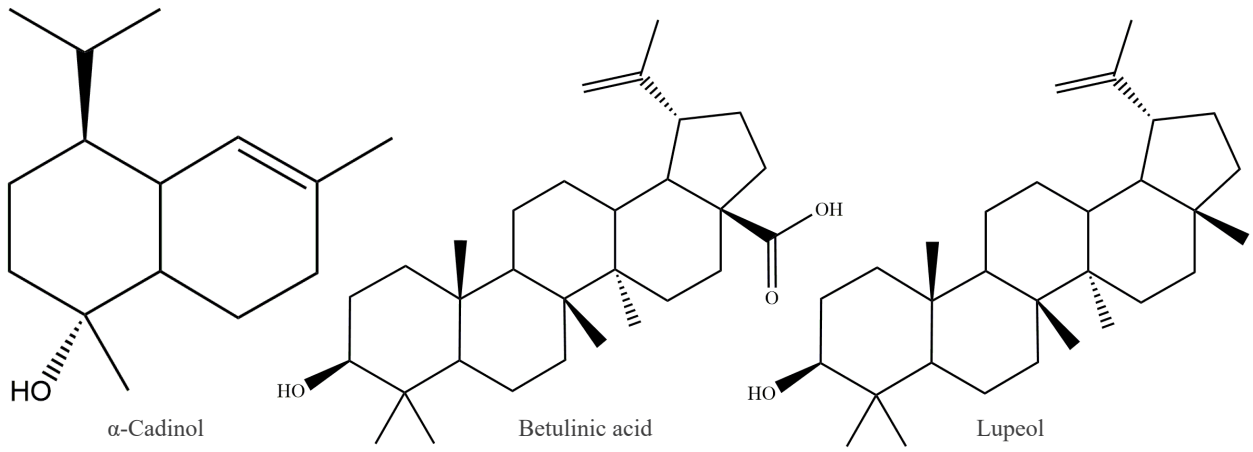
Leaves: Hentriacontane, β-carotene, and lupeol (Mishra et al., 1968).

Rootes: Hentriacontane, β-carotene, and lupeol, (Saxena et al., 1988).

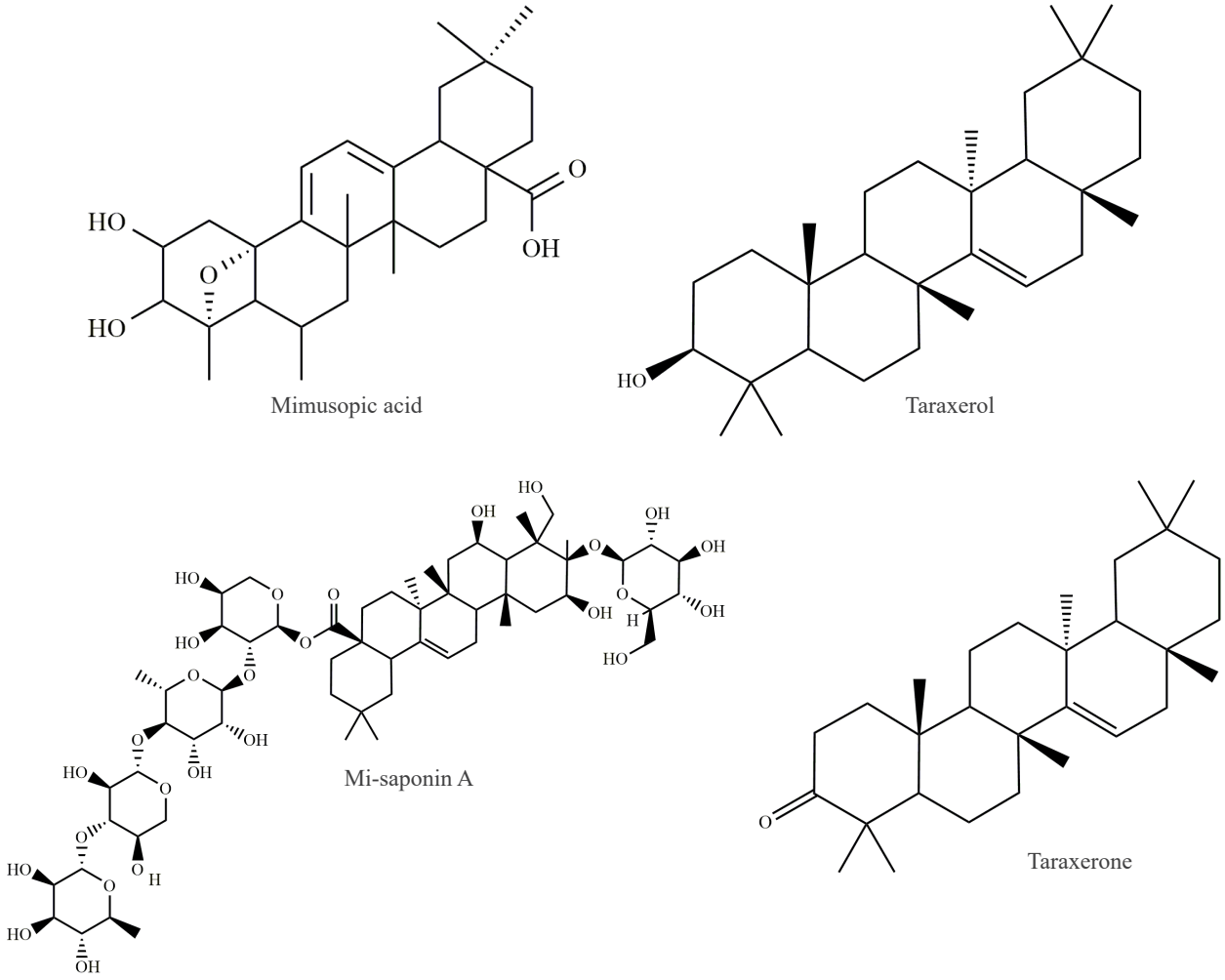
Flowers: D-Mannitol, β-sitosterol, β-sitosterol-D-glucoside, quercitol, ursolic acid, lupeol (Bharat et al., 2007).

Biological activity:

Antiviral Activity: The crude aqueous and methanol extracts of *M. elengi* inhibited HIV type 1 protease (PR) by more than 70 % at a concentration of 0.2 mg/ml and the enzyme activity was determined by HPLC (Kusumoto et al., 1995).



α-Cadinol Betulinic acid Lupeol



Structures of Important and Characteristic Chemical Constituents of *Mimosops elangi*

Antibacterial Activity: Two antibacterial compounds, 2,3-dihydro-3,3′4′5,7- pentahydroxyflavones and 3,3′,4′,5,7- pentahydroxyflavone, isolated from the seeds of *Mimusops elengi*, demonstrated strong inhibitory activity against *Escherichia coli* ATCC 25922, *Bacillus subtilis* ATCC 6633, and *Salmonella typhi* ATCC 6539 (Hazra et al., 2007; Jebashree et al., 2011). The chloroform extract of the bark exhibited significant antibacterial activity at a concentration of 200 mg against various microorganisms present in the tooth-tartar of dental patients (Murudkar et al., 2007).

Fruit extracts showed relatively lower antibacterial potency compared to bark and leaf extracts and the leaf extracts displayed notable activity against *B. subtilis* (Ali et al., 2008). The ethanolic bark extract of *M. elengi* was also tested for its antimicrobial efficacy against bacterial isolates such as *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *E. coli* showing inhibitory activity against three *Staphylococcus* isolates including *S. aureus* with a minimum inhibitory concentration (MIC) of 128 mg/l (Rangama et al., 2009). In contrast, ethanol leaf extracts and water extracts did not exhibit activity against any of the bacterial isolates tested. Further studies using spectrophotometric methods evaluated the antibacterial activity of extracts prepared from the bark, fruit and seeds of *M. elengi* against both Gram-positive and Gram-negative strains including *Nocardia asteroides*, *Micrococcus luteus*, *B. subtilis*, *B. licheniformis*, *Proteus mirabilis*, and *Salmonella typhimurium*. Among these, only the stem bark extracts showed antibacterial activity against all tested bacterial strains while the fruit and seed extracts were found inactive (Shahwar et al., 2009). Additionally, the leaf extract of *M. elengi* was evaluated using the agar well diffusion method and was found effective against Gram-positive bacteria such as *B. cereus* ATCC 11778, *Micrococcus*

luteus TISTR884, methicillin-resistant *S. aureus* 142 (MRSA142), and *S. aureus* TISTR157 though it was ineffective against Gram-negative bacteria (Piboonpol et al., 2020). Different solvent extracts of the leaves were also screened for antibacterial activity against Gram-negative strains including *Escherichia coli* (MTCC 40), *Pseudomonas aeruginosa* (MTCC 424), *P.vulgaris* (MTCC 426) and Gram-positive strains such as *Streptococcus pneumoniae* (MTCC 237), *S. epidermidis* (MTCC 2639) and *S. aureus* (MTCC 87). These extracts exhibited significant antibacterial activity in a dose-dependent manner when evaluated at 200 and 300 mg/ml using the cup-plate method (Padhi and Mahapatra, 2013).

Antifungal Activity: Different extracts of the bark, fruits and leaves of *Mimusops elengi*–specifically petroleum ether, ethyl acetate and methanol extracts–were tested for their antifungal activity against six pathogenic fungi: *Penicillium* sp., *Aspergillus niger*, *Trichoderma viride*, *Aspergillus flavus*, *Candida albicans* and *Helminthosporium sativum*. The fruit extracts were less potent against most of the tested organisms compared to those from the bark and leaves and were found inactive against *T. viride*. In contrast, the leaf extracts exhibited good activity against *T. viride* (Ali et al., 2008).

Anthelmintic Activity: In vitro anthelmintic activities of *M. elengi* using methanolic bark extract (25, 50, and 100 mg/ml) were reported against earthworms (*Pheretimaposthuma*) (Nasrin et al., 2010; Jana et al., 2010). In another study, the anthelmintic activity of ethanolic and aqueous extracts of *M. elengi* against adult earthworm *Eisenia foetida* (redworm) at 4 mg/ml or more was studied (Dhamija et al., 2011).

Antiulcer Activity: The effects of oral administration of 50 % alcoholic extract of *M. elengi* and its different fractions namely ethyl acetate, n-butanol, methanol, and aqueous were studied against ethanol-induced gastric damage and it was observed that ethyl acetate fraction possessed anti-ulcer activity against experimental gastric ulcers (Shah et al., 2003). Further in a study, the effect of alcoholic and petroleum ether extracts of bark (200 mg/kg body weight) of *M. elengi* was evaluated in rats. The alcoholic extract showed significant antiulcer activity compared to petroleum ether extracts of bark. Furthermore, the ethyl-acetate-soluble fraction of the alcohol extract of the bark showed anti-ulcer activity against experimental gastric ulcers. This activity was attributed to a decrease in gastric acid secretory activity along with strengthening of mucosal defensive mechanisms (Dabadi et al., 2011).

Diuretic Activity: The diuretic and electrolyte excretion activities of petroleum ether, chloroform and alcohol extracts (200 mg/kg body weight, p.o.) from the bark of *M. elengi* were investigated. Among these, the alcoholic extract exhibited the highest diuretic and electrolyte excretion activities (Koti et al., 2010). Additionally, ethyl acetate ethanol, and aqueous extracts (250 mg/kg body weight, p.o.) of *M. elengi* were evaluated for their diuretic activity, with the aqueous extract demonstrating significant diuretic effects compared to the other extracts (Katedeshmukh et al., 2010).

Wound Healing Activity: A methanol extract from the bark of *M. elengi* was evaluated for wound healing activity using three types of wound models on mice: excision, incision, and dead space. The extract, formulated as an ointment, demonstrated significant wound healing effects compared to the standard Betadine ointment. It showed improvements in wound contraction, closure time, tensile strength and dry granuloma weight. Histological analysis supported these findings indicating that the extract has considerable wound healing properties (Gupta et al., 2011).

Larvicidal Activity: Hexane and ethyl acetate extracts from the bark of *M. elengi* exhibited promising larvicidal activity against IV instar larvae of *Aedes aegypti* and *Culex quinquefasciatus*. These extracts show potential for developing a cost-effective, environmentally friendly larvicide for mosquito control (Ruikar et al., 2009).

Hypotensive Activity: The methanol extract (at a dose range of 2-16 mg/kg body weight, i.v.) of *M. elengi* caused hypotensive activity in anesthetized rats and produced about a 7-38 % fall in mean arterial blood pressure in a dose-dependent manner. The effect was independent of adrenergic, muscarinic and histaminergic receptors. The hypotension was also unchanged after autonomic ganglion or angiotensin-converting-enzyme blockade. Administration of calcium channel blockers, however, including nifedipine (0.9 mg/kg) and verapamil (3.9 mg/kg),

caused corresponding reductions of 81 and 64 % in extract-induced hypotension (Behbahanian et al., 1999).

Anti-tumor activity: The alcohol bark extract of *M. elengi* was evaluated for cytotoxic and anti-tumor activity using the SRB assay and the Ehrlich ascites carcinoma (EAC) model in mice. The results indicated that the plant has potential as a therapeutic candidate with cytotoxic and anti-tumor properties (Kumar et al., 2015).

Spermicidal activity: The aqueous, ethanol and petroleum ether extracts of *M. elengi* fruits were tested for spermicidal potential in wild mice. The ethanol extract showed significant effects causing a severe reduction in sperm motility, viability and plasma membrane integrity, resulting in 100% immobilization with no revival of sperm at 80 mg/mL after 15 seconds (Gupta, 2014).

Anti-cholesterol activity: The aqueous extract of *M. elengi* leaves was assessed for anti-cholesterol activity in mice. The extract significantly reduced cholesterol levels, demonstrating its potential for managing cholesterol (Tristantini and Pradana, 2017).

Immunostimulatory activity: The methanol bark extract of *M. elengi* was evaluated for immunostimulatory activity in mice using tests for specific and non-specific immunity, including the carbon clearance test, haemagglutination antibody test and delayed-type hypersensitivity. The results showed a dose-dependent increase in immunostimulatory response (Shivatare et al., 2014).

Hepatoprotective activity: The methanol extract of *M. elengi* leaves and isolated myricitrin were tested for hepatoprotective activity in male rats exposed to γ-radiation. Myricitrin exhibited greater hepatoprotective effects compared to the leaf extracts against irradiation-induced hepatic inflammation (Sayed et al., 2023).

Antioxidant activity: Methanol extracts from the petals and sepals of *M. elengi* flowers were assessed for antioxidant activity. The extract from sepals showed higher antioxidant activity than petals with IC_{50} values of 98.20 µg/mL and 236.13 µg/mL in DPPH and ABTS radical scavenging assays respectively (Natungnuy and Poeaim, 2018). In another study, n-hexane, dichloromethane and methanol extracts of *M. elengi* leaves were evaluated for antioxidant activity with dichloromethane extract showing significant activity compared to standard butylated hydroxyl anisole (BHA) and methanol extract in a dose-dependent manner (Vinay et al., 2016).

Toxicology: No adverse effects have been reported from the normal use of *Mimusops elengi*. However, prolonged exposure or excessive intake of its flowers may cause mild intoxicating effects in some individuals. (Kumar and Kumar, 2020).

Patent and Commercial Products

- Antioxidant and/or antimicrobial composition based on *Mimusops elengi*, Patent No: 202311038356

Scope of further R&D: The scope for further research and development on *Mimusops elengi* is extensive considering its diverse pharmacological and ethnobotanical applications. Future studies could explore the optimization of extraction processes and bioactive compound isolation to enhance the efficacy of its medicinal properties. Additionally, research into its ecological and commercial applications including sustainable cultivation practices and the development of innovative products could further highlight its economic value and environmental benefits. The plant's traditional uses and ongoing commercial interests underline the importance of continued exploration to fully harness its potential.

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Moringa oleifera Lam.

Synonyms:
Guilandina moringa (L.), *Hyperanthera moringa* (L.) Vahl., *Moringa moringa* (L.) Millsp., *Moringa pterygosperma* Gaertn, *Moringa zeylanica* Burmann.

Local/Common/Popular Name(s):
English: Drumstick tree, Horseradish tree, Benzolive tree; ***Hindi/Orissa:*** Sanjna, Saijna, Shajna, Soandal; ***Sanskrit:*** Danshamula, Shobhanjana, Sigru Shobhanjan, Sobhan jana; ***Rajasthan:*** Lal Sahinjano; ***Bengalese:*** Munga ara, Sajna, Sojna, Sujana; ***Gujarati:*** Midho-saragavo, Saragavo, Saragvo, Suragavo; ***Kanarese:*** Nugga egipa, Nugge, Noogay, Nuggi Mara; ***Kumao-Himalayan region:*** Sunara; ***Konkani/Goa:*** Moosing, Mosing; ***Malayalam:*** Sigru, Moringa, Muringa, Murinna, Morunna; ***Marathi:*** Sujna, Shevga, Shivga; ***Oriya:*** Munigha, Sajina; ***Punjabese:*** Sanjina, Soanjana; ***Tamil:*** Morunga, Murungai, Murunkak-kai; ***Telegu:*** Sajana, Tella-Munaga; ***Teling:*** Morunga, Morungai; ***Urdu:*** Sahajna

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Brassicales
Family	:	Moringaceae
Genus	:	*Moringa*
Species	:	*Moringa oleifera*

Botanical Description: *Moringa oleifera*, commonly known as the drumstick tree, is widely distributed throughout India, thriving in warm, dry and moist climates. This fast-growing, deciduous tree typically reaches a height of 10–12 meters (32–40 feet) with a trunk diameter of about 45 centimeters (1.5 feet). It is notable for its ability to bear both fruits and flowers particularly in drought-prone areas. The bark of the tree is whitish-grey and thickly corked while the roots have a horseradish-like taste. Young shoots display a purplish or greenish-white hairy bark. The tree has an open crown with drooping, fragile branches and feathery, tripinnate foliage. The leaves are compound, tripinnate with green to dark green elliptical leaflets measuring 1–2 centimeters (0.4–0.8 inches) in length. The leaves are typically 20–70 centimeters long, grayish-downy when young and have long petioles with 8–10 pairs of pinnae, each bearing two pairs of opposite, elliptic or obovate leaflets, along with one at the apex. The flowers of *M. oleifera* are fragrant, bisexual and conspicuous, with five unequal, thinly veined, yellowish-white petals. The flowers, about 1.0–1.5 centimeters (0.5 inch) long and 2.0 centimeters (0.75 inch) wide, grow on slender, hairy stalks in spreading or drooping clusters 10–15 centimeters long. Flowering occurs from February to March followed by fruiting from March to April, though some trees may flower and fruit multiple times a year. Each healthy tree can yield up to 1,000 fruits annually (Anonymous, 1962). The tree is highly valued for its tender pods, commonly used as a vegetable. Its flowers and tender leaves are also consumed as pot herbs while the roots serve as a condiment or garnish. Oil extracted from the seeds is used for lubricating fine machinery and the wood pulp is suitable for newsprint.

M. oleifera generally has a straight stem, although it can occasionally be poorly formed, reaching a height of 1.5–2 meters before branching and potentially growing up to 3 meters. The extended branches grow in a disorganized manner forming an umbrella-shaped canopy. The flowers borne on inflorescences 10–25 centimeters (4–10 inches) long, are typically white to cream-colored, with some varieties tinged with pink. They are produced

in axillary, drooping panicles with five reflexed, linear-lanceolate sepals and five slender-spatulate petals enclosing five stamens and five staminodes and the lowest being reflexed.

The fruits of *M. oleifera* are trilobed capsules, or pods. Immature pods are green with some varieties exhibiting a reddish hue. These pendulous, brown, triangular pods split lengthwise into three parts when dry, measuring 30–120 centimeters in length and 1.8 centimeters in width. Each pod contains about 20 seeds embedded in the pith with a 9-ribbed structure tapering at both ends. The seeds are round with a brownish semi-permeable seed hull and three papery wings. Seed hulls are typically brown to black but can be white if the kernels have low viability. Viable seeds germinate within two weeks with each tree capable of producing between 15,000 and 25,000 seeds per year. The average weight per seed is 0.3 grams with a kernel-to-hull ratio of 75:25 (Matic et al., 2018).

Distribution: *M. oleifera* is a well-known and widely distributed species of the monogeneric family Moringaceae. Indigenous to South Asia, particularly the Himalayan foothills from northeastern Pakistan to Northern West Bengal, India. It is found both in the wild and under cultivation throughout the plains, often in hedges and house yards. The plant thrives best in tropical insular climates, especially near sandy riverbeds and streams. *M. oleifera* is most commonly found in South and Southeast Asia, particularly in the Philippines. It is widely cultivated in Africa, Central and South America, Sri Lanka, Rajasthan, Mexico, Malaysia and Indonesia. In India, it is found in Ajmer, Jhalawar, Kota and Udaipur in Rajasthan, and in the Aravali range near Sabarkantha in Gujarat (Nadkarni, 1976; Ramachandran et al., 1980; Anonymous, 1962; Qaiser, 1973; Somali et al., 1984; Mughal et al., 1999).

The tree grows well in both humid tropics and hot, dry lands and can survive in poor soils. However, it is slightly affected by drought. *Moringa oleifera* can tolerate a wide range of rainfall, from a minimum of 250 mm to over 3000 mm annually and thrives in soils with a pH range of 5.0 to 9.0 (Morton, 1991; Palada and Chang, 2003).

Ethnobotanical Significance: *M. oleifera* and its healing potential were first documented around 5000 years ago in the Vedic literature of India (Patwardhan, 2000). Almost all parts of this plant–including the root, bark, gum, leaves, fruits (pods), flowers, seeds, and seed oil–have been used in South Asian indigenous medicine to treat various ailments such as inflammation, infectious diseases and cardiovascular, gastrointestinal, hematological, and hepatorenal disorders. The leaves and young buds are used as vegetables and can be applied to the temples to relieve headaches. The root bark known for their anti-scorbutic properties are used externally as counterirritants (Anwar et al., 2007). The juice of the leaves when mixed with honey is used to treat eye diseases. *Moringa oleifera* is also known for its high nutritional value and is traditionally used to treat ailments related to pain and inflammation (Sulaiman et al., 2008). The dried seeds are employed in ophthalmic preparations and treatments for venereal diseases and are known for their anti-inflammatory, purgative and tonic properties. Traditionally, the plant is also used as an antispasmodic, stimulant, expectorant and diuretic. The fresh root is acrid and vesicant, with a taste similar to horseradish and is used internally as a stimulant, diuretic and antilithic. The flowers, which are cholagogue, stimulant, tonic, and diuretic to help increase bile flow and serve as a cardiac circulatory tonic and antiseptic (Nadkarni, 2009, El-Alfy et al., 2005). The pods are antipyretic and anthelmintic; fried pods are used to manage diabetes. The root juice is employed as a cardiac tonic and antiepileptic and is used for nervous debility, asthma and conditions like liver and spleen enlargement, as well as deep-seated inflammation. It also acts as a diuretic in cases of calculous affections. The decoction is used as a gargle for hoarseness and sore throat while the root and fruit have anti-paralytic properties. Leaf juice is used to treat hiccups (though emetic in high doses) and cooked leaves are given for influenza and catarrhal conditions. An infusion of seeds is anti-inflammatory, antispasmodic and diuretic and is also used for venereal diseases.

The Ayurvedic pharmacopoeia of India recommends the dried root bark for treating goiter, glycosuria and lipid disorders (including dried seeds) and the leaf, seed, root bark, and stem bark for internal abscesses and piles (Khare, 2007).

Phytochemistry:

Leaves: Quercetin; gallic acid; caffeic acid (Leone et al., 2015; Mbikay, 2012; Brilhante et al., 2017); vitamin A; β-carotene (Stohs & Hartman, 2015; Abdull et al., 2014); kaempferol; quercetin; catechin; p-coumaric acid; vanillin; ferulic acid; protocatechuic acid; cinnamic acid; epicatechin (Gopalakrishnan et al., 2016); phenolic acid (Tsao, 2010); resveratrol (Lancon et al., 2013); 4-(α-l-rhamnopyranosyloxy)-benzylglucosinolate; quercetin-3-O-glucoside; quercetin-3-O-(6''-malonyl-glucoside); kaempferol-3-O-glucoside; kaempferol-3-O-(6''-malonyl-glucoside); 3-caffeoylquinic acid; 5-caffeoylquinic acid (Bennett et al., 2003); kaempferide 3-O-(2'', 3''-diacetylglucoside); kaempferide 3-O-(2''-O-galloylrhamnoside); kaempferide 3-O-(2''-O-galloylrutinoside)-7-O-α-rhamnoside; kaempferol 3-O-[β-glucosyl-(1→2)]-[α-rhamnosyl-(1→6)]-β-glucoside-7-O-α-rhamnoside; kaempferol 3-O-[α-rhamnosyl-(1→2)]-[α-rhamnosyl-(1→4)]-β-glucoside-7-O-α-rhamnoside; benzoic acid 4-O-β-glucoside; benzoic acid 4-O-α-rhamnosyl-(1→2)-β-glucoside; benzaldehyde 4-O-β-glucoside; kaempferol 3-O-α-rhamnoside; kaempferol; syringic acid; gallic acid; rutin; quercetin 3-O-β-glucoside (Manguro & Lemmen, 2007); gallic acid; chlorogenic acid; ellagic acid; ferulic acid; kaempferol; quercetin; vanillin (Singh et al., 2009); β-sitosterol; campesterol; stigmasterol (Abd El Baky & EL-baroty, 2013); marumoside A; marumoside B; pyrrolemarumine-4''-O-α-L-rhamnopyranoside (Sahakitpichan et al., 2011); gallic acid; ellagic acid; ferulic acid; caffeic acid; o-coumaric acid; chlorogenic acid; gentisic acid; syringic acid; p-coumaric acid; sinapic acid (Leone et al., 2015a, b, Teixera et al., 2014); hexadecanoic acid; ethyl palmitate; palmitic acid ethyl ester; 2,6-dimethyl-1,7-octadiene-3-ol; 4-hexadecen-6-yne; 2-hexanone; 3-cyclohexyliden-4-ethyl-E2-dodecenylacetate; high-oleic safflower oil; safflower oil (Nepolean et al., 2009, Lopez-Teros et al., 2017).

Seeds: 4-(α-L-rhamnosyloxy)benzyl isothiocyanate (Eilert et al., 1981); 4-(L-rhamnosyloxy) phenylacetonitrile; 4-hydroxyphenylacetonitrile; 4-hydroxyphenylacetamide (Villasenor et al., 1989; Rastogi & Mehrotra, 2004); niazirin; niazirinin; 4-[(4'-O-acetyl-α-L-rhamnosyloxy) benzyl]isothiocyanate; niaziminin A; niaziminin B (Faizi et al., 1994); O-ethyl-4-(α-L-rhamnosyloxy) benzyl carbamate (Guevara et al., 1999); 4-(α-L-rhamnopyranosyloxy)benzyl glucosinolate (Bennett et al., 2003); gallic acid; chlorogenic acid; ellagic acid; ferulic acid; kaempferol; quercetin; vanillin (Singh et al., 2009); β-sitosterol (Maiyo et al., 2016); roridin E; veridiflorol; 9-octadecenoic acid; 9-octadecen-1-ol; cis-9-octadecen-1-ol; oleol; satol; ocenol; sipo; decanoic acid; dodecanal (Nepolean et al., 2009); moringyne; 4-(α-L-rhamnosyloxy) benzyl isothiocyanate (Gupta, 2008; Rastogi & Mehrotra, 2004, Aluko et al.,2013, Dehshahri et al., 2012, Lalas et al., 2002).

Fruits/Pods: O-[2'-hydroxy-3'-(2"-heptenyloxy)]-propyl undecanoate; O-ethyl-4-[(α-L-rhamnosyloxy)-benzyl]carbamate; methyl p-hydroxybenzoate; β-sitosterol (Faizi et al., 1998); D-galactose; 6-O-Me-D-galactose; D-galacturonic acid; L-arabinose; L-rhamnose (Roy et al., 2007); gallic acid; chlorogenic acid; ellagic acid; ferulic acid; kaempferol; quercetin; vanillin (Singh et al., 2009, Faizi et al., 1995).

Roots: 4-(α-L-rhamnopyranosyloxy)-benzyl glucosinolate; benzyl glucosinolate (Bennett et al., 2003); aurantiamide acetate; 4,1,3-dibenzyl urea (Sashidhara et al., 2009); benzyl isothiocyanate; spirochin; pterygospermin (Anon, 2005).

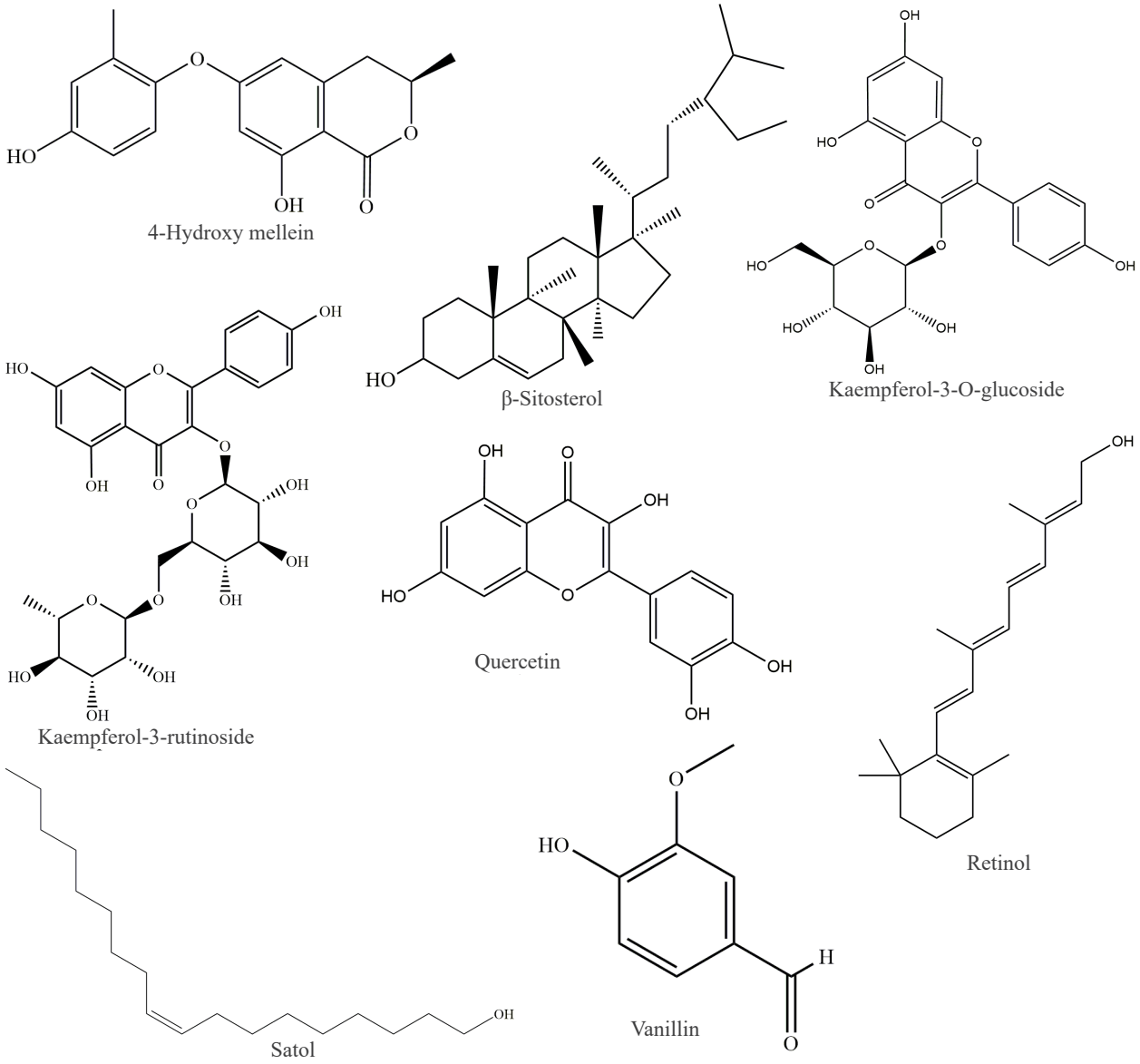
Stem: 4-hydroxy mellein; vanillin; octacosanoic acid; β-sitosterol; β-sitosterone (Rastogi & Mehrotra, 2006, vol. II); kaempferol-3-rutinoside (Rastogi & Mehrotra, 2004, vol. IV).

Bark: 4-(α-L-rhamnopyranosyloxy)-benzyl glucosinolate (Bennett et al., 2003); deoxy-Niazimicine characterized as N-benzy, S-ethyl thioformate (Nikkon et al., 2003); β-sitosterol-3-O-β-D-galactopyranoside (Bargah & Das, 2014).

Biological Activities:

Antioxidant activity: Aqueous and alcoholic extracts (methanolic and ethanolic) of the leaves and roots of *M. oleifera* exhibit strong in vitro antioxidant and radical scavenging activity. The leaves are a rich source of antioxidant compounds and may protect against diseases induced by oxidative stress. Administration of *M. oleifera* leaf extract appears to prevent oxidative damage caused by a high-fat diet (Sharma et al., 2011, Tumer et al., 2015, Wang et al., 2017).

Anti-diabetic activity: The aqueous extract of *M. oleifera* leaves has been shown to exhibit



Structures of Important and Characteristic Chemical Constituents of *Moringa oleifera*

anti-diabetic properties, effectively controlling glycemia (Ndong et al., 2007). In one study, the *in vitro* antioxidant and *in vivo* antidiabetic effects of methanol extracts of *M. oleifera* pods were tested in streptozotocin (STZ)-induced diabetic albino rats. Diabetic rats were treated with 150 or 300 mg/kg of extract for 21 days and the antidiabetic effects were evaluated by measuring changes in biochemical parameters in serum and pancreatic tissue. The progression of diabetes was significantly reduced after treatment with the extract with both doses inducing a significant reduction in serum glucose and nitric oxide levels alongside increased serum insulin and protein levels (Gupta et al., 2012). Another study investigated the antidiabetic activity of *Moringa* seed powder at doses of 50 and 100 mg/kg in STZ-induced diabetic male rats. The diabetic positive control group showed increased IL-6 levels, elevated lipid peroxides and decreased antioxidant enzyme levels in serum and kidney tissue homogenates compared to the negative control group (Al-Malki & El Rabey, 2015, Waterman, et al., 2015).

Cardiovascular activity: The ethanolic extract of *M. oleifera* leaves has demonstrated significant antihypertensive (hypotensive) activity. An in vivo study on animals identified thiocarbamate and isothiocyanate glycosides as the compounds responsible for this potent effect (Gilani et al., 1994).

Anti-fertility activity: The aqueous extract of *M. oleifera* roots has been shown to be an effective antifertility agent both in the presence and absence of estradiol dipropionate and progesterone. An in vivo study investigated its antifertility effects and its impact on the histoarchitecture of the uterus during pre- and post-implantation stages (Shukla et al., 1998).

Anti-asthmatic activity: A study investigated the effects of *M. oleifera* seed kernels in patients with mild-to-moderate bronchial asthma. Patients received 3 g of finely powdered dried seed kernels daily for 3 weeks. Clinical efficacy was assessed using a spirometer before and after treatment. The majority of patients showed an increase in hemoglobin (Hb) levels and a reduction in erythrocyte sedimentation rate (ESR). Additionally, improvements were noted in symptom scores and the severity of asthmatic attacks. After 3 weeks, significant improvements were observed in forced vital capacity, forced expiratory volume in one second, and peak expiratory flow rate (Agarwal & Mehta, 2008). Alcoholic extracts of *Moringa oleifera* seed kernels also demonstrated spasmolytic effects in bronchospasm induced by acetylcholine, histamine, $BaCl_2$, and 5HT (Mehta & Agarwal, 2008).

Hepatoprotective activity: The ethanolic extract of *M. oleifera* leaves and the alcoholic extract of its seeds were evaluated for their hepatoprotective effects against liver damage induced by isoniazid, rifampicin and pyrazinamide. Additionally, the methanolic extract of *M. oleifera* roots was assessed for its impact on hematological and hepatorenal functions including liver and kidney function at various doses (Mishra et al., 2011).

Anti-tumor activity: Ethanolic extracts of *M. oleifera* leaves and seeds exhibit potent antitumor activity. This effect is attributed to the presence of thiocarbamate and isothiocyanate-related compounds which act as inhibitors of tumor promoters. In vivo studies have shown that these compounds inhibit the tumor promoter teleocidin B-4-induced Epstein-Barr virus (Nadkarni, 1994, Murakami et al., 1998).

Anti-microbial activity: The leaves, roots, bark, and seeds of *M. oleifera* exhibit antimicrobial activity against various bacteria and fungi. In vitro studies using the disc diffusion method have demonstrated its effectiveness against bacteria, yeast, dermatophytes and helminths. Fresh leaves and aqueous seed extracts specifically inhibit the growth of *Pseudomonas aeruginosa* and *Staphylococcus aureus* (Caceres et al., 1991, Chuang et al., 2007, Lürling et al., 2010, Nikkon et al., 2003).

Anthelmintic activity: An in vitro study evaluated the efficacy of macerated, infused aqueous, and ethanolic extracts of *M. oleifera* against fresh eggs, embryonated eggs and L1 and L2 larvae of *Haemonchus contortus*. Extracts were prepared at concentrations of 0.625, 1.25, 2.5, 3.75 and 5 mg/mL. Fresh eggs were exposed for 48 hours, while embryonated eggs and larvae were exposed for 6 and 24 hours, respectively. Distilled water and 1.5% DMSO served as negative controls. The ethanolic leaf extract of *M. oleifera* was the most effective, inhibiting 60.3% ± 8.2% and 92.8% ± 6.2% of egg embryonation at 3.75 and 5 mg/mL, respectively (Tayo et al., 2014). In another study, different concentrations of ethanolic extracts of *M. oleifera* and *Vitex negundo* were assessed for anthelmintic activity against *Pheretima posthuma*. *Piperazine citrate* (10 mg/mL) was used as a reference standard and distilled water as a control. *M. oleifera* exhibited greater anthelmintic activity compared to *Vitex negundo* in a dose-dependent manner (Rastogi et al., 2009).

Anti-convulsant activity: *M. oleifera* leaf extract has been shown to restore brain monoamine levels, potentially aiding in the treatment of Alzheimer's disease. The in vitro anticonvulsant activity of aqueous root extract and ethanolic leaf extract was studied using penicillin-induced convulsions. The study assessed locomotor behaviour and levels of brain serotonin (5-HT), dopamine, and norepinephrine (Talhaliani & Kar, 2000).

Analgesic activity: Aqueous and methanolic root extracts reduced locomotor activity in rats and decreased the number of seizures induced by penicillin and strychnine (Gupta et al., 1999; Ray & Hazra, 2003). The aqueous extract increased brain levels of 5-HT, reduced dopamine levels in the brain cortex, cerebellum and caudate nucleus, and decreased noradrenaline levels in the cerebral cortex (Ray & Hazra, 2003). The methanolic extract caused CNS depression, reduced mortality in strychnine and leprazole-treated animals, increased

sleep duration, induced analgesia and enhanced the analgesic effects of morphine (Gupta et al., 1999, Waterman, et al. (2014).

Toxicology: An aqueous extract of *M. oleifera* leaves administered orally to Wistar albino mice at doses up to 6,400 mg/kg did not cause mortality. However, higher doses (3,200 and 6,400 mg/kg) led to dullness and reduced locomotion in rats. Despite these effects, there were no significant changes in sperm quality or in hematological, histological and biochemical parameters. The LD50 value was determined to be 1,585 mg/kg (Awodele et al., 2012). In another study, high doses of *M. oleifera* leaves (3,000 mg/kg) resulted in the presence of micronucleated polychromatic erythrocytes in the femur bone marrow of Sprague-Dawley rats (Asare et al., 2012). This study also noted that doses exceeding 3,000 mg/kg caused acute toxicity and increased urea levels in the rats. The observed effects were attributed to high concentrations of nitrogenous compounds, potentially from proteins, in *M. oleifera*.

Patent and Commercial Products (if any):

- Meat product composition containing drumstick-tree and manufacturing method for meat product, Patent No: Kr20160041349a
- Formulation of malunggay (*Moringa oliefera*) sticky rice peanut filling, Patent No: Ph22016000936y1
- A kind of preparation method and its usage of polysaccharides from leaves of *Moringa oleifera*, Patent No: Cn104829743b
- Leaf of *Moringa* and the composition of brown sugar and its preparation method and application, Patent No: Cn105248820b
- Water-soluble extractive containing leaf of *Moringa* is used to treat or prevent the composition of cancer and the preparation method of *Moringa oleifera* leaf extractive for active ingredient, Patent No: Cn104224862b
- Extract of *Moringa peregrina* seed cake, process for obtaining it and its use in cosmetic or nutricosmetic compositions, Patent No: Fr3110346b1
- Cosmetic use of a protein extract from *Moringa oleifera* seeds, Patent No: Fr3076460b1

Scope of further R&D: *Moringa oleifera*, a deciduous tree in the Moringaceae family, is renowned for its traditional medicinal applications. Extensive research shows that *M. oleifera* is rich in phytochemicals and bioactive compounds, including flavonoids, tannins and sterols, which offer a broad spectrum of pharmacological and medicinal benefits. This underscores the potential for further scientific research to uncover new treatments and preventive measures for various diseases and disorders.

Despite the wealth of studies on the pharmacological activities of *M. oleifera* and its various parts, its full pharmacological potential, as indicated by traditional uses, remains underexplored. Modern techniques such as Liquid Chromatography-Mass Spectrometry (LC-MS) and Nuclear Magnetic Resonance (NMR) present valuable opportunities for identifying both known and novel phytochemicals in *M. oleifera*. These advancements could lead to the discovery of unique compounds with specific pharmacological activities, potentially revolutionizing their use in medical and health-related applications. Continued research could unlock new therapeutic benefits and enhance the plant's role in healthcare.

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Neolitsea pallens
(D.Don) Momiy. &H.Hara

Synonyms:
Litsea consimilis (Nees) Nees,
Litsea umbrosa var.*consimilis* (Nees) Hook. fil,
Tetradenia consimilis Nees,
Tetranthera pallens D. Don,
Tetradenia pallens
D. Don (The plant list).

Local/Common/Popular Name(s):
Pale Litsea

Vernacular Names:
Himachal Pradesh: Nairkhi and Kaula or Kaalu

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Laurales
Family	:	Lauraceae
Genus	:	*Neolitsea*
Species	:	*Neolitsea pallens*

Botanical Description: *Neolitsea pallens* belongs to the Lauraceae family and is native to warm tropical, humid subtropical, and mild temperate regions in both the northern and southern hemispheres, typically found at elevations ranging from 1500–3000 m. These are small trees, reaching a height of 5-15 meters. The young branchlets and petioles are yellowish-brown and pubescent, becoming glabrous as they mature. The leaves are either alternate or clustered in groups of 3-5 towards the apex of the branchlet. The petioles measure 6-15 mm in length, and the leaf blades are elliptic or elliptic-lanceolate, measuring 5-8 cm by 2-3 cm. The leaves are glabrous on both surfaces when mature, with triple veins and 4-5 pairs of lateral veins. The lowermost pair of lateral veins arise 3-6 mm from the base, sometimes with inconspicuous veinlets near the margin. The leaf base is cuneate to broadly cuneate or rotund, with a margin that often becomes undulate when dried, and an apex that is acuminate to caudate-acuminate. The fruit is globose, 8 mm in diameter, glabrous, and apiculate at the apex. It is seated on a flat, discoid perianth tube and has a slender, yellowish-brown, pubescent fruiting pedicel measuring 10-12 mm. In India flowering and fruiting occurs between March-October (Chakrabarty, 2020, Pal et al., 2014).

Distribution *N. pallens* is found in India, specifically distributed across various regions in Uttarakhand, Himachal Pradesh, and Jammu and Kashmir. In Uttarakhand, it occurs in Kaudia (Tehri Garhwal) at an elevation of approximately 2500 meters, Kalimath (Garhwal), and Okhimath (Garhwal). It is also found along the route to Deoban from Chakrata at elevations ranging from 1980 to 2590 meters, near Pandukeshwar at around 1830 meters on the way to Badrinath, and in the Ralan Valley at 2710 meters. Additional locations include Mussoorie, The Mall Road Mussoorie, the route to the Municipal Garden in Mussoorie, Kathyan Mundali in the Chakrata Forest Division, near Taluka in the Tons Forest Division (Tehri Garhwal), and areas around Konain, Koetikimoeon, and Forest Bata Guard Chowki in Mussoorie. In Himachal Pradesh, *N. pallens* is found in Kullu at about 1830 meters, Vakana (Shimla), Tali Nala to Thalli, Sarahan Bashahr, Shalabag, Khajjiar,

Mashobra, and Dalhousie (Chauhan et al., 2022. , Pal *et al*., 2014). In Jammu and Kashmir, it occurs in Banjal Kathma and Latidhuna (Udhampur). The species thrives in warm, tropical, humid subtropical, and mildly temperate regions. (Xie et al., 2015, Simpson, 2010).

Ethnobotanical Significance: *N. pallens* is of considerable ethnobotanical importance, being employed for multiple uses. The leaves and bark are used as spices, while the plant's freshly extracted juice is valued for its effectiveness as a hair tonic (Joshi *et al*., 2010). The fruits yield an oil that is applied topically for the treatment of skin conditions and also utilized as an illuminant (Pal et al., 2020). Moreover, in Himachal Pradesh, local communities gather its stems and leaves to use as fuel for cooking (Singh et al., 2010).

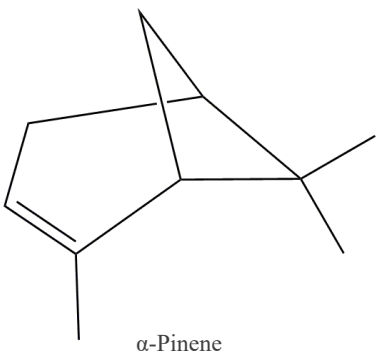
Phytochemistry:

Leaves: Essential oil [(α-pinene, α-thujene, camphene, sabinene, β-pinene, myrcene, α-phellandrene, α-terpinene, p-cymene, β-phellandrene, 1,8-cineole, trans-β-ocimene, γ-terpinene, cis-sabinene hydrate, terpinolene, terpinen-4-ol, cis-myrtenol, bornyl acetate, citronellyl acetate, α-ylangene, β-cubebene, β-caryophyllene, α-guaiene, α-himachalene, α-humulene, germacrene D, cis-β-guaiene, α-selinene, α-bulnesene, δ-cadinene, caryophyllene oxide, globulol, 10-epi-γ-eudesmol, 1-epi-cubenol, germacrone, curcumenol, furanogermenone) (Padalia et al., 2007, Joshi et al., 2009)].

Bark: Essential oil [(α-pinene, α-thujene, sabinene, β-pinene, α-phellandrene, p-cymene, β-phellandrene, 1,8-cineole, trans-β-ocimene, γ-terpinene, cis-sabinene hydrate, terpinolene, terpinen-4-ol, bornyl acetate, citronellyl acetate, α-ylangene, β-cubebene, β-caryophyllene, α-guaiene, α-himachalene, α-humulene, germacrene D, cis-β-guaiene, α-selinene, α-bulnesene, δ-cadinene, caryophyllene oxide, globulol, 10-epi-γ-eudesmol, 1-epi-cubenol, germacrone, curcumenol, furanogermenone) (Padalia et al., 2007)].

Fruit: Essentail oil [(α-pinene, α-thujene, camphene, sabinene, β-pinene, myrcene, α-phellandrene, α-terpinene, p-cymene, β-phellandrene, 1,8-cineole, trans-β-ocimene, cis-sabinene hydrate, terpinolene, terpinen-4-ol, cis-myrtenol, bornyl acetate, citronellyl acetate, α-ylangene, β-cubebene, β-caryophyllene, α-guaiene, α-humulene, germacrene D, cis-β-guaiene, α-selinene, α-bulnesene, δ-cadinene, caryophyllene oxide, globulol, 10-epi-γ-eudesmol, 1-epi-cubenol, germacrone, curcumenol, furanogermenone) (Padalia et al., 2007)].

Seed: Fatty oil [(capric acid, lauric acid, myristic acid, stearic acid, oleic acid, linoleic acid and linolenic acid, (Maikhuri et al., 2021)]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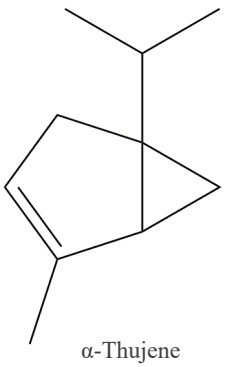
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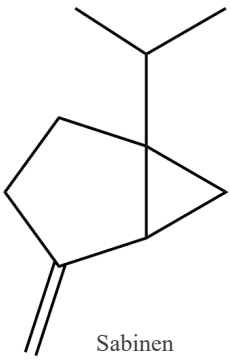
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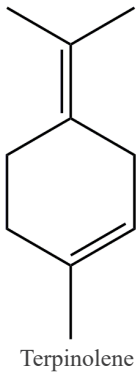
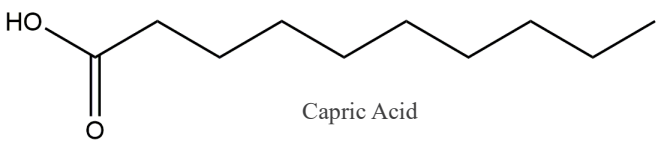
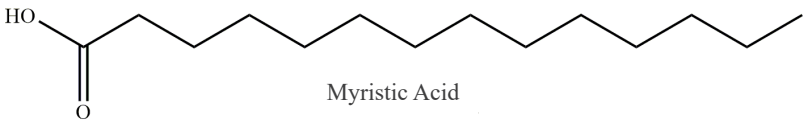
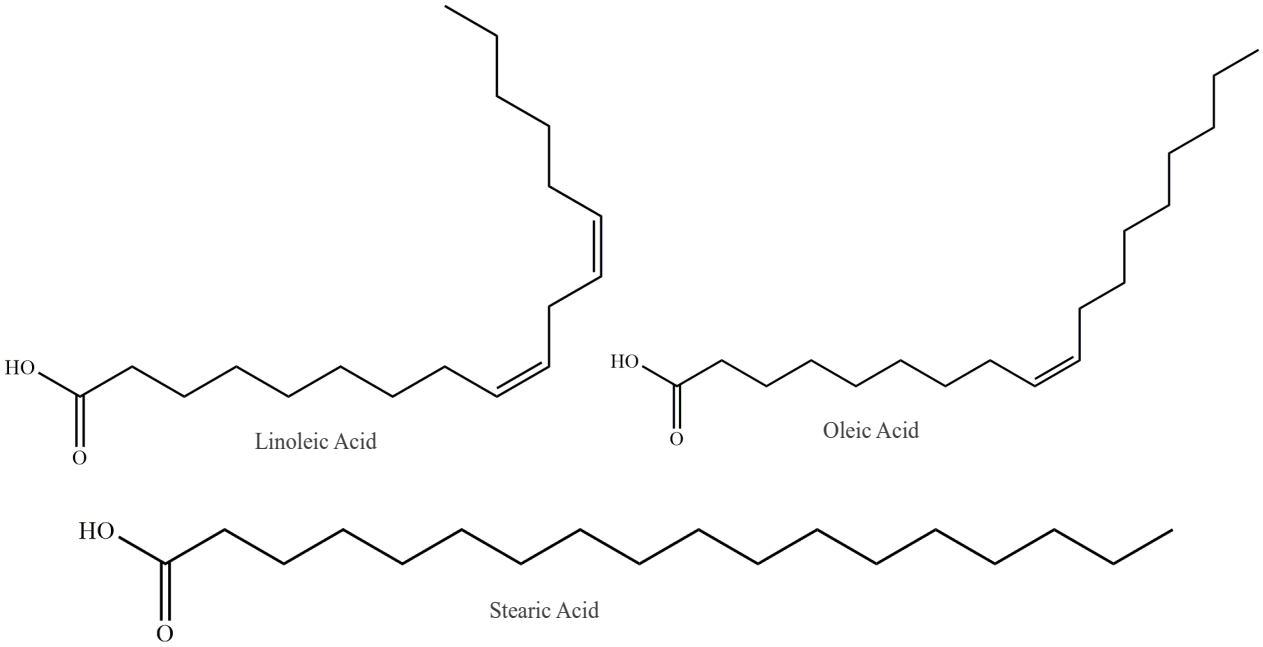

Terpinolene



Capric Acid



Myristic Acid



Structures of Important and Characteristic Chemical Constituents of *Neolitsea pallens*

Biological activities:

Antioxidant activity: The in vitro antioxidant activity of the essential oil extracted from the leaves of *N. pallens* was evaluated using various methods, including the β-carotene bleaching assay, reducing power, DPPH radical scavenging, and inhibition of lipid peroxidation. The oil demonstrated strong free radical scavenging activity, as indicated by low IC50 values for DPPH radicals (0.032 mg/ml and 0.087 mg/ml, respectively) and for lipid peroxidation inhibition (ranging between IC50 = 0.44 mg/ml and IC50 = 0.74 mg/ml, respectively). (Joshi et al., 2010).

Antibacterial activity: The essential oil extracted from the leaves of *N. pallens* was evaluated against three Gram-negative bacteria (*Escherichia coli, Salmonella enterica,* and *Pasteurella multocida*) and one Gram-positive bacterium (*Staphylococcus aureus*) at various concentrations using disc diffusion and tube dilution methods. The inhibition zones (IZ) and minimum inhibitory concentration (MIC) values for these bacterial strains ranged from 8.7 to 22.0 mm and 3.90 to 31.25 µl/ml, respectively (Joshi et al., 2010). Similarly, the essential oil derived from the seeds of *N. pallens* was tested against the same bacterial strains using the same methods, yielding comparable results in terms of IZ (8.7–22.0 mm) and MIC (3.90–31.25 µl/ml). The seed oil demonstrated significant antibacterial activity, suggesting its potential as a natural alternative to synthetic drugs with fewer side effects (Joshi et al., 2010).

Toxicology: No data are reported.

Scope of further R&D: *N. pallens* has traditionally been used to treat different ailments and as a flavoring agent in cuisine. *N. Pallens* is a lesser know plant and has not been explored in chemical and biological examination. Therefore, further research should be focused on investigating the phytochemical investigation and its pharmacological properties through modern scientific methods. Additionally, expanding the toxicological data will be crucial to ensure the safe application of *N. pallens*-derived products in medicinal and commercial contexts. Collaborative efforts between ethnobotanists, phytochemists, and pharmacologists could lead to the discovery of new uses and the sustainable commercialization of this valuable plant species..

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Oroxylum indicum
(L.) Kurz

Synonyms:
Arthrophyllum ceylanicum Miq., *Arthrophyllum reticulatum* Blume ex Miq., *Bignonia indica* L., *Bignonia lugubris* Salisb., *Bignonia pentandra* Lour., *Bignonia quadripinnata* Blanco, *Bignonia tripinnata* Noronha, *Bignonia tuberculata* Roxb. ex DC., *Calosanthes indica* (L.) Blume, *Hippoxylon indica* (L.) Raf. *Oroxylum flavum* Rehder, *Oroxylum indicum* Vent. nom. inval., *Spathodea indica* (L.) Pers (Nakahara Ketal., 2002).

Vernacular Names:
Ayurvedic: Shayonak Kul, ***Chinese:*** Hanyu pinyin, Mu hudie, Butterfly tree, ***English:*** Broken bones plant, Indian calosanthes, Indian trumpet, Indian trumpet flower, Mid night horror, Tree of Damocles, ***Malaysia:*** Bonglai, ***Gujrati:*** Tentu, ***Hindi:*** Patrorna, Putiveriksha, Shallaka, Shuran, Son, Vatuk, Arlu, Urru, Sauna, ***Karnataka:*** Ane-Mungu, ***Konkani:*** Devamadak, ***Nepalese:*** Tatelo, ***Malaylam:*** Palakappayyani, Vella, Pathiri, ***Sanskrit:*** Aralu, Shyonaka, ***Singhala-Sri-Lanka:*** Totila, Thotila, ***Tamil:*** Carikonnai, Kalai-y-utaicci, Puta-puspam, Achi, Pana, Peimaram, Vengamaram, Peruvaagai, ***Telugu:*** Manduka-paramu, Pampena, Suka-nasamu, Dundilamu, Pampini, Nemali, Chettu. ***Other common names:*** Kampong, Sonapatta, Sonaapaathaa, Urru, Saona, Tatpalenga, Kinnauriphool, Shoshana, Tuntuka, Kutunata, Mandukparna, Bhalluka, Prthushimba, Katvan (Chauhan, 1999;Warrier, 1995; Jayaram, 2008).

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Lamiales
Family	:	Bignoniaceae
Genus	:	*Oroxylum*
Species	:	*Oroxylum indicum*

Botanical Description: *Oroxylum indicum* (Family: Bignoniaceae) is a semi-deciduous tree, reaching up to 27 meters in height, with a trunk diameter of up to 40 cm. The bark is gray, and the tree features prominent leaf scars, thick twigs, and initially pithy stems that become hollow and lenticellate over time. The leaves are large, imparipinnate, and 3-4 times pinnate, measuring 0.5 to 2 meters in length, with a long petiole and swollen rachis at the points of insertion. The leaflets are ovate to oblong, measuring 4-11(-15) cm x 3-9 cm, with a wedge-shaped or mostly oblique base, acuminate apex, entire margins, and scattered glands on the lower surface. The inflorescence is a terminal, erect raceme, 25 to 150 cm long, with a peduncle and partitioned rachis. The bisexual flowers have a 2-4 cm long pedicel and are bracteolate. The sepals are coriaceous, bell-shaped, 2-4 cm in length, 1.5-2 cm in diameter, and brown or dirty violet, becoming woody when in fruit. The petals are penta-lobular and funnel-shaped, about 10 cm long, subequal, with wrinkled margins, reddish on the outside, and yellowish to pinkish on the inside. There are five stamens inserted in the throat, hairy at the base. The ovary is superior, 2-celled, with multiple ovules. The fruit is a pendent, sword-shaped capsule, measuring up to 120 cm x 6-10 cm, with flat valves that turn woody and eventually black. The seeds are 9 cm x 2.5-4 cm, with membranous, transparent wings. Seedlings undergo epigeal germination, characterized by elongated hypocotyls and leafy cotyledons (Chauhan, 1999).

Distribution: *Oroxylum indicum* is native to the Indian subcontinent, including the Himalayan foothills, with extensions into Bhutan, southern China, Indo-China, and Malaysia. In Vietnam, the tree is known as *núcnác* or *sòđo* and can be found in Cat Tien National Park. In India, it is observed in the forest biome of Manas National Park in Assam and is widely planted in the forest areas of Banswara district, Rajasthan. The species is listed among the rare, endangered, and threatened plants of Kerala (Yoganarasimhan, 1996). *O. indicum* is distributed throughout the tropical forests of India, including the northeastern, central, and southern regions, with a higher frequency in the Vindhyas

and southward in mixed-deciduous forests, up to an altitude of 1000 meters. It naturally occurs near rivers and streams but is generally absent in the dry climates of western India. The plant thrives in tropical areas with well-distributed annual rainfall between 85 cm and 130 cm. It prefers sandy-loam fertile soil but can also grow well in medium to deep black soils and sandy loams (Warrier et al., 1995).

Ethnobotanical Significance: *O. indicum* is often cultivated as an ornamental plant due to its unusual appearance. The tree is valued for its wood, tannins, and dyes. In the Himalayas, sculptures or garlands made from *O. indicum* seeds, known as *shyonaka* in Sanskrit, are hung from rooftops for protection. The large young pods, called *Lin mai* or *Lin fa* in Loei, are consumed in Thailand and Laos, often grilled and eaten with *lap* after scraping out the bitter inner pulp (Yuan et al., 2008). Among the Bodos of Northeast India, the flowers and fruits are eaten as a bitter side dish with rice, typically prepared with fermented or dried fish and believed to have medicinal properties. The Chakma people in the Chittagong Hill Tracts of Bangladesh and India also consume the pods. In Malaysia, the plant is traditionally used to treat a range of ailments including toothache, rheumatism, wounds, splenomegaly, gastralgia, dysentery, cholera, loss of appetite, and fever. Various parts of the plant are used in decoctions for external applications during childbirth and to treat diarrhea and constipation. In India, Indonesia, and Malaysia, the bitter root bark serves as an astringent and tonic, while in the Philippines, it is used as an anti-rheumatic, anti-dysenteric, and diaphoretic agent. An alcoholic maceration of the fresh bark is applied externally to relieve allergic dermatitis. The leaves are used in decoctions to treat gastralgia, loss of appetite, rheumatism, and wounds, and are also used externally for cholera, fever, and rheumatic swelling. Boiled leaves are applied during and post-delivery, and for dysentery and splenomegaly. They are also used to alleviate toothache and headaches. The seeds are utilized by Chinese practitioners to relieve abdominal pain, mouth ulcers, sore throat, chronic cough, and gastralgia (Warrier et al., 1995).

Phytochemistry:

Leaves: Baicalein (5,6,7-trihydroxy flavone), chrysin (5,7-dihydroxy flavone) (Yuan et al., 2008, Subramanaya et al., 1972), scutellarein, anthraquinone, and aloe-emodin (Jayaram et al., 2008, Dalal et al., 2004, Dey et al.,1978), chrysin-7-O-glucuronide, chrysin-diglucoside, baicalein 7-O-glucoside, baicalein-7-O-diglucoside (Yuan et al., 2008), oroxylin-A (Sankara & Nair, 1972), quercetin-3-O-α-L-arabinopyranoside, 1-(2-hydroxyethyl)-cyclohexane-1, 4-diol, apigenin (Yuan et al., 2008), Ar-tumerone, methyl hexadecanoate, laurenan-2-one, isopropyl butanoate, baicalein-6-O-glucuronide, dihydrobaicalein, ellagic acid, dihydrooroxylin-A, methyl-3,-4,5-trihydroxy-6-(5-hydroxy-6-methoxy-4-oxo-2- phenylchroman-7-yloxy)-tetrahydro-2H-pyran-2-carboxylate, 5-hydroxyl-7-methoxy-2-(2-methoxy-6-(3,4,5-trihydroxy-6-(hydroxymethyl)-tetrahydro-2H-pyran-2-yoloxy) phenyl)-4H-chromen-4-one, oroxyloside, hispidulin (Subramanian and Nair, 1972, Zaghloul et al., 2015).

Bark: Oroxylin A (5,7-dihydroxy-6-methoxy flavone), chrysin, baicalein, scutellarin-7-rutinoside, tannic acid, β-sitosterol, biochanin-A, ellagic acid (Dalal et al., 2004), 2, 5-dihydroxy-6, 7-dimethoxy flavone, 3,7,3′,5′, tetramethoxy-2-hydroxy flavones (Kawsar et al., 2003), prunetin, (Zaveri et al., 2008), 5-hydroxy 8-methoxy-7-O-β-D-glucopyranosyl flavone, stigmast-5-en-3-ol, pratensol, 3-(4-hydroxy phenyl) 2-propenoic acid, 3,4′,5,7-tetrahydroxy-flavonol, 5-hydroxy-4′,7-dimethoxy flavone, 7-O-methyl chrysin (Sankara and Nair, 1972, Nair and Joshi, 1979, Polya, 2003, Bays and Finch, 1990, Kumar et al., 1999) dihydrooroxylin-A, methyl-3,4,5-trihydroxy-6-(5-hydroxy-6-methoxy-4-oxo-2-phenylchroman-7-yloxy)-tetrahydro-2H-pyran-2-carboxylate, 5-hydroxyl-7-methoxy-2-(2-methoxy-6-(3,4,5-trihydroxy-6-(hydroxymethyl)tetrahydro-2H-pyran-2-yoloxy)phenyl)-4H-chromen-4-one (Hari Babu et al., 2010), dihydrobaicalein (Yin et al., 2007), pectolinarigenin, (2S)-dihydrobaicalein-7-O-(6″-benzoylglucopyranoside) (SilSarma et al., 2014), hispidulin (Tran et al., 2014), methyloroxylopterocarpan, dodecanyloroxylopterocarpan, hexyl oroxylopterocarpan, heptyl oroxylopterocarpan (Ali et al., 1999), lapachol, dehydro-iso-α-lapachone (Ali et al., 1998), β-sitosterol (Dinda et al, 2007), β-sitosterol glucoside (SilSarma et al., 2014), p-coumaric acid (Subramanian and Nair 1972), biochanin A (Zaveri et al., 2008), 2-(1-hydroxymethylethyl)-4H, 9H-naphtho-[2,3-b]-furan-4,9-dione, 2-acetylnaphtho [2,3-b]-furan-4, 9-dione, (3R,4R)-3,4-dihydro-4-hydroxy-3 (3-hydroxymethyl-(2Z)- butenyl)-1-(2H)-naphthalenone, catalponol, (3R,4R)-3,4-dihydro-4-hydroxy-3(3-methyl-2- butenyl)-1(2H)-naphthalenone, (2S,3S,4R)-3,4-dihydro-3,4 dihydroxy-2(3-methyl-2-butenyl)-1(2H)- napthalenone , (2R, 3aS, 9S, 9aR)

9-hydroxy-2-isopropenyl-2,3,9,9a-tetrahydro-3aH-naphtho [2,3-b]- furan-4-one, (2R*, (2aR*, S*, (b R*, (2an-a,4,5,9b-hexahydro-2-(1-hydroxy-1-methylethyl)-5-naphtho- [1,2-b]-furanol, (2R*, (aR*R (bR*R (2anol ([1,2-hydroxy-1-methylethyl,9b-tetrahydro-4H-naphtho- [1,2-b]-furan-5-one, [3S, 4aR, 10bR]-2,2-dimethyl-3-hydroxy-3,4,4a,10b-tetrahydro-5H-naphtho [1,2- b]-pyran-6-one, faramol, spiro [(1aS, 2R, 7aS)-2,3-dihydroxy-1a,2,7,7a-tetrahydronaphtho [2,3-b]-oxirene-7,20 -naphtho-[1,8-de]-10 ,30 -dioxin] (Kizu et al., 1994)

Root: Oroxylin A, baicalein, chrysin, pterocarpan, rhodioside, p-hydroxy phenyl ethanols, (Vasanth et al., 1990, Dey et al., 1978, Theobald et al., 1981) 2,5-dihydroxy-6,7-dimethoxy flavone, 3,7,3′,5′ -tetra-methoxy-4-hydroxy flavone, lapachol, β-sitosterol, baicalein-6-glucoside, oroxindin, oroxylin-A, scutellarin, baicalein, oroxin A, oroxin B, baicalin, quercetin, apigenin, kaempferol, quercetin-3-O-arabinopyranoside, lupeol, lup-20 (29)-ene-2α,3β-diol, pinosylvin, dihydropinosylvin, cholest-5-ene-3, 7-diol, rengyol, isorengyol, zarzissine, (E)-pino-sylvin-3-O-β-D-glucopyranoside, adenosine, daucosterol, chrysin 6-C-β-D-glucopyranosyl-8-O-β-D-glucuronopyranoside, baicalein 7-O-β-D-glucuronopyranosyl(1→3)-[β-D-glucopyranosyl-(1→6)]-β-D-glucopyranoside (Rasadah et al., 1998, Zaveri et al., 2008, Uddin et al., 2003, Yadav et al., 2013)

Stem: Oroxylin A, baicalein, chrysin, pterocarpan, rhodioside, p-hydroxyphenylethanols (Vasanth et al., 1990, Dey et al., 1978, Theobald et al., 1981), apigenin, ficusal, balanophonin, 2-(1-hydroxy-methylethyl)-4H,9H-naphtho[2,3-b]furan-4,9-dione, salicylic acid, ρ-hydroxybenzoic acid, protocatechuic acid, isovanillin, oroxylin, pinostrobin, stigmast-7-en-3-ol, 3,4′ ,5,7 tetrahydroxy flavonol, 5,6,7-trimethoxyflavone-8-O-β-D-glucopyranoside, oroxylin A-7-O-β-D-glucuronide butyl ester, 6-methoxy-baicalein, oroxylin-A-7-O-glucoside, 5,7-dihydroxyflavone, baicalein- 6-methoxy-7-glucuronide, dehydro-iso-α-lapachone, lapachol, ellagic acid, biochanin-A, hispidulin (Rasadah et al., 1998, Lalrinzuali et al., 2018, Luitel et al., 2010, Babu et al., 2010, Nguyen et al., 2012, Islam et al., 2010, Fan et al., 2015)

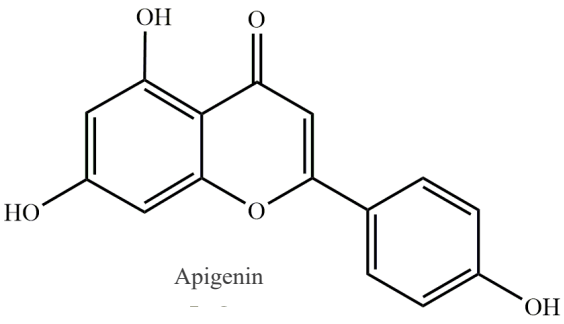
Fruits: Oroxylin A, chrysin, baicalein, ursolic acid (Roy et al., 2007), Aloe-emodin (Kupchan and Karim, 1976), orlumin A (Chumkaew and Srisawat, 2021), Salidroside, 2(3,4-dihydroxyphenyl)-ethyl glucoside, acetoside, rengyol, 5,6-dihydrocornoside, 6α-hydroxydihydrocornoside, cornoside, regyolone, dihdryorengyolone, 6α-methoxydihydrorengyolone (Teshima et al., 1996).

Seeds: Chrysin, oroxylin A, baicalein, baicalein-7-O-diglucoside (Oroxylin B), baicalein-7-O-glucoside, apigenin (Tomimori et al., 1988), tetuin, benzoic acid (Chen et al., 2003, Chen et al., 2005), glucuronide-oroxindin, chrysin-7-O-diglucoside, caprylic acid, lauric acid, myristic acid, palmitic acid, palmotoleic acid, stearic acid, oleic acid, linoleic acid, scutellareinscutellarein and (Kapoor, 2001, Subramaniam, 1972), ellagic acid (Vasanth et al., 1991), scutellarein 7-O-β-D-glucopyranosyl-(1-6)-β-D-glucopyranoside, chrysin-7-O-gentiobioside, scutellarein-7-O-glucopyranoside, chrysin-7-O-glucuronide, chrysin-6-C-β-D-glucopyranosyl-8-C-α-L-arabinopyranoside, pinocembrin, pinobanksin, 2-methyl-6-phenyl-4H-pyran-4-one, lupeol, 2α-hydroxyllupeol, echinulin, adenosine, dimethyl sulfone, β-sitosterol, baicalein-7-O-gentiobioside, baicalein-7-O-glucoside, baicalein-7-O-glucuronide, oroxin C, oroxin D (Mehta and Mehta, 1953, Nair and Joshi, 1979, Chen et al., 2003, Yan et al., 2011, Wei et al., 2013, Kruger and Ganzera, 2013, Li et al., 2021, Rojsanga et al., 2020), norwogonin, acacetin, isorhamnetin (Wen et al., 2011), wogonin-7-O-β-D-glucuronide, lupeol, 2α-hydroxylupeol, β-sitosterol (Yan et al., 2011), cholest-5-ene-3,7-diol, β-sitosterol glucoside (Wei et al., 2013), (E)-dihydropinosylvin-2-carboxyl-5-O-β-D-glucopyranoside, (E)-dihydropinosylvin-3-O-β-D-glucopyranoside, (E)-pinosylvin-3-O-β-D-glucopyranoside, pinosylvin, dihydropinosylvin (Xie et al., 2014), rengyol, isorengyol (Wei et al., 2013) myristoleic acid (Grover and Rao, 1980) 2-methyl-6-phenyl-4H-pyran-4-one, echinulin, adenosine, dimethylsulfone (Yan et al., 2011), zarzissine (Wei et al., 2013)

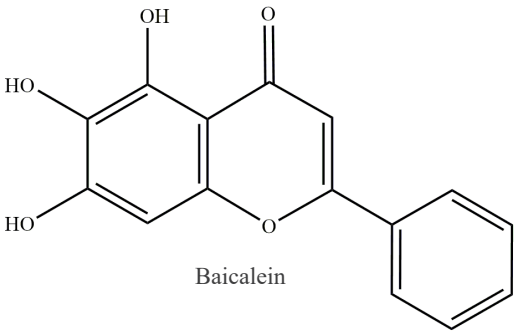
Flower: Baicalein, chrysin **(**Rojsanga et al., 2017**).**

Biological Activities:

Anti-inflammatory activity: The anti-inflammatory activity of *Oroxylum indicum* was assessed using a carrageenan-induced rat paw edema model, with diclofenac sodium serving as the standard drug. Two different doses of the aqueous extract, 150 mg/kg and 300 mg/kg, were administered. The study found a significant reduction in paw volume in a dose-dependent manner, with the 300 mg/kg dose demonstrating the highest anti-inflammatory



Apigenin



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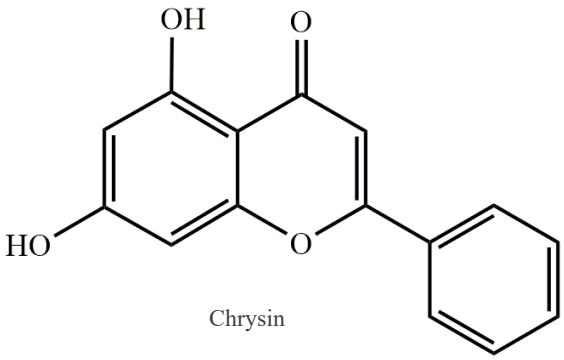

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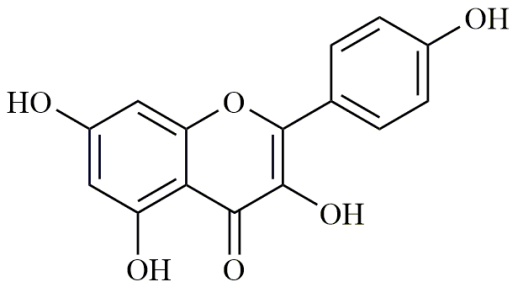
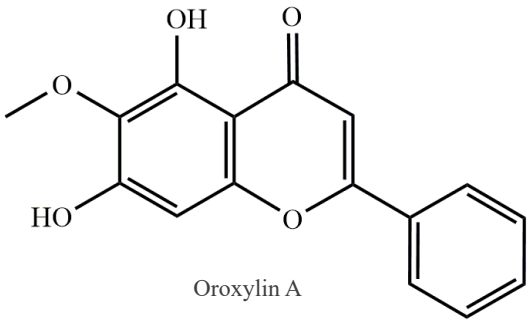
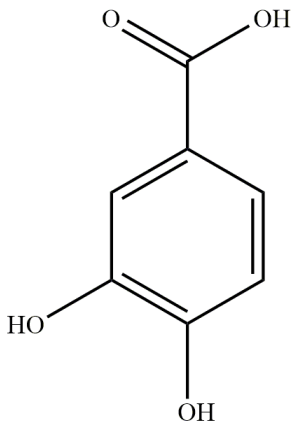


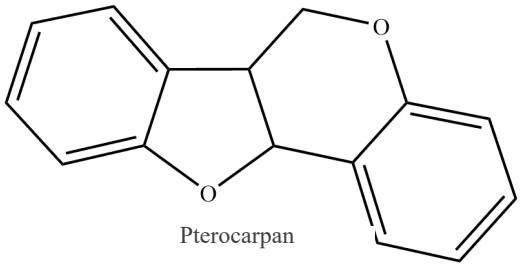
Kaempferol



Oroxylin A



Protocatehuic acid



Pterocarpan

Structures of Important and Characteristic Chemical Constituents of *Oroxylum indicum*

effect. Both doses of the extract, however, showed significant anti-inflammatory activity overall (Upaganlawar et al., 2009). Additionally, both the aqueous and alcoholic extracts of *O. indicum* leaves were reported to exhibit effective anti-inflammatory properties (Laupattarakasem et al., 2003).

Analgesic activity: The butanol extract of *O. indicum* root bark has been reported to possess analgesic effects, attributed to the presence of flavonoids such as baicalein, ellagic acid, and biochanin-A (Zaveri and Jain, 2010).

Nephroprotective activity: o assess nephroprotective activity, an ethanolic extract of *O. indicum* root and chrysin isolated from the roots were tested in rats with cisplatin-induced renal damage. The study revealed that both the extract and chrysin exhibited significant nephroprotective activity (Adikay et al., 2011).

Anti-ulcer activity: The 50% alcoholic extract of *Oroxylum indicum* root bark, along with its petroleum ether, chloroform, ethyl acetate, and n-butanol fractions, was evaluated against ethanol-induced gastric mucosal damage. The extract and its fractions significantly reduced gastric ulcers, with the petroleum ether and n-butanol fractions showing the highest inhibition of gastric lesions. The results were comparable to omeprazole, the reference standard. The active fraction of the root bark significantly reduced the ulcer index, total acidity, total acid output, pepsin activity, and pepsin output, while significantly increasing the total carbohydrate-to-protein ratio in pyloric-ligated rats. The anti-ulcer activity is likely due to decreased gastric acid secretion and antioxidant properties, which contribute to gastric cytoprotection. This effect may be attributed to the presence of baicalein in the root bark (Khandhar et al., 2006).

Anti-microbial activity: The antimicrobial potential of *Oroxylum indicum* was assessed using crude extracts (petroleum ether, ethyl acetate, and methanol) and two isolated compounds: 2,5-dihydroxy-6,7-dimethoxy flavone (compound 1) and 3,7,3',5'-tetramethoxy-2-hydroxy flavone (compound 2). These were tested against fourteen pathogenic bacteria (5 Gram-positive and 9 Gram-negative) and seven pathogenic fungi. Nutrient agar and nutrient broth were used as bacteriological media, while potato dextrose agar (PDA) was used for fungal growth. The results demonstrated that the crude extracts (petroleum ether and ethyl acetate) and both isolated compounds exhibited significant antibacterial and antifungal activities, though they were less potent compared to standard drugs kanamycin and clotrimazole, used as reference standards for antibacterial and antifungal activities, respectively. The methanol extract showed minimal antimicrobial activity. These findings support the traditional use of *O. indicum* for treating bacterial and fungal infections (Kawsar et al., 2003; Chopade et al., 2008).

In a separate study, the methanol, ethyl acetate, and ethanol extracts of *O. indicum* stem bark were tested against *Bacillus subtilis*, *Escherichia coli*, and *Pseudomonas aeruginosa*, revealing notable antibacterial and antifungal properties. These activities were attributed to the presence of 2,5-dihydroxy-6,1-dimethoxyflavone and 3,7,3',5'-tetramethoxy-4'-hydroxyflavone. Additionally, hexane, CCl4, and chloroform fractions derived from methanolic stem bark extract exhibited effective antibacterial and antifungal activities against several Gram-positive and Gram-negative bacteria and fungi. The dichloromethane extract also showed considerable antifungal activity against dermatophytes and wood rot fungi (Uddin et al., 2003; Islam et al., 2009; Ali et al., 1998)

Anti-oxidant activity: The antioxidant potential of *Oroxylum indicum* was evaluated using ethanol extracts of its leaves in two in vitro models: radical scavenging activity by 1,1-diphenyl-2-picrylhydrazyl (DPPH) reduction and nitric oxide radical scavenging activity in the Griess reagent system. The ethanol extract demonstrated significant antioxidant activity in both models, indicating its free radical scavenging capabilities (Upaganlawar et al., 2007).

In a separate study, methanol extracts from various parts of *O. indicum*–including root, leaves, stem, fruits, root bark, and stem bark–were assessed for antioxidant properties. The results showed that the leaves and bark extracts exhibited the highest reducing capacity and free radical scavenging activity compared to the other parts (Mishra et al., 2010).

Anti-cancer activity: The methanol extract of *O. indicum* fruits demonstrated inhibitory effects on the in vitro proliferation of HL-60 cells, with baicalein identified as the active component. Further studies on baicalein revealed its ability to reduce cell viability and induce apoptosis in the HL-60 cell line. After 24 hours of treatment with baicalein, a 50% inhibition of HL-60 cells was observed at a concentration of 25-30 µM. These findings suggest that baicalein exhibits anti-tumor effects on human cancer cells (Roy et al., 2007).

Anti-mutagenic activity: The methanol extract of *O.indicum* showed strong inhibition of Trp-P-1 mutagenicity using the Ames pre-incubation method with *Salmonella typhimurium* in the presence of an

S9 mix. A mere 5 µl of the crude extract inhibited 91±5% of the mutagenesis induced by 50 ng of Trp-P-1. This potent antimutagenic effect is attributed to the high content of baicalein in the extract. Baicalein acts as a desmutagen by inhibiting the N-hydroxylation of Trp-P-2, a process catalyzed by P450 monooxygenases in the S9 mix (Nakahara et al., 2001)

Photocytotoxic activity: The photocytotoxic activity of the methanol extract of *O. indicum* leaves was tested against the HL-60 promyelocytic leukemia cell line. Cells were incubated with 21 µg/ml of the extract for 2 hours and then irradiated with 9.6 J/cm² of broad-spectrum light. Cell survival was assessed 24 hours later using the MTT colorimetric assay. Pheophorbide-a, a known photosensitizer, served as the positive control, with a parallel non-irradiated assay. The results showed that the extract exhibited significant photocytotoxic activity at the tested concentration (Ong et al., 2009).

Anti-arthritic activity: An aqueous extract of *O. indicum* was tested for its effect on the in vitro release of myeloperoxidase (MPO) from rat peritoneal leukocytes, a marker elevated in rheumatoid arthritis. The results demonstrated that the extract significantly inhibited MPO release by 64%, indicating potential anti-arthritic activity (Laupattarakasem et al., 2003).

Immunostimulant Activity: The n-butanol extract of *O. indicum* root bark was studied for its immunomodulatory effects in rats, focusing on immune responses to sheep red blood cells (SRBC) and delayed-type hypersensitivity (DTH) reactions. Treatment with the n-butanol fraction significantly increased circulating haemagglutinating antibody (HA) titers during secondary antibody responses, suggesting an enhancement of humoral immunity. Additionally, the treatment led to a significant rise in paw edema formation, indicative of an increased DTH response. Histopathologic analysis revealed increased cellularity in lymphoid tissues, including T-lymphocytes and sinusoids. In a triple antigen-mediated immunological edema model, the treated rats exhibited greater edema compared to controls, further confirming the enhancement of DTH responses. The immunostimulant activity of *O. indicum* may be attributed to its ability to enhance both humoral and cell-mediated immune responses (Zaveri et al., 2006).

Antiproliferative Activity: The antiproliferative activity of *O. indicum* was studied on human breast tumor cell lines. Results indicated that *O. indicum* exhibits antiproliferative effects against MCF7 and MDA-MB-231 breast cancer cell lines (Lambertini et al., 2006).

Hepatoprotective Activity: The hepatoprotective effects of *O. indicum* were studied against carbon tetrachloride (CCl_4)-induced hepatotoxicity in mice and rats. Biochemical analyses revealed that alcohol, petroleum ether, and n-butanol extracts significantly lowered elevated serum glutamic oxaloacetic transaminase (SGOT), serum glutamic pyruvate transaminase (SGPT), alkaline phosphatase (ALP), and total bilirubin (TB) levels compared to the control group. The increased lipid peroxide (LPO) formation, reduced glutathione (GSH) levels, and decreased antioxidant enzyme activities of superoxide dismutase (SOD) and catalase (CAT) in the tissues of CCl_4-treated animals were significantly normalized by *O. indicum* treatment. Histopathological studies also revealed that pretreatment with *O. indicum* restored CCl_4-induced alterations in the antioxidant status of the tissues. It is suggested that the root bark's significant antioxidant activity may be responsible for its hepatoprotective effects (Zaveri et al., 2009). Additionally, the aqueous extract of the root bark of *O. indicum* is reported to protect against paracetamol-induced liver damage in rats (Sastry et al., 2011).

Antihelmintic Activity: The antihelmintic activity of *O. indicum* was evaluated against equine strongyle eggs. A dosage of 2×10^{-4} g/mL or higher was found to inhibit the viability of eggs and larvae of equine strongyle eggs (Downing, 2000).

Antidiabetic Activity: The methanol and aqueous extracts of *O. indicum* leaves were shown to exhibit antidiabetic activity in experimental rats with alloxan-induced diabetes. The methanol extract was found to be more effective than the aqueous extract (Kaldate et al., 2011).

COVID-19 Restriction: Molecular docking and surface plasmon resonance studies have revealed that oroxylin A from *O. indicum* can suppress the entry of the SARS-CoV-2 virus into cells with ACE2 receptors. The baicalein component of *O. indicum* has also been reported to inhibit COVID-19 viral

replication. Further molecular docking studies indicate that baicalein-7-O-diglucoside, chrysin-7-O-glucuronide, oroxindin, and scutellarein have the potential to inhibit the SARS-CoV-2 virus replication enzyme, thereby restricting the infection (Gao et al., 2021; Huang et al., 2020; Shah et al., 2021).

Toxicity: The toxicological studies on *Oroxylum indicum* have shown that the root and stem extracts of the plant are toxic to brine shrimp nauplii. However, multiple studies evaluating the toxicity of these extracts have revealed that the plant is non-toxic to humans and experimental animals, even when administered in high doses (Chowdhury et al., 2005).

Commercial Products: The root extract of *O. indicum* is used as an ingredient in various haircare products, including shampoos and conditioners, as well as in skincare products like anti-aging creams. (https://incidecoder.com/ingredients/oroxylum-indicum-root-extract).

Patents:

- *Oroxylum indicum* general flavone extraction and purification method and application thereof. Patent No: CN104958330A
- Flavonoids isolated from *Oroxylum indicum* for treatment of gastrointestinal toxicity, associated symptoms, and ulcers. Patent No: WO2007080484A2
- Indian trumetflower seed heat-clearing tea and production method thereof. Patent No: CN105360407A
- A phytomedicine and its derivatives effective against hand, foot, and mouth disease (hfmd) based upon *Oroxylum indicum.* Patent No: WO2021257006A1
- Fritillary bulb and *Oroxylum indicum* porridge for treating unsmooth speech after stroke. Patent No: CN105558465A
- *Oroxylum indicum* health care cigarette. PatentNo: CN108201165A
- Oroxylum indicum-fructus momordicae honey tea preparation method. Patent No: CN105533008A
- Oroxylum-indicum-containing rice dumpling with effects of clearing away lung heat and relieving sore throat and production method of *Oroxylum indicum*-containing rice dumpling. Patent No: CN104522502A
- Method for separating seed wing and seed kernel of seed of *Oroxylum indicum*, Patent No: CN105536962A
- Quality control method of *Oroxylum indicum* freckle-removing cream. Patent No: CN115078282A
- *Oroxylum indicum* antiinflammatory analgesic tea and production method thereof. Patent No: CN105454552A
- *Oroxylum indicum* oral liquid with effects of clearing lung and relieving sore-throat and preparation method thereof. Patent No: CN106806688A
- Bioactive molecules from *Oroxylum indicum* and their therapeutic applications. Patent No: US10959980B2
- Separation method and application of *Oroxylum indicum* seed iron-promoting endophytic fungi. Patent No: CN115637228A
- *Oroxylum indicum* lotus-flavored eyesight-improving dried whitebait and preparation method thereof. Patent No: CN104770761A
- Preparation method of *Oroxylum indicum* throat-clearing buccal tablet. Patent No: CN104825530A
- Bioactive molecules from *Oroxylum indicum* and their therapeutic applications. Patent No: US2020188350A1
- Osmanthus-fragrans-fragrance *Oroxylum indicum* health tea beverage and preparation method thereof. Patent No: CN105475561A
- Traditional Chinese medicine composition of *Oroxylum indicum* sore-throat-relieving tea and preparation method. Patent No: CN105613855A
- Application of *Oroxylum indicum* extract in preparation of insecticide, and application of insecticide, Patent No: CN114766518A
- A method for obtaining lutein standard from *Oroxylum indicum.* Patent No: MY170300A
- Applications of extracts from Chinese herbal medicine *Oroxylum indicum* in preparation of slimming and lipid-lowering medicine or preparation of medicine with inhibition effect on activity of lipase. Patent No: CN102366428A
- Pickling method of Indian trumetflower seeds. Patent No: CN104431901A

- Lung-moistening milk-flavored cellophane noodles containing *Oroxylum indicum* and preparation method of cellophane noodles. Patent No: CN105029157A
- Phenyl ethanoid glycoside from the bark of *Oroxylum indicum* Vent: a potential inhibitor of DNA topoisomerase IB of Leishmania donovani, Patent No: AU2021100265A4
- *Oroxylum indicum* polysaccharide and medical application of *Oroxylum indicum* polysaccharide in preparation of medicine for treating ulcerative colitis. Patent No: CN115232224A
- Method for increasing germination rate of *Oroxylum indicum* seeds. Patent No: CN106233869A
- Rapid propagation method for tissue culture of *Oroxylum indicum.* Patent No: CN104255503A
- Application of *Ooroxylum indicum* as anti-oxidative stress injury agent. Patent No: CN112007058A
- Application of *Oroxylum indicum* extract in preventing and/or repairing ultraviolet-induced skin injury. Patent No: CN115120624A
- *Oroxylum indicum* extract and application to using same as sun-screening agent. Patent No: CN102614100A
- Preparation method of beef sausage containing *Oroxylum indicum*. Patent No: CN105520077A
- Beverage made of *Oroxylum indicum* Vent. Patent No: TH46078

Scope of further R&D: The comprehensive ethnobotanical uses and rich phytochemistry of *Oroxylum indicum* highlight its immense potential for further research and development (R&D). Given its wide distribution across tropical regions and its occurrence in diverse habitats, R&D efforts could focus on sustainable cultivation practices that optimize its growth in varying environmental conditions. Additionally, the documented medicinal properties and bioactive compounds, including flavonoids like baicalein and oroxylin A, present opportunities for exploring new pharmacological applications, particularly in developing novel therapeutic agents for treating diseases. Further investigation into its phytochemical profile could also lead to the discovery of new compounds with unique biological activities. Moreover, its traditional uses in various cultures suggest potential for developing functional foods or nutraceuticals, which could be standardized for broader consumption. Collaborations with indigenous communities and modern scientific methodologies could unlock new avenues for product development, ensuring both the conservation of this valuable species and its integration into contemporary healthcare and wellness industries.

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Pithecellobium dulce
(Roxb.) Benth.

Synonyms:
Acacia obliquifolia M. Martens & Galeotti, *Albizia dulcis* (Roxb.) F. Muell, *Feulleea dulcis* (Roxb.) Kuntze, *Inga camatchili* Perr, *Inga dulcis* (Roxb.) Willd, *Inga javana* DC, *Inga leucantha* C. Presl, *Inga pungens* Willd, *Inga javanic* DC, *Inga lanceolata* Sensu Blanco, non Kuntze, *Mimosa dulcis* Roxb, *Mimosa edulis* Gajnep, *Mimosa pungens* (Willd) Poir, *Mimosa unguis-cati* Blanco, *Pithecellobium lttorale* Record

Common Names:
Madras thorn, Jungle julebi, Manila tamarind, Konapuli, Kodukkaapuli, Vilayati babul, Gaumuche.

Vernacular Names:
Arab: Showkat Madras, ***Bengali:*** Dekhani babul, ***Chinese:*** Niutidou, ***English:*** Quamachil, Madras thorn, manila tamarind, ***French:*** Campeche (New Caledonia), Cassie de Manille, ***German:*** Camambilarinde, ***Greek:*** Pithekosellobion, ***Hindi:*** Vilayati babul, Vilayatiimli, Jangle jalebi, ***Japanese:*** Huamuche, Guamuche, Javanese: Asemlondo, Asambelanda, ***Kannada:*** Seemehunase, ***Philippines:*** Camachile, ***Sanskrit:*** Kodukkaapuli, ***Spanish:*** Guamuchil, Guamaamericano, Quamachil, ***Tamil:*** Kodukkaapuli, ***Telugu:*** Seemachintakaya.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Fabales
Family	:	Fabaceae
Genus	:	*Pithecellobium*
Species	:	*Pithecellobium dulce*

Botanical Description: *Pithecellobium dulce* is a small to medium-sized tree that typically reaches a height of 15-20 m, with a diameter ranging from 30-50 cm, and occasionally up to 100 cm. It is often multiple-stemmed and may appear as a bush or a branchy tree with an irregularly rounded crown and flexible, pendulous branches. Some slender branches extend beyond the rest of the crown. The bark of younger trees and branches is smooth, pale whitish-grey, and lenticellate, often with horizontal ribs. On older trunks, the bark becomes rougher and fissured. The shoots are generally armed at the nodes with pairs of straight, stout, stipular spines (4-13 mm long), though some shoots are thornless. The leaves are abruptly bipinnate, with one pair of pinnae per leaf and two pairs of leaflets per pinna (totaling four leaflets per leaf). Leaflets are 25-56 mm long and 9-32 mm wide, obliquely elliptic or oblong-elliptic, with 4-7 pairs of pinnate veins. They are deep olive-green above and paler grey-green below, with small glands (0.3-0.8 mm high and 0.4-0.7 mm in diameter) at the tip of the petiole and pinnular rachis. The flowers are clustered in small, dense, sub-spherical heads, 7-12 mm in diameter, with 20-30 flowers per head. These heads are arranged in fascicles of 2-4 in the leaf axils. The flowers are pale whitish-green with white stamen filaments, and have 5 sepals and 5 petals fused into a tube, with 22-42 stamens per flower, also united into a staminal tube. The fruits are distinctive, spirally curved or coiled into 1-2 circles, noticeably constricted between the seeds. They turn from green-tinged red to bright rose or red as they ripen, and become reddish-brown after dehiscence. Unripe pods are fleshy but become dry and papery after opening. The pods open along both sides to reveal 8-12 seeds, which persist attached by the fleshy white, pale pink, or occasionally red aril. The seeds are shiny black, compressed, lentiform, and measure 7-13 mm x 6-11 mm x 2-4 mm.

Distribution: *Pithecellobium dulce* originates from Brazil, Argentina, Bolivia, and Colombia. However, it has become widespread beyond its native range. It is now naturally distributed in many countries, including India, tropical Africa, and coastal regions, among others (Orwa et al., 2009).

Ethnobotanical Significance: Various parts of *P. dulce* have been traditionally used as remedies for earache, leprosy, peptic ulcer, toothache, venereal disease, and more. The plant exhibits emollient, abortifacient, anodyne, and larvicidal properties. The bark is used as an astringent for dysentery, a febrifuge, and a treatment for dermatitis and eye inflammation (Pithayanukul et al., 2005). Additionally, *P. dulce* is a potential source of antioxidants and has medicinal uses for adulticide problems.(Megala and Geetha (2010); Megala, N., and Geetha, A. (2010). The leaves are traditionally used in folk medicine for treating leprosy, intestinal disorders, peptic ulcers, toothache, earache, and as an emollient and larvicide. When applied as a plaster, the leaves can relieve the pain of venereal sores and convulsions, and when taken with salt, they can cure indigestion but may also induce abortion (Sunarjono et al., 1991). The fruit of *P. dulce* is used to treat gastrointestinal disorders, including peptic ulcers (Megala, 2015). In the northwest region of Tamil Nadu, India, the fruit peel is used by locals to control diabetes, either by chewing it raw or drinking its decoction (Sukantha et al., 2011).In Haiti, root and bark decoctions are taken orally for diarrhea, while in Guiana, root bark is used for dysentery and as a febrifuge (Orwa et al., 2009).

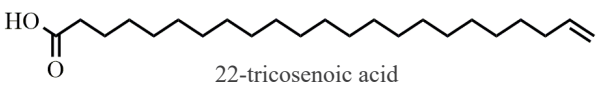
Phytochemistry:

Leaves: Dulcitol, octacosanol, α-spinasterol, kaempferol 3-O-rhamnoside, quercetin, afzelin (Zapesochnaya et al., 1980), kaempferol, coumaric acid, ferulic acid, luteolin 7-O-rhamnoside, quercetin 3-O-rhamnoside (Juarez et al., 2022).

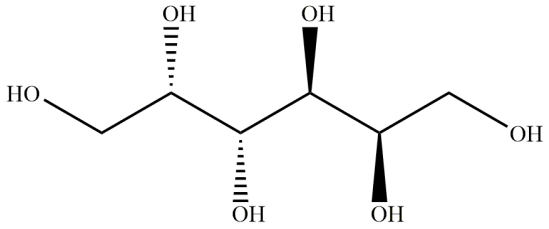
Fruit: 2, 5, 6-trimethyl 1, 3-oxathiane, trans-3-methyl-2-N-propylthiophane, 2- carboxaldehyde-5-(hydroxymethyl), D-pinitol, heptacosanoic acid, hexadecanoic acid, tetracosanol, 22-tricosenoic acid, methyl-2-hydroxy icosanoate, stigmasterol (Preethi and Saral, 2014).

Seeds: Valine, histidine, threonine, leucine, tyrosine (Singhal, 2014), D-turanose, hexadecanoic acid, indole-1-acetic acid, inositol, octadecanoic acid (Aldarhami et al., 2023); D-turanose, hexadecanoic acid, indole-1-acetic acid, inositol, octadecanoic acid, heptadecanoic acid, myo-inositol, altronic acid,11-eicosenoic acid, 9-octadecenoic acid, elaidic acid, hexanoic acid, 9,10-dihydrooctadecanoic acid, azelaic acid, octadecanoic acid, 9,12-octadecadienoic acid (Aldarhami et al., 2023, Kumari, 2017, Khanzada et al., 2023)

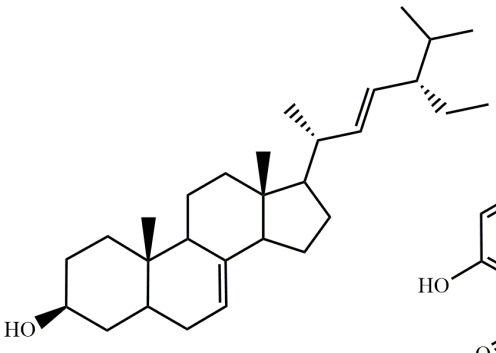
Fruit Peel: Stigmasterol, sitosterol, quercetin, D-pinitol (Sukantha and Shubashini, 2015).



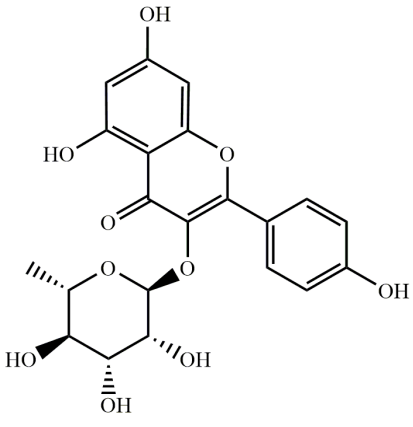
22-tricosenoic acid



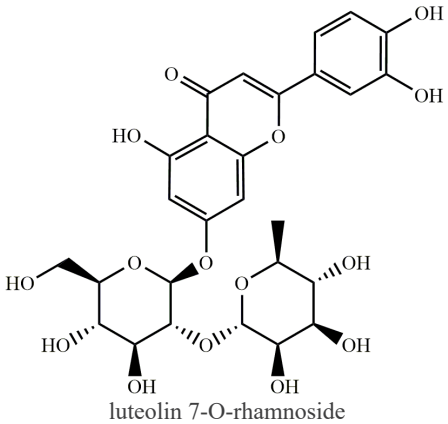
Dulcitol



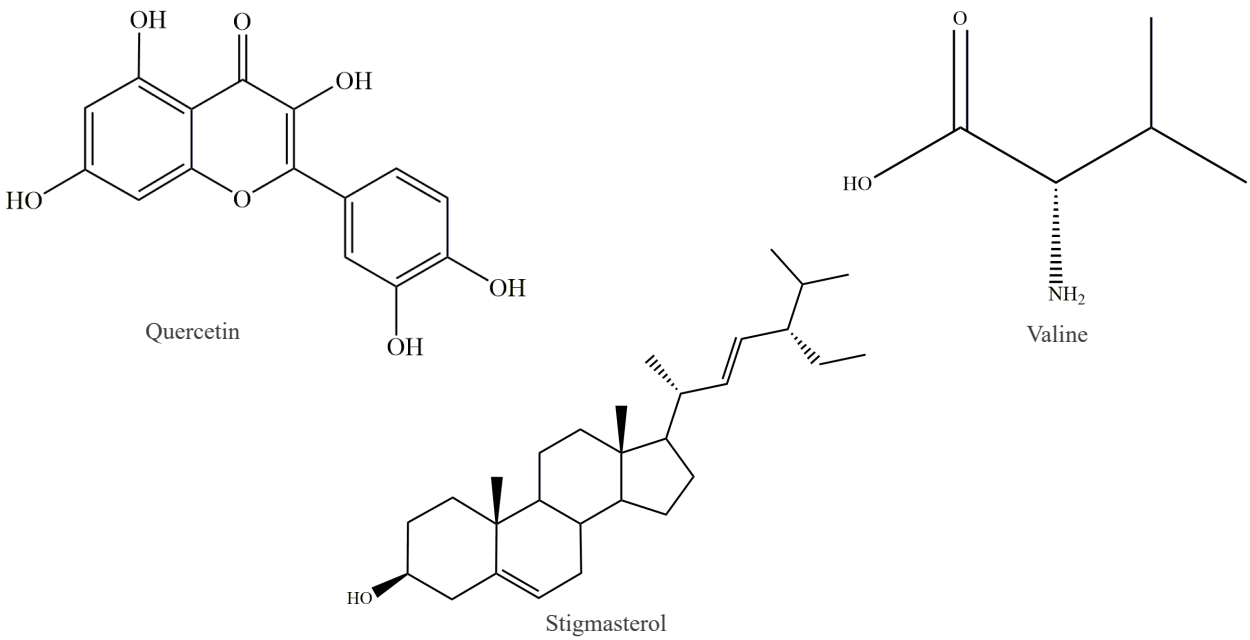
β-spinasterol



Kaempferol-3-rhamnoside



luteolin 7-O-rhamnoside



Structures of Important and Characteristic Chemical Constituents of *Pithecellobium dulce*

Biological Activity:

Anti-inflammatory activity: The ethanol extract of *P. dulce* demonstrated 62.80% inhibition of protein denaturation and 59.25% HRBC membrane stabilization, compared to the standard drug Aspirin (Kalavani et al., 2016). Additionally, both ethanol and aqueous leaf extracts of *P. dulce* exhibited significant anti-inflammatory activity in a carrageenan-induced paw edema model in rats. The aqueous extract showed greater efficacy, comparable to the standard anti-inflammatory drug diclofenac sodium (Sugumaran et al., 2009).

Anti-microbial activity: The leaf extract of *P. dulce* was analyzed using the agar well diffusion technique against a range of Gram-positive bacteria (*Bacillus subtilis, Enterococcus faecalis, Micrococcus luteus, Staphylococcus aureus, Staphylococcus epidermidis*), Gram-negative bacteria (*Aeromonas hydrophila, Alcaligenes faecalis, Enterobacter aerogenes, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Salmonella typhimurium*), and pathogenic fungi (*Aspergillus flavus, Aspergillus niger, Aspergillus oryzae, Aspergillus terreus, Alternaria alternata, Alternaria brassicicola, Alternaria solani, Alternaria vitis*). The results indicated that the plant contains phytochemicals with antimicrobial activity (Kumar et al., 2013). Additionally, different extracts of *P. dulce* bark were tested for antimicrobial activity, showing effectiveness against pathogenic microbes, with higher activity observed against fungal strains compared to bacterial strains (Kumar and Nehra, 2014).

Antibacterial activities: The ethyl acetate extract of *P. dulce* fruit peel was found to be effective against *Staphylococcus epidermidis, Escherichia coli, Klebsiella pneumoniae, Staphylococcus aureus, Enterococcus faecalis, Pseudomonas aeruginosa,* and *Pseudomonas putida*. The methanolic extract was active against *K. pneumoniae, S. aureus,* and *P. putida*, while the aqueous extract was effective against *K. pneumoniae* and *S. aureus* only. The petroleum ether extract showed activity only against *P. putida*. The results also indicated that the peel extracts, particularly the methanol, ethyl acetate, and aqueous extracts, exhibit strong antioxidant activity by quenching DPPH radicals (Sukantha et al., 2011).The pod pulp extract of *P. dulce* demonstrated effective inhibitory activity against the Gram-positive bacterium *Bacillus subtilis* and the Gram-negative bacterium *Klebsiella pneumoniae*. *B. subtilis* showed a larger clearance zone compared to other Gram-positive bacteria, and *K. pneumoniae* showed the largest clearance zone among Gram-negative bacteria (Pradeepa et al., 2014). Additionally, hexane, benzene, ethyl acetate, and ethanol extracts of *P. dulce* root were evaluated for antibacterial activity against Gram-positive *Staphylococcus aureus* and Gram-negative

Acetobacter aceti, Klebsiella pneumoniae, and *Enterobacter aerogenes*. These extracts exhibited significant antibacterial activity (Bhat et al., 2018).

Antioxidant activities: The antioxidant activity of *P. dulce* leaf extract was evaluated using different solvents (acetone, methanol, and water) through assays analyzing phenolic content, FRAP, DPPH, and nitric oxide radical scavenging activity. The extract contained phenolic compounds like alkaloids, terpenoids, phlobatannins, coumarins, tannins, and flavonoids, with the methanol extract showing the highest content. The IC_{50} values for FRAP, DPPH, and nitric oxide radical scavenging assays were reported as 72.17, 13.70, and 50.7 for acetone; 49.77, 74.89, and 35.7 for methanol; and 91.5, 67.41, and 81.80 for water extracts, confirming the antioxidant and antifungal activities (Kumari, 2017). Additionally, methanol and 70% acetone extracts of *P. dulce* wood bark and leaves were assessed for antioxidant activity, revealing significant total antioxidant capacity with high phenolic and flavonoid content (Shankar, 2014). The methanol extract of *P. dulce* leaves was further analyzed for antioxidant activity in Ehrlich ascites carcinoma (EAC) cells. The isolated compound, kaempferol-3-O-α-L-rhamnoside, inhibited AAPH-induced oxidation in DNA, human erythrocyte models, and lipid peroxidation, and demonstrated strong DPPH radical scavenging activity, indicating significant antioxidant potential (Akter et al., 2022).

Anti-tumor activity: The methanol extract of *P. dulce* leaves was evaluated for anti-tumor activity against Ehrlich ascites carcinoma (EAC) cells by assessing viable tumor cell count, hematological profiles, and morphological changes in experimental mice. The isolated compound, kaempferol-3-O-α-L-rhamnoside, demonstrated significant anti-tumor activity (Akter et al., 2022)

Anti-cancer activity: The seed extract of *P. dulce* was studied for its impact on apoptosis, cell cycle, migration, and inflammation in LoVo colorectal cancer cells. The extract demonstrated significant anti-cancer activity by inducing apoptosis, causing cell cycle arrest, and reducing cell migration. Additionally, it suppressed key cancer-related genes such as *MMP2*, *MMP9*, and *IL-8*, while upregulating pro-apoptotic genes like *BAX* and *P53* (Alhamed et al., 2023).

Anti-diabetic activities: In alloxan-treated rats, there was a significant increase in blood glucose, cholesterol, and triglyceride levels. Oral treatment with 200 mg/kg and 400 mg/kg of hydroalcohol extract of *P. dulce* bark significantly reduced these levels, comparable to the standard drug glibenclamide. Additionally, oral administration of *P. dulce* fruit extract (300 mg/kg/day) to diabetic rats for 30 days significantly reduced blood glucose, glycosylated hemoglobin, urea, and creatinine levels. The altered serum aminotransferases and alkaline phosphatase levels were normalized, and plasma protein, insulin, and hemoglobin levels were elevated to near normal. The glycogen content also improved, indicating the fruit extract's non-toxic and anti-diabetic nature (Pradeepa et al., 2013). Furthermore, the methanol extract of *P. dulce* seeds was evaluated in streptozotocin-induced diabetic male Wistar rats, showing a significant decrease in fasting blood glucose and HbA1C, along with an increase in body weight, serum insulin, total protein, and liver glycogen levels. This suggests the extract's antihyperglycemic, antihyperlipidemic, and antioxidant potential (Nagmoti et al., 2015). Similarly, *P. dulce* leaves were analyzed for anti-diabetic activity in alloxan-induced diabetic rats, where aqueous and ethanol extracts significantly reduced blood glucose, triglycerides, total cholesterol, urea, uric acid, creatinine, AST, and ALT levels, demonstrating the plant's anti-diabetic potential (Mule et al., 2016)

Anticonvulsant activities: The anticonvulsant activity of the crude flavonoid fraction from *P. dulce* leaves (CFFPD) was evaluated using subcutaneous Pentylenetetrazole (PTZ) and Maximal Electroshock Test (MES) models in rats. The CFFPD significantly reduced the duration of hindleg extension and delayed the onset of convulsions in both models (Divya and Babu, 2013). Additionally, the ethanol and aqueous leaf extracts of *P. dulce* were studied for anticonvulsant activity using MES-induced seizures in rats. Both extracts significantly reduced the duration of the extension phase, with the aqueous extract showing results comparable to phenytoin sodium, a standard antiepileptic drug (Sugumaran et al., 2008)

Cardioprotective activities: The cardioprotective effects of ethanol and aqueous extracts of *P. dulce* fruit were evaluated in rats subjected to isoproterenol

(ISO)-induced biochemical and histopathological changes. ISO-induced rats showed a significant increase in the activities of marker enzymes such as serum glutamate pyruvate transaminase (SGOT), serum glutamic-oxaloacetic transaminase (SGPT), creatine phosphokinase (CPK), and lactate dehydrogenase (LDH). Pretreatment with *P. dulce* fruit peel extracts positively altered the activities of these marker enzymes and improved biochemical parameters (Thangarajan et al., 2014). Similarly, aqueous extracts of *P. dulce* fruit and flowers reversed ISO-induced cardiac damage, showing effects comparable to the standard cardioprotective agent, Verapamil (Bhavani et al., 2014).

Anti-diarrhoeal activity: The ethanol and aqueous leaf extracts of *P. dulce* were evaluated for anti-diarrheal activity using a castor oil-induced diarrhea model in Wistar albino rats. Both extracts significantly reduced the frequency and wetness of feces compared to the control group, with the aqueous extract showing more pronounced effects than the ethanol extract (Thangarajan et al., 2014). In another study, the ethanol extract of *P. dulce* was found to be nearly as effective as the standard antidiarrheal drug Loperamide, reducing diarrheal droppings by 70.90% compared to 70.94% by Loperamide. The extract significantly ($P<0.01$) decreased the number of wet feces and total feces in a dose-dependent manner (Venu et al., 2016).

Larvicidal and ovicidal activities: The larvicidal and ovicidal potential of crude extracts from *P. dulce* leaves and seeds, prepared using hexane, benzene, chloroform, ethyl acetate, and methanol, was assessed against the filariasis vector mosquito *Culex quinquefasciatus*. The methanol extract proved most effective, with LC_{50} and LC_{90} values of 164.12 mg/L and 214.29 mg/L for leaves, and 289.34 mg/L and 410.18 mg/L for seeds, respectively, after 24 hours of exposure. Methanol was followed in efficacy by ethyl acetate, chloroform, benzene, and hexane extracts. Complete mortality was achieved at 500 mg/L for leaf and 750 mg/L for seed methanol extracts (Marimuthu and Mohan, 2014). Similar larvicidal effects were observed against *Anopheles stephensi* and *Aedes aegypti*, indicating the potential of *P. dulce* seed extracts as eco-friendly mosquito control agents (Govindarajan et al., 2013). Additionally, a hydroalcohol extract of *P. dulce* leaves demonstrated significant ovicidal activity against *Haemonchus contortus* eggs, suggesting the presence of bioactive compounds that inhibit egg hatching (Juarez et al., 2022).

Anti-obesity: The anti-obesity effects of petroleum ether, ethyl acetate, and methanol extracts from the peel of *P. dulce* were evaluated in high-fat diet (HFD) induced obese rats. Orlistat (50 mg/kg) was used as the standard drug. The study assessed anti-obesity activity based on body weight gain, food intake, organ fat pads, and liver and kidney weights. The results indicated that all three extracts demonstrated potential anti-obesity effects (Jagadeeshwar et al., 2021).

Antiulcerogenic activity: *P. dulce* has been reported to exhibit proton pump inhibitor-like activity. In rats pre-treated with *P. dulce*, the expression of MUC6 and MUC2 genes in the gastric and duodenal mucosa was significantly higher ($P<0.05$) compared to disease models. This indicates an upregulation of these gastro-protective proteins, similar to the control animals. Additionally, Western blot and densitometric analysis showed downregulation of the H+, K+-ATPase β subunit in the gastric mucosa of the control, gastric ulcer model, drug control, and drug pre-treated groups (Megala, 2015).

Antifungal Activity: The minimum inhibitory concentration (MIC) of the extract against tested fungi was determined through solvent fractionation. For *Aspergillus fumigatus*, the MIC was 0.62 mg/ml, and for *Aspergillus niger*, it was 1.25 mg/ml. These results were comparable to the effective synthetic drug Amphotericin B (Kumari, 2017). A lysozyme was isolated, purified, and identified from *P. dulce* seeds using chromatography and tandem mass spectrometry with Mascot database searching. The lysozyme had a molecular mass of 14.4 kDa, closely resembling the 14.3 kDa mass of chicken egg white lysozyme and showing high partial amino acid sequence similarity. The plant lysozyme also exhibited antifungal activity against *Macrophomina phaseolina* and demonstrated high thermal stability, maintaining activity at up to 80°C for 15 minutes (pH=8.0) (Sawasdipuksa et al., 2011).

Anti-venom activity: Polyphenols from the aqueous extracts of *Pentace burmanica*, *Pithecellobium dulce*, *Areca catechu*, and *Quercus infectoria* were evaluated for their ability to inhibit *Naja kaouthia*

(NK) venom using an in vitro neutralization method. The first three extracts completely neutralized the venom's lethality at a 4 LD50 concentration and inhibited its necrotizing activity at the minimum necrotizing dose. Additionally, they reduced up to 90% of NK venom's acetylcholinesterase activity at lower tannin concentrations compared to *Quercus infectoria*. The effective dose (ED50) of plant tannins in inhibiting NK venom activity varied based on the type and concentration of tannins present in the extracts. The anti-venom activities of these plant polyphenols are thought to occur through selective blockade of nicotinic acetylcholine receptors and non-selective precipitation of venom proteins. (Pithayanukul et al., 2005).

Toxicology: The hydroalcohol extract of *P. dulce* stem bark was assessed for acute and sub-acute toxicity in Wistar rats. A dose of 5 g/kg did not induce mortality or signs of acute toxicity. The findings suggest that the extract is relatively safe for oral administration in rats, though it may have a mild atrophic effect on female reproductive organs (Toudji et al., 2017).

Patents:

- Quorum sensing inhibitor from the bark of *Pithecellobium dulce* (kamatsile) and the process of making thereof, Patent No: PH12018000156A1
- Anti-carcinogenic extract from Pithecellobium dulce, Patent No: 2972/DEL/2011
- Extracts of *Pithecellobium dulce* (benth) fruit peel and use thereof as anti-diabetic formulation, Patent No: 2844/che/2013
- Method of extracting bioactive compounds with antidiabetic and anticancer activity from pods of *Pithecellobium dulce*, Patent No: 201741034217
- Development of antioxidant-rich muffin cake from manila tamarind (*Pithecellobium dulce*) pulverize, Patent No: 202211067291

Scope of Further R&D: The scope for further research and development (R&D) on *Pithecellobium dulce* is promising, given its rich ethnobotanical history and diverse phytochemical composition. Its traditional uses in treating ailments such as earaches, ulcers, and inflammation highlight its potential as a source of natural therapeutic agents. The plant's various parts, including leaves, fruit, seeds, and bark, contain bioactive compounds which exhibit significant biological activities. Future R&D could explore the isolation and characterization of novel compounds from *P. dulce*, investigate their mechanisms of action, and develop standardized extracts for use in pharmaceuticals, nutraceuticals, and cosmetics. Additionally, given the plant's adaptability to various climates and regions, studies on its cultivation and sustainable harvesting practices could enhance its availability for commercial applications.

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Prinsepia utilis Royle

Synonym:
Cycnia spinosa Griff.

Local/Common/Popular Name(s):
Himalayan cherry

Vernacular Names:
Hindi: Bekkra, Bhekal, Cherara, Dhatila, Jhatela, Karnga, Krungora, ***Himachal Pradesh:*** Arund, Bekkli, Garandu, Gurinda, Kharngura, Phulwara, Tatua, ***Garhwal:*** Bhekor, Burkhui, Bhikal, Bekkra, Datelo, ***Jaunsar:***Bhekoi, Bhek; Khasi- Sohmon-Rit, Dieng-Sia-Soh-Kher

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Rosales
Family	:	Rosaceae
Genus	:	*Prinsepia*
Species	:	*Prinsepia utilis*

Botanical Description: *P. utilis* is a thorny shrub growing up to 3 m in height (The Wealth of India, 1976). The average circumference of the thickets is 4-6m and are profusely branching above the ground. The bark is rough pinkish or gray which exfoliates in thin papery strips. The stem is green about 6cm in diameter with stout prickles (Maikhuri et al, 1994). The leaves are elliptical or lanceolate up to 12.5cm in length and the flowers are white to yellowish (The Wealth of India, 1976), 0.5-0.8cm in diameter occurring in axillary racemes with cup-shaped calyx. The fruit is usually relatively small, cylindrical with about 12-15mm in length and 18-20mm in diameter, pointed to one edge, and somewhat bell-shaped. The large peanut-sized seeds of length 8-10mm and diameter 12-14mm contain a well-developed endosperm rich in oil and protein (Maikhuri et al, 1994).

Distribution: *P. utilis* is a deciduous shrub growing in uncultivated land found beside brooks and in bushes up to 1000-3000m above sea level, mainly in Yunnan, Sichuan, Tibet (Xie, 1975; Guan et al., 2013; Guan et al., 2014). It is also found in India, Bangladesh, Taiwan, and China (Gupta et al., 2015). In India, it is found in Garhwal Dehradun, Near Kathyan Chakrata Forest Division, Hill sides above mussoorie 5560ft, Triyuginarayan village in Rudraprayag district, Uttarakhand, Tehri Garhwal to Bekal 6000ft, Mussoorie on the way to kamptee fall 5500ft, Garhwal Dehradun, Near Ghala Uttarkashi Forest division Tehri Garhwal India, Mussorie On the way to municipal Garden 6500ft, Way to Kyunkaleshwar Mahadev Temple located in Pauri Garhwal 2000m, Chakrata 7300ft, Chopdiyal near Chamba (Garhwal), Jankichalti (Uttarkashi distt), Basarkhet (Almora Distt), Naintital (Kumaon), Lilam (Kumaon), Narkachiyatal (Kumaon), The mall Road (Mussoorie), Loharkhet (Kumaon), Lambgaon (Tehri Distt), (Mussoorie), Munciari (Kumaon), Near lanka bridge (Uttarkashi), Pangusosa path (Pithoraghar Distt), Lilam (Kumaon), On The way to Seema (Dehradun), Company garden area (Mussoorie), Dhanaulti 2440m (Tehri Distt), Pithoragarh 1800m, Rathi (Kumaon), Loay to Jakhmolla (Garhawal), Okhimath, Mussoorie Champawat (Kumaon), Company garden (Mussoorie), Khirsu 1800m

(Pauri Distt), Loay to Jakhmolla (Garhawal), Sobla sela (Pithoragarh Distt), Loharkhet (Kumaon), Anjanisen 1600 -2000m (Tehri Distt), Dungri (Almora), Dinapadni 1859m, Bhyundar Valley (Garhwal), Anusuyia Area (Garhwal), Sitapur (Garhwal), Pithoragarh, Kimari (Garhwal) regions of Uttarakhand. It is also found between Kulel & musroond Chamba 4000ft, Pulga Kullu Valley, Shimla, Shimla, Kufri (Shimla), Geori (Himachal Pradesh), On hill opposite (HP), Road to shilt (HP), Way to Bir (HP), Kasol regions of Himachal Pradesh and in Batote J&K State, Ramban (Kashmir), Bhadrawah 1800-2000m, Bahramgao 200-2500m (Kashmir), Jai road Bhderwah (J&K), Kote (J&K), Dinapam 1859m, Sudhamadev (Udhampur Distt) in Jammu and Kashmir. (FRI and BSI Records).

Habitat: *Prinsepia utilis* is commonly found in temperate to sub-temperate regions of the Himalayas, typically at elevations ranging from 1000 to 3000 meters above sea level. It thrives in open, sunny habitats such as forest margins, scrublands, rocky slopes, and along roadsides. The species prefers well-drained soils and is tolerant of dry, stony conditions, making it well-adapted to disturbed or degraded sites. It is native to countries like India, Nepal, Bhutan, and China.

Ethnobotanical Significance: *P. utilis* has been utilized in Chinese and Indian folk medicine to treat skin diseases, (Jiangsu, 1977), inflammation (Weckerle et al., 2006; Dafni, 2007; Guan et al., 2014), and leprosy (Guan et al., 2014). The roots and seeds are used in the treatment of diarrhea and stomachache (Malik et al., 2015). The seed oil is particularly beneficial for human health and medical therapy (Wang et al., 2013). The oil also finds uses as a medicine, food, and cosmetics additive (Ruan, 2001). A paste of the oil cake is used to treat ringworm or eczema and warm oil is applied to treat body aches (Manandhar, 1995). The oil is also used as a medicine to treat joint pains, rheumatism, and pains resulting from over-fatigue (The Wealth of India, 1976; Negi, 1986; Maikhuri et al, 1994), and it is also potentially effective for high blood pressure and atherosclerosis (Gupta et al., 2015). Leaves and seed oil of *P. utilis* are traditionally used in rheumatic pain, arthritis, analgesics, bone disorders, and joint ailments. The roots and seed oil are used in arthritis (Gautam et al., 2007). The oil extracted from *P. utilis* seed is consumed in the winter season because it keeps the body warm. The mild heated oil is also used for massages specifically for newborn children. It is also reported to be suitable for hydrogenation and soap making, used as a source of fuel wood and fodder, and for erosion control and bio-fencing. The oil is used as fuel in the absence of kerosene in Urgamvelley of the Himalayas (Maikhuri et al, 1994).

Phytochemistry:

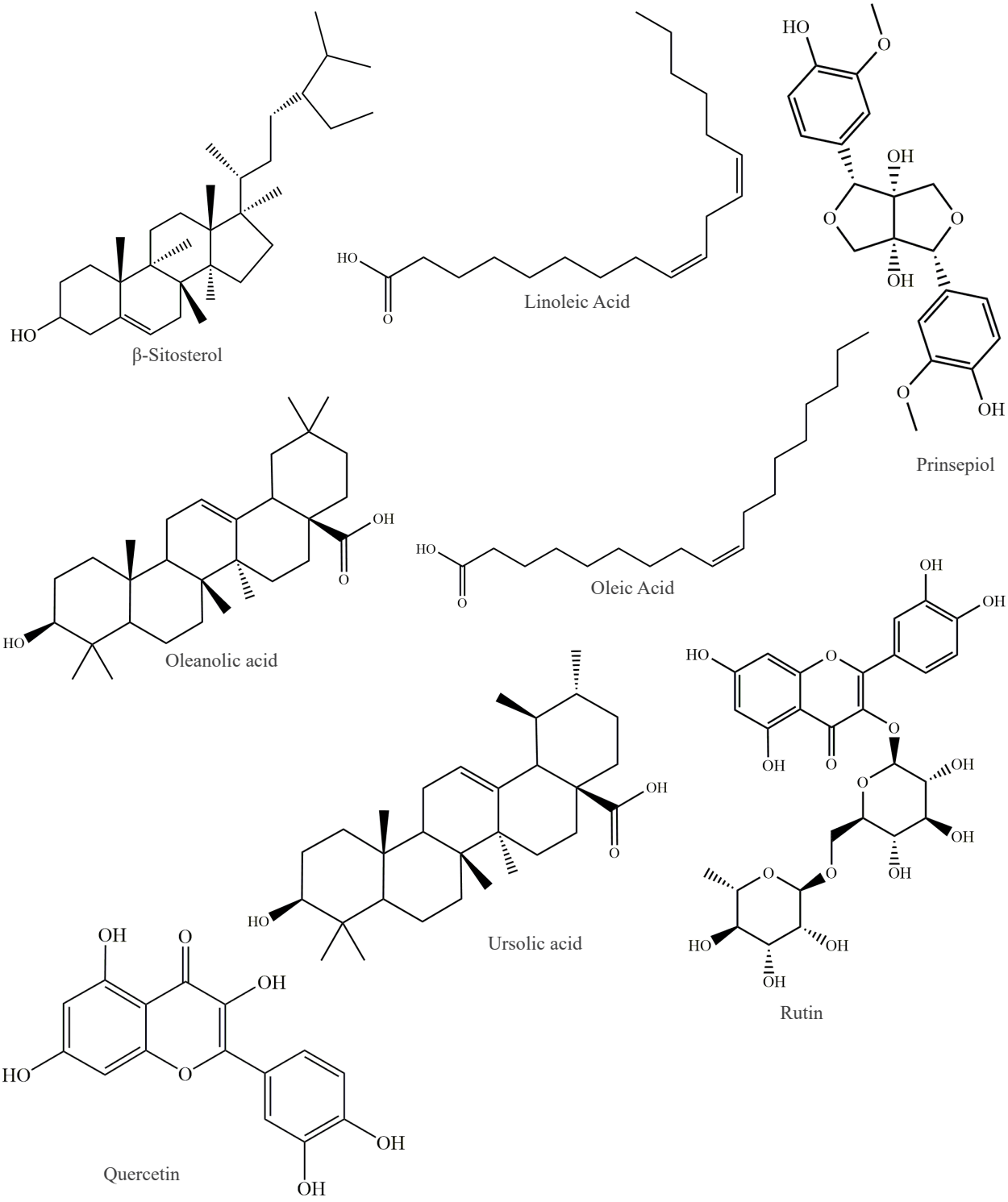
Aerial parts: 2α-O-trans-p-coumaroyl-3β,19α-dihydroxy-urs-12-en-28-oic acid, 2α-O-cis-p-coumaroyl-3β,19α-dihydroxy-urs-12-en-28-oicacid (Guan et al., 2013), 3-O-trans-p-coumaroyl tormentic acid, 3-O-cis-p-coumaroyl tormentic acid (Numata et al., 1989), 3-O-trans-p-coumaroyl-2α-hydroxyursolic acid, 3-O-cis-p-coumaroyl-2α-hydroxyursolic acid (Häberlein and Tschiersch, 1994), 3-O-trans-p-coumaroylmaslinic acid, 3-O-cis-p-coumaroylmaslinic acid (Akira et al., 1978), ursolic acid (Tundis et al., 2002), oleanolic acid (Wang, 2008).

Leaves: β-sitosterol, prinsepiol, ursolic acid (The Wealth of India,1962; Gupta et al.,2015), (+)-(2R,3S)-2-chloro-3-hydroxy-3-methyl-γ-buty-rolactone (Yang et al., 2008), utililactone, epiutililactone, corosolic acid, maslinic acid, pomolic acid, tormentic acid, oleanolic acid**,**cecropiacic acid, 3-O-trans-p-coumaroyltormentic acid, 3-O-cis-p-coumaroyltormentic acid (Xu et al., 2007). Limonene, 1-8-cineole, o-cymene, bergamal, cis-linalool oxide, cis-sabinene hydrate, linalool, trans-terpineol, 2-undeca-none, isomenthol, α-terpineol, 2-dodecanol, tridecanone (Rai et al., 2003).

Seeds: Hydrocyanic acid (Plouvier, 1948; Fikenscher et al., 1981), Prinsoside A, Prinsoside B, Prinsoside C (Zhang et al., 2015), Prinsepicyanoside A, Prinsepicyanoside B, Prinsepicyanoside C, Prinsepicyanoside D, Prinsepicyanoside E (Guan et al., 2014), Osmaronin (Lechtenberg et al., 1994; Guan et al., 2014), quercetin 3-O-b-D-glucoside (Lei et al., 2012; Guan et al., 2014), quercetin 3-O-b-D-rutinoside(Wang et al., 2001; Guan et al., 2014), p-hydroxybenzoic acid(Chen et al., 1999; Guan et al., 2014), 3,4-dihydroxybenzoic acid (Zhang et al., 1998; Guan et al., 2014), β-sitosterol(Guan and Zhao, 2007; Guan et al., 2014), daucosterol(Liang et al., 2008; Guan et al., 2014), dimethyl 2-methylsuccinate (Hargrave et al., 2006; Guan et al., 2014), monoethyl oxalate(Yamasaki et al., 1977; Guan et al., 2014)4-(hydroxylmethyl)-5H-furan-

2-one (Lalonde et al., 1990; Guan et al., 2014) palmitic acid, dimethyl 2-methylsuccinate,myristic acid,oleic acid,linoleic acid,stearic acid,lignoceric acid,vaccenic acid**,** Palmitoleic acid, Linolenic acid, Arachidic acid, Erucic acid

Fruits: Protocatechuic acid, Coumaric acid, Kaempferol-3-O-glucoside, Kaempferol-3-O-rhamnosylhexose, Dihydroquercetinrhamnoside, Catechin, Isoschaftoside, Rutin, Quercetin-3-O-glucoside, Quercetin 3-(6-O-acetyl-beta-glucoside),Isorhamnetin-3-O-rutinoside, Kaempferol-3-O-hexoside,Isorhamnetin-3-O-glucoside, Cyanidin-3-O-glucoside, Cyanidin-3-O-rutinoside**,** Peonidin-3-O-sophoroside-5-glucoside, Delphinidin-3-O-rutinoside, Petunidin-3-O-glucoside, Peonidin-3-O-rutinoside



Structures of Important and Characteristic Chemical Constituents of *Prinsepia utilis*

(Zhang et al., 2018). Rutin, quercetin-3-O-glucoside, isorhamnetin-3-O-rutinoside, Cyanidin-3-O-glucoside, cyanidin-3-O-rutinoside (Zhang et al., 2018).

Stem: Prinsepiol, L-epicatechin, β-sitosteryl-β-glucoside (Kilidhar, 1982) quercetin, eriodictyol, kaempferol, (+)-catechin (Yang et al., 2015).

Seeds: Myristic acid, oleic acid, linoleic acid, palmitic acid, stearic acid, lignoceric acid, resin acid (The Wealth of India, 1976).

Pharmacology:

Antioxidant activity: The antioxidant activity of *P. utilis* fruits, using DPPH, ABTS, and intracellular ROS inhibition methods were evaluated in total phenolic fraction (TPF), flavonoid fraction (FF), and anthocyanin fraction (AF). A stronger DPPH radical scavenging activity in the flavonoid fraction was observed than in the total phenolic and anthocyanin fractions. The IC_{50} values of TPF, FF, and AF were 4.72 ± 0.31 µg/mL, 2.46 ± 0.11 µg/mL, and 4.20 ± 0.14 µg/mL, respectively. The fractions also exhibited ABTS radical scavenging activity. The IC_{50} values of TPF, FF, and AF were 3.45 ± 0.48 µg/mL, 3.2 ± 0.26 µg/mL, and 2.93 ± 0.35 µg/mL, respectively. All three fractions also exhibited good inhibition of cellular reactive oxygen species (ROS) generation in H_2O_2-induced HepG2 cells, as evaluated by DPPH and ABTS assays (Zhang et al., 2018). Rutin extracted from *P. utilis* exerted good antioxidant activities, as evaluated by DPPH and ABTS radical scavenging assays with IC_{50} values of 29.63 µg/mL and 5.34 µg/mL, respectively (Patil et al., 2013). Anti-oxidant activity *in vitro* using the methanolic extract of *P. utilis* was determined by DPPH scavenging assay which showed prominent free radical scavenging potential(Gupta et al., 2015). The antioxidant activities of native and fermented seeds of *P. utilis* during digestion were also evaluated through DPPH and ABTS radical scavenging methods. The study showed that the fermentation with the three fungi (*A. oryzae* var. effuses, *R. oryzae*, and *R. oligosporus*) significantly increased the DPPH as well as ABTS radical scavenging activity of *P. utilis*Royle seeds ($p < 0.05$) (Huang et al., 2017). In another study, flowers, stems and leaves of *P. utilis* were evaluated for antioxidant activity using scavenging effects of DPPH and ABTS free radicals and ferric-reducing antioxidant power. The results revealed that the samples exhibited significant antioxidant activity and also inhibited the alpha-glucosidase, pancreatic lipase, and tyrosinase activity in a dose-dependent manner (Zheng et al., 2022).

Hypoglycemic activity: The hypoglycemic effect of flavonoids from *P. utilis* in alloxan-induced diabetic mice after oral administration of 300 mg/kg of flavonoids from *P. utilis* for four weeks was evaluated. It was observed that flavonoids from *P. utilis* had an influence on the body weight increase of diabetic mice in three weeks, but had no influence in the fourth week and significantly reduced GLU, TG, and AST levels in diabetic mice compared with the model control group ($P<0.01$), markedly reduced VLDL-C, ALT and BUN level in diabetic mice compared with the model control group ($P<0.05$), but had little influence on TC. Flavonoids can improve the hypothepatia of diabetic mice and have a protective effect on the renal function of diabetic mice (Jia et al., 2008).

Antimicrobial activity: Antimicrobial effects of extracts on eight pathogenic microorganisms using the water-soluble extract, of different parts, including seeds, roots, stems, and leaves from *P. utilis* under three conditions of water bath at 60℃ for 12 h, boiling 10 min and 20 min. It is shown that the antimicrobial effect could effectively increase by extending the extraction time. The minimal inhibitory concentration of seed extract was 0.125 g/ml (Zhang et al., 2007). The antibacterial characteristics of alkaloids from *P. utilis*, for the determination of the minimum inhibitory concentration and the minimum bactericidal concentration of *Prinsepia* on *Staphylococcus aureus*, *Escherichia coli*, *Shigella,* and *Candida albicans* have been studied. Results showed the minimum inhibitory concentration (MIC) of *P. utilis* Royle was 0.08 mg/mL, 0.625mg/mL, 1.25 mg/mL, 2.5 mg/mL, respectively, while the minimum bactericidal concentration (MBC) was 0.16mg/mL, 1.25 mg/mL, 2.5 mg/mL, 5 mg/mL, respectively (Sun et al., 2014). The alkaloids from *P. utilis* were analyzed for antibacterial activity using the dilution method for determining minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) on *Staphylococcus aureus, Escherichia coli, Shigella,* and *Candida albicans.* The MIC for *Staphylococcus aureus, Escherichia coli, Shigella,* and *Candida albicans* was determined to be 0.08, 0.635, 1.25, and 2.5 mg/mL respectively, and MBC for *Staphylococcus aureus,*

Escherichia coli, Shigella and *Candida albicans* was determined to be 0.16, 1.25, 2.5 and 5 mg/mL respectively. Therefore, the plant is deduced to exhibit antimicrobial activity (Sun et al., 2014).

Anti-inflammatory activity: The anti-inflammatory activity of methanolic flower extracts of *P. utilis* in Wistar rats was evaluated, which exhibited significant anti-inflammatory activity at both doses of 100mg/kg body weight (64.38% inhibition) and 200 mg/kg body weight (65.75%inhibition) (Thakur et al., 2018). A study on two chemical compounds, tetra triacontanol and ursolic acid obtained from *P. utilis* showed anti-inflammatory activity (Wang et al., 2006). The methanolic flower extracts of *P. utilis* were evaluated in Wistar rats through carrageenan-induced rat pedal enema. The extract was found to exhibit significant anti-inflammatory activity at both doses of 100 and 200 mg/kg body weight and was comparable to standard, indomethacin. Therefore, it can be concluded that the plant possesses anti-inflammatory properties (Vinay et al., 2018).

Immunosuppressive effect: The isolated compounds, ursolic acid and pomolic acid showed a significant inhibitory effect ($P < 0.05$, n=6) on lymphocyte transformation (Xu et al., 2007).

Cytotoxic activity: The isolated compounds including, 2α-O-transp-coumaroyl-3β,19α-dihydroxy-urs-12-en-28-oic acid, O-trans-p-coumaroyltormentic acid, 3-O-cis-p-coumaroyltormentic acid, 3-O-trans-p-coumaroyl-2α-hydroxy ursolic acid, 3-O-cis-p-coumaroyl-2α-hydroxy ursolic acid, 3-O-trans-p-coumaroylmaslinic acid, 3-O-cis-pcoumaroylmaslinic acid, ursolic acid, and oleanolic acid from *P. utilis* exhibit significant cytotoxicity against four human cancer cell lines A549 (lung carcinoma), HCT116 (colon adenocarcinoma), MDA-MB- 231 (breast carcinoma), and CCRF-CEM (leukemia), especially against the CCRF-CEM cell line (by cell growth inhibition)(Guan et al., 2013).Another study on. *utilis* extraction in the treatment of cancer as it contained anti-cancer active substances, which can directly kill and act on cancer cells, *P. utilis* Royle Ext. was used in the preparation of a drug for inhibition of colon cancer cells CT-26 and inhibition of prostate cancer cells PC-3 growth, its toxic side effect is small, and exhibits good anticancer effect (Lin et al., 2016).

Antibacterial activity: The crude extracts (petroleum ether, ethanol, and water) of *P. utilis* were tested for antibacterial activity against the standard and drug-resistant bacteria strains *in vitro*. It was observed that ethanol extract and aq. extract of petroleum ether showed the weakest inhibition. MIC values of the aq. *P. utilis* showed significant effects against bacteria, while ethanol extracts against three standard bacteria (*S. aureus* ATCC25923, *E. coli* 44,102, *Salmonella* 50,041) were 25, 25, 50 mg/mL-1 and 50, 100, 100 mg/mL-1, MIC values of three drug-resistant bacteria (*S. aureus* GL17, *E. coli* EYAC08-56, *Salmonella* STQD2G.) were 50, 50, 50 mg/mL^{-1}, and 100, 100, 200 mg/mL^{-1}, resp. MBC values of two extracts against three standard strains were 25, 50, 100 mg/mL^{-1}, and 50, 100, 200 mg/mL^{-1}, while for three drug-resistant bacteria, MIC values were 100, 100, 100 mg/mL^{-1}, and 200, 200, 200 mg/mL^{-1}, respectively (Pu et al., 2010). To evaluate the antibacterial activities *in vitro* of the ethyl acetate extract of *P. utilis* by disc diffusion method. The bacterial strains *Staphylococcus aureus* ATCC25923, *Escherichia coli* ATCC44102, and *Salmonella sp.* CMCC (B) 50041 was used for the study and the result showed the antibacterial activity of active fractions separated from ethyl acetate extract of *P. utilis* Royle was better against *Staphylococcus aureus* ATCC25923 as compared to *Escherichia coli* ATCC44102 and *Salmonella sp*. CMCC (B) 50041 (Pu et al., 2014). The inhibition effect of *P. utilis* oil meal extracts on normal pathogenic bacteria and the effect of temperature, pH value, and ultraviolet light on its antibacterial activities were tested on *Staphylococcus aureus, E. coli,* and *Salmonella sp.* by the method of paper dispersion. The results showed that *P. utilis* oil meal extract had a good anti-bacterial effect (Cheng et al., 2009). Prinsepicyanoside A, osmaronin, and 4-(hydroxymethyl)-5H-furan-2-one exhibited borderline antibacterial activity against *Salmonella gallinarum, Vibrio parahaemolyticus*, and *Vibrio cholera* with MIC values of 30.1, 20.7, and 22.8 µg/mL, respectively (Guan et al., 2014). The aqueous, hexane, ethyl acetate, and methanol extracts of the leaf and seed of *P. utilis* were evaluated for antibacterial activity using the disc diffusion method. The ethyl acetate and hexane leaf extracts were found to exhibit strong antibacterial activity against *Staphylococcus epidermis* while methanolic leaf and seed extract exhibited strong antibacterial activity against *Staphylococcus aureus* and *K. pneumoniae* respectively. Therefore,

it can be deduced that the extracts exhibit potential antibacterial activity (Bagale et al., 2022).

***a*- Glucosidase Inhibitory Activity:** *a*-Glucosidase Inhibitory activities of Phenolic Fractions i.e. (TPF), (FF), and (AF) from *P. utilis* fruits were studied and showed the strongest inhibitory capacity in FF at each concentration ranging from 50.0 µg/mL to 250.0 µg/mL, followed by TPF ($p < 0.05$). The inhibition ratios of TPF and FF were more than 50% at 50.0 µg/mL. However, the AF showed the weakest inhibition. The IC50 values of the FF, TPF, and AF were 15.93 ± 0.63 µg/mL, 20.48 ± 0.37 µg/mL, and 149.06 ± 6.34 µg/mL, respectively showing a positive α -glucosidase inhibitory activities (Zhang et al., 2018). *P. utilis* peel and pulp extracts can be used as α -glycosidase inhibitors to prepare healthy food and drugs for reducing postprandial glucose. The study also stated that all extracts can effectively inhibit the hydrolysis of carbohydrates such as starch in the gastrointestinal tract and reduce the absorption of glucose (Cai et al., 2019).

Pancreatic lipase activity: *In vitro*, pancreatic lipase activity using an extract from the pericarp and pulp of *P. utilis*, showed that all the extracts can effectively inhibit the activity of pancreatic lipase, effectively inhibiting the hydrolysis and absorption of fat in the gastrointestinal tract (Cai et al., 2019).

Lipase inhibitory effects: Rutin, isorhamnetin-3-O-glucoside, and cyanidin-3-O-glucoside extracted from *P. utilis* fruits were tested for their lipase inhibitory effects, The IC50 values of rutin, isorhamnetin-3-O-rutinoside, and cyanidin-3-O-glucoside were 176.18 ± 5.11 µg/mL, 237.87 ± 8.20 µg/mL, and 249.20 ± 3.87 µg/mL, respectively (Zhang et al., 2018).

Osteoprotective effect: The leaves of the *P. utilis* Royle have a protective effect against induced osteoporosis and improved bone quality, attenuated bone resorption, enhanced the rate of bone formation, and restored bone density as studied by Gupta et al. (2015). The findings further suggested that the surgical removal of ovaries caused pathological changes similar to osteoporosis and produced a significant increase in bone density, bone strength, alkaline phosphatase activity, serum calcium, and serum phosphorous using *P. utilis* extracts 50, 100, and 200 mg/kg and a decrease in urine hydroxyproline levels, as compared to ovariectomized control rats (Gupta et al., 2015).

Commercial Products: The seed oil of *P. utilis* is one of the ingredients of cosmetic and skincare products such as serums, eye creams, and face masks (*Prinsepia utilis Seed Oil (with Product List)*, n.d.)

Patent:

- Method for extracting effective components from *Prinsepia utilis* royle, Patent No: CN109364132B
- *Prinsepia utilis* royle extract and preparation method and application thereof, Patent No: CN107308226B
- Preparation method of high-quality *Prinsepia utilis* royle oil suitable for cosmetic raw materials, Patent No: CN115261129A
- Preparation process of *Prinsepia utilis* royle oil with long oxidation induction time, Patent No: CN112175713A
- The preparation process of high stable *Prinsepia utilis* royle oil liposome and its application in cosmetics, Patent No: CN109589278A
- *Prinsepia utilis* royle oil meal fermentation liquor, preparation method thereof and application thereof in cosmetics, Patent No: CN109363984B
- A kind of *Prinsepia utilis* royle oil liposome and preparation method thereof, Patent No: CN109106657A
- Tender leaf extract of *Prinsepia utilis* royle and preparation method and application thereof, Patent No: CN105982979B
- Method for effectively reducing peroxide value of *Prinsepia utilis* royle oil, Patent No: CN104263508A
- *Prinsepia utilis* Royle oral nursing soft capsules, Patent No: CN101278994A
- Preparation method of total flavone extract of *Prinsepia utilis* royle, Patent No: CN108553527B
- A kind of extracting method of *Prinsepia utilis* royle oil composition, Patent No: CN109260057A
- A kind of high-content stable type *Prinsepia utilis* royle oil microemulsion and preparation method thereof, Patent No: CN106031705B
- Processing method of *Prinsepia utilis* royle oil, Patent No: CN110724591A
- Preparation process for *Prinsepia utilis* royle grease, Patent No: CN102628002A

- A kind of micro-capsule of *Prinsepia utilis* polysaccharide and its preparation method, Patent No: CN104027322B
- Massage oil containing *Prinsepia utilis* royle oil and preparation method thereof, Patent No: CN112274468A
- A kind of lipstick containing *Prinsepia utilis* royle oil and preparation method thereof, Patent No: CN104382813B
- *Prinsepia utilis* oil filtering device, Patent No: CN211435372U
- Screening machine is selected for use to *Prinsepia utilis* royle branch, Patent No: CN211412324U
- *Prinsepia utilis* oil squeezing device, Patent No: CN110696413A
- *Prinsepia utilis* royle soap and preparation method thereof, Patent No: CN105602768A
- *Prinsepia utilis* tea preparing method, Patent No: CN105230885A
- *Prinsepia utilis* royle oil filter, Patent No: CN203971504U
- *Prinsepia utilis* Royle tea preparation method, Patent No: CN103931829A
- *Prinsepia utilis* royle oil-containing composition and dispersing method and application thereof, Patent No: CN114469802A
- A method of quickly preparing *Prinsepia utilis* royle oil, Patent No: CN109022139A
- *Prinsepia utilis* royle tea preparation method, Patent No: CN105309696A
- Method for cultivating *Prinsepia utilis* royle, Patent No: CN106358917A
- Preparation method of *Prinsepia utilis* royle extract and cosmetics, Patent No: CN115040445A
- Preparation method of *Prinsepia utilis* royle oil and cosmetic, Patent No: CN114921284A
- Preparation of eurotiumcristatum solid-state fermented *Prinsepia utilis* tea and blood fat reducing product thereof, Patent No: CN106509252B
- Qualitative analysis method of flavones extract of stem and leaf of *Prinsepia utilis* royle and quantitative analysis method of schaftoside in extract, Patent No: CN113063869A
- Application of Wilkham yeast in preparing *Prinsepia utilis* extract, Patent No: CN116376731A
- Making process of *Prinsepia utilis* tea, Patent No: CN104430950A
- Preparation method of *Prinsepia utilis* royle oil, product thereof and application of *Prinsepia utilis* royle oil in hair products, Patent No: CN116376630A
- Skin-protecting and hair-protecting products containing *Prinsepia utilis* royle oil, Patent No: CN101199461A
- *Prinsepia utilis* royle oil ceramide and synthesis method and application thereof, Patent No: CN116003286A
- *Prinsepia utilis* royle container seedling raising method, Patent No: CN113348946A
- Low-fat pork ball with *Prinsepia utilis* protein high internal phase emulsion as fat substitute and preparation method thereof, Patent No: CN115152949A
- *Prinsepia utilis* royle foot soaking powder and manual manufacturing method thereof, Patent No: CN116270956A
- Preparation method and application of deodorized *Prinsepia utilis* royle oil, Patent No: CN115820338A
- Hair moisturizing composition containing *Prinsepia utilis* royle oil and preparation method and application thereof, Patent No: CN115919692A
- Cultivation method for increasing content of *Prinsepia utilis* royle essential oil, Patent No: CN113575160A
- Pickling method for improving taste and quality of pickled *Prinsepia utilis* royle, Patent No: CN114304566A
- Scar-removing and repair *Prinsepia utilis* royle and lithospermum essential oil and manual preparation method thereof, Patent No: CN116459308A
- *Prinsepia utilis* royle shell breaking machine, Patent No: CN211430978U
- A kind of *Prinsepia utilis* royle oil extraction element, Patent No: CN209260035U
- *Prinsepia utilis* royle puree cosmetic and preparation method and application thereof, Patent No: CN105919889A

- Application of *Prinsepia utilis* royle extract in preparation of medicines for treating skin allergy and allergic dermatitis, Patent No: CN112641833B
- *Prinsepia utilis* royle frying machine, Patent No: CN211431007U
- *Prinsepia utilis* royle fruit oil microsphere and preparation method thereof, Patent No: CN103933905A
- *Prinsepia utilis* material frying machine, Patent No: CN203976760U
- A kind of *Prinsepia utilis* royle oil extraction system, Patent No: CN107513477A
- Use of *Prinsepia utilis* royle oil on preparing products for treating mosquito sting, Patent No: CN101229249A
- Infant skin care oil containing *Prinsepia utilis* rogle oil and preparation method thereof, Patent No: CN103271842A
- Use of *Prinsepia utilis* royle oil for preparing baby buttocks care product, Patent No: CN101229108A
- Cold press of *Prinsepia utilis* royle, Patent No: CN211441285U
- A kind of lipstick containing *Prinsepia utilis* royle oil, Patent No: CN109419647A
- *Prinsepia utilis* Royle oil-containing functional skin care product and preparation method thereof, Patent No: CN102406576B
- A kind of *Prinsepia utilis* royle oil filter device, Patent No: CN208362286U
- Processing method of *Prinsepia utilis* flowers, Patent No: CN105412273A
- Multi-effect shampoo containing *Prinsepia utilis* rogle oil and preparation method thereof, Patent No: CN104306261A
- Use of *Prinsepia utilis* royle oil on preventing bedsore, Patent No: CN101229250A
- Health-care *Prinsepia utilis* royle food with function of reducing blood fat and preparation method thereof, Patent No: CN104489650A
- *Prinsepia utilis* royle tip pickles and preparation method thereof, Patent No: CN103549353A
- Application of *Prinsepia utilis* rogle oil in preparation of medicine for treating cancers, Patent No: CN105832844A
- Massage oil containing *Prinsepia utilis* royle oil and preparation method of massage oil, Patent No: CN103271852A
- Extraction process of *Prinsepia utilis* royle pigment, Patent No: CN107955393A
- *Prinsepia utilis* royle health food with blood sugar lowering function and preparation method of health food, Patent No: CN104256587A
- *Prinsepia utilis* royle ‘s cold squeezer, Patent No: CN205951338U
- *Prinsepia utilis* royle healthcare food with antioxidant function and preparation method thereof, Patent No: CN104397696A
- Application of gibberellin in promoting increase of quantity, growth and quality of spina in *Prinsepia utilis* Royle, Patent No: CN113767774B
- Functional food containing *Prinsepia utilis* royle and preparation method of functional food, Patent No: CN104223071A
- *Prinsepia utilis* royle ‘s breaker, Patent No: CN205949006U
- *Prinsepia utilis* royle granules capable of benefiting smooth and preparation method thereof, Patent No: CN112293735A
- Preparation method of high-quality *Prinsepia utilis* royle oil suitable for cosmetic raw materials, Patent No: CN115261129A
- Processing method of *Prinsepia utilis* flowers, Patent No: CN105412273A
- Qualitative analysis method of *Prinsepia utilis* royle stem leaf flavone extract and quantitative analysis method of schaftoside in *Prinsepia utilis* royle stem leaf flavone extract, Patent No: CN113063869A
- Method for extracting active ingredients in *Prinsepia utilis* and *Prinsepia utilis* extract gel, Patent No: CN109364132A
- Method for effectively reducing peroxide value of *Prinsepia utilis* royle oil, Patent No: CN104263508A
- *Prinsepia utilis* royle fruit extract, preparation method and applications thereof, Patent No: CN107308226A
- Application of *Prinsepia utilis* royle in anti-benign prostatic hyperplasia drug, Patent No: CN106177018A

- Use of *Prinsepia utilis* royle oil on preparing products for treating mosquito sting, Patent No: CN101229249A
- Composition containing *Prinsepia utilis* royle oil and dispersion method and application thereof, Patent No: CN114469802A
- Microcapsules of *Prinsepia utilis* royle polysaccharides and preparation method of microcapsules, Patent No: CN104027322A
- *Prinsepia utilis* royle tip pickles and preparation method thereof, Patent No: CN103549353A
- Use of *Prinsepia utilis* royle oil on preventing bedsore, Patent No: CN101229250A
- *Prinsepia utilis* royle soap and preparation method thereof, Patent No: CN105602768A
- *Prinsepia utilis* royle puree cosmetic and preparation method and application thereof, Patent No: CN105919889A
- *Prinsepia utilis* roylelipido some and preparation method thereof, Patent No: CN109106657A
- Preparation method and application of deodorized *Prinsepia utilis* royle oil, Patent No: CN115820338A
- Container seedling raising method for *Prinsepia utilis* royle, Patent No: CN113348946A
- Preparation process of *Prinsepia utilis* royle oil with long oxidation induction time, Patent No: CN112175713A
- Preparation of eurotiumcristatum solid-state fermentation tender *Prinsepia utilis* royle stem and leaf tea and prepared products capable of reducing blood lipid, Patent No: CN106509252A
- Preparation process for high-stability *Prinsepia utilis* royle liposome and application of high-stability *Prinsepia utilis* royle liposome in cosmetics, Patent No: CN109589278A
- Cultivation method for increasing essential oil content of *Prinsepia utilis* royle, Patent No: CN113575160A
- Application of *Prinsepia utilis* rogle oil in preparation of medicine for treating cancers, Patent No: CN105832844A
- *Prinsepia utilis* royle health food with blood sugar lowering function and preparation method of health food, Patent No: CN104256587A
- Infant skin care oil containing *Prinsepia utilis* rogle oil and preparation method thereof, Patent No: CN103271842A
- Single plant *Prinsepia utilis* selfing method, Patent No: CN114731946A
- Tender leaf extract of *Prinsepia utilis* as well as preparation method and applications of tender leaf extract, Patent No: CN105982979A
- Health-care *Prinsepia utilis* royle food with function of reducing blood fat and preparation method thereof, Patent No: CN104489650A
- Preparation method of *Prinsepia utilis* royle extracting solution and cosmetics, Patent No: CN115040445A
- High-content stable *Prinsepia utilis* royle oil microemulsion and preparation method thereof, Patent No: CN106031705A
- Lipstick containing *Prinsepia utilis* oil, Patent No: CN109419647A
- Skin care essential oil containing *Prinsepia utilis* royle oil and preparation method thereof, Patent No: CN106236646A
- Application of *Prinsepia utilis* royle peel and pulp extract, Patent No: CN109222099A
- *Prinsepia utilis* Royle oral nursing soft capsules, Patent No: CN101278994A
- Screening machine for *Prinsepia utilis* royle sorting, Patent No: CN211412324U
- Application of *Prinsepia utilis* royle pericarp and pulp extract, Patent No: CN109364131A
- *Prinsepia utilis* royle loading attachment that grows seedlings, Patent No: CN207340878U
- *Prinsepia utilis* royle extract cake fermentation broth, as well as preparation method and application in cosmetics thereof, Patent No: CN109363984A
- Preparation method for extract of total flavonoids in kernel of *Prinsepia utilis*, Patent No: CN108553527A
- Functional food containing *Prinsepia utilis* royle and preparation method of functional food, Patent No: CN104223071A
- *Prinsepia utilis* royle ozone oil drug for removing senile plagues and preparation method of *Prinsepia utilis* royle ozone oil drug, Patent No: CN107595880A

- Multi-effect shampoo containing *Prinsepia utilis* rogle oil and preparation method thereof, Patent No: CN104306261A
- Drug for treating haemorrhoids by utilizing *Prinsepia utilis* royleozonization oil and preparation method, Patent No: CN107343894A
- Foot pad support with bionic *Prinsepia utilis* vein structure, Patent No: CN115072009A
- Squeezing die for *Prinsepia utilis* royle, Patent No: CN209350930U
- Low-fat pork ball with *Prinsepia utilis* royle protein high-internal-phase emulsion as fat substitute and preparation method of low-fat pork ball, Patent No: CN115152949A
- High-efficiency extraction process of *Prinsepia utilis* extract, Patent No: CN113621435A
- Automatic cuttage of spraying of *Prinsepia utilis* royle full gloss device of growing seedlings, Patent No: CN206698892U
- Screening machine is selected for use to *Prinsepia utilis* royle branch, Patent No: CN207325257U
- *Prinsepia utilis* royle shell breaker of band elimination dirt function, Patent No: CN207187847U

Scope of further R&D: Various plant components, including leaves, roots, fruits, seeds, and flowers, have been documented in traditional medicine for treating a range of human ailments. Consequently, there is a compelling need for in-depth research to unravel the medicinal properties of *P. utilis*, with the potential for validating traditional medicine through scientific investigation. Additionally, a crucial aspect involves scrutinizing the nutritional composition of its fruits and seeds to discern possible applications in both human and animal diets. Furthermore, the research imperative extends to the development of value-added products, including oils, extracts, and other derivatives, with the prospect of significant economic value.

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Pterocarpus santalinus L. f.

Synonyms:
Lingoum santalinum (L.f) Kuntze

Local/Common/Popular Name(s):
Indian Redwood, Red Sanders, Red sandalwood

Vernacular Names:
English: Red sandalwood, red sanders, Rubywood, Saunderswood, Agaru, Red sanders; ***Malayalam:*** Chenchandanam, Rakthachandanam; ***Hindi:*** Lalchandan, Raktachandan, Chandan, Senchandanam, Sivappu Sandhanam; ***Kannada:*** Agaru, Honne; ***Malayalam:*** Patrangam, Tilaparnni; ***Marathi:*** Tambadachandana; ***Sanskrit:*** Aktachandana; ***Tamil:*** Rathasandanam, Chenkunkumam, Sivappuchandanam, Sandana; ***Telugu:*** Agarugandhami, Yerrachandanamu, Raktachandanamu; (https://indiabiodiversity.org; Ravikumar and Ved, 2000)

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Fabales
Family	:	Fabaceae
Genus	:	*Pterocarpus*
Species	:	*Pterocarpus santalinus*

Botanical Description: *Pterocarpus santalinus* Linn. is a deciduous tree of modest to medium size, known for its dense, dark purple heartwood with a distinct bitter taste (Dhanabal et al., 2007). The bark, 1-1.5 cm thick, is blackish-brown with deep vertical and horizontal cracks that form rectangular plates. When cut, the bark reveals a pale yellow blaze with numerous pink streaks, and it exudes a copious amount of red, sticky, thick gum. The branchlets are gracefully pendulous and hairless. The tree's leaves are typically trifoliate, measuring 10-18 cm in length, with a swollen rachis at the base. Each leaflet is broadly ovate to orbicular, with a rounded or slightly heart-shaped base and an apex that is either rounded or deeply notched. The leaf margin is entire, leathery, shiny, and hairless, with distinct petioles. *P. santalinus* produces bisexual flowers, which are yellow, fragrant, and about 2 cm long, appearing in stalked axillary racemes that are simple or sparingly branched. The pods are unequal, orbicular, and flat, measuring about 5×4.5 cm including the wing, and gradually tapering into a short tip of approximately 1 cm. The seeds are typically kidney-shaped, 1-1.5 cm long, and have a smooth, reddish-brown surface (Azamthulla et al., 2015).

Distribution: *P. santalinus* is endemic to the southeastern portion of the Indian Peninsula, specifically in the states of Andhra Pradesh, Tamil Nadu, and Karnataka (Hedge et al., 2012; Arunkumar and Joshi, 2014). In Andhra Pradesh, it is predominantly found in the Palakonda and Seshachalam hill ranges of the Kadapa-Chittoor Districts, including the Rajampet, Rayachoti, Ballepalle, and Kodur ranges, as well as the Ganganapalle forest of Vempalle village and the Lankamal Reserve Forest (Hedge et al., 2012; Arunkumar and Joshi, 2014). The species is less common in Chengalpattu, Tamil Nadu, and the North Arcot Hills (Hedge et al., 2012). It is also cultivated in Sri Lanka, China, and within its native range in India, including Kerala, Maharashtra, Odisha, and West Bengal (Jain and Sastry, 1980).

P. santalinus is an evergreen tree that thrives on dry, hilly terrain, often on rocky slopes at altitudes ranging from 200 to 1500 m. It is commonly found on precipitous hillsides where soils are typically

shallow, poor, stony, and well-drained (Raju and Nagaraju, 1999). The species is a heavy light demander and avoids waterlogged areas. In its natural habitat, the tree experiences a hot, dry climate with temperatures ranging from 11°C to 46°C, and receives 88-105 cm of rainfall, primarily from the northeast and southwest monsoons, indicative of an excessively dry climate year-round. While *P. santalinus* prefers these challenging conditions, it has also been successfully planted on rich alluvial soils (Hedge et al., 2012).

Ethnobotanical Significance: *P. santalinus* has a rich history of traditional use in various therapeutic applications. The stem of *P. santalinus*, along with the root of *Piper longum* and the rhizome of lotus, is taken with cow urine on an empty stomach for 7 days to treat intermittent fever and fever due to cold. In the Western Ghats' Shimoga region of Karnataka, the stem bark extract is used by tribal groups to treat diabetes, fever, snakebite, and particularly jaundice (Manjunatha, 2006b).

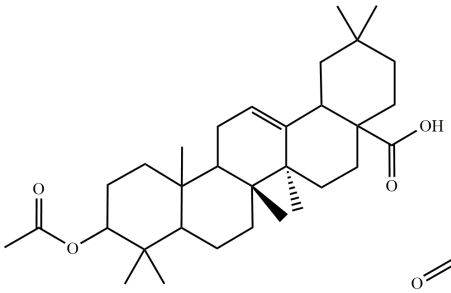
Stem bark powder mixed with soft porridge is employed in treating diarrhoea, while a wood paste is used externally as a cooling agent to treat inflammations, headaches, mental aberrations, and ulcers (Krishnaveni and Srinivasa Rao, 2000b). A brew made from the wood and bark is taken orally to relieve chronic dysentery, worms, blood vomiting, weak vision, and hallucinations (Arunakumara et al., 2011). Decoctions of the bark and resin are traditionally used to treat glandular tumors, urethral discharges, and as an abortifacient (Kirtikar and Basu, 2001). The Yerukula and Irula tribes use the entire plant for ulcer treatment (Vedavathy et al., 1997), while the Malamalasar tribe applies wood paste as a blood purifier and to cure skin diseases and poisonous affections (Yeshodharan and Sujana, 2007). The sap is used by ethnic communities to treat conjunctivitis (Faruque and Uddin, 2011), and various tribes use Red Sanders to treat herpes (Bhandari and Chandrashekar, 2011). *P. santalinus* is also employed in treating bilious affections, skin diseases, as anthelmintic, aphrodisiac, and alexiteric, and for conditions such as vomiting, thirst, eye diseases, ulcers, and blood disorders (Kirtikar and Basu, 2001; Latheef et al., 2008). The heartwood is used in the treatment of dysentery, blood diseases, diabetes, stomach ulcers, and as anthelmintic and diaphoretic. Externally, wood paste is applied to cure skin inflammation, headaches, fever, scorpion stings, skin diseases, and to strengthen eyesight (Soundararajan et al., 2016). The tree has remarkable properties for healing pimples, scars, boils, wounds, burn marks, black spots, eczema, bilious affections, and other skin blemishes, making the skin smooth and attractive. A decoction of the fruit is used as an astringent tonic in chronic dysentery (Krishnaveni and Srinivasa Rao, 2000c; Cho et al., 2001).

Phytochemistry: Kino tannic acid; Kinonin; Kinored; Pyrocatechin; Gallic acid (Tiwari *et al*., 2015), β-Amyrone; Lupenone; Epi-lupeol; Lupeol; Sitosterol; Lupenediol (Kumar and Seshadri, 1975); Pterrocarptriol; Iso pterocarpene; Pterocarpdiolone; Santalin A and B; Isopterocarpolone; Acyl oleanolic aldehyde; Pterocarpol; Acetyloleanolic acid; Isoflavone glycoside 4',5-dihydroxy 7-methyl Isoflavone; 3'-O-β-D-glucoside (Krishnaveni and Srinivasa Rao, 2000a); Santal; Pterocarpin; Homopterocarpin; Kino-tannic acid (Krishnaveni and Srinivasa Rao, 2000a; Cho et al., 2001); Pterocarpol; Santalins A, B, and Y; Pterocarptriol; Isopterocarpolone; Pterocarpodiolones; Cryptomeridol (Yoganarasimhan et al., 2000); β-Sitosterol; Lupeol; Epicatechin; Lignans; Pterostilbenes; β-Amyrone; Lupenone; Lupeol; epi-Lupeol; 2α-Hydroxy-epi-lupeol (Krishnaveni and Srinivasa Rao, 2000a, 2000b, 2000c); 6-Hydroxy-5-methyl-3',4',5'-trimethoxyaurone 4-O-α-L-rhamnopyranoside; 6,4'-dihydroxyaurone 4-O-rutinoside (Kesari et al., 2004); Dalbergin; Pterolinus K (Wu et al., 2011); Melannein; Pterolinus J; Pterolinus F; Pterolinus G; Pterolinus I; Pterolinus Ha; Pterolinus Hb; S-3′-Hydroxy-4,4′-dimethoxydalbergione; Pterolinus A; Pterolinus B; Pterolinus C; Dehydromelanoxin; Melanoxin; Pterolinus D; Pterolinus E (Cherdtrakulkiat et al., 2015); Pterolinus L (Wu et al., 2011); Santalin A & C (Kinjo et al., 1995); Santalin (Shah, 1975); β-eudesmol; Isopterocarpolone; Pterocarpdiolone; Cryptomeridiol; Pterocarptriol (Kumar et al., 1974).

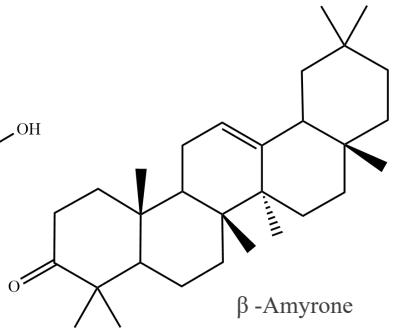
Heartwood: Santalin A; santalin B; savinin; calocedrin; pterolinus K; pterolinus L. (Bulle et al., 2016) canusesnol K; canusesnol L; 12,15-dihydroxy curcumene (Li et al., 2017)

Biological Activities:

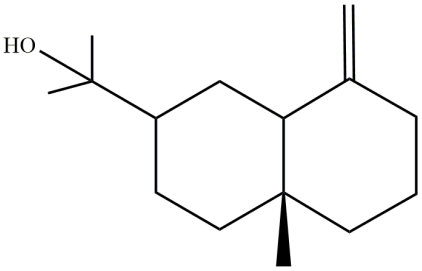
Antimicrobial activity: *P. santalinus* has been reported to possess significant antimicrobial activity. Studies have shown that the methanolic extract of the plant exhibits greater inhibitory activity



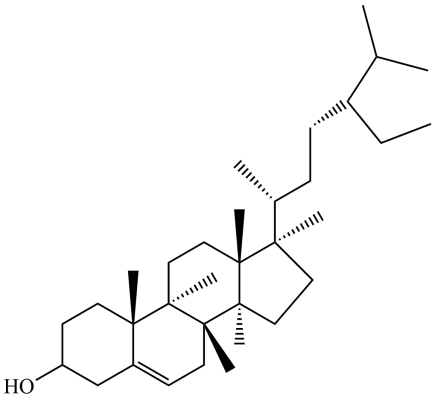
Acetyloleanolic acid



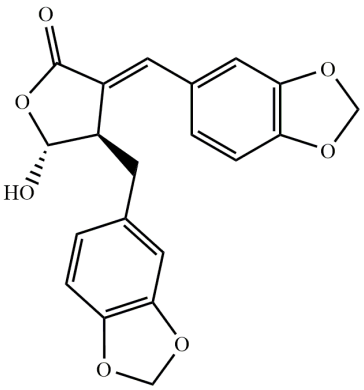
β -Amyrone



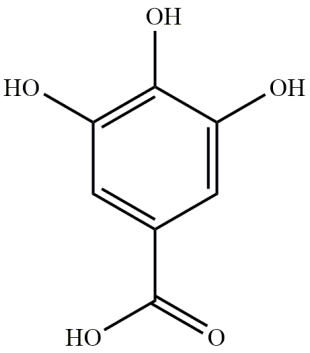
β-Eudesmol



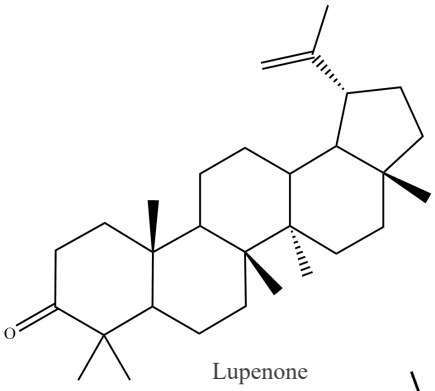
β- Sitosterol



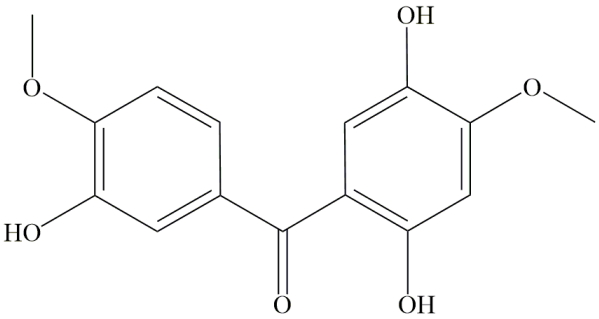
Calocedrin



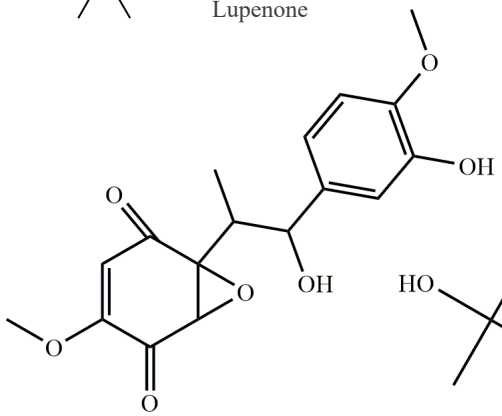
Gallic acid



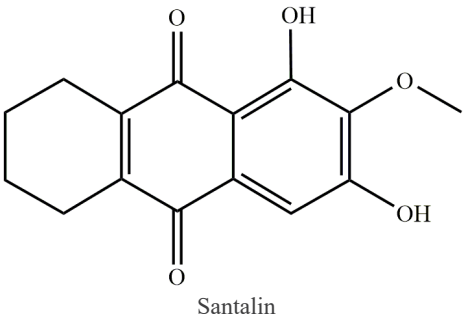
Lupenone



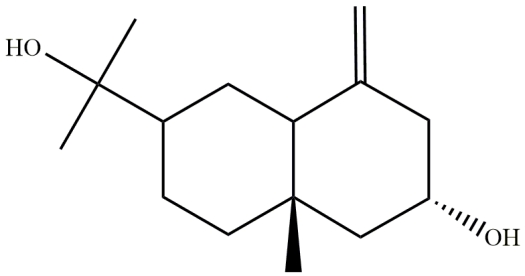
Melanoxoin



Pterolinus D



Santalin



Pterocarpol

Structures of Important and Characteristic Chemical Constituents of *Pterocarpus santalinus*

than the aqueous extract (Mishra and Padhy, 2013; Dey et al., 2014). When tested against Gram-positive bacteria such as *Staphylococcus aureus, Staphylococcus epidermidis, Bacillus subtilis,* and *Enterococcus faecalis*, as well as Gram-negative bacteria like *Escherichia coli* and *Pseudomonas aeruginosa*, the bark extract demonstrated stronger inhibition than the leaf extract (Krishnamoorthy et al., 2011; Manjunatha, 2006). The methanolic bark extract showed potent antibacterial activity against a range of pathogens including *Enterobacter aerogenes, Alcaligenes faecalis, Escherichia coli, Pseudomonas aeruginosa, Proteus vulgaris, Bacillus cereus, Bacillus subtilis,* and *Staphylococcus aureus* (Manjunatha, 2006b). Silver nanoparticles synthesized from the leaf extract also exhibited antibacterial potential against both Gram-positive and Gram-negative strains (Gopinath et al., 2013; Yamauchi et al., 2005), and gold nanoparticles (GNPs) prepared from the plant showed similar antibacterial activity (Keshavamurthy et al., 2018). The stem heartwood extract was particularly effective against *Enterobacter aerogenes, Alcaligenes faecalis, Escherichia coli, Pseudomonas aeruginosa, Proteus vulgaris, Bacillus cereus, Bacillus subtilis,* and *Staphylococcus aureus* (Borris, 1996; Savan Donga et al., 2017). Additionally, the bark extract demonstrated better antifungal activity than the leaf extract against fungi such as *Trichophyton rubrum, Trichophyton mentagrophytes, Trichophyton simmi, Epidermophyton floccosum,* and *Scropulariopsis* species (Arokiyaraj and Perinbam, 2010). The ethyl acetate extract of the leaves also exhibited antifungal properties against these pathogens. When tested against various microbial strains including *Staphylococcus mutans, Escherichia coli, Pseudomonas aeruginosa,* and *Candida* species, the petroleum ether, methanol, n-butanol, chloroform, and ethanol extracts were evaluated for antimicrobial activity. Among these, the ethanol and methanol extracts showed significant antimicrobial activity, while the others did not. The results were compared with standard antibiotics Ciprofloxacin and Fluconazole using the disc diffusion test (Jain et al., 2013).

Antidiabetic activity: Several experimental studies have demonstrated the antidiabetic potential of *Pterocarpus santalinus* extracts. Whole extracts of the bark and heartwood have shown the ability to reduce blood sugar levels in chemically-induced diabetes models (Kondeti et al., 2010; Maheswari et al., 1980; Nagaraju, 1991). Oral administration of an aqueous extract at a dosage of 0.7 g/kg body weight significantly reduced blood glucose levels in streptozotocin (STZ)-induced diabetic rats, without causing hypoglycemia in normal rats (Challa et al., 2019a). The ethanolic bark extract was found to decrease hyperglycemia induced by STZ by enhancing glycolysis and reducing gluconeogenesis (Kondeti et al., 2010, Kasneswara et al., 2001). In vitro studies of the heartwood methanolic extract using C_2C1_2 cell lines revealed significant antidiabetic activity through increased glucose uptake and cytotoxic effects on these cells (Challa et al., 2019b). Additionally, the aqueous extract of red sandalwood exhibited hypoglycemic, antioxidant, hypolipidemic, and nephroprotective effects in STZ-induced diabetic rats, particularly when combined with vitamin E (α-tocopherol) supplementation, suggesting its potential in managing diabetes (Halim and Misra, 2010). Another study indicated that the aqueous extract ameliorates diabetes mellitus via anti-inflammatory pathways and enhances insulin function in STZ-induced diabetic rats (El-Badawy et al., 2019, Rao, et al., 2001).

Anti-inflammatory activity: Specific lignans found in the heartwood extract of *P. santalinus*, including savinin, calocedrin, and eudesmin, have been reported to inhibit Tumor Necrosis Factor (TNF)-α, a pro-inflammatory cytokine involved in chronic inflammatory and allergic diseases (Kwon et al., 2006). Savinin, in particular, inhibits TNF-α production and T cell proliferation, contributing to its anti-inflammatory effects. This activity is attributed to its structural similarity to the butyrolactone ring and its polarity at the C9 position (Cho et al., 2001). The heartwood extract also contains five new benzofurans, six new neoflavonoids, and known compounds such as dehydromelanoxin, melanoxin, and S-30-hydroxy-4,40-dimethoxydalbergione. Among these, dehydromelanoxin, melanoxin, and S-30-hydroxy-4,40-dimethoxydalbergione exhibited potent anti-inflammatory activity with IC50 values of 0.19 µg/mL. Additionally, phenanthrenedione (Pterolinus K) and chalcone (Pterolinus L), isolated from the heartwood, significantly inhibited superoxide anion generation and elastase release in human neutrophils, with IC50 values of 0.99 µM

and 0.94 µM, respectively (Wu et al., 2011a). The methanolic extract of *P. santalinus* formulated as a gel demonstrated superior anti-inflammatory effects compared to diclofenac gel in a carrageenan-induced rat paw edema model of acute inflammation (Arokiyaraj et al., 2008). A topical application of bark wood powder gel also showed significant anti-inflammatory and mild analgesic effects in a chronic inflammation rat model. Further studies using molecular docking identified phloridzin as a key metabolite responsible for the anti-inflammatory and antipyretic effects of *P. santalinus* heartwood extract, showing higher affinity for COX-1, COX-2, PGES-1, and 5-LOX than ibuprofen and paracetamol (Shanti et al., 2020). The gel formulation containing 1% *P. santalinus* extract outperformed diclofenac gel in anti-inflammatory efficacy (Majumdar and Dave, 2013). Additionally, wood extract at doses of 100, 250, and 500 mg/kg showed significant inhibition of carrageenan-induced paw inflammation (Kumar, 2011, Priti et al., 2017).

Antioxidant activity: *P. santalinus* has demonstrated potential in reducing ibuprofen-induced gastric lesions, likely due to its active constituents such as triterpenes, lignans, and flavonoids, which are known for their antioxidant and antiulcer effects (Krishnaveni and Srinivasa Rao, 2000; Ratty, 1988; Santosh et al., 1998; Rodriguez et al., 2003). The methanolic extract of *P. santalinus* has been evaluated for its free radical scavenging abilities through various assays, including total antioxidant activity (thiocyanate method), diphenyl-picrylhydrazyl (DPPH) assay, and nitric oxide (NO) assay, all of which confirmed its significant antioxidant potential (Jenive Stella et al., 2011). In vitro studies using glucose uptake and DPPH assays also revealed the heartwood methanolic extract's strong antioxidant activity (Challa et al., 2019b). Additionally, methanol extracts from the leaves, bark, and wood of *P. santalinus* exhibited substantial free radical scavenging activities of 61.7%, 52.7%, and 68.7%, respectively, at a 10 mg/ml concentration, with wood extracts showing the highest activity (Jyothi et al., 2014). The ethanolic extract of the leaves demonstrated radical-scavenging activity against DPPH, nitric oxide, and hydrogen peroxide (Arokiyaraj et al., 2008; Krishnamoorthy et al., 2011). The antioxidant activity of the methanolic extract from the heartwood increased with concentration and was comparable to butylated hydroxyanisole (BHA) (Kumar, 2011). Furthermore, pterostilbene isolated from *P. santalinus* exhibited strong in vitro antioxidant activity against free radicals such as DPPH, ABTS, hydroxyl, superoxide, and hydrogen peroxide (Achary and Ghaskadbi, 2013).

Wound healing activity: The wound healing potential of *P. santalinus* wood was evaluated by preparing an ointment from its wood powder and testing it on punch and burn wound models in normal and diabetic rats. The study, which included untreated and vehicle controls as well as standard therapy comparisons, found that wounds treated with the test ointment healed significantly faster, demonstrating its safety and effectiveness in treating acute wounds in animal models (Biswas et al., 2004). Additionally, the wound healing efficiency of ethanol extracts from the leaves and stem bark of *P. santalinus* was assessed. The extracts significantly reduced the period of epithelialization, increased the rate of wound contraction, and enhanced skin breaking strength, granulation tissue dry weight, hydroxyproline content, and the breaking strength of granulation tissue.

Anticancer activity: Benzofuran compounds isolated from *P. santalinus* heartwood demonstrated cytotoxicity against Ca9-22 cancer cells with an IC50 value of 0.46 µg/mL (Wu et al., 2011a). Savinin, particularly from the methylene chloride extract, showed the highest inhibitory activity on T cell proliferation at 25 µg/mL (Kwon et al., 2006). Pterostilbene, another compound from *P. santalinus*, exhibited therapeutic efficacy against breast, lung, colon, prostate, and pancreatic cancers (Wu et al., 2011b). Additionally, Pterolinus K and Pterolinus L, isolated from the heartwood, displayed significant anticancer activity with IC50 values of 10.86 µM, 9.81 µM, and 17–8.2 µM against HepG2, Hep3B, and A549 cancer cell lines, respectively (Wu et al., 2011a). Pterostilbene was found to inhibit cell proliferation factors such as Akt and Bcl-2 while inducing mitochondrial apoptotic signals like Bax and caspases. It also inhibited metastasis inducers Matrix Metalloproteinase 9 (MMP-9) and α-Methyl Acyl CoA racemase (AMACR), making it a potential treatment for breast and prostate cancer (Chakraborty et al., 2010).

Antipyretic Activity: The aqueous extract of *P. santalinus* heartwood demonstrated significant antipyretic activity in Wistar albino rats with doses of

400 and 800 mg/kg, though the effect was slower compared to paracetamol (Vasudevan et al., 2019).

Anti-Melanogenic Activity: The hot water extract of *P. santalinus* bark inhibited melanin production in Bacillus cereus in a dose-dependent manner (Prasad et al., 2016).

Toxicology: Ethanol and chloroform extracts of *P. santalinus* heartwood were well-tolerated up to 2 g/kg in acute toxicity studies, with no significant changes observed in subacute toxicity tests. Thus, the extracts are considered safe for use (Azamthulla et al., 2013).

Commercial Products: *P. santalinus* wood extract and oil are used in haircare and skincare products, including shampoos, serums, and face masks.

Patent:

- Method for identifying *Pterocarpus santalinus* wood species by fluorescence spectrum, Patent No: CN111157507A
- Method for identifying *Pterocarpus santalinus* pen container based on two-dimensional correlation infrared spectrum, Patent No: CN112697743A
- Preparation method of *Pterocarpus santalinus* essential oil with antibacterial activity, Patent No: CN106987316B
- Seedling culture method for promoting *Pterocarpus santalinus* to form heartwood early, Patent No: CN106688631B
- Spectrophotometry for identifying *Pterocarpus santalinus* and *Pterocarpus santalinus*, Patent No: CN115615940A
- Processing method for making white tea by using tender leaves of *Pterocarpus santalinus*, Patent No: CN111345362A
- Method for nondestructively identifying *Pterocarpus santalinus* and *Pterocarpus santalinus* wood and products thereof, Patent No: CN114113408A
- Organic fertilizer production device and process for the symbiotic potted plant of *Pterocarpus santalinus* and dendrobium nobile, Patent No: CN111841371A
- Culture medium for tissue culture of *Pterocarpus santalinus* and tissue culture method thereof, Patent No: CN114731950A
- Method for preparing *Pterocarpus santalinus* water extract used as direct vasodilation agent and applications of the method, Patent No: CN101530453A
- *Pterocarpus santalinus* nursery stock grafting breeding method, Patent No: CN106688630A
- Composition containing *Pterocarpus santalinus* extract for the prevention and treatment of hyperlipidemia and fatty liver, Patent No: KR100756550B1
- A liposomal composition of *Pterocarpus santalinus* and the process thereof, Patent No: WO2021260712A1
- Seedling raising method for *Pterocarpus santalinus* seeds, Patent No: CN112931009A
- Standard gene for identifying *Pterocarpus santalinus* molecules and molecular identification method, Patent No: CN105838806A
- HPLC fingerprint spectrum-based quality detection method for Mongolian medicine *Pterocarpus santalinus* heart medicinal material, Patent No: CN110068640B
- *Pterocarpus santalinus* pseudo-patch up guqin and preparation process thereof, Patent No: CN115116412A
- Processing method for preparing green oolong tea by using tender winged leaf of *Pterocarpus santalinus*, Patent No: CN111345364A
- Method for extracting *Pterocarpus santalinus* and method for using extracting liquid solution for surface decoration of wooden products, Patent No: CN101624554A
- Processing method for Indian venus *Pterocarpus santalinus* Buddha beads, Patent No: CN105291235A
- Standard gene for molecular identification of *Pterocarpus santalinus* and molecular identification method, Patent No: CN105779633A
- Grafting method for promoting early fruiting of *Pterocarpus santalinus*, Patent No: CN103314791B
- Processing method for quickly forming oxidation layers on *Pterocarpus santalinus* Buddha beads, Patent No: CN105455330A
- Rapid propagation method for tissue culture of *Pterocarpus santalinus* seedlings, Patent No: CN106577292A
- *Pterocarpus santalinus* tissue culture seedling nutrient solution conveying device, Patent No: CN216753108U
- *Pterocarpus santalinus* extract and preparation method and application thereof, Patent No: CN104479398A
- Identification method of P*terocarpus santalinus* wood and *Pterocarpus tinctorius* wood and products of *Pterocarpus santalinus* wood and *Pterocarpus tinctorius* wood, Patent No: CN105572263A
- Cosmetic composition containing extract of *Pterocarpus santalinus*, Patent No: KR100732563B1

- A rack cultivated in a pot that is used for *Pterocarpus santalinus* and stem of noble dendrobium intergrowth to be cultivated in a pot, Patent No: CN111727766A
- Processing method for making black tea by using tender leaves of *Pterocarpus santalinus*, Patent No: CN111345363A
- Composition for anti-allergy and skin hydration comprising *Pterocarpus santalinus* extracts, Patent No: KR101618309B1
- Preparation method and medicinal use of *Pterocarpus santalinus* antitumor extract and composition thereof, Patent No: CN105982946A
- A composition for promoting skin regeneration comprising extract of *Pterocarpus santalinus* as active ingredient, Patent No: KR102009239B1
- Organic fertilizer for killing *Pterocarpus santalinus* tree diseases and insect pests through biocompatibility and manufacturing method thereof, Patent No: CN106045743A
- Composition for treating or preventing atopic dermatitis comprising *Pterocarpus santalinus* and *Buddleia officinalis*, Patent No: KR101659740B1
- Nutritional herbal red sandalwood wine and preparation process thereof, Patent No: CN114480057A
- A process for the isolation of total santalins from *Pterocarpus santalinus* l., Patent No: 1101/del/2001
- "a liposomal composition of *Pterocarpus santalinus* and the process thereof", Patent No: 202021027131
- Composition containing *Pterocarpus santalinus* extract for the prevention and treatment of hyperlipidemia and fatty liver, Patent No: kr100756550b1
- Grafting method for promoting early fruiting of *Pterocarpus santalinus*, Patent No: CN103314791A
- Composition For Anti-Allergy and Skin Hydration Comprising *Pterocarpus Santalinus* Extracts, Patent No: Kr101618309b1
- Method for preparing *Pterocarpus santalinus* water extract used as direct vasodilation agent and applications of method, Patent No: CN101530453A
- Pterocarpus santalinus nursery stock grafting breeding method, Patent No: CN106688630A
- A Composition for Promoting Skin Regeneration Comprising Extract of *Pterocarpus Santalinus* as Active Ingredient, Patent No: Kr102009239b1
- Seedling raising method for promoting *Pterocarpus santalinus* to form heartwood as soon as possible, Patent No: CN106688631A
- Method for identifying *Pterocarpus santalinus* wood species by fluorescence spectrum, Patent No: CN111157507A
- Rapid propagation method for tissue culture of *Pterocarpus santalinus* seedlings, Patent No: CN106577292A
- Standard gene for identifying *Pterocarpus santalinus* molecules and molecular identification method, Patent No: CN105838806A
- *Pterocarpus santalinus* extract and preparation method and application thereof, Patent No: CN104479398A
- Miniature DNA (deoxyribonucleic acid) bar code for identifying *Pterocarpus santalinus* and *Pterocarpus tinctorius,* and identifying method and application of identifying method, Patent No: CN106929575A
- *Pterocarpus santalinus* dyestuff and fabric dyeing method, Patent No: CN107266933A
- HPLC standard fingerprint of *Pterocarpus santalinus,* and constructing method and application thereof, Patent No: CN110031575A
- *Pterocarpus santalinus* Alpha-glycosidase inhibitory activity active extract and medical use of the composition of *Pterocarpus santalinus* Alpha-glycosidase inhibitory activity active extract and preparation method, Patent No: CN106265855A
- Preparation method and medicinal use of *Pterocarpus santalinus* antitumor extract and composition thereof, Patent No: CN105982946A

Scope of further R&D: The scope of further research on *P. santalinus* is broad and promising. There is a need for rigorous scientific studies to validate the traditional medicinal claims associated with this species, confirming its efficacy in treating various diseases. Further research should focus on isolating and characterizing the bioactive compounds in *P. santalinus*, understanding their mechanisms of action, and exploring their therapeutic potential. Additionally, optimizing the extraction processes for natural colorants derived from *P. santalinus* warrants further investigation. Research into sustainable cultivation and harvesting practices is also crucial to ensure the long-term availability of this valuable resource while minimizing environmental impact. Sustainable approaches will support both medicinal and colorant uses of *P. santalinus*, ensuring its conservation for future generations.

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Punica granatum L.

Synonyms:
Granatum punicum St.-Lag., *Punica florida* Salisb., *Punica grandiflora* hort. ex Steud., *Punica multiflora* hort. ex Siebold & Voss, *Punica nana* L., *Punica spinosa* Lam.

Local/Common/Popular Name(s):
Himachal Pradesh: Daru, Darhim, Darmu (Singh and Thakur 2014); ***Jammu & Kashmir:*** Dhurniin (Murtaza and Ahmad 2017); ***Iran:*** Golnar (Talebpour et al., 2017); ***Pakistan:*** Anargul (Nafees et al., 2016); ***Southern Italy:*** Shegga (Pieroni et al., 2005).

Vernacular Names:
India: Daru, Dalimb; ***English:*** Pomegranate; ***Spanish:*** Granda, Mangrano; ***French:*** Granades, Grenadier, ***Russion:*** Granat; ***Arabic:*** Drabhte-naiy; ***Chinese:*** Shiliu; ***Portuguese:*** Romeira

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Myrtales
Family	:	Lythraceae
Genus	:	*Punica*
Species	:	*Punica granatum*

Botanical Description: *P. granatum*, commonly known as wild pomegranate or Daru, belongs to the family Lythraceae. It is a monoecious, erect, small deciduous shrub or tree, typically reaching a height of 8 to 10 meters. The plant features a hard, light yellowish, stern, and thorny or spiny woody stem, with a main stem girth ranging from 48 to 78 cm. The bark is yellowish or dark grey. The leaves are ornamental, glossy, and arranged opposite or sub-opposite, often clustered on arrested branchlets. They are lanceolate with entire margins, measuring 3-7 cm in length and 1.7 cm in width, with thin petioles approximately 4 cm long (Parmar and Kaushal, 1982). The leaves shed in December, with new light red leaves emerging in mid-March (Rana et al., 2007). The flowers are sessile, ebracteate, complete, actinomorphic, bisexual, and appear solitary or in axillary clusters. They are bright scarlet red, about 3 cm in diameter, with three to seven globular petals crowned by a persistent calyx (Rana et al., 2007). The fruit, a hard rind measuring 4.2 to 6.6 cm in diameter, has a yellowish-green color with a red tinge, and varies in shape from round to oblate or obovate (Narzary et al., 2010). The fruits contain angular, fleshy arils with color shades ranging from red to pinkish-white (Singh et al., 2019). Flowering occurs from mid-April to late May or June, with two off-season blooms of lesser intensity appearing in July and November (Parmar and Kaushal, 1982; Rana et al., 2007; Bakshi et al., 2014). Fruiting begins in August and continues until October (Bakshi et al., 2014).

Distribution: *P. granatum* L. is native to Central Asia, Iran, Turkmenistan, and northern India (Holland et al., 2009). It is also found in Transcaucasia, Kopet-Dag, Syria, Afghanistan (Holland et al., 2009; Kingsley and Singh, 2007), as well as in parts of Europe, Africa, and the Americas (Levin, 2006). The species is present in Dagestan, Asia (Mars, 2000), and the western Himalayan region of India, including Himachal Pradesh, Uttarakhand, and Jammu and Kashmir. In India, it is extensively found in the districts of Solan, Sirmour, Mandi, Darlaghat (Shimla), Kullu, and Chamba in Himachal Pradesh; and in Tehri, Dehradun, Nainital, and Almora in Uttarakhand, at altitudes ranging from 900 to

1800 meter (Thakur et al., 2011; Thakur et al., 2013; Rana et al., 2007). In Jammu and Kashmir, it is found in Ramban, Rajouri, Doda, and Udhampur at altitudes of 1000 to 2500 meter (Murtaza and Ahmad, 2017).

Ethnobotanical significance: *P. granatum* holds significant ethnobotanical value and is widely utilized by communities, making it a valuable livelihood option in developing countries. The arils, which are sour in taste, are sun-dried to produce *anardana*, a popular ingredient in Indian and Persian cuisine. *Anardana* is used in chutneys, curries, and other culinary practices to enhance appetite and as a spice or condiment for salad dressings, marinating meat, and topping for yogurt or ice cream (Kingsley et al., 2006; Sharma and Thakur, 2016; Singh et al., 2019; Murtaza and Ahmad, 2017). Chutney made from arils is known to relieve stomach aches, constipation, and heat-related discomfort (Thakur et al., 2018a). *Anardana* is also considered a good substitute for dried mango powder (Amchur) (Dhumal et al., 2014). In Turkey, wild pomegranate is used to make sauces, salad dressings, marinated meats, juice, vinegar, and liquor (Bakshi et al., 2013; Ercisli et al., 2011). Liquor made from wild pomegranate in Turkey and Portugal is considered superior to that made from cultivated varieties (Galego et al., 2012). Various parts of the plant, including the arils, rind (flavedo), flowers, bark, leaves, roots, and seeds, are used for herbal treatments. *Anardana* is prized for its health benefits, particularly in aiding digestion, and is used in Ayurvedic medicine to treat stomach aches, sore eyes, sore throats, diarrhea, bronchitis, dysentery, inflammation, and other ailments (Kingsley et al., 2006; Singh and Kingsley, 2008; Kirtikar and Basu, 1935; Bakshi et al., 2013; Chauhan, 1999). In Azerbaijan, the fruit is used to produce citric acid and sodium citrate, which are used as blood preservatives and treatments for scurvy, urinary acid diathesis, and other conditions (Amin, 1999; Ashton, 2006). Unripe fruits and flowers are used to induce vomiting (Kanwar et al., 2010). Tannin extracts (bark, leaves, and immature fruit) are traditionally used to treat diarrhea and hemorrhage, while dried and crushed flower buds are brewed into tea for bronchitis (Thakur et al., 2018a). Leaves are also used to treat dysentery and skin diseases (Hamayun, 2003). The rind is employed as a laxative, diuretic, stomachic, cardiotonic, refrigerant, and for treating diarrhea, astringency, helminthiasis, aphrodisiac, and dental infections. Mixed with honey, it provides relief from cough (Devi et al., 2011; Hamid et al., 2020a). The bark is used to treat tapeworms, as a mouthwash, antipyretic, and expectorant (Kashyap et al., 2017; Hamayun, 2003). The roots are used as a decoction to treat diarrhea (Pieroni et al., 2005).

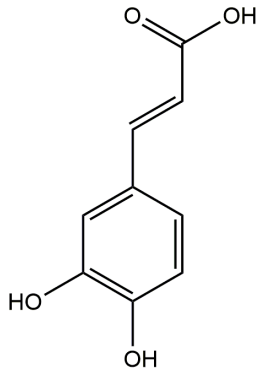
Phytochemistry:

Arils: Hydroxycinnamic acid, caffeic acid, chlorogenic acid, ferulic acid, p-coumaric acid, sinapic acid, hydroxybenzoic acid, gallic acid, ellagic acid, ellagitannin, punicalagin, procyanidin, galloyl glucose, Homo-vanillin (Singh et al., 2019) flavonol, quercetin, quercetin-3-glucoside, rutin, kaempferol, nariengenin (Zeyanlova et al., 2020; Singh et al., 2019) cyanidin, delphinidin, pelargonidin, delphinidin-3,5-O-diglucsode, delphinidin 3-O-glucoside, cyanidine -3,5-diglucoside, cyanidin-3-diglucoside, Pelarogonidin- 3,5-diglucoside, Pelarogonidine-3-O-glucoside (Singh et al., 2019), Citric acid, malic acid, succinic acid, oxalic acid, tartaric acid (Kingsley and Singh, 2007; Singh et al., 2019; da Silva et al., 2013). Ascorbic acid, fructose, glucose mannitol, maltose, starch, pectin (Singh et al., 2019) nicotinic acid, thiamine, riboflavin, carotene (Kingsley et al., 2006; Kashyap et al., 2017; Sharma et al., 2018) corilagin, brevifolin carboxylic acid, galloyl-HHDP-hexoside, granatin B, ellagic acid, eschweilenol C.

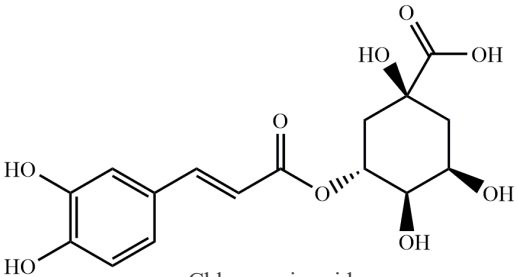
Flower: Caffeic acid, chlorogenic acid, cinnamic acid, ferulic acid, p-coumaric acid, sinapic acid, gallic acid (Zeynalova and Novruzov, 2018), delphinidin-3-glucoside, delphinidin-3,5- di-glucoside, cyanidin-3-glucoside, cyanidin-3,5-di-glucoside, pelargonidine-3-glucoside, pelargonidin-3,5-diglucoside (Zeyanalova et al., 2019) Ursolic acid, maslinic acid, β-sitosterol (Chauhan 1999)

Peels/Rind: Gallotannic acid, Catechin, epicatechin, vanillin (Sharma and Thakur, 2016; Talebpour et al., 2017) delphinidin-3,5-diglucoside (Dp-3,5-digluc), cyanidin-3,5-diglucoside (Cy-3,5-digluc), delphinidin-3-glucoside (Dp-3-gluc), pelargonidin-3,5-diglucoside (Pg-3,5-digluc), cyanidin-3-glucoside (Cy-3-gluc), pelargonidin-3-glucoside (Pg-3-gluc).

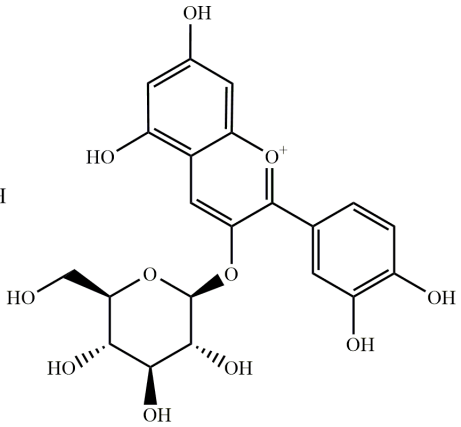
Seeds: Punicic acid, oleic acid, linoleic acid, palmitic acid, stearic acid, lignoceric acid, arachidic acid, behenic acid (Đurđević et al., 2017)



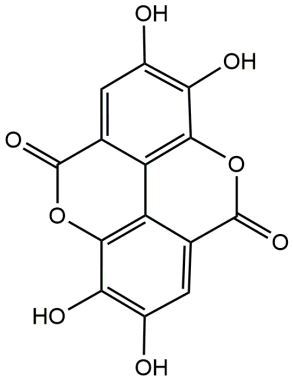
Caffeic acid



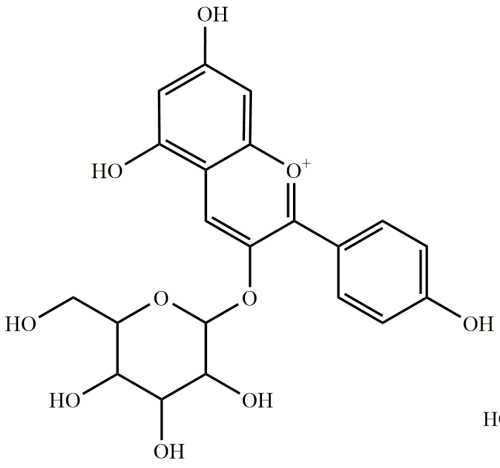
Chlorogenic acid



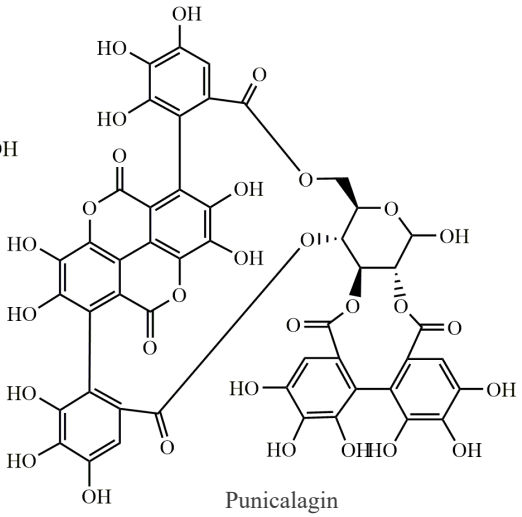
Cyanidin 3-g1ucoside



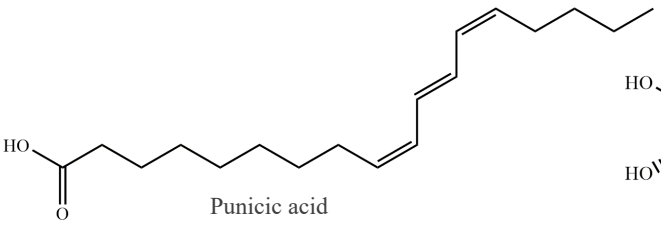
Ellagic Acid



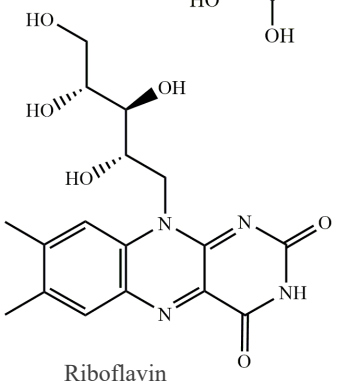
Pelargonidin -3-glucoside



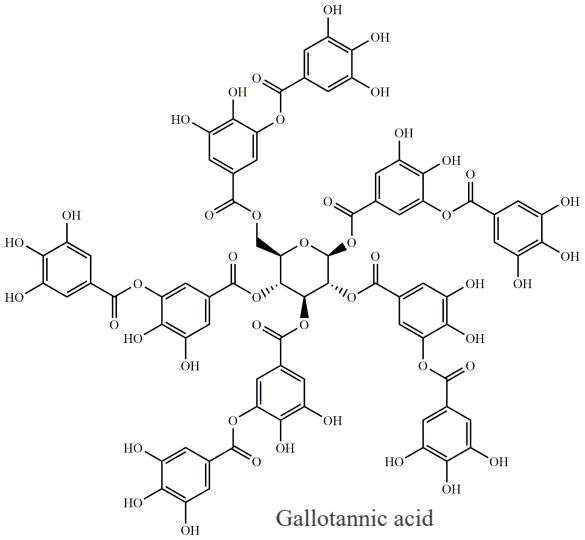
Punicalagin



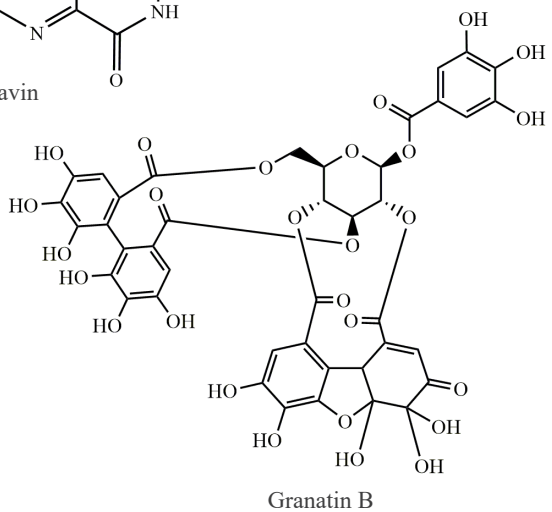
Punicic acid



Riboflavin



Gallotannic acid



Granatin B

Structures of Important and Characteristic Chemical Constituents of *Punica granatum*

Biological Activities:

Antioxidant activity: *P. granatum* L. exhibits antioxidant activity across various plant parts, including fruits, flowers, and leaves. The antioxidant capacity of *P. granatum* collected from Patnitop, J&K, was analyzed using *in vitro* DPPH and FRAP assays. In the DPPH (di-phenyl picryl-hydrazyl) assay, the effective concentration (EC50) of different extracts was compared to the synthetic standard BHT (Butylated Hydroxytoluene) with an EC50 value of 23.5 µg/ml. The highest antioxidant activity (AA) was observed in red fruits (EC50 = 70.33 µg/ml), followed by flowers (EC50 = 123.51 µg/ml), leaves (EC50 = 120.78 µg/ml), and green fruits, which showed the lowest activity (EC50 = 111.51 µg/ml). In the FRAP (Ferric Reducing Antioxidant Power) bioassay, the reduction of the TPTZ–Fe(III) complex to TPTZ–Fe(II) indicated that red fruits had the highest AA (310.99 ± 0.98 µmol Fe2+/g of extract), followed by green fruits (253.99 ± 0.67). Among the extracts, flowers exhibited the highest antioxidant activity (95.99 ± 0.31), while leaves showed the lowest (69.99 ± 0.45). In Himachal Pradesh, antioxidant activity was evaluated in *P. granatum* samples from various locations using the DPPH assay, reporting a range of AA between 32.11% and 40.72%. Metal chelating activity ranged from 10.45% to 12.57%, with the lowest values in Narag and the highest in Basantpur and Karsog, H.P (Thakur et al., 2018). In Azerbaijan, antioxidant activity was assessed in wild pomegranate, revealing a hierarchy of aril juice > membrane > peel, although this trend varied by location, with some reports suggesting higher AA in wild pomegranate compared to its cultivars (Zeynalova et al., 2019). Additionally, the rind of *P. granatum* was investigated, showing 88.12% DPPH scavenging activity, 816.10 µmol Fe2+/g of extract, and 68.50% metal chelating activity following 4 hours of Soxhlet extraction and lyophilization, which was slightly higher than that of the arils (Hamid et al., 2020b).

Antimicrobial Activity: The antibacterial activity of *P. granatum* peel extracts in various solvents (ethanol, petroleum ether, and distilled water) has been evaluated against *Streptococcus sp.*, *Lactobacillus sp.*, *Staphylococcus sp.*, and *Proteus sp.* The ethanolic extract demonstrated the highest activity, showing an inhibition zone of 27 mm against *Streptococcus sp.*, and the least activity against *Proteus sp.*, with an inhibition zone of 24 mm. For *Lactobacillus sp.* and *Staphylococcus sp.*, the inhibition zone was 26 mm. Distilled water showed the least activity overall, particularly against *Proteus sp.* (Devi et al., 2011). Further studies assessed the antimicrobial activity of different extracts in solvents such as ethanol, acetone, ethyl acetate, and diethyl ether for 2, 4, and 6 hours against *Escherichia coli* (Gram-negative) and *Staphylococcus aureus* (Gram-positive). The lyophilized ethanol extract, obtained after 4 hours of Soxhlet extraction, showed the maximum inhibition zones of 22 mm for *Staphylococcus aureus* and 20 mm for *Escherichia coli* at a concentration of 100 ppm (Hamid et al., 2020b).

Antimalarial Activity: Wild pomegranate water infusions made from the peels, leaves, and membranes exhibit significant antimalarial activity. *In vitro* semi-quantitative methods were employed to assess the antimalarial effects of peel and membrane extracts, using the β-hematin inhibition mechanism. Ultra-pure water served as the negative control, while chloroquine was the positive control. All extracts demonstrated higher antimalarial activity compared to the cultivated variety of pomegranate (Akkwai et al., 2019).

Insecticidal Activity: The insecticidal potential of wild pomegranate (*P. granatum*) peels and seeds was evaluated against rose aphids (*Macrosiphum rosaeformis*), showing increased toxicity after 24 hours. Extracts from both peels and seeds, combined with three key flavonoids (Kaempferol, Quercetin, and Myricetin), exhibited notable LC50 values. At 48 hours, the LC50 values were 34.9, 4.7, and 0.6 mg/ml, respectively, and at 72 hours, they decreased to 16.1, 0.000001, and 0.00001 mg/ml. A significant reduction in aphid populations was observed, with ratios of 22:53 for peels and 23:77 for seeds compared to untreated specimens. Importantly, the non-target predator *Coccinella septempunctata* (the ladybird beetle) was unaffected by the treatment. The effectiveness of these extracts is attributed to the presence of flavonoids, which not only exhibit insecticidal properties but also combat bacterial and fungal diseases. Among these flavonoids, quercetin was identified as the most potent in inducing aphid mortality while benefiting generalist predators like the ladybird beetle.

Anticoccidial Activity: The anticoccidial activity of *P. granatum* fruit peel extracts were tested in broiler chickens with experimentally induced coccidial infections, using amprolium as a reference drug. The activity was measured based on the reduction in oocyst output, mean weight gain of birds, and feed conversion ratio. The results indicated that the alcoholic extract of the fruit peel has significant anticoccidial potential (Ahad et al., 2018).

Anthelmintic activity: The methanolic extract of *P. granatum* peel demonstrated significant anthelmintic activity against live adult *Allolobophora caliginosa* worms. The extract caused paralysis and death of the worms at concentrations of 100, 200, and 300 mg/mL (Dkhil et al., 2013).

Anti-Inflammatory Activity: The hydrophilic fraction, specifically an 80% aqueous methanol extract of *P. granatum* seed oil, was evaluated for anti-inflammatory activity in human colon, liver, breast, and prostate cancer cell lines. The study observed a dose-dependent decrease in pro-inflammatory cytokines expressed by breast cancer cell lines with increasing amounts of the extract, indicating significant anti-inflammatory effects (Costantini et al., 2014). Additionally, ellagic acid, gallic acid, and punicalagin A and B, isolated from the ethyl acetate fraction of *P. granatum*, were tested for anti-inflammatory activity. These compounds inhibited LPS-induced nitric oxide (NO), prostaglandin E2 (PGE-2), and interleukin-6 (IL-6) production in RAW264.7 cells, further demonstrating their anti-inflammatory potential (BenSaad et al., 2017).

Anticancer Activity: Galactomannan polysaccharide, isolated from the fruit rind of *P. granatum*, was assessed for anticancer activity in human cancer cell lines (A375, HCT116, HepG2) and murine cancer cell lines (DLA, EAC). The results indicated that this compound possesses potent anticancer properties (Joseph et al., 2013).

Wound Healing Activity: The fruit skin extract of *P. granatum* was tested for wound healing activity in rats using an excision wound model. Extract-treated animals showed a 95% reduction in wound area compared to controls, and the treated wounds epithelialized more rapidly (Nayak et al., 2013).

Toxicology: An acute oral toxicity study in broiler chickens revealed that crude extracts of *P. granatum* were safe up to a dosage of 2000 mg/kg body weight (Ahad et al., 2018). Additionally, a study on BALB/c mice evaluated the safety and tolerability of pomegranate peel extract. The results showed no toxic effects, clinical signs, histopathological changes in the epithelial cells of the tongue, larynx, and trachea, behavioral alterations, adverse effects, or mortality, concluding that the extract exhibited no toxicity (Jahromi et al., 2015).

Patent:

- A kind of implantation method of red *Punica granatum* L. as one wishes, Patent No: CN106258774A
- Facial mask containing *Punica granatum* fruit extract and preparation method of facial mask, Patent No: CN105878102A
- For alleviating the *Punica granatum* L. extract with high-load ellagic acid of the menopausal symptom of women, Patent No: CN106491667A
- Fermentation product of *Punica granatum* and uses thereof, Patent No: US11123386B2
- The preparation method of one kind *Punica granatum* L. structural composite material, Patent No: CN104300125B
- *Punica granatum* L. Fructus Mori cream production method, Patent No: CN106262353A
- A kind of functional composite microsphere with *Punica granatum* L. shape structure and preparation method thereof, Patent No: CN104525067B
- Pasty bath salt containing *Punica granatum* fruit extract, Patent No: CN105878152A
- *Punica granatum* L. quintessence oil hydrogel plaster and preparation method thereof, Patent No: CN104147152B
- Containing the *Punica granatum* L. extract of a large amount of ellagic acid and the purposes of *Punica granatum* L. extract, Patent No: CN102892416B
- The application of *Punica granatum* L. concentrate, Patent No: CN104116131B
- Use of an extract of *Punica granatum* for combating canities, Patent No: US20120263812A1
- A kind of *Punica granatum* L. fruit grain facilitates dropping the device, Patent No: CN205757119U
- A kind of breeding method of soft seed *Punica granatum* L. seedling, Patent No: CN104126395B

- A kind of electronic *Punica granatum* L. threshing machine, Patent No: CN205728999U
- A kind of blueberry *Punica granatum* L. bland and preparation method thereof, Patent No: CN104172369B
- A kind of implantation methods of organic selenium-rich *Punica granatum* L., Patent No: CN106465631A
- Skin-whitening *Punica granatum* L. extract and preparation method thereof, Patent No: CN108434043A
- A kind of nourishing healthy jasmin *Punica granatum* L. ginger sugar, Patent No: CN106490288A
- A kind of method that grafting leaf bud cultivates the nursery stock of multiple *Punica granatum* L. on same stock, Patent No: CN106171541A
- A kind of device measuring *Punica granatum* L. freezing point and method of work thereof, Patent No: CN104374796B
- A kind of *Punica granatum* L. taste nutrient soya-bean milk and preparation method thereof, Patent No: CN106172821A
- *Punica granatum* peel antitumor polyphenol effective part, its preparation method and application, Patent No: CN103505480A
- *Punica granatum* plant extracts for treating osteoporosis and the extraction process thereof, Patent No: WO2008084282A2
- A kind of *Punica granatum* L. loquat wine, Patent No: CN106497728A
- One crawl formula cultivation *Punica granatum* L. shaping support, Patent No: CN205794328U
- A kind of special urea aldehyde organic fertilizer of *Punica granatum* L. and preparation method thereof, Patent No: CN104045452B
- Eye cream containing fucoidin and *Punica granatum* L. extract and preparation method thereof, Patent No: CN104027294B
- A kind of leaf of Semen Maydis high yield *Punica granatum* L. special medicated fertilizer, Patent No: CN106116918A
- A kind of method for culturing seedlings of *Punica granatum* L. fruit tree, Patent No: CN106105958A
- *Punica granatum* L. automatic remove seed machine, Patent No: CN205993585U
- A kind of honey peach *Punica granatum* L. composite health care beverage and preparation method thereof, Patent No: CN106261312A
- Products for oral administration comprising extracts of *Punica granatum* (pomegranate), intended for a pet, and applications of same, Patent No: EP2779839B1
- Chinese herbal medicine facial cleanser containing red *Punica granatum* L. and preparation method thereof, Patent No: CN103655448B
- Use of a combination of extract of lotus, extract of pomegranate (*Punica granatum*) and methylxanthine comprising e.g. caffeine and theophylline, or plant extract rich in methylxanthines, as agent to prevent signs of aging of skin or hair, Patent No: FR2968214A1
- *Punica granatum* root cleaning products, Patent No: CN1673335A
- A kind of *Punica granatum* L. removes the breeding method of stone, Patent No: CN106069523A
- *Punica granatum* L. moon cake formula, Patent No: CN106259741A
- Active principle comprising a particular extract of *Punica granatum* and uses for preventing and/or treating acne, Patent No: US20230092216A1
- A *Punica granatum* extract and its cosmetic uses, Patent No: US20220362139A1
- A kind of *Punica granatum* L. rice crust and preparation method thereof, Patent No: CN106235011A
- *Punica granatum* L. Chinese medicinal liquor, Patent No: CN105213883A
- Pharmaceutical formulations containing the lyophilized hydroalcoholic extract of *Punica granatum*, l sheets and its use in inflammatory processes, patent no: br102015004328a2
- *Punica granatum* anti-cracking lip moisturizing balm, Patent No: CN104688599A
- A kind of preparation method of Chinese rose *Punica granatum* L. cultivation matrix, Patent No: CN106278616A
- A kind of *Punica granatum* L. taste crisp shortcakes with sesame and preparation method thereof, Patent No: CN106135365A
- Composition for prevention or treatment of diabetes or obesity comprising *Punica granatum*

extract and red ginseng extract, Patent No: KR20100013040A

- Phyto complex and extract of a meristematic cell line selected from *Punica granatum*, Patent No: WO2022112864A1
- A kind of *Punica granatum* L. blue berry composite health care beverage wine and preparation technology thereof, Patent No: CN106281912A
- A kind of fruits and vegetables detergent containing *Punica granatum* L. extract, Patent No: CN107779297A
- *Punica granatum* planting method, Patent No: CN105475065A
- A kind of compound dried meat of *Punica granatum* L. body-building fruit and preparation method thereof, Patent No: CN106259670A
- Use of a combination of Curcuma long, *Punica granatum*, and zingiber officinale extracts in the prevention and/or treatment of mucosal injuries, Patent No: br112017026422b1
- Cultivation method of ornamental *Punica granatum*, Patent No: CN105309259A
- Inhibitory effects of *Punica granatum* extracts on adipocyte differentiation in 3t3-l1, Patent No: KR20100076842A
- A kind of *Punica granatum* L. taste potato chips and preparation method thereof, Patent No: CN106262167A
- A kind of prescription for treating oral ulcers with *Punica granatum* L., Patent No: CN106491666A
- Antitumor formulations with potential apoptosis-inducing potential containing *Punica granatum*, Patent No: BR102015005038A2
- Composition based on pomegranate (*Punica granatum* L.) and its use as a pesticide against bacterial phytopathogens, Patent No: br102021013032a2
- A kind of *Punica granatum* L. milk product formula, Patent No: CN109452364A
- Cosmetic composition containing *Punica granatum* extract for skin soothing effect, Patent No: KR20110038547A
- Oral formulation containing P*unica granatum* extract for treatment of stomatitis, Patent No: br102012018037a2
- Composition that inhibits antibody production, and method for producing *Punica granatum* seed extract, Patent No: JP2018087177A
- Lobster feed containing chitosan and *Punica granatum* bark and production method thereof, Patent No: CN105876094A
- Preparation method of good *Punica granatum* fruit tea, Patent No: CN110810593A
- A natural food additive comprising an extract of *Punica granatum* as an active ingredient, and the preparation thereof, Patent No: KR20130048302A
- A kind of *Punica granatum* L. convergence astringing intestine to stop diarrhoea is concentrated in vacuo blueberry fruit juice and preparation method thereof, Patent No: CN106071470A
- *Punica granatum* plant named 'PIIPG-I', Patent No: USPP21031P3
- Fermentation product of *Punica granatum* and uses thereof, Patent No: TWI693899B
- *Punica granatum* plant named 'Orange Blossom Special', Patent No: USPP22742P2
- Fast hard branch cutting seedling raising method for *Punica granatum* with soft seeds, Patent No: CN114009231A
- Fermentation product of *Punica granatum* and use of the fermentation product of *Punica granatum* for inhibiting melanogenesis and whitening, Patent No: TWI694843B
- A composition comprising extract of *Punica granatum* for prevention and treatment of stress diseases, Patent No: KR101401612B1
- *Punica granatum* plant named 'PQ2009', Patent No: USPP27747P2
- A composition for preventing or treating neurological disorder comprising an extract of *Punica granatum*, Patent No: KR20100061245A
- Method for producing functional Dutch coffee for relieving woman menopausal symptoms using *Punica granatum* fruit and *Pueraria lobata* root extracts, Patent No: KR101915031B1
- Novel *Punica granatum* Extracts-Zinc oxide Nanoparticles and its use, Patent No: KR20220117942A
- Cosmetic composition containing *Punica granatum* l. extract for anti-aging effect, Patent No: KR20030055950A

- Chemical in vitro preservation method for *Punica granatum* germplasm, Patent No: WO2022194312A2
- *Punica granatum*-flavored *Zingiber officinale* Roscoe crystal particles and preparation method thereof, Patent No: CN104473072A
- Female menopause alleviation use of composition containing composite extract of red clover and pomegranate as active ingredient, Patent No: CN106456684A
- Beverage, in which pomegranate seed oil (*Punica granatum* seed oil) is dissolved by a solubilizer or an emulsifier, Patent No: DE102009019103A1
- Mixture of seed component of *Punica granatum*, Patent No: JP2003113028A
- Tissue culture method for *Punica granatum* and culture medium, Patent No: CN105454044A
- Therapeutic composition produced using *Punica granatum* and hydrogen peroxide, Patent No: US8343552B2
- Anti-obesity composition comprising *Punica granatum* and *Citrus junos* extract as effective component, Patent No: KR102112599B1
- Pomegranate fermented lactic acid drink, Patent No: CN105767178A
- Preparing method of pomegranate enzyme, Patent No: CN106343563A
- Method for cultivating potted pomegranates, Patent No: CN106358905A
- Pomegranate tree cultivation method, Patent No: CN105941070A
- Soft-seed pomegranate greenhouse planting method, Patent No: CN105941065A
- Special pomegranate cultivation shelf and pomegranate cultivation method, Patent No: CN105638374A
- Application of pomegranate and sour pomegranate medicine composition to preparation of drug for treating hyperlipidaemia, Patent No: CN105726589A
- Preparation method of pomegranate extracting liquid, Patent No: CN105147546A
- Pomegranate beer, Patent No: CN105670846A
- *Punica granatum* L.var. nana Pers chemical fertilizer, Patent No: CN105399480A
- Cosmetic composition for the pore-minimizing and inhibition of sebum secretion containing the extracts of the *Punica granatum* and *Centella asiatica*, Patent No: KR20090044213A
- Chemical fertilizer for *Punica granatum* L. var. nana Pers. and preparation method of chemical fertilizer, Patent No: CN104355743A
- Yoghurt-making added with pomegranate (*Punica granatum*) and method thereof, Patent No: KR20110023134A
- Blood uric acid level reduction agent having extract of *Punica granatum* l. as active ingredient, Patent No: JP2006016340A
- A kind of preparation method of feature ice pomegranate wine, Patent No: CN106544224A
- Making method of pomegranate tea product, Patent No: CN105901213A
- A device for pomegranate is picked fast, Patent No: CN206165211U
- Processing method for preventing pomegranate cracking, Patent No: CN106332722A
- Toilet soap containing pomegranate polyphenol microcapsule and preparation method of pomegranate polyphenol microcapsule, Patent No: CN105435723A
- Electric pomegranate threshing machine, Patent No: CN105795872A
- Method for increasing complete flowers of pomegranates, Patent No: CN106577105A
- Pomegranate-taste American chips and processing technique thereof, Patent No: CN106579156A
- High-yield pomegranate planting method, Patent No: CN106358903A
- Anti-aging natural pomegranate skin-care product and preparation method thereof, Patent No: CN105687093A
- Method for preparing pomegranate culture medium, Patent No: CN106316608A
- Plantation method for increasing sugar content of pomegranates, Patent No: CN106588263A
- Pomegranate yield increasing planting method, Patent No: CN106576545A
- Anti-freezing technology for pomegranate trees, Patent No: CN106332703A
- Health-care drink containing pomegranates and processing process of health-care drink, Patent No: CN105995300A

- Preparation method of pomegranate polyphenols, Patent No: CN106666739A
- Manual pomegranate thresher, Patent No: CN205866567U
- Application of pomegranate in preparing medicament for treating or preventing Hepatitis B virus infection, Patent No: CN102631384B
- Pomegranate disease prevention and treating agent, Patent No: CN106577828A
- Pomegranate seed oil composition, Patent No: US9205117B1
- Fruit protection technology without bagging for pomegranate, Patent No: CN106342605A
- Planting method for improving the quality of pomegranate fruits, Patent No: CN106358904A
- Method of increasing fruit setting rate of pomegranates through artificial pollination, Patent No: CN106359075A
- Development of a viable protocol for in vitro propagation of pomegranate, Patent No: WO2010113178A2
- Disinfectant agent extracted from *Punica granatum* and its preparation procedure, Patent No: it1120041b
- Extract derived from *Punica granatum* peels for the prevention and treatment of viral infections, Patent No: it202000018949a1
- Alcoholic drink based on *Punica granatum* and preparation procedure, Patent No: itub20154084a1
- Body lotion containing extracts of *Punica granatum* linne, Patent No: KR20190095054A
- Peel-off type pomegranate facial mask and preparation method thereof, Patent No: CN103356469B
- A process for the extraction of the antioxidants from pomegranate peels (*Punica granatum*), Patent No: 392/del/2001
- A process of preparation of anticoagulant and antiplatelet aggregation agent from the epicarp, pulp and seed with pulp of pomegranate (*Punica granatum*), Patent No: 896/del/2003
- *Punica granatum* plant extracts for the treatment of osteoporosis and the extraction process thereof, Patent No: 1195/che/2006
- An improved process of purification of *Punica granatum* (pomegranate) alkaline phosphatase by aqueous two phase extraction", Patent No: 749/del/2012
- Ophthalmic solution comprising dalimba (*Punica granatum*) juice., Patent No: 1312/mum/2012
- Effervescent granules containing *Punica granatum* fruit peel for antiulcer and analgesic activity, Patent No: 1573/mum/2013
- Fabrication of printed circuit board using hybrid of *Punica granatum* and *Calotropis gigantea* reinforced composites, Patent No: 2995/che /2015
- Use of *Punica granatum* l. seed as an exfoliating agent, a skin scrub composition containing same, and method of making and using compositions, Patent No: 201821000098
- Nanoliposomes of *Punica granatum* pericarp for the management of diabetic cataractogenesis, Patent No: 201841004297
- Micropropagation protocol of *Punica granatum* L., cultivar phule arakta, Patent No: 201811033955
- Anticandidal activity of *Punica granatum* peel, Patent No: 201941021023
- A *Punica granatum* extract and its cosmetic uses, Patent No: 201921039821
- *Punica granatum* peel extract preparation and antimicrobial application in fabric, Patent No: 202141015929
- Candy made from the peel of *Punica granatum* L. (lythraceae), Patent No: 202241054378
- Antimicrobial cream of *Punica granutum* seed oil, Patent No: 202321002628
- Polyherbal tablet composition of *Aegle marmelos* and *Punica granatum* extract for antidiarrheal property & thereof, Patent No: 202321025609
- Isolation of ethyl henicosanoate from leaf extracts of *Punica granatum* and their anticancer activity, Patent No: 202341026943
- Composition and method for development and analysis of *Punica granatum* incorporated carbopol gel, Patent No: 202311035578

Scope of further R&D: *P. granatum* L. (daru), a wild and underexplored variety of pomegranate, offers significant potential for further research and development. While it shares morphological similarities with its cultivated counterpart, there is a need for comprehensive chemical profiling to uncover potential variations in bioactive compounds.

Additionally, the exploration of other plant parts, particularly the rind, which is rich in polyphenolics and tannins, could lead to the development of new formulations for various diseases and the production of natural dyes for the textile industry. Given its rich ethnobotanical significance and bioactive constituents, *P. granatum* holds promise as a valuable resource for pharmaceutical, nutraceutical, and industrial applications, presenting an opportunity for income generation in these sectors.

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Samanea saman
(Jacq.) Merr.

Synonyms:
Acacia propinqua A. Rich., *Albizia saman* (Jacq.) F. Muell, *Calliandra saman* (Jacq.) Griseb, *Enterolobium saman* (Jacq.) Prain, *Feuilleea saman* (Jacq.) Kuntze, *Inga cinerea* Humb. & Bonpl. Ex Willd., *Inga salutaris* Kunth, *Inga saman* (Jacq.) Willd, *Mimosa saman* Jacq, *Pithecellobium saman* (Jacq.) Benth., *Zygia saman* (Jacq.) Lyons.

Local/Common/Popular Name(s):
Rain tree, Monkeypod, Cow tamarind, Giantthibet, Ingasaman, Saman.

Vernacular Names:
Akasya, Belati siris, Bodu gas, Campano, Carabeli, Cenizaro, Chaam-churii, Cong, Cow tamarind, Filiganga, French tamarind, Genixaro, Gouannegoul, Gumornispanis, Hujan-hujan, Jahmjuree, Kasia kula, Kayu hujan, Marmar, Mohemohe, Monkey Pod, ʻohai, Pukul lima, Reethigas, Saman, Sirsa, Tamaligi, Tamalini, Thinbaw-kokko, Trong-kon-mames, Vaivai nivavalangi.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Fabales
Family	:	Fabaceae
Genus	:	*Samanea*
Species	:	*Samanea saman*

Botanical Description: *Samanea saman* is a wide-canopied tree known for its large, symmetrical, umbrella-shaped crown. It typically reaches a height of 15–25 m (49–82 ft) with a crown diameter of up to 30 m (98 ft) (Craig & Elevitch, 2006). The tree's leaves fold during rainy weather and at night, giving rise to its common names: "rain tree" and "five o'clock tree" ("Pukul Lima" in Malay). The tree produces pinkish flowers with white and red stamens, arranged in heads of 12–25 flowers each. These flower heads can number in the thousands, covering the entire canopy. The famous *Samán de Güere*, a historic tree in Venezuela, has a crown circumference of approximately 180.8 m (576 ft) and a diameter of 59.6 m (190 ft). The trunk of this tree measures about 2.8 m (9 ft) in diameter and reaches nearly 19 m (60 ft) in height (Von Humboldt & Bonpland, 1820).

This ancient tree, regarded as a national treasure of Venezuela, is believed to be as old as the famous dragon tree (*Dracaena draco*) of Icod de Los Vinos in Tenerife, although its exact age remains indeterminate. Another notable specimen, the "Brahmaputra Rain Tree" in Guwahati, India, boasts the thickest trunk of any *S. saman*, with a diameter of approximately 3.66 meters (12 ft) at breast height (DBH) (Landmark Trees of India, 2012). The tree produces pollen grains that measure around 119 microns in size and form polyads of 24 grains. Large branches of the tree are prone to breaking, particularly during rainstorms.

Distribution: *S. saman* (Jacq.) Merr., commonly known as the rain tree, is widely distributed across tropical regions, including Bangladesh (Duke & Warin, 1981). In the Pacific, it is found on numerous islands such as American Samoa (Tutuila), the Northern Mariana Islands (Saipan, Rota), the Federated States of Micronesia (Chuuk, Kosrae, Pohnpei), Fiji (Kanacea, Taveuni, Vanua Levu, Viti Levu), French Polynesia (Tahiti, Marquesas, Moorea, Raiatea, Rurutu in the Tubuai Islands), Guam, Hawaiʻi, the Marshall Islands (Jaluit, Kwajalein), Niue, Palau (Koror), Papua New Guinea, the Philippines, Pitcairn, Samoa (ʻUpolu), and Tonga (Tongatapu, ʻEua, Vavaʻu, Lifuka/ Foa). The species is also naturalized in parts of

the Caribbean, including Puerto Rico (Barneby & Grimes, 1996). This evergreen tree thrives in various soil types and climatic conditions, making it well-suited for cultivation and naturalization throughout the tropics (Durr, 2001).

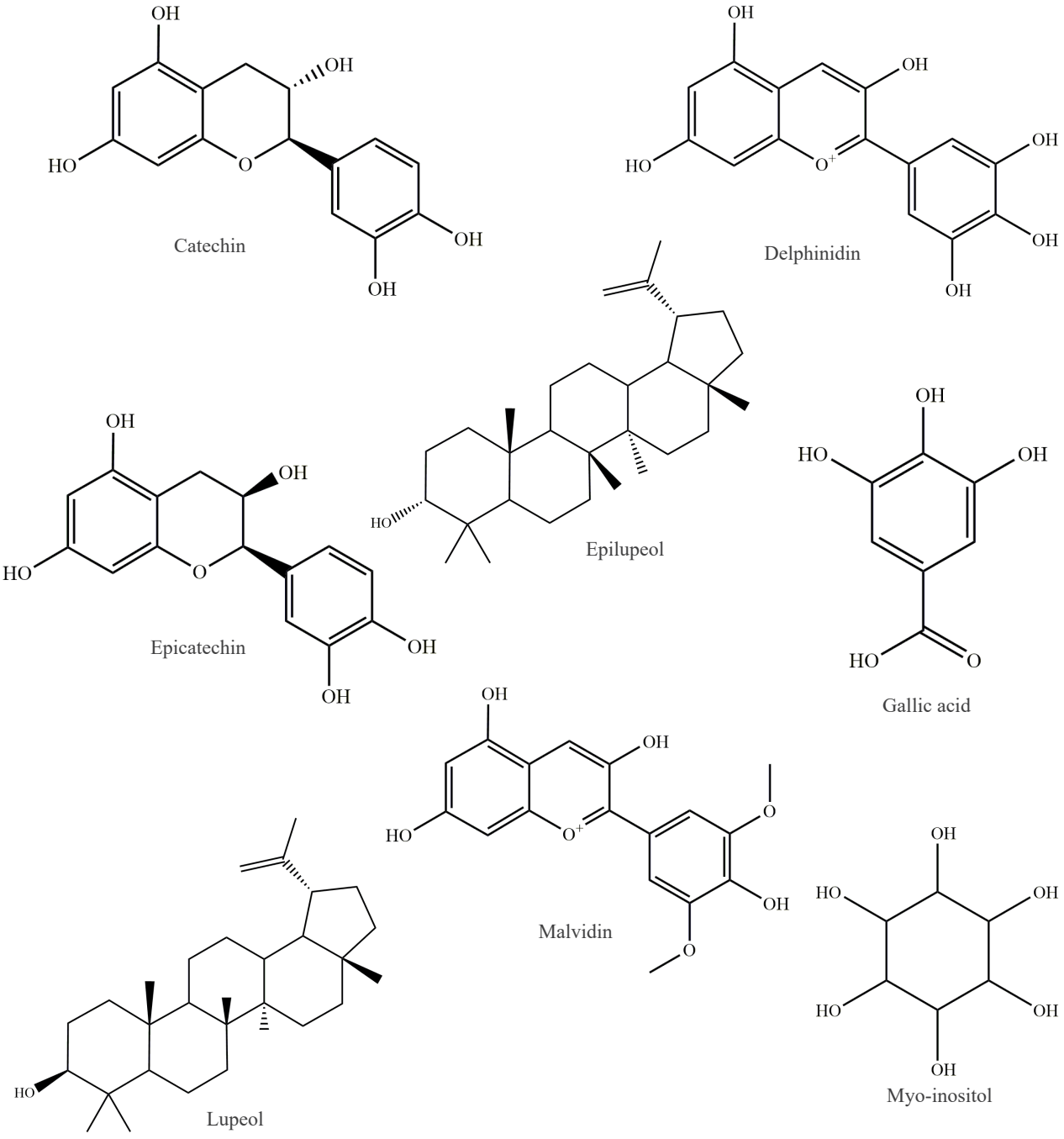
Ethnobotanical Significance: The rain tree (*S. saman*) is used in traditional medicine as a folk remedy for treating colds, diarrhea, headaches, intestinal ailments, and stomach aches (Duke & Warin, 1981).

Phytochemistry:

Leaves: Gallic acid; catechin; malvidin; delphinidin; epicatechin; octacosanoic acid; α- spinasterol; α-spinasterone; lupenone (Duke, 1993, Naveen Prasad et al., 2008)

Flower: Myo-inositol

Bark: Lupeol; epilupeol (Ferdous *et al.,* 2010).



Structures of Important and Characteristic Chemical Constituents of *Samanea saman*

Biological activities:

Antioxidant activity: The antioxidant activity of *S. saman* was evaluated using various extracts: petroleum ether, ethyl acetate, chloroform, aqueous, and HCl. The antioxidant activity increased with concentration, following the order: petroleum ether > ethyl acetate > chloroform > aqueous > HCl, as determined by the DPPH radical scavenging assay and reducing power assay. Extracts of 10-15 mg showed 68% DPPH scavenging activity (Arulpriya et al., 2010). Further tests on n-hexane, chloroform, and carbon tetrachloride fractions of crude methanolic bark extract revealed antioxidant activity through free radical scavenging and total antioxidant activity tests. The carbon tetrachloride fraction exhibited the highest activity, followed by n-hexane and chloroform fractions, as determined by the Phosphomolybdenum method (Ferdous et al., 2010). Additionally, various extracts containing flavonoids and tannins were selected for their antioxidant properties. The leaves of *S. saman* demonstrated significant antioxidant and organo-protective effects, with the hexane-soluble fraction showing the highest antioxidant potential (IC50 = 14 µg/mL). The carbon tetrachloride fraction of the methanolic extract showed moderate antioxidant activity (IC50 = 65 µg/mL). A 70% alcoholic extract of *S. saman* increased reducing power against the standard (ascorbic acid) at 20 µg/mL and demonstrated nitric oxide radical scavenging activity. Alcoholic extracts also showed inhibitory effects on anion scavenging activity, with ascorbic acid as the standard (50 µg/mL) (Patel, 2011).

Anti-Ulcer Activity: The anti-ulcer potential of *S. saman* bark was evaluated in ethanol and stress-induced gastric lesions in albino rats. Gastric ulcers were induced by administering absolute ethanol (5 mL/kg) orally and by water immersion stress. The methanolic extract of *S. saman* was tested at doses of 100 mg/kg, 200 mg/kg, and 400 mg/kg, and its effects were compared to sucralfate (100 mg/kg). The extract showed ulcer inhibition of 65.67%, 72.43%, and 86.49% at the respective doses, while sucralfate exhibited 92.16% inhibition. At 200 mg/kg and 400 mg/kg doses, the methanolic extract significantly ($P<0.001$) reduced acid parameters compared to ulcer control animals. In water immersion stress-induced ulcers, the extract demonstrated significant ($P<0.001$) ulcer inhibition with mean score values at 53.30%, 71.11%, and 87.69% for 100 mg/kg, 200 mg/kg, and 400 mg/kg doses, respectively, compared to 92.68% for the standard treatment. The results exhibit anti-ulcer activity likely through its free radical scavenging and inhibition of hydrogen cation (H+), potassium cation (K+), and ATPase (Arumugam et al., 2011).

Antimicrobial Activity: The antimicrobial potential of *S. saman* has been investigated through various studies. The aqueous extract of *S. saman* leaves was tested for antibacterial activity using the cup diffusion method against three phytopathogenic *Xanthomonas* pathovars. Both aqueous and methanol extracts exhibited significant antibacterial activity against human pathogenic bacteria, with the active fraction, confirmed as alkaloids, showing highly significant activity *in vitro*, with a minimum inhibitory concentration (MIC) of 6.6 and 4 µg/mL for *Xanthomonas pathovars.* The screening of antibacterial activity was carried out with the standard antibiotics such as Baciterimycin 2000 and streptocycline discs for human pathogenic bacteria (Ragavendra et al., 2008). Further investigation revealed that methanol extracts displayed the highest antibacterial activity against 21 microorganisms, with inhibition zones ranging from 3.5 mm to 11.0 mm at a concentration of 1 mg/mL. The MIC for the methanol extract against tested bacteria ranged between 15 µg/mL and 500 µg/mL. *Streptococcus faecalis* was the most susceptible organism (MIC 15 µg/mL), followed by *Staphylococcus aureus* (MIC 62 µg/mL). The ethanol extract demonstrated significant antifungal activity, with inhibition percentages ranging from 20.4% to 81.6%, depending on the fungal species (Thippeswamy et al., 2011). Additional studies tested various solvent extracts of *S. saman* against *E. coli*, *S. aureus*, and *K. pneumoniae* using the well diffusion method. The plant extracts showed inhibitory activity against all tested organisms. Specifically, the dichloromethane fraction exhibited strong antimicrobial activity against *E. coli* and *S. aureus*, while the hexane and acetone fractions showed moderate sensitivity against *E. coli*. For antifungal activity, the chloroform and dichloromethane fractions were particularly effective against *Aspergillus niger*, and all fractions showed good activity against *Candida albicans* (Arulpriya et al., 2010). The ethanol and aqueous extracts of *S.*

saman were also evaluated for antifungal activity. The ethanol extract significantly inhibited the radial growth, sporulation, and biomass of *Fusarium solani in vitro*, while the aqueous extract was effective in vivo against *F. solani* in dragon fruit, with efficacy comparable to the fungicide Antracol at 0.2% (Rita et al., 2016).

Analgesic Activity: The analgesic activity of methanol extracts from the leaves of *S. saman* was evaluated using the tail immersion test in mice (Ahmed et al., 2013). The mice were subjected to thermal stimuli by immersing their tails in hot water. The methanol extract, administered intraperitoneally at a dose of 100 mg/kg body weight, demonstrated significant analgesic effects. Pethidine, used as a standard at 50 mg/kg body weight, served as the reference drug. The study confirmed that *S. saman* extracts exhibit notable analgesic properties.

Insecticidal Activity: Hexane and methanol extracts of *S. saman* were evaluated for insecticidal activity against pathogenic species. The hexane extract demonstrated 50% mortality against *Rhyzopertha dominica* and *Tribolium granarium*, while the methanol extract showed no significant activity against the tested insects (Iqbal Azhar et al., 2009).

Cytotoxic Activity: Bioassay-guided fractionation of 80% methanolic extracts from *S. saman* leaves led to the isolation of two macrocyclic spermine alkaloids, Pitheceolobine-1 and Pitheceolobine-2. Spectral analysis confirmed their structures, and both compounds exhibited significant cytotoxic activity within a concentration range of 0.019-0.625 mg/mL (Sahib Ajam et al., 2012).

Anti-inflammatory Activity: The chloroform extract of *S. saman* was assessed for anti-inflammatory properties and was found to moderately inhibit the initial phase of inflammation, reducing edema formation when compared to the reference drug dexamethasone (Barbosa, 2014).

Immunoadjuvant Activity: The butanolic extract of *S. saman* showed potential as an immunoadjuvant, demonstrating significant adjuvant effects compared to the standard extract from *Quilaja saponaria* (Barbosa, 2014).

Antimitotic Activity: Aqueous, hexane, and carbon tetrachloride extracts of *S. saman* leaves were tested for antimitotic activity using in vitro development of *Tripneustes gratilla* embryos. The extracts exhibited significant antimitotic effects, suggesting potential as alternative antimitotic agents (Lam et al., 2023).

Toxicology: Currently, no scientific reports are available on the toxicology of *S. saman*.

Patent: Composition based on *Samanea saman* for protecting the skin, Patent No: wo2012172200a1

Scope of further R&D: *S. saman*, commonly known as the rain tree or monkey pod tree, is a versatile and ecologically significant species native to Central and South America. Its traditional use in treating various ailments highlights its medicinal and nutritional potential. Future research should explore the bioactive compounds in its leaves, bark, and other parts to validate and expand its medicinal applications. Additionally, investigating the wood properties of *S. saman* for uses in furniture, construction, and pulpwood could provide valuable insights into its quality and utility as a timber source.

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Sapindus emarginatus
Vahl

Synonyms:
Sapindus laurifolius var. *emarginatus* Cooke.

Local/Common/Popular Name(s):
Soapnut tree, Indian soapberry, Laundry tree

Vernacular Names:
Hindi: Ritha; ***Kannada:*** Kookatakayi, Kudale-kaye, Kukate-kayi; ***Marathi:*** Aritha, Rimthi, Rimg; ***Oriya:*** Ritha; ***Tamil:*** Poovandikottai, Ponnankottai, Manipungan Maram; ***Telugu:*** Kungititkaya, Kukudu-kayalu, Kunkudu-chettu; (India Biodiversity Portal <indiabiodiversity.org>).

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Sapindales
Family	:	Sapindaceae
Genus	:	Sapindus
Species	:	*Sapindus emarginatus*

Botanical Description: *Sapindus emarginatus* is a medium to large deciduous tree, reaching up to 18 meters in height with a trunk girth of about 1.5 meters (Flowers of India, 2016). The tree has a dense, broad crown. The bark is grey, shiny, and covered with rough, falling scales. The leaves are paripinnate, alternate, and exstipulate, with a stout, tomentose rachis measuring 25-100 mm in length and about 12-30 cm overall. The leaflets are arranged in 2-3 pairs, with each leaflet measuring 3-15 x 1.5-5.5 cm. They are oblong-obovate, oblanceolate, or elliptic in shape, with a long-pointed or notched tip, a cuneate or obtuse base, and an entire margin. The leaf surface is dull above, with prominent reticulate intercostal veins. The flowers are white and polygamous, occurring in terminal and axillary panicles with pubescent branches. The male flowers are numerous, with a few bisexual flowers present in the same rusty-velvety panicles. Each flower has 5 unequal sepals arranged in two series, and 5 equal, clawed petals that are glabrous on the inner surface except for tufts of white hairs above the claw. The stamens number 8 and are inserted within the disc, with unequal pilose filaments and free oblong anthers. The bisexual flowers have a superior ovary that is trigonus and 3-celled, each cell containing a single ovule. The style is terminal with a 3-lobed stigma. The fruit is a drupe composed of 3 indehiscent cocci, which are partially fused and then separate. The pericarp is saponaceous and fibrous, initially smooth and slightly pubescent, becoming glabrous and wrinkled as it matures. The seeds are globose, smooth, and black, enclosed in a hard, blackish endocarp. Flowering occurs from December to February, with fruiting from May to June, and seed maturation in August (Sharma, 1984; Manjunatha *et al*., 2004).

Distribution: *S. emarginatus* is primarily endemic to South India but has a broader distribution across South Asia, including India, Sri Lanka, and Myanmar. In India, it is typically found in dry deciduous forests and along the margins of grasslands in the Deccan region, extending to the eastern slopes of the Nilgiris and Palani Hills. Notable locations include the Bellary and Kolar districts of Karnataka, and various districts in Andhra Pradesh like Guntur, Kurnool, Prakasham, West Godavari, and Srikakulam. It

also occurs in Palakkad, Idukki, and Malappuram districts of Kerala. The species is sparsely distributed across different geographical regions such as the Gangetic Plains, Western Ghats, and Deccan Plateau, with its range extending into the West-Central-North Indian biogeographical regions (India Biodiversity Portal, 2008; Mahar *et al*., 2011). The plant is commonly found in open forests at low elevations, particularly within dry deciduous forests. It thrives in temperatures ranging from 32-40°C, with annual rainfall between 1000-2500 mm. The species prefers well-drained soils with a pH of 6-6.5, especially loamy clay or black cotton soils, which are ideal for its growth.

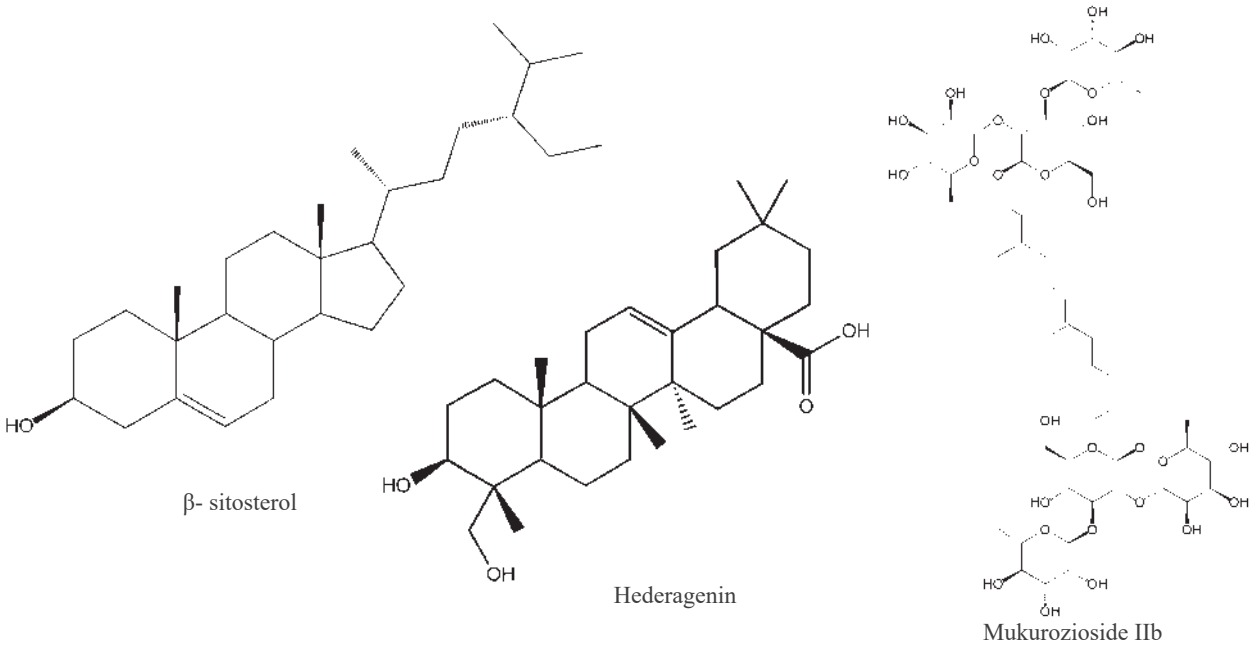
Ethnobotanical Significance: *S. emarginatus* holds a prominent place in Indian traditional and folklore medicine, where it is utilized to treat a variety of human ailments. The plant is known to be effective against headaches, skin diseases, itching, boils, and Kapha-related disorders. A paste made from the fruits is applied externally to alleviate burning sensations in body parts, while fruit juice is used as a nasal drop for treating headaches. The fruit is widely used as a natural soap substitute, particularly for washing delicate fabrics like silk (Sajeev & Sasidharan., 1997; Moghimipour & Handali, 2015; Bajad & Pardeshi, 2016). Additionally, a fruit paste is applied to reduce pain from scorpion stings (Ahirrao et al., 2009). A paste made from seeds and water is traditionally used as a remedy for dandruff. The plant is also employed as an anti-inflammatory, antipruritic, and blood purifier, with its powder being used for nasal insufflation (Jeyabalan & Palayan, 2009).

Phytochemistry:

Fruits: Hederagenin-3-O-β-D-galactopyranosyl-(1→2)-β-D-glucopyranosyl; hederagenin-3-O-β-D-glucuronopyranosyl-(1→2)-β-D-galactopyranoside (Arora et al., 2012).

Pericarp: Mukurozioside IIb; hederagenin; hederagenin 3-O-α-L-arabinopyranoside; hederagenin-3-O-[β-D-xylopyranosyl-(1→3)-α-L-rhamnopyranosyl(1→2)-α-L-arabinopyranosyl]; hederagenin-3-O-[α-L-arabinopyranosyl(1→3)-α-L-rhamnopyranosyl(1→2)-α-L-arabinopyranosyl]; hederagenin-3-O-(3,4-di-O-acetyl-β-D-xylopyranosyl)-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranoside; hederagenin 3-O-(2-O-acetyl-β-D-xylopyranosyl)-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranoside; 23-O-acetyl-hederagenin 3-O-(4-O-acetyl-β-D-xylopyranosyl)-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranoside; oleanolic acid 3-O-(4-O-acetyl-β-D-xylopyranosyl)-(1→3)-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranoside; β-sitosterol (Kanchanapoom et al., 2001; Sharma et al., 2011).

Seed: Fatty acid diester of l-cyano-2-hydroxymethylprop-l-ene-3-ol (Gowrikumar et al., 1976).



Structures of Important and Characteristic Chemical Constituents of *Sapindus emarginatus.*

Biological activities:

Anti-Mosquito Activity: The aqueous kernel extract of *S. emarginatus* has demonstrated significant anti-mosquito activity against three major vector mosquito species: *Aedes aegypti*, *Anopheles stephensi*, and *Culex quinquefasciatus* (Koodalingam *et al.,* 2011).

Anti-Bacterial Activity: Various extracts of *S. emarginatus* have shown potent antibacterial properties. The 1,4-dioxane extract of the leaves exhibited strong antibacterial activity against several bacterial strains, including *Pseudomonas testosteroni* NCIM5098, *Staphylococcus epidermidis* ATCC12228, *Proteus morganii* NCIM2040, *Bacillus subtilis* ATCC6633, *Micrococcus flavus* ATCC10240, and *Klebsiella pneumoniae* NCIM2719 (Vaghasiya *et al.,* 2009). Additionally, methanol extracts of powdered plant material were found to be highly effective against *Staphylococcus aureus* and *S. epidermidis* (Patil & Khan, 2015). Spherical silver nanoparticles synthesized using the pericarp extract of *S. emarginatus* further enhanced antibacterial activity against gram-positive bacteria such as *Bacillus subtilis* and *Staphylococcus aureus* (Swarnavalli et al., 2017).

Anti-Obesity Activity: The methanol extract of *S. emarginatus* flowers has shown an anti-obesity effect in a rat model induced with monosodium glutamate (Suneetha *et al.,* 2013).

Hyperlipidemic Activity: Methanol extracts of the pericarp of *S. emarginatus* have been found to be effective in managing hyperlipidemia (Jeyabalan & Palayan, 2009).

Nephroprotective Activity: The bark of *S. emarginatus* has demonstrated nephroprotective activity, offering potential benefits for kidney health (Jedage & Manjunath, 2016).

Immunosuppressive Activity: The aqueous kernel extract of *S. emarginatus* was evaluated for its immunosuppressive effects against hemocyte-mediated immune responses in the larvae and pupae of *Aedes aegypti*. The study demonstrated the plant's potential as an immunosuppressive agent, which could be utilized in developing botanical biocides against mosquitoes (Koodalingam et al., 2013).

Laxative Activity: The hydroethanolic pericarp extract of *S. emarginatus* demonstrated significant laxative effects in various animal models. The extract increased fecal weight, peristalsis index, and moisture content in a dose-dependent manner, suggesting that the triterpene saponins present in the extract are likely responsible for this activity (Vivekanandan et al., 2021).

Anti-Diabetic Activity: The ethanolic extract of *S. emarginatus* seed kernels was found to exhibit significant anti-diabetic effects in albino rats. The extract reduced levels of glycogen, total cholesterol (TC), triglycerides (TG), low-density lipoprotein (LDL), and very-low-density lipoprotein (VLDL), while increasing high-density lipoprotein (HDL) levels, indicating its potential for managing diabetes (Archana et al., 2022).

Larvicidal Activity: Various leaf extracts of *S. emarginatus* have been shown to disrupt enzyme activity in the larvae and pupae of houseflies, thereby inhibiting their growth (Raja & Suresh, 2015).

Anti-Inflammatory Activity: The aqueous extract of *S. emarginatus* leaves demonstrated anti-inflammatory properties. In an in vitro study, it stabilized human red blood cell (RBC) membranes, and in an in vivo study, it significantly reduced formalin-induced paw edema in rats. The extract's effectiveness was dose-dependent, indicating its potential as an anti-inflammatory agent (Reddy et al., 2014).

Toxicology: No toxicology studies on *S. emarginatus* have been reported in the literature to date.

Patent:

- Detergent product, useful to prepare washing powder, preferably for linen, comprises packaging (film of polymer) and detergent composition having product from Sapindus fruit and stain removing- and bleaching- agent (e.g. sodium carbonate), Patent No: FR2924123A1
- Use of a herbal extract containing formulation for prophylactic and/or therapeutic treatment of plant diseases, which is supported or caused by pathogens, where the formulation contains extract of plants or its parts of Sapindus, Patent No: DE102007004500A1
- An improved process for the extraction of pure saponin from the fruit pericaarp of *Sapindus emarginatus*. Patent No: IN179171B

- Development of protocols for decellularization of dermis & diaphragm of animals, and fish swim bladder using soapnut (Sapindus sp.) and other plants extract having like properties., Patent No: 201811019495
- Development of protocols for decellularization of periosteum and small intestinal submucosa of animals using soapnut (Sapindus sp.) and other plants extract having like properties., Patent No: 201811019496
- A cellularization of omasum, abomasum urinary bladder, and gall bladder of ruminants using soapnut (Sapindus sp.) and other plants extract having like properties., Patent No: 201811019497

Scope of Further R&D: *S. emarginatus*, commonly known as soapberry or reetha, has been traditionally used for cleaning, medicinal, and pesticidal purposes. Extensive literature has documented its rich phytochemical profile, including saponins, flavonoids, tannins, and sterols, which contribute to its diverse pharmacological and medicinal properties. However, there remains significant potential for further research and development in several key areas. Further studies are needed to scientifically validate the traditional uses of *S. emarginatus* in medical practices such as Ayurveda and traditional Chinese medicine. Research should focus on developing and standardizing herbal formulations like powders, extracts, or creams for various medicinal applications, ensuring consistency and efficacy. Additionally, the plant should be explored for its potential in natural and sustainable cosmetic products, offering alternatives to synthetic options. Further, comprehensive research is essential to evaluate the safety profile and toxicity of *S. emarginatus*, ensuring its safe application across various domains, particularly in long-term use. The exploration in these areas could unlock new applications and improve the understanding and utilization of this valuable plant.

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Sapindus trifoliatus L.

Synonyms:
Sapindus laurifolius Vahl,
Sapindus abstergens Roxb. Ex Wight & Arn.,
Sapindus acutus Roxb. Ex Wight & Arn.,
Sapindus mollis Bl.

Local/Common/Popular Name(s):
Soapnut Tree, Small Soapnuts, Soapberry, Wash Nuts, Reetha, Soapnut, Reetha, Aritha, Dodan, Doadni.

Vernacular Names:
Hindi: Phenil, Risht, Rishtak; ***English:*** Three-leaf soapberry; ***Gujarati:*** Arithi, aritho, arithu; ***Kannada:*** Amtalakkyi, norekaayi, togate mara; ***Sanskrit:*** Hrishtah, phenaka, phenil, rishtak, rita, sarishta, urdhvashodhanah; ***Bengali:*** Ritha; ***Assamese:*** aritha; ***Malayalam:*** cavakkaay, uruvanchi; ***Marathi:*** Phenil, rinthi, ritha; ***Oriya:*** Ritha; ***Tamil:*** Punalai, punthi, puvanti; ***Telugu:*** Kunkuduchettu, phenilamu; ***Urdu:*** Phenil.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Sapindales
Family	:	Sapindaceae
Genus	:	*Sapindus*
Species	:	*Sapindus trifoliatus*

Botanical Description: *Sapindus trifoliatus* is a deciduous tree that can grow up to 25 meters. The leaves are alternate, pinnate and measure 15-40 cm in length, typically with 14-30 leaflets, though the terminal leaflet is often absent. The leaflets are elliptic-lance-shaped, smooth and end in a pointed tip with a slightly oblique base. They are usually found in pairs of 2 or 3, each measuring 8-18 cm long and 5-7.5 cm wide. The flowers bloom between November and January are small and greenish-white, arranged in large panicles. The fruit is a small, leathery-skinned drupe, about 1-2 cm in diameter, appearing as solitary globose structures in July-August. When young, the fruit is velvety but it hardens and becomes smooth as it matures (Meena et al., 2012; Rao et al., 2012; Kommalapati et al., 1998).

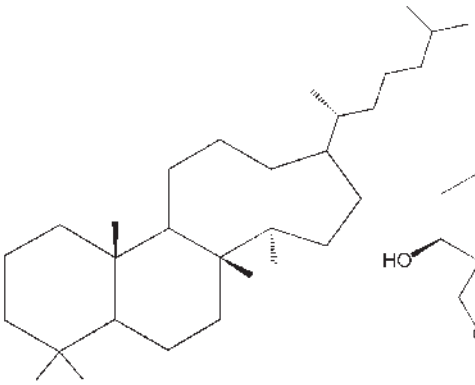
Distribution: *S. trifoliatus* is commonly cultivated in South India and thrives in the moist low-country regions of Sri Lanka. The species also grows in East Asia, India and Pakistan. It flourishes in deep clay loamy soils with an annual rainfall of around 200 mm (Jayaweera et al., 1982; Meena et al., 2012; Rao et al., 2012; Kommalapati et al., 1998).

Ethnobotanical Significance: *S. trifoliatus* is widely used in traditional medicine across Asia, particularly in the Ayurvedic system, as well as in Unani and Tibetan practices (Rao et al., 2012; Jayasinghe et al., 1979). Tribes in Orissa, India, use its aerial parts to treat diabetes mellitus. The fruits are valued as a tonic for treating stomach issues, dysentery, diarrhea, cholera and uterine conditions. The roots are used for eye ailments while the seeds stimulate the uterus during childbirth and enhance menstruation. The plant is also key in Ayurvedic Panchakarma therapies like Vamana Karma and Virechana Karma. Its fruits are a common ingredient in Ayurvedic shampoos used for dandruff and as a hair tonic. Soap nuts from *S. trifoliatus* are traditionally employed for washing clothes and treating skin conditions such as eczema and psoriasis (Meena et al., 2012; Sharma et al., 2011; Kishore et al., 2010; Arulmozi et al., 2005; Ediriweera et al., 2021; Fern et al., 2021).

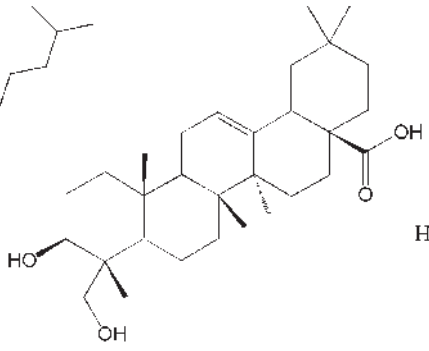
Phytochemistry:

Fruits: Sapindosides A, B, C, D; Mukorozi Saponins (E1 and Y1) (Sharma et al., 2011; Deepa et al., 2012; Suhagia et al., 2011; Arora et al., 2012; Saxena et al., 2004); Sapogenin (Francis et al., 2002); Oleanane; Dammarane; Tirucullane; Sapindoside A, B, C, D, E; Hederagenin (Goyal, 2014; Bharti et al., 2012).

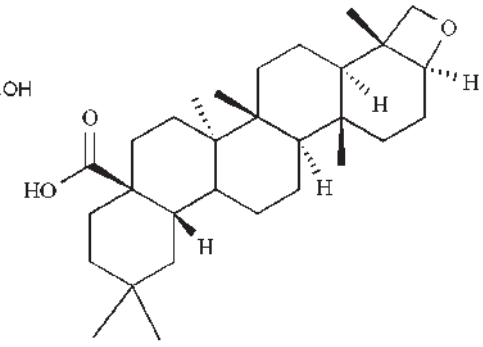
Seeds: Hederagenin 3-o (3-o-acetyl-β–D-xylose) (Grover et al., 2005; Krishnaveni et al., 2008); Arachidonic acid; Behenic acid; Oleic acid; Linoleic acid; Palmitic acid; Stearic acid; Oleanolic acid; Sapindic acid; Trifolioside A; Sapindoside C, D, E; Stigmasterol; Kaempferol; Quercetin; β-sitosterol; Hederagenin (Prajapati et al., 2003).



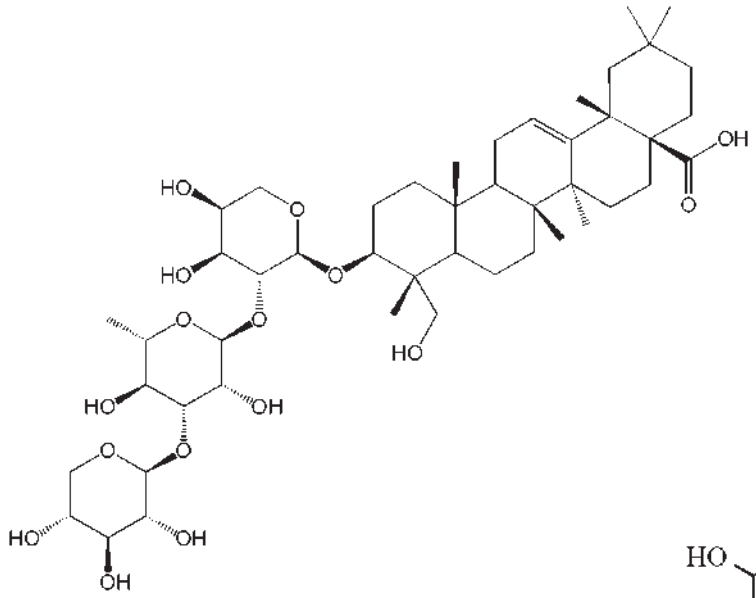
Dammarane



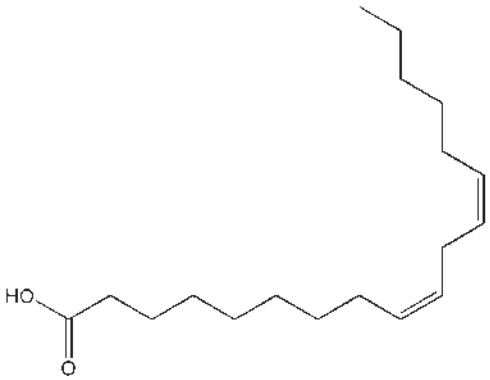
Hederagenin



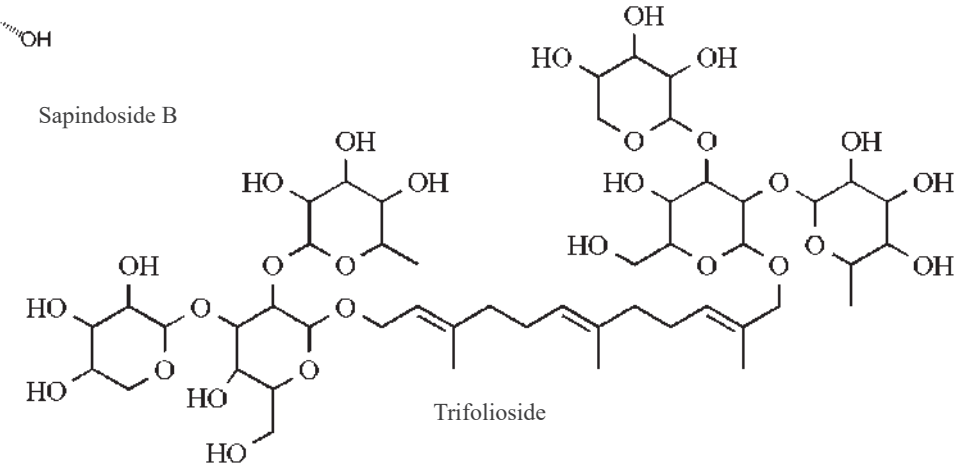
Sapandic acid



Sapindoside B



Linoleic acid



Trifolioside

Structures of Important and Characteristic Chemical Constituents of *Sapindus trifoliatus*

Biological activities:

Anti-cancer activity: The fruit extract of *S. trifoliatus* has been reported to inhibit the proliferation of human breast cancer cell lines SKBR3 and MDA-MB435 (Rao et al., 2012; Man et al., 2010).

Anti-inflammatory activity: Studies on *S. trifoliatus* seed's ethanol extract demonstrated significant anti-inflammatory effects using paw-edema and pleurisy models. The extract reduced paw edema, pleural fluid volume and leukocyte migration and decreased granuloma weight (Arul et al., 2004). Additionally, an aqueous lyophilized extract of the fruit's pericarp showed in-vivo and in-vitro anti-inflammatory activity by inhibiting 5-lipoxygenase, cyclooxygenase, leukotriene B4, and nitric oxide synthase. The extract significantly reduced paw and ear edema caused by various inflammatory agents, indicating its action through the 5-lipoxygenase and cyclooxygenase pathways (Arulmozi et al., 2005).

Antidiabetic activity: The metabolic effects of *S. trifoliatus* (100 mg/kg i.p. dose) were evaluated in mice and rats focusing on glucose, triglycerides (TG) and total cholesterol (TC). In mice, *S. trifoliatus* caused a moderate increase in plasma glucose levels by 18.26% but no differences in TG or TC levels compared to vehicle-treated animals. In rats, glucose levels significantly increased (95.62 ± 4.56 mg/dl vs. 157.80 ± 13.55 mg/dl in the treated group), with no changes in TG or TC levels. Additionally, hyperglycemic responses during the oral glucose tolerance test (OGTT) were significantly higher than in the control group indicating that *S. trifoliatus* has diabetogenic potential in normal animals (Arulmozhil et al., 2006).

Anti-hyperalgesia activity: The aqueous pericarp extracts of *Sapindus trifoliatus* fruits were evaluated in an in vivo migraine hyperalgesia model. The study suggested that the plant's anti-hyperalgesic activity might be due to antagonism of dopamine D2 receptors (Arulmozhi et al., 2005).

Anti-ulcer activity: The anti-ulcer potential of *S. trifoliatus* was studied using methanolic and aqueous extracts of its leaves and seeds. In a pylorus ligation-induced ulcer model in rats an oral dose of 400 mg/kg body weight of both extracts showed significant ulcer inhibition with methanolic and aqueous extracts demonstrating 64.82% and 60.13% inhibition respectively. Lower doses (200 mg/kg) showed moderate inhibition (52.27% and 49.32%). In comparison, the standard drug Ranitidine provided 71.79% protection. Additionally, in an ethanol-induced ulcer model, both methanolic and aqueous extracts of seeds (100–400 mg/kg) significantly reduced ulcer index with the aqueous extract showing the most protection at 400 mg/kg (Kishore et al., 2010; Surendra et al., 2012).

Anti-fertility activity: The saponin-rich butanol extract of *S. trifoliatus* fruits exhibited anti-fertility activity in animal models. At a dose of 20 mg/kg body weight, the extract inhibited fetal implantation and showed anti-estrogenic effects by significantly altering gonadal and gonadotrophic hormone levels in serum. These findings suggest its potential use in pregnancy interception (Pal et al., 2013).

Anti-convulsant activity: The ethanolic extract of *S. trifoliatus* leaves was tested for anti-convulsant effects on chemically and electrically induced seizures. At doses of 100, 200 and 400 mg/kg, the extract significantly reduced seizure duration in maximal electroshock-induced seizures (MES) and protected animals from tonic seizures induced by pentylenetetrazole (Jennifer et al., 2013).

Toxicology: No scientific studies are available regarding the toxicology of *S. trifoliatus*.

Commercial Products: The fruit extract of *S. trifoliatus* is commonly used as an ingredient in haircare and skincare products including shampoos, body washes and cleansers (Search Results - *Sapindus trifoliatus*, n.d.).

Patent:

- Detergent product, useful to prepare washing powder, preferably for linen, comprises packaging (film of polymer) and detergent composition having a product from Sapindus fruit and stain removing- and bleaching- agent (e.g. sodium carbonate), Patent No: FR2924123A1Use of a herbal extract containing formulation for prophylactic and/or therapeutic treatment of plant diseases which is supported or caused by pathogens, where the formulation contains extract of plants or its parts of Sapindus, Patent No: DE102007004500A1
- An improved process for the extraction of pure saponin from the fruit pericarp

of S*apindus emarginatus*, Patent No: IN179171B

- Development of protocols for decellularization of dermis & diaphragm of animals and fish swim bladder using soapnut (sapindus sp.) and other plants extract having like properties., Patent No: 201811019495
- Development of protocols for decellularization of periosteum and small intestinal submucosa of animals using soapnut (sapindus sp.) and other plant extract having like properties., Patent No: 201811019496
- A cellularization of omasum, abomasum urinary bladder, and gall bladder of ruminants using soapnut (sapindus sp.) and other plants extract having like properties., Patent No: 201811019497
- Herbal extract comprising a mixture of saponins obtained from *Sapindus trifoliatus* for anticonvulsant activity, Patent No: NZ538518A
- *Sapindus trifoliatus* extracts, Patent No: GB2081580A
- Antimigraine combination comprising *Sapindus* and *Emblica* extracts, Patent No: US7632528B1
- Production technology of *sapindus saponin* 'completely green' fruit and vegetable cleaner, Patent No: CN113549498A
- Extract of pericarp of the fruit *Sapindus trifoliatus* comprising saponin, Patent No: 896/MUM/2003
- Contraceptive effects of saponins from *Sapindus trifoliatus* DC, Patent No: 1/MUM/2007

Scope of further R&D: *Sapindus trifoliatus*, commonly known as the soapberry or soapnut tree, is a deciduous tree with a range of traditional and potential modern applications. Future research should focus on the detailed analysis of its chemical composition to identify novel compounds using advanced scientific techniques. The plant has been traditionally used for its anti-inflammatory, anti-fungal, and anti-microbial properties; therefore, further investigation into these medicinal properties could lead to the development of new pharmaceutical products. Additionally, given its saponins, which have natural cleaning properties, research should explore the creation of more efficient and eco-friendly cleaning products using soapnut extracts. Moreover, evaluating the safety and potential side effects of *S. trifoliatus*-based products on human, animal, and environmental health is crucial for ensuring their safe application.

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Schima wallichii
(DC.) Korth.

Synonyms:
Gordonia wallichii DC., *Schima bancana* Miq., *Schima crenata* Korth. *Schima noronhae* Reinw. ex Blume.

Local/Common/Popular Name(s):
Bengali: Cheloni, Mukriasal, Makrisal; ***English:*** Needle wood, Schima; ***Hindi:*** Makusal, Kanak, Dieng-shyr-nagan, Chilauni, Nogabhe; ***Nepali:*** Sule-chilauni, Aule-chilaune, Chilaune, Goechassi; ***Trade Name:*** Simartolu, Chinese guger tree, Samak, Needle Wood, Schima, Mang tan, Chilauni [Orwa et al., 2009].

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Ericales
Family	:	Theaceae
Genus	:	*Schima*
Species	:	*Schima wallichii*

Botanical Description: *S. wallichii* is an evergreen, medium to large tree that can grow up to 47 meters tall. It has a cylindrical bole, branchless for up to 25 meters, with a diameter ranging from 125 to 250 cm.

The tree features steep buttresses, occasionally up to 1.8 meters high. Its bark is ruggedly cracked into small, thick, angular pieces, with a red-brown to dark grey surface, while the inner bark is fibrous and bright red in color (Orwa et al., 2009; Hong et al., 1996; Troup, 1975). The leaves are spirally arranged, oblong to broadly elliptic, measuring 6-13 cm in length and 3-5 cm in width. They have a wedge-shaped base, acute to acuminate apex, and toothed margins, with 6-8 pairs of secondary veins. The petioles are about 3 mm long (Orwa et al., 2009). The flowers are solitary, found in axils at the twig apices, with two bracteoles and are pentamerous. They have subequal sepals that persist in fruit, and white petals with a rosy flush that are connate at the base. The tree has numerous stamens attached to the corolla base, versatile anthers, a superior ovary with 5 locules, and 2-6 ovules per cell, along with a simple style (Orwa et al., 2009; Anon, 1986; Troup, 1975). The fruit is a woody, silky, subglobose capsule, 2-3 cm in diameter, that opens by 5 valves, containing seeds that are winged all around (Orwa et al., 2009; Anon, 1986; Troup, 1975).

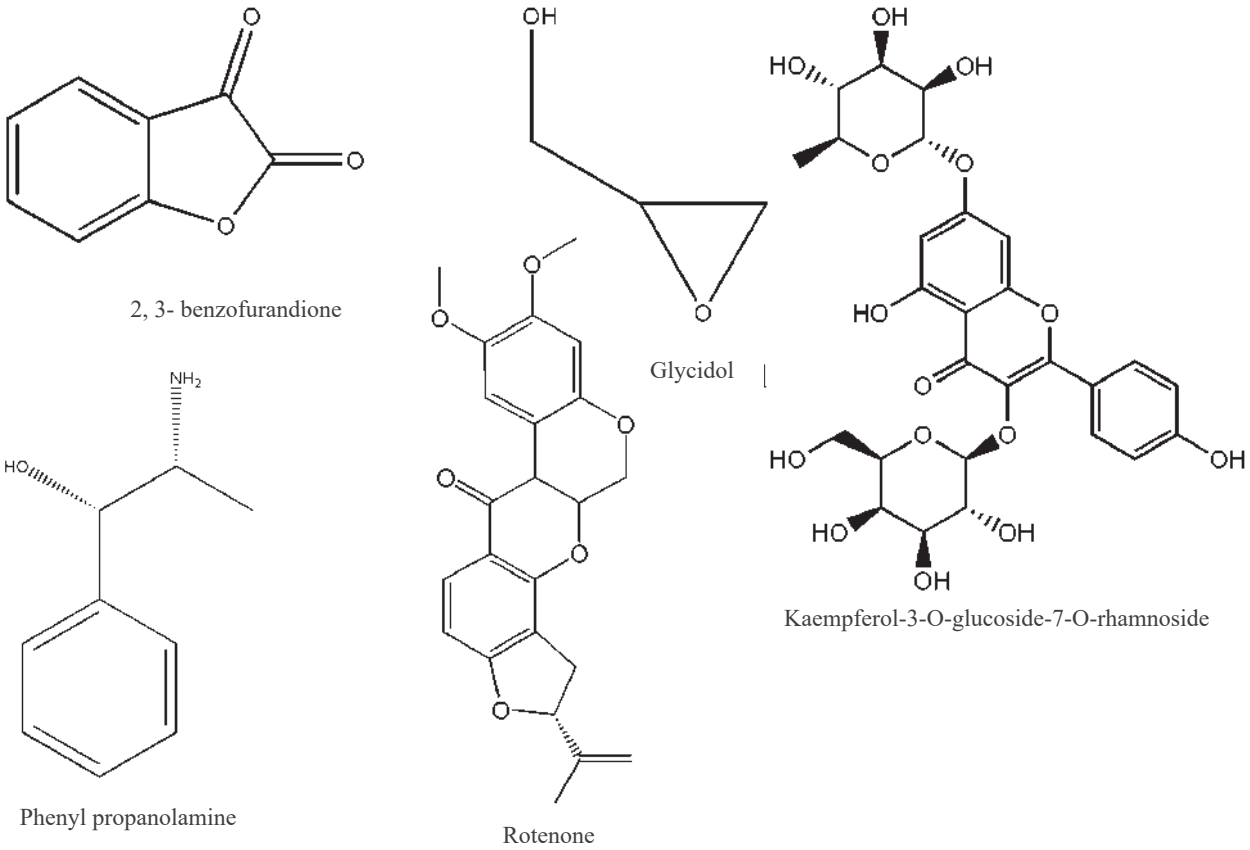
Distribution: The distribution of *Schima wallichii* spans Southeast Asia, including countries like India, Bhutan, Nepal, Myanmar, Thailand, Laos, and Vietnam. This evergreen tree thrives in subtropical and tropical regions. In India, it is primarily found in the northeastern states, such as Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura, and also occurs in parts of northern West Bengal and Sikkim. It is a common tree in the Eastern Himalayas. *S. wallichii* can grow in diverse climates, habitats, and soil types, often thriving in primary lowland to montane forests. It is particularly prevalent in disturbed and secondary forests, scrublands, grasslands, and even areas with brackish water. The tree is capable of growing at altitudes ranging from 2400 to 3900 meters, withstanding mean annual temperatures from 0-5°C to 37-45°C and rainfall between 1400-5000 mm. While it typically prefers well-drained soils, it can also be found in swamps and along riverbanks,

adapting to various soil textures and fertility levels (Orwa et al., 2009; Kebler & Sidiyasa, 1994).

Ethnobotanical Significance: *S. wallichii* is utilized extensively in traditional medicine and various practical applications. The plant's leaves are often made into a paste that is applied to cuts and wounds, while a root decoction is consumed to treat diarrhea and dysentery. The juice extracted from the young plant, rootstock, and leaves is traditionally used to reduce fever and treat gastric issues. Additionally, pounded stem bark or bark powder is applied to infected skin areas to cure skin diseases, as observed in certain villages. Specifically, in Sybru village, Rashuwa district, the bark powder is used for treating cuts and burns (Orwa et al., 2009; Das & Ghosh, 2013; Jeyaseelan & Jashothan, 2012; Fakruddin et al., 2012). In East Nepal, the Satars community uses pounded stem bark to treat fever, stomach pain, and even for bone fractures. Similarly, the Gurungs of Western Nepal apply crushed roots to scorpion bites and to reduce fever and gastric problems (Das & Ghosh, 2013a; Gurung, 2002; Kebler & Sidiyasa, 1994). The leaves, although of medium quality, are used as fodder and for bedding purposes. The bark, containing tannin, is utilized for dyeing and in processing skins, though the tannin content in the leaves is not sufficient for economic tanning purposes (Orwa et al., 2009; Joshi, 2007). The wood of *S. wallichii* is valued for its medium to heavy hardwood, with a density of 450-920 kg/m³ at 15% moisture content. It is used in medium-heavy construction, particularly for covered structures like columns, beams, flooring, and interior fittings. The wood is also employed in ship and boat building, vehicle bodies, agricultural tools, and even for making pallets, boxes, crates, poles, toys, turnery, and treated railway sleepers. It has been used in bridge construction in mountainous areas, and young trees serve as rafters. Moreover, high-quality plywood and wood-wool boards can be produced from *S. wallichii* wood (Orwa et al., 2009). The seeds of *S. wallichii* contain about 19% oil, and the bark contains an alkaloid used as fish poison (Orwa et al., 2009).

Phytochemistry:

Leaves: Kaempferol-3-O-glucoside-7-O-rhamnoside; 2, 3- benzofurandione; Glycidol; Phenylpropanolamine and Rotenone (Joshi and Kunjani, 2007; Lalhminghlui and Jagetia, 2018; Das et al., 2012).



Structures of Important and Characteristic Chemical Constituents of *Schima wallichii*

Biological Activities:

Anticoagulant Activity: The alcohol extract of *S. wallichii* has demonstrated anticoagulant properties, which may have therapeutic potential in managing blood clot-related conditions (Sarma & Manash, 2019).

Antimicrobial Activity: The bark extract of *S. wallichii* has shown significant antimicrobial activity against a range of pathogens. The hydroethanolic extract was particularly effective against Gram-negative bacteria such as *Escherichia coli*, *Pseudomonas aeruginosa*, and *Shigella* spp., while showing lesser activity against Gram-positive bacteria like *Sarcina lutea*, *Bacillus pumilus*, and *Bacillus subtilis*. The extract also exhibited antifungal activity against *Candida albicans* (Das & Ghosh, 2013b; Dewanjee et al., 2008). Additionally, benzene, acetone, and aqueous extracts from the fruits of *S. wallichii* displayed antibacterial activity against gram-positive bacteria (*Staphylococcus aureus* NCTC 8530 and *Bacillus liherfernis*10341) and gram-negative bacteria (*Escherichia coli* HD10, *Salmonella paratyphi* A2 and *Vibrio chloera* 64) using disc diffusion method, It was found that the acetone extract was most active against *Escherichia coli* HD10 and *Bacillus liherfernis* 10341 (Barma et al., 2015).

Antiseptic Activity: The bark of *S. wallichii* is traditionally used as an antiseptic for cuts and wounds. It also exhibits anthelmintic properties and is used as a vermicide, mechanical irritant, and in the treatment of gonorrhea (Dewanjee et al., 2008; Dewanjee et al., 2009).

Anti-inflammatory Activity: Polyphenol-enriched extracts from the bark of *S. wallichii* have shown anti-inflammatory effects, which could be beneficial in treating inflammatory conditions (Dewanjee et al., 2009, 2011; Fakruddin et al., 2011).

Antiplasmodial Activity: Kaempferol-3-O-rhamnoside, isolated from the leaves of *S. wallichii*, has demonstrated antiplasmodial activity against chloroquine-resistant *Plasmodium falciparum*, suggesting potential use in malaria treatment (Joshi & Kunjani, 2007; MI et al., 2014).

Anti-malignant Activity: Various extracts of *S. wallichii* have shown anti-cancer properties, which may offer therapeutic potential in cancer treatment (Lalhminghlui & Jagetia, 2018).

Antioxidant Activity: The chloroform, ethanol, and aqueous extracts of *S. wallichii* have been found to possess antioxidant activity, effectively scavenging free radicals like DPPH, hydroxyl, superoxide, nitric oxide, and ABTS. This activity is attributed to the presence of flavonoids and polyphenols (Lalhminghlui & Jagetia, 2018). Furthermore, ethyl acetate, methanol, and butanol extracts from *S. wallichii* leaves have shown significant antioxidant activity in DPPH assays (Widiyarti et al., 2018, 2021).

Wound Healing Activity: The wound healing properties of *S. wallichii* leaves were evaluated using an excision wound model in Swiss albino rats. The study revealed that the extract accelerated the wound healing process by reducing the epithelialization period and increasing the rate of wound closure compared to the control group (Dev et al., 2023).

Toxicology: The toxicity of various extracts from *S. wallichii* leaves was assessed using the Brine Shrimp Lethality Test (BSLT). The results indicated that all extracts were active against *Artemia salina* with LC50 values ranging from 107.35 to 902 µg/mL, suggesting potential toxicity at higher concentrations (Widiyarti et al., 2018).

Patent:

- Method for transplanting wild *Schima wallichii* choisy big tree, Patent No: CN101536659A

Scope of further R&D: *S. wallichii*, commonly known as needlewood or Chilauni, is an evergreen tree of the family Theaceae. Known for its valuable timber and traditional medicinal uses, this species has great potential that remains underexplored. Despite its widespread use in traditional medicine, there has been limited phytochemical and pharmacological research conducted on *S. wallichii*. Comprehensive studies are needed to identify and characterize the bioactive compounds present in *S. wallichii*. This could lead to the discovery of novel compounds with potential medicinal or nutraceutical applications. Advanced analytical techniques such as HPLC, GC-MS, and NMR spectroscopy should be employed to isolate and identify these compounds. While *S. wallichii* has been traditionally used to treat various ailments, systematic pharmacological studies are necessary to validate these claims. Research should focus on

evaluating the plant's biological activities, including antimicrobial, anti-inflammatory, antioxidant, and anticancer properties. Additionally, studies on the safety and efficacy of these bioactive compounds will be crucial for their potential application in modern medicine. Investigating the traditional medicinal uses of *S. wallichii* in various cultures can provide valuable insights into its therapeutic potential. Ethnobotanical studies should be conducted to document and scientifically evaluate these traditional practices. This could lead to the development of new pharmaceutical formulations based on traditional knowledge. *S. wallichii* offers various non-timber forest products (NTFPs), such as resin, edible nuts, and other medicinal products. Research should focus on sustainable harvesting practices and assessing the economic potential of these NTFPs. This could contribute to the conservation of *S. wallichii* and provide livelihood opportunities for local communities. The economic potential of *S. wallichii*, beyond its timber value, should be explored through sustainable harvesting and value addition of its NTFPs. This includes studying the market potential for its resin, edible products, and medicinal extracts, as well as developing sustainable management practices to ensure the species' long-term viability. By addressing these research areas, *S. wallichii* could be further developed into a valuable resource for both medicinal and economic purposes, contributing to biodiversity conservation and rural development.

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Simmondsia chinensis
(Link) C.K.Schneid.

Synonyms:
Buxus chinensis Link (1822),
Simmondsia californica Nuttall. (1844),
Simmondsia californica.

Common Name:
Jojoba, Goat nut (En). Deer nut, Pignut, Wild Hazel, Quinine nut, Coffeeberry, and Gray box bush.

Vernacular Names:
None

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Caryophyllales
Family	:	Simmondsiaceae
Genus	:	*Simmondsia*
Species	:	*Simmondsia chinensis*

Botanical Description: *Jojoba* (*Simmondsia chinensis*) is an evergreen, perennial shrub that typically reaches up to 3 meters in height. It has a multi-stemmed woody growth and a natural lifespan of up to 200 years, with mature plants developing hard and heavy yellowish stems that lack a distinctive smell. The plant's growth form can vary from being almost prostrate with lateral branches to upright, depending on environmental conditions (Gentry, 1958; Kuepper, 1981). The leaves of jojoba are lanceolate, deep green, stiff, thick, and leathery, typically measuring 2.5–5.0 cm in length and 1.5–2.5 cm in width (Kuepper, 1981). They possess a waxy coating that helps reduce transpiration, allowing the plant to conserve water in arid environments. The leaves have a lifespan of two to three seasons, depending on moisture and shade availability, after which they fall off upon developing an abscission layer. The petioles are less than 0.5 cm long, and the leaves are easily detached when bent along the twig (Thomson, 1982; Chaudhary et al., 2015). Jojoba is dioecious, with separate male (staminate) and female (pistillate) flowers. Staminate flowers are small (approximately 0.4 cm), yellow, and borne in clusters in the leaf axils. Pistillate flowers are pale green to colorless, solitary, and lack nectaries or scent glands. They have five sepals that increase in size as the fruit develops, with three styles and a superior ovary (Thomson, 1982; Kuepper, 1981). Jojoba flowers from March to May, triggered by cold weather and winter rains. Pollination is primarily wind-driven, requiring a cool period of at least one month at temperatures between 15-20°C for successful flowering (Hogan, 1980; Nord, 1974). The plant has a well-developed taproot system that initially grows to a depth of 30 to 45 cm by the time the shoot begins to emerge from the soil. In mature plants, the taproot can extend 15 to 25 meters deep, with numerous taproots frequently branching below the crown. Additionally, small, hairy rootlets are found at depths of about 0.6 to 1.0 meters. This extensive network of parallel lateral and secondary roots enables the plant to absorb moisture and nutrients from a broad area of soil, allowing it to thrive in harsh growing conditions (Weiss, 1983).

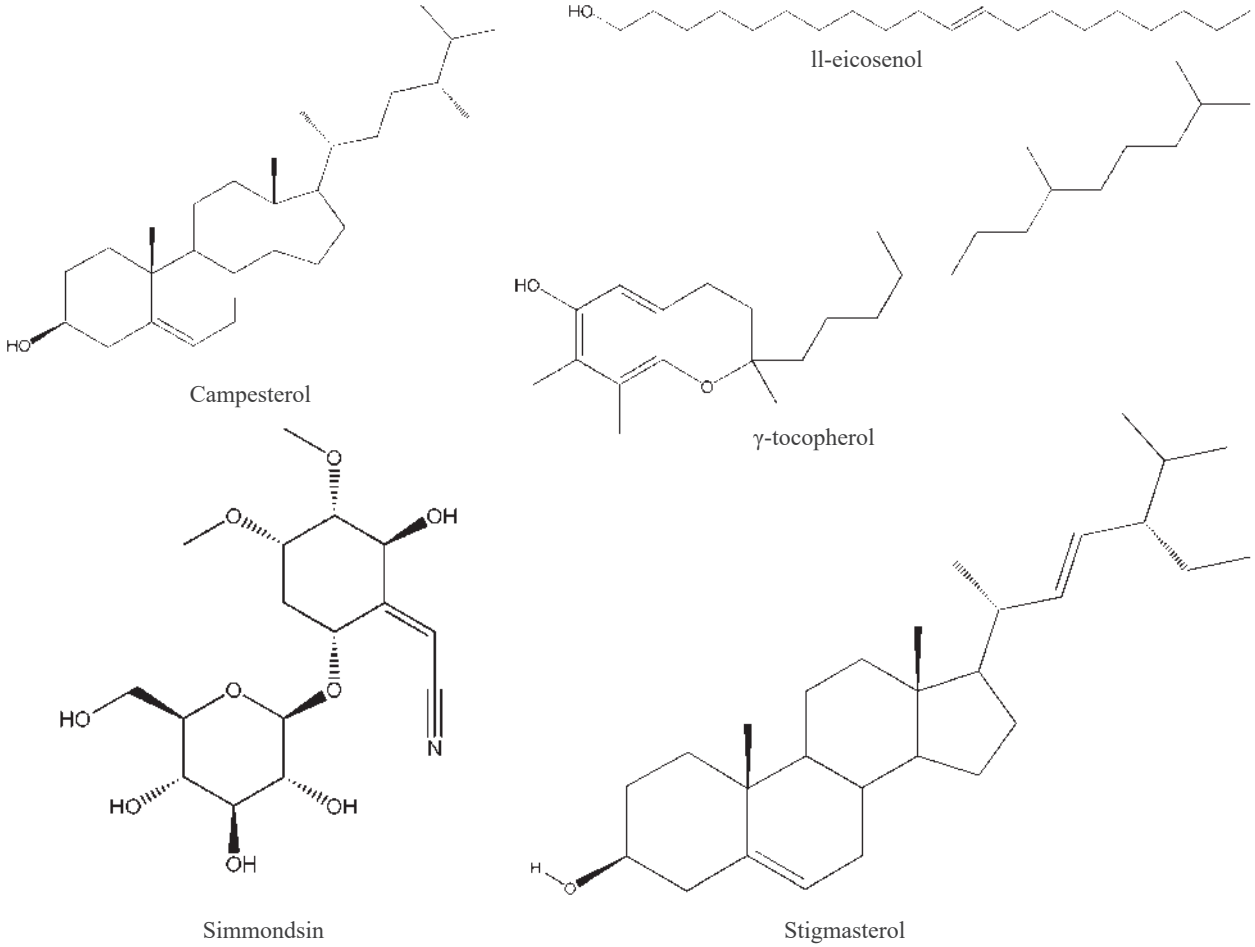
Distribution: Jojoba is native to the Sonoran Desert of Northern Mexico and the United States, particularly in Southwest Arizona and Baja California (Forster, 2002; Gentry, 1958). Due to its high economic value, jojoba is now cultivated commercially in various parts of the world, including Argentina, Australia, India, Egypt, Israel, Mexico, Peru, Kenya, Brazil, South Africa, Costa Rica, Haiti, Paraguay, Chile, and Iran. Jojoba is particularly well-suited to marginal and arid lands, making it an ideal desert shrub (Forster, 2002; Phillips, 2000).

Ethnobotanical Significance: *S. chinensis* has been utilized by South American indigenous peoples for food and other purposes. Jojoba oil has numerous applications in pharmaceuticals and cosmetics, where it is primarily used as a moisturizer in skincare products, hair conditioners, and lubricants (Jaime, 1994; Mosovich, 1985). Additionally, jojoba oil serves as a bio-diesel fuel and a biodegradable lubricant, offering a sustainable solution for future fuel needs (Abbassy, 2007). Research on jojoba oil has focused on its alcoholysis and the emissions of NOx, CO, and CO2 when blended with conventional fuel in diesel engines. The long monounsaturated alcohols (11-eicosenol, 13-docosenol, and 15-tetracosenol) derived from jojoba oil have significant market value due to their pharmaceutical properties against enveloped viruses, while the co-product can be used for energy purposes, potentially paving the way for bio-refinery implementation (Verbiscar et al. 1980).

Phytochemistry:

Jojoba oil: 11-eicosenol; 13-docosenol and 15-tetracosenol; gamma-tocopherol; alpha-tocopherol; beta-tocopherol; delta-tocopherol; sitosterol; campesterol; stigmasterol; simmondsin (El-Shamy et al., 2001; Hill et al., 2009; Lawal et al., 2013; Suarez et al., 2009).

Seeds/ Leaves/ Roots: Simmondsin (Abbott et al., 1999; Bellirou et al., 2005; Labib et al., 2012).



Structures of Important and Characteristic Chemical Constituents of *Simmondsia chinensis*

Biological Activities:

Antioxidant Activity: The flavonoids and glycosides isolated from *Simmondsia chinensis* exhibit strong antioxidant and lipoxygenase inhibitory effects. Flavonoids, in particular, showed enhanced activity compared to their glycoside counterparts, with the presence of a sugar moiety significantly reducing their effectiveness (Abdel-Mageed et al., 2016). Essential oil extracted from jojoba demonstrated a 7.81% inhibition in a DPPH radical scavenging assay (Abdul-Hafeez, 2014). Additionally, jojoba's ethanolic extract was found to inhibit oxidative stress in rat hepatocytes induced by Fumonisins, mycotoxins that interfere with ceramide synthase and cause lipid peroxidation (Abdel-Wahhab, 2010). The antioxidant properties of jojoba are linked to its phenolic compounds, phytosterols, tocopherol, and fatty acids, as well as simmondsin and its derivatives: simmondsin-3′-ferulate, 4, 5-didemethyl simmondsin, and 4-demethylsimmondsin-2′-ferulate (Al-Qizwini, 2014). Various extracts of jojoba seed residue, particularly the 70% ethanol extract, displayed high antioxidant activity in DPPH assays (Siahaan et al., 2020; Sharma et al., 2011).

Antimicrobial Activity: Jojoba extracts have shown antimicrobial and antifungal activities against several pathogens. Studies reported antimicrobial and antiproliferative effects of jojoba oil from Sudan (Elnimiri, 2011). Jojoba extracts and latex effectively inhibited bacterial species like *Bacillus cereus*, *Salmonella typhimurium*, *Clostridium perfringens*, and *Escherichia coli*, as well as fungal species like *Aspergillus flavus* and *Candida albicans* (Abu-Salem, 2014). The antifungal properties of simmondsin and its derivative simmondsin 2′-ferulate were also noted, with simmondsin showing higher inhibition against most fungi, particularly *Botrytis fabae*, while simmondsin 2′-ferulate was more effective against *Rhizocotonia solani* and *B. fabae* (Abbassy, 2007). In a similar study, the crude extracts of jojoba seeds were reported to possess significant antimicrobial and antifungal properties, demonstrating good activity against selected test bacteria and fungi (Menghani et al., 2011).

Anticancer Activity: *S. chinensis* exhibits anticancer activity, notably through the inhibition of cyclooxygenase-2 (COX-2), which induces apoptosis and suppresses cell proliferation. A non-cyanogenic COX-2 inhibitor isolated from jojoba demonstrated significant anticarcinogenic properties (Abdel-Mageed, 2016).

Antiviral Activity: The wax of *S. chinensis* has been evaluated for its antiviral properties, particularly against the herpes simplex virus. The wax significantly reduced viral plaque formation, as confirmed by real-time PCR and viral protein expression via immunohistochemical staining (Tietel et al., 2021).

Antihyperlipidemic Activity: The 70% ethanol extract of *S. chinensis* seeds was tested for antihyperlipidemic effects in atherogenic rabbits. The extract successfully reduced serum cholesterol and triglyceride levels to normal, indicating its potential as an antihyperlipidemic agent (Shahwan, 2014).

Commercial Products: The leaf extract, seed extract, seed oil, fruit oil, and seed powder of *S. chinensis* are commonly used as ingredients in a variety of cosmetic, skincare, and haircare products. These include shampoos, foundations, primers, serums, conditioners, face masks, and more (Search Results - *Simmondsia Chinensis*, n.d.).

Patent:

- The extracting process of *Simmondsia chinensis* seed oil, Patent No: CN106753771A
- *Simmondsia chinensis* cultivation seedbed and seedling cultivation method thereof, Patent No: CN111587705B
- Cosmetic active ingredient based on *Simmondsia chinensis* seed bread and cosmetic uses, Patent No: FR3092249A1
- Process for stimulating asexual propagation of *Simmondsia chinensis* tissue, Patent No: US4478000A
- Pharmaceutical serum comprising an alkyl lactate and *Simmondsia chinensis* seed oil, Patent No: GB2507639A
- Method for breeding *Simmondsia chinensis*, Patent No: CN1214701C
- CDS (Coding Sequence) of *Simmondsia chinesis* ScMnSOD gene and application, Patent No: CN102994523A
- Cosmetic combination containing *Simmondsia chinensis* and arbutin and preparation method of cosmetic combination, Patent No: CN105213227A

- Process for stimulating asexual propagation of *Simmondsia chinensis* tissue, Patent No: US4478000A
- Pharmaceutical serum comprising an alkyl lactate and *Simmondsia chinensis* seed oil, Patent No: GB2507639A

Scope of further R&D: *S. chinensis*, an evergreen shrub in the family Simmondsiaceae, produces oil that closely resembles human sebum, making it highly valuable in cosmetics and skincare. To fully harness its potential, further research should focus on optimizing extraction and processing methods for jojoba oil, particularly cold-press and solvent extraction techniques. Additionally, there is a need for in-depth phytochemical examination and pharmacological studies to explore its chemical, medicinal, and nutritional properties. Investigating its traditional medicinal uses and the potential development of dietary supplements could offer new avenues for health applications. Furthermore, research should be conducted to develop innovative products and applications for jojoba oil, such as biofuels, lubricants, and biodegradable plastics.

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Skimmia laureola
(DC.) Decne.

Synonyms:
Limonia laureola,
Skimmia melanocarpa

Local/Common/Popular Name(s):
Nair, Nairpati, Kedarpati, Nair Pat

Vernacular Names:
Hindi: Nair, Nairpati, Kedarpati, Nair Pat; ***Kashmiri:*** Patar, Barru; ***Punjabi (Pakistan):*** Sheshar; ***Nepali:*** Guras, Dhupi ***English:*** Ner; ***Gujri:*** Ner; ***Pashto:*** Namer, Nazar Panra

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Sapindales
Family	:	Rutaceae
Genus	:	*Skimmia*
Species	:	*Skimmia laureola*

Botanical Description: *Skimmia laureola* is an evergreen, aromatic shrub, typically reaching up to 1 meter in height, with grayish-green, dichotomous branches. The leaves are fragrant, measuring 7.5 to 15 cm in length and 2 to 3.8 cm in width, featuring elliptical-lanceolate or ovate shapes, thick and leathery textures, and acute glands on both surfaces (Shah et al., 2012). The small, greenish-white flowers are either sessile or subsessile. *S. laureola* produces polygamous flowers, meaning both unisexual and bisexual forms are present. The calyx consists of 5 sepals, and the corolla has 5 petals. The androecium comprises 5 stamens, while the gynoecium consists of 2 to 5 carpels. The fruit is a bright red, ovoid berry (Barkatullah et al., 2012).

Distribution: *S. laureola* is distributed across Southeast Asia, including the Northwest Himalayas and the Philippine Islands (Shah et al., 2013; Dutt, 2015). Native to Northern China and the Northern Himalayan region, it is commonly found in India and Pakistan. In India, it grows throughout the Western and Central Himalayas, from Jammu and Kashmir to the Khasya Hills in the East (Shah et al., 2012). Specific locations include Jammu and Kashmir (Gulmarg, Kuttangalikeihangang Valley, and Poonch), Himachal Pradesh (Shimla), Uttarakhand (Sarutal, Nainital, West Almora, Lachhiwala), and Haryana (Kurukshetra). In Uttar Pradesh, it is found in Faizabad and Mahoba Hamirpur. In Pakistan, *S. laureola* is common in the Hazara region, Murree Hills, Kashmir, upper Swat, Shangla, and Upper Dir (Ibrar & Rauf, 2012; Muhammad et al., 2013). It thrives at altitudes of 1800 to 3000 meters under shady forest conditions (Ibrar & Rauf, 2012). In the Northwest Himalayas, it occurs from Sioj Dhar (3200 msl; 32°55/N-75°39/E) to Ashapatti Glacier (3400 msl; 32°53/N-75°46/E), including Kaplash Mountain (4300 msl; 32°52/N-75°40/E), with two distinct populations: one in association with *Aconites* and the other isolated from them (Dutt, 2015).

Habitat: *S. laureola* is naturally distributed in mixed coniferous forests at elevations between 2,500 and 3,000m in the Himalayan region, including India, Nepal, Bhutan, and Pakistan. It thrives in well-drained, humus-rich soils with sufficient moisture and prefers partial to full shade. The species

flourishes under temperate to subalpine climatic conditions.

Ethnobotanical Significance: The leaves of *S. laureola* are widely used in traditional medicine. In the Bhadarwah area of Jammu and Kashmir, India, they are used to treat stomach issues such as stomachaches, dysentery, nausea, and worms (Dutt, 2015). Dried, ground leaves are taken with water to treat smallpox, worm infestations, and colic (Ahmad et al., 2014). The dried leaves are also burned during religious rituals to exorcize evil spirits and purify the air (Jangwan et al., 2010; Dutt, 2015). Crushed leaves mixed with wheat flour are used as anthelmintics for livestock, and garlands made from the leaves are considered sacred in Pakistan. The bright red fruits are often used for decorative purposes. The smoke from burning leaves is believed to clear the nasal tract and is used as a remedy for colds, fever, and body pain (Barkatullah et al., 2013; Sultana, 2013). The local population of Hazara inhales soot from burned leaves to treat flu and fever. A paste made from leaves mixed with cow's urine is applied to the skin to treat psoriasis and leukoderma (Mehmood, 2013). In northwestern Pakistan, dried leaves are considered antiseptic and are used to ward off the "evil eye" (Sher et al., 2015). They are also used as an insect repellent to protect clothing and food. In Pakistan, aqueous extracts of the plant are given to children to boost immunity against skin diseases, and leaves are used as a remedy for diabetes (Riazuddin et al., 1987; Ahmed et al., 2015b; Qureshi et al., 2009).

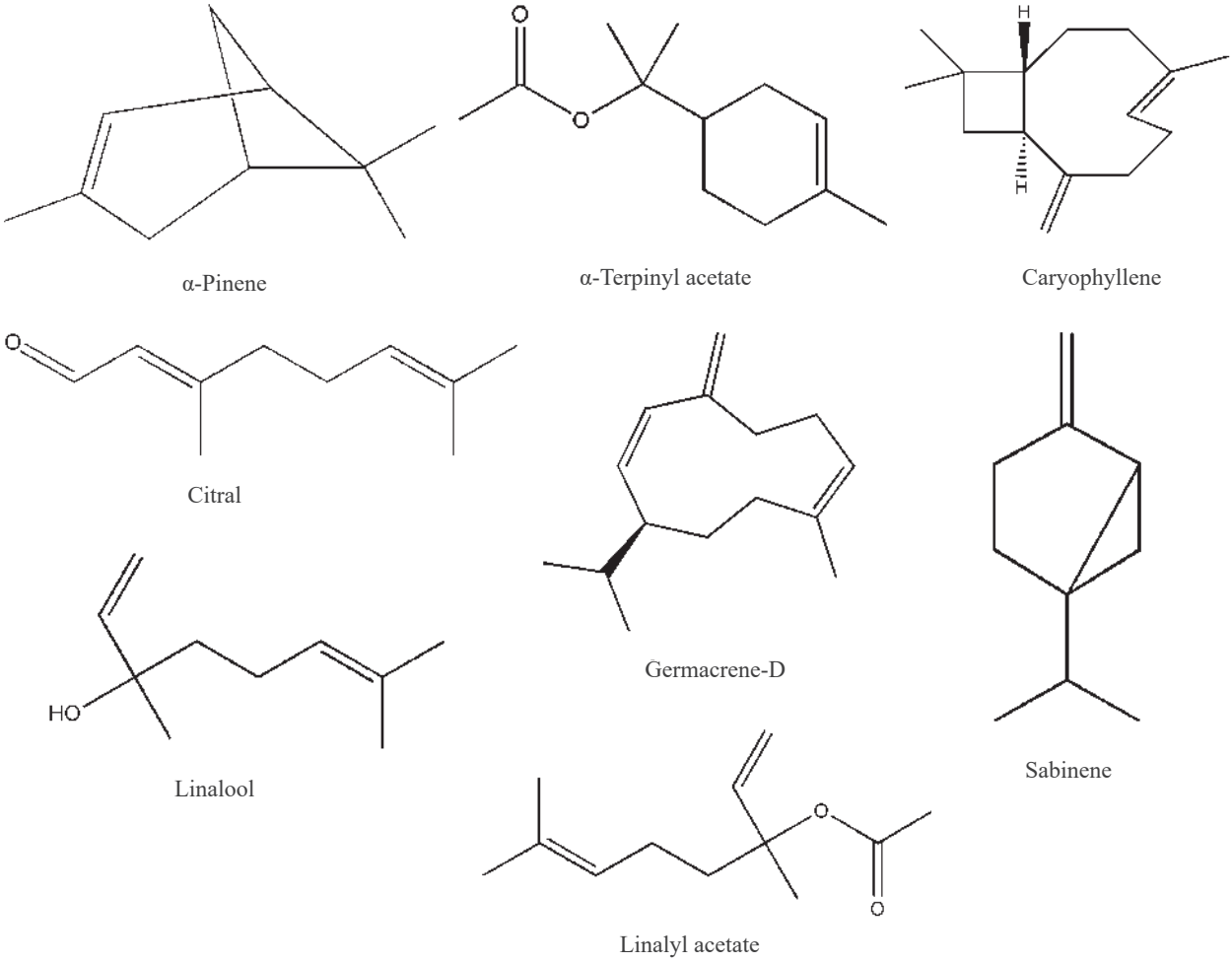
Phytochemistry:

Aerial Parts (leaves): Ptelefoliarine; Acetoxyptelefoliarine; Acetoxyedulinine; Orixiarine; Chimanines A; Chimanines B; Chimanines C; Chimanines D; Methyl Isoplatydesmine (Atta-ur-Rahman et al., 1998a); Skimmianine (Sood et al., 1978); Ribalinine (Sultana et al., 2008; Sultana and Sultana, 2009); Dictamnine; 3-hydroxy, 2,2,6-trimethyl–3,4,5,6-tetrahydro-2H-pyrano[3,2-c]quinoline 5 one; 4-methoxy-1-methyl-3-(2'S-acetoxy-3'-hydroxy butyl)-2-quinolone; 4-methoxy-1-methyl-3-(2'-oxo-3'-methyl butyl)-2-quinolone; 4-methoxy-1-methyl-3-(2'S-acetoxy-3'-ene butyl)-2-quinolone; 4-methoxy-1-methyl-3-(2'S-hydroxy-3'-ene butyl)-2-quinolone (Sultana and Sultana, 2009); Scopoletin; Umbelliferene; Bergapten (Razdan et al., 1987); Isogospherol; (+)-Ulopterol; (+)-7-methoxy-6-(2'R-methoxy-3'-hydroxy-3'-methyl butyl); 5,8-dimethoxy coumarin-2H-1-benzopyran-2-one; 7-methoxy-6[2'-oxo-3'-methyl butyl] coumarin (Atta-ur-Rahman et al., 2002); Heraclenol (Atta-Ur-Rahman et al., 2002; Razdan et al., 1987); Heraclenin; Esculetin; Isoscopoletin; Scoparone; Osthol; 7,8-dimethoxycoumarin; Isooxypeucedanin; Alloimperatorin; Xanthotoxol; Imperatorin; Alloisoimperatorin; Psoralen (Razdan et al., 1987); 7-O-β-D-glucopyranoside-2H-1-benzopyran-2-one (Rahman et al., 2006); O-methyl cyclolaudenol (Atta-Ur-Rahman et al., 2002; Hussain et al., 2009); Lupenone; Lupeol; Skimmianone; Skimmial; Skimmiol (Razdan et al., 1987); Taraxerone (Parvez et al., 1999); Taraxerol; 3-oxo-lanosta-20-25-diene-3-one (Atta-ur-Rahman et al., 1998b); 24-Methyllanosta-7,25-dien-3-one (Hussain et al., 2010); Linalool (Mehmood et al., 2011; Stappen et al., 2015; Simonsen et al., 1921); Linalyl acetate (Pandey et al., 2015; Shah et al., 2012); α-Pinene (Jangwan et al., 2010); Sabinene (Jangwan et al., 2010; Pandey et al., 2015); Myrcene; p-Cymene; β-Phellandrene; β-Pinene; α-Thujene; Linalool; α-Terpineol; Nerol; Linalyl acetate; Geranyl acetate; Neryl acetate; Isoborneol; Neral (Citral b) ; Elemol acetate; cis-Thujone; cis-Linalool oxide; trans-Linalool oxide; cis-Pinocamphone; Geijerene; (Z)-γ-macrocarpene; β-Elemene; Elemol; Z, E-Farnesol; Dictamnol; Spathulenol; 8-epi-Dictamnol; (2E,6E)-Farnesyl acetate (Pandey et al., 2015); α-Phellandrene; α-Terpinene; Methyl geranate; Germacrene-D; β-Caryophyllene; Eremophyllene (Jangwan et al., 2010); β-Ocimene; (-)-Camphene (Barkatullah et al., 2015; Pandey et al., 2015); γ-Terpinolene; Δ3-Carene; 1,8-Cineole; Citral; cis-p-Menth-2-en-1-ol; Bornyl acetate; cis-Limonene oxide; Caryophyllene oxide ; Caryophyllene; γ-Elemene; Nerolidol t (Barkatullah et al., 2015); Limonene (Shah et al., 2013); α-Terpinyl acetate; α-Bergamotene; Terpinene-4-ol; Geyrene; α-Farnesene; Alloaromadendrene; α-Cadinene; α-Santalol (Shah et al., 2012); Geraniol (Pandey et al., 2015; Shah et al., 2012); Nerol Oxide; 5-Acetoxylinalool (Stappen et al., 2015); Phytol; Trans-2-Hexanal; Benzyl acetaldehyde (Jangwan et al., 2010); Cryptone; (2E,6Z)-Dodecadienal; 2-Undecanone; 2-Nonanone; 2-Heptyl acetate; neoiso-Dihydro carveol acetate; Geranyl formate; Methyl chavicol (Pandey et al., 2015); 2, 3-Butenediol; 2,3-Hexenol; n-Hexanol; Dimethyl anthranilate (Jangwan et

al., 2010). Anthranilic acid (Irshad et al., 2012); Octanol; 8-Hydroxylinalool; p-Cymen-8-ol; 6-Methyl-5-hepten-2-one; cis-3-Hexenyl butyrate; Nerylformate (Stappen et al., 2015; Gondwal et al., 2015); 1,3-cycloheptadiene; Cyclohexene, 5,6-diethenyl, 1-methyl; 1,3-Dimethylcyclopentene; Psi-cumene; Mesitylene; Solanone (Mehmood et al., 2016); Pregeijerene (Shah et al., 2012); Octyl acetate; α-Limonene diepoxide (Barkatullah et al., 2015); (+)-Skimmilaureol (Sultana et al., 2008); Rimantadine (Mehmood et al., 2012); β-Sitosterol; Sucrose (Sood et al., 1978); Isopimpinellin; Bergaptol; 8-Geranyloxypsoralen; Peucenin; Peucenin-7-methyl ether; Skimminin (Razdan et al., 1987; Epifano et al.,2015; Shah, et al., 2003).

Stem: Linalool; Linalyl acetate; Solanone (Pandey et al., 2015).

Root: Scopoletin; Umbelliferene; Bergapten; Heraclenol; Xanthotoxin; Psoralen; Scopoletin glucoside; Isoimperatorin; Skimmianone; 1,3-cycloheptadiene; Nerol acetate; Isobutyrate.



Structures of Important and Characteristic Chemical Constituents of *Skimmia laureola*

Biological Activities:

Antipyretic Activity: The antipyretic activity of the crude ethanolic leaf extract of *S. laureola* was evaluated in animal studies. At a dose of 300 mg/kg, a reduction in body temperature (hypothermia) was observed within the first hour. At 200 mg/kg, the temperature reduction occurred from the second to the fifth hour. The effects were significant compared to the negative control but were less pronounced than those of paracetamol, the positive control (Barkatullah et al., 2013).

Antinociceptive Activity: The antinociceptive effects of the crude ethanolic leaf extract were tested using the acetic acid-induced writhing test.

The highest dose of 300 mg/kg provided 72.45% protection against pain, followed by 200 mg/kg (58.34%) and 100 mg/kg (24.23%). Although effective, the results were less potent than those of diclofenac sodium (10 mg/kg). The mechanism of action may involve blocking the release of endogenous substances that stimulate pain nerve endings (Barkatullah et al., 2013).

Anthelmintic Activity: The essential oils from the root, stem, and leaves of *S. laureola* were tested for anthelmintic activity against adult *Haemonchus contortus* worms. In vitro trials with doses of 10 µL, 35 µL, and 50 µL showed that the stem essential oil was the most effective, killing the worms within 1.5 hours at 50 µL. Leaf and root essential oils also demonstrated activity, with the maximum effect occurring after 2.5 hours at 35 µL and 50 µL doses. The effect was comparable to that of the positive control, Levamisole, significantly reducing the survival time of the worms (Mehmood et al., 2011).

Antifungal Activity: The crude ethanolic extract of *S. laureola* was evaluated for its antifungal activity against the animal pathogen *Microsporum canis* and the plant pathogen *Fusarium solani* var. *lycopersici*. The extract inhibited *Microsporum canis* growth by 67.7% at a concentration of 400 µg/ml, compared to Miconazole and Ketoconazole, which inhibited the growth by 72.10% and 62.25%, respectively. It also showed activity against *Fusarium solani* at 400 µg/ml, with Benlate completely inhibiting growth at 73.25 µg/ml. Additionally, the coumarin compound Ulopterol and the alkaloid 4-methoxy-1-methyl-3-(2'S-hydroxy-3'-ene butyl)-2-quinolone were tested; Ulopterol demonstrated antifungal activity against *Drechslera rostrata* and *Curvularia lunata* with a minimum inhibitory concentration (MIC) of 200 µg/ml, while another compound alkaloid inhibited *Microsporum canis* and *Pseudoallescheria boydii* with MICs of 200 µg/ml, reducing growth by 68.7% and 56.8%, respectively (Ahmad et al., 2003; Alam, et al., 2019).

The essential oil from the leaves showed antifungal activity against *Candida albicans*, *Aspergillus flavus*, *Fusarium solani*, *Microsporum canis*, *Candida glabrata*, and *Trichophyton longifusis*. It performed similarly to Miconazole against *T. longifusis* and *C. albicans* and was more effective than Miconazole against *A. flavus* (Barkatullah et al., 2015). The antifungal compounds linalool and linalyl acetate were also identified as active agents (Pattnaik et al., 1997; Hristova et al., 2013). Essential oil exhibited strong antifungal activity against *Penicillium chrysogenum* and *Aspergillus niger* with inhibition zones of 39 mm and 40 mm, respectively, outperforming the drug fluconazole. The essential oil also demonstrated moderate activity against *Colletotrichum* species (*C. acutatum*, *C. fragariae*, and *C. gloeosporioides*) (Stappen et al., 2015; Ahmed et al., 2015a).

Insecticidal Activity: The essential oil from the leaves of *S. laureola* was evaluated for its insecticidal activity against *Lasius niger* (black ant). The oil demonstrated significant insecticidal activity with an LC_{50} value at a concentration of 10.15 µL. The compound β-linalool, an oxygenated monoterpene, is reported to be responsible for this insecticidal effect (Mehmood et al., 2016).

Antibacterial Activity: The essential oil derived from the aerial parts of *S. laureola* was tested for antibacterial activity. At a concentration of 0.1 ml, it exhibited activity against the gram-positive bacterium *Staphylococcus aureus* and the gram-negative bacteria *Escherichia coli* and *Pseudomonas aeruginosa*, with inhibition zones of 4 mm, 8 mm, and 6 mm, respectively (Jangwan et al., 2010). Cold and hot water extracts of the plant were also evaluated. The cold-water extract showed activity against *Bacillus subtilis*, *S. aureus*, and *Proteus mirabilis*, with inhibition zones of 10 mm, 11 mm, and 9.66 mm, respectively. The hot water extract was effective against *E. coli*, *B. subtilis*, and *S. aureus*, with inhibition zones of 11.6 mm, 14 mm, and 19.6 mm, respectively (Zeb et al., 2016). Further testing of the leaves' essential oil revealed activity against *Micrococcus luteus*, *E. coli*, *S. aureus*, *Pasteurella multocida*, and *Streptococcus viridans* (Barkatullah et al., 2015). It was also effective against *B. subtilis*, *S. epidermidis*, *S. aureus*, *Pseudomonas aeruginosa*, and *Proteus vulgaris*, showing greater susceptibility towards gram-positive bacteria, similar to the effects of ampicillin and vancomycin (Shah et al., 2013). The high lipophilic content of the essential oil, including limonene, linalool, and linalyl acetate, contributes to its strong antibacterial activity against gram-positive bacteria by penetrating cell membranes. In contrast, its lower effectiveness against gram-negative bacteria is due to their protective lipopolysaccharide layer

(Trombetta et al., 2005). Recent assessments using the agar well diffusion method demonstrated strong antibacterial activity of the essential oil against *E. coli*, *Citrobacter brundii*, *S. aureus*, *Enterococcus faecalis*, *Salmonella typhimurium*, *Proteus vulgaris*, *B. subtilis*, *Klebsiella pneumoniae*, *Salmonella enterica* typhi, *S. epidermidis*, and *Streptococcus pyogenes*. The antibacterial effects are attributed to the presence of linalyl anthranilate and L-linalool (Bisht et al., 2024; Sharma et al., 2008).

Antioxidant Activity: The antioxidant activity of *S. laureola* essential oil was evaluated using the DPPH radical scavenging assay, demonstrating 93.1% inhibition. However, its activity was weaker compared to the synthetic antioxidant butylated hydroxytoluene (BHT) (Irshad et al., 2012). Another study showed that the essential oil of *S. laureola* leaves exhibited concentration-dependent antioxidant activity, attributed to the presence of linalyl anthranilate and L-linalool (Bisht et al., 2024).

Antidiabetic Activity: The ethanolic extract of *S. laureola* was tested for antidiabetic effects, showing a reduction in blood sugar levels between 2 to 6 hours post-administration. The effect was comparable to glibenclamide, a drug used to treat type 2 diabetes, at a concentration of 300 mg/kg (Ibrar et al., 2012b).

Antispasmodic Activity: The antispasmodic effect of *S. laureola* ethanolic extract was tested on isolated rabbit jejunum. Significant relaxation was observed at concentrations of 5-10 mg/ml in both spontaneous and potassium chloride-induced contractions. The mechanism of action is thought to involve blocking calcium channels or the release of calcium from the sarcoplasmic reticulum (Ibrar et al., 2012a).

Toxicology: In the Northwest Himalayas, *S. laureola* is found in two distinct populations, one associated with *Aconitum* species, which is considered poisonous, and another in isolation. Collectors report that the plants associated with *Aconitum* are toxic (Dutt, 2015).

Scope of Further R&D: *S. laureola*, an evergreen shrub of the Rutaceae family, holds significant promise due to its extensive use in traditional medicine. Future research should focus on a comprehensive analysis of its chemical composition to identify bioactive compounds and their medicinal properties. Detailed pharmacological studies are essential to understand its mechanisms and potential for treating specific ailments. Moreover, its market potential should be explored, including the development of *S. laureola*-based products such as herbal supplements, skincare formulations, and other commercially viable applications. These studies could pave the way for its integration into modern pharmaceuticals and wellness industries.

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Soymida febrifuga
(Roxb.) A.Juss.

Synonyms:
Swietenia febrifuga Roxb.,
Swietenia obtusifolia Stokes

Local/Common/Popular Name(s):
Indian redwood

Vernacular Names:
Hindi: Rakat rohan;
English: Bastard cedar, Indian redwood;
Tamil: Sumi; ***Telugu:*** Somida, Somi;
Marathi: Potar Merwara;
Sanskrit: Agniruha, Atiruh, Chandravallabha, Kashamansi, Lomakarani, Mahamansi, Mansarohini, Praharavalli, Patranga, Suloma, Vasa, Vikasha, Viravali, Vritta
(Rajput & Kachhava, 2019).

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Sapindales
Family	:	Meliaceae
Genus	:	*Soymida*
Species	:	*Soymida febrifuga*

Botanical Description: *Soymida febrifuga* is a tall tree with leaves 23-45 cm long, clustered towards the ends of branches. The leaflets, in 3-6 pairs, are opposite, elliptic or oblong, obtuse, glabrous, and penninerved, with conspicuous nerves underneath. The base is asymmetrically rounded, with the lower side extending further down the petiole than the upper. The petioles are red. The greenish-white flowers appear from February to May in large, terminal or auxiliary, divaricately branched panicles. The sepals are 5, rotund with membranous, slightly lacerate margins. The petals are 5, obovate, 6 mm long, clawed, and often notched at the apex. The staminal tube is half the length of the petals, slightly urceolate with anthers attached by the middle of the back. The glabrous ovary has a large discoid stigma, with ovules attached to parietal placentae. Fruits ripen between May and June, consisting of 2.5-6.3 cm long capsules that are 5-celled and split into 5 valves. Each cell contains numerous flat seeds winged at both ends. The bark is reddish, scale-like, tough, and exfoliates in plates or scales. Upon incision, the bark releases a blood-red exudate (Fig. 1). Whole fruits are sold as wild lily flowers, while the columella is sold as lily pods, and segments of the pericarp or valves are sold as lily petals (Murthy and Gupta, 1976; Anonymous, 2005; Sukhadiya et al., 2019; Patel, 1971).

Distribution: *S. febrifuga* is a tall, deciduous medicinal tree indigenous to India, found primarily in the dry forests of peninsular India, extending to Kerala, Gujarat, Uttar Pradesh, Bihar, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, and Sri Lanka (Kirtikar & Basu, 2003; Rajput & Kachhava, 2019). It thrives in the hilly districts of northwest, central, and southern India and is common in the dry forests of Telangana and Andhra Pradesh (Rao et al., 2015; Naidu & Kumar, 2016). The tree grows well in lime soils, black cotton soils, well-drained areas, and dry stony hills. It tolerates annual daytime temperatures ranging from 32-40°C, and extreme temperatures of 10-47°C. It prefers a mean annual rainfall of 800-1,300 mm but can withstand 600-1,500 mm (Rajput & Kachhava, 2019). *S. febrifuga* is usually found in regions with a distinct dry season

(Sukhadiya et al., 2019). Propagation is traditionally done by seeds, but they have a low germination rate and seedlings are vulnerable to insect attacks. Attempts to propagate through stem cuttings are limited due to poor rooting success. Direct sowing of seeds on ridges at 30 cm height has a higher success rate than transplanting nursery-raised seedlings. Seed germination is best in porous, well-drained soils, but growth is slow and sensitive to frost (Chiruvella et al., 2011; Chiruvella et al., 2014a, 2014b).

Ethnobotanical Significance: The Ayurvedic properties of *S. febrifuga* include Rasa (taste) - Kashaya (astringent) and Katu (pungent); Guna (quality) - Laghu (light) and Rooksha (dry); Virya (potency) - Sheeta (cool); Vipaka (post-digestive effect) - Katu (pungent), which contribute to its actions as astringent (Stambhana), wound healing (Vranaropana), digestive (Grahi), and nutritive (Paustika). Historically, *S. febrifuga* has been recognized as a substitute for cinchona bark in treating intermittent fevers since 1791 (Chakrabarti, 2010). The bark extracts are used for treating rheumatoid arthritis (Ambaye et al., 1971), asthma, and ulcers (Kirtikar & Basu, 2003). The bark decoction, known for its bitter resin, is used in cases of vaginal infections, rheumatic pains, stomach pains, and is also employed as an anti-cancer remedy for wounds, dental diseases, uterine bleeding, and hemorrhage (Ambaye et al., 1971). It is known for its refrigerant, anthelmintic, aphrodisiac, and laxative properties and is used to treat sore throat, fevers, cough, asthma, ulcers, leprosy, dysentery, and as an anti-inflammatory agent (Yoganarasimhan, 1996). In traditional Unani medicine, the bark is used for treating fevers, dysentery, and diarrhea, and as a substitute for oak bark in remedies for mouth and vaginal infections (Kirtikar & Basu, 2003). The bark decoction is used to treat tongue sores, loose teeth, gum infections, and cough (Murthy et al., 2001). It is also administered orally in cases of snake bites and applied externally for swelling (Chiranjibi et al., 2008). The powdered bark is applied as a poultice for conditions such as leucorrhoea and leucoderma. In some regions, it is used to enhance sexual vitality and regulate menstruation. In Odisha, the bark juice is taken for kala azar and general debility (Rajput et al., 2019). The bark powder mixed with boiled rice is used to treat leg lameness, while a mixture with whey is given for dysentery (Pocchi, 2018). In postpartum care, a bark decoction is administered after delivery (Raju et al., 2011). A combination of *Hemidesmus indicus*, *S. febrifuga* bark, and *Terminalia bellerica* fruit is used to treat indigestion, stomach disorders, and acidity (Behera et al., 2006). The bark extract mixed with *Phoenix sylvestris* toddy is used for fever and vitality (Ranjalkar & Ramakrishna, 2018). A paste of stem bark, tender tips and *Phoenix sylvestr* toddy is used for gynecological disorders (Reddy et al., 2010). In the tribal areas of Telangana, the bark juice is used for epilepsy as nasal drops, tender tips for body pain, and in cases of snake bites, a decoction is administered orally (Krishna et al., 2014; Ramakrishna & Saidulu, 2014). The tribal communities of Odisha use bark juice for treating dysentery (Rout et al., 2009), and it is also used for this purpose in North Coastal Andhra Pradesh (Prayaga et al., 2012). Leaf juice is traditionally used to control menstrual bleeding, and the warmth of boiled leaves is applied to fractures in animals (Reddy et al., 2008). The flowers and fruit juice are used to relieve earaches, and a combination of flowers, leaves, *Ocimum tenuiflorum*, *Embelia ribes* fruits, asafoetida, and castor oil is given to relieve headaches caused by constipation (Vedavathy et al., 1997).

Phytochemistry:

Bark: Lupeol; sitosterol; methyl angolensate; deoxyandirobin (Ambaye et al., 1971; Adesida and Taylor, 1972; Purushothaman and Chandrasekharan, 1974; Purushothaman et al., 1977); [(3R)-6,4'-dihydroxy-8-methoxyhomoisoflavan; (2R)-7,4'-dihydroxy-5-methoxy-8-methylflavan; 7-hydroxy-6-methoxy-3-(4'-hydroxybenzyl)coumarin; 6-hydroxy-7-methoxy-3-(4'-hydroxybenzyl)coumarin (Awale et al., 2009)]; soymidin A; soymidin B (Yadav et al., 2012); 5,7-dihydroxy-3,4-dimethoxy flavone (Vijay and Seetharam, 2018; Palei et al., 2013; Rani et al., 2002).

Root and Stem heartwood: Obtusifoliol; syringetin; dihydrosyringetin (Pardhasaradhi et al., 1972); febrifugin (Murali Krishna et al., 1978); febrinin A; febrinin B; naringenin; quercetin; myricetin; dihydromyricetin (Rao et al., 1979); methyl angolensate; luteolin-7-O-glucoside (Adesida et al., 1971; Chiruvella et al., 2007; Ashalatha & Thejaswini et al., 2015).

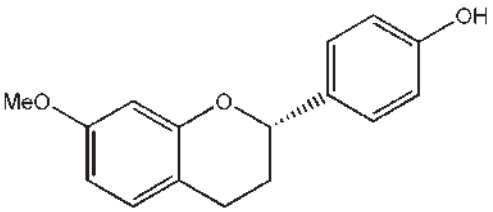
Leaves: Quercetin 3-O-rhamnoside; quercetin 3-O-rutinoside (Nair and Subramanian, 1975; Rastogi and Mehrotra, 1993); β—sitosterol; lupeol; quercetin; quercetin glycosides (Attarde et al., 2008;

Attarde et al., 2010); 2-acetyl soymidin B; soymidin D; soymidin E; swiemahogin A; 6-desoxyswietenine; angolensin A; methyl-3β-acetoxy-1-oxomeliac-14,15-enoate; methyl-3β-acetoxy-1-oxo-meliac-8,30-enate; fissinolide; methyl-3β-acetoxy-1-oxomeliacate; methyl angolensate; swietephragmin C; swietephragmin H; swietephragmin F; swietenitin O (Yadav et al., 2014).

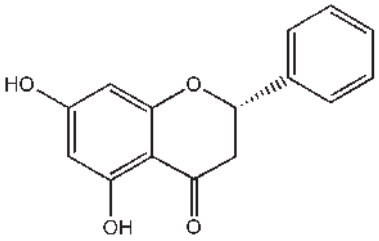
Fruit: Epoxyfebrinin B; 14, 15-dihydroepoxyfebrinin B; febrinolide; deoxyandirobin; 17β-hydroxy-6α-acetoxyzadiradione; methyl angolensate; sitosterol (Mallavarapu et al., 1985).

Seed: Lupeol; sitosterol; methyl angolensate (Laxmi, 1987); linolenic acid; linoleic acid; oleic acid; palmitic acid; stearic acid; sitosterol (Yoganarasimhan, 1996).

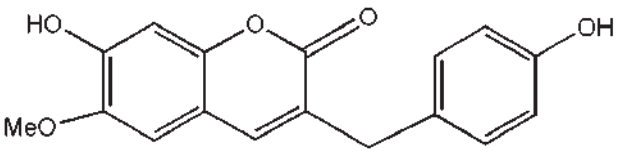
Gum: Arabinose; galactose; ribose (Bhushette and Annapure, 2018).



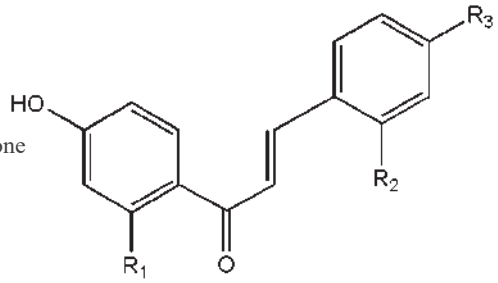
4'-hydroxy-7 -methoxyflavan



5,7 -dihydroxyflavanone

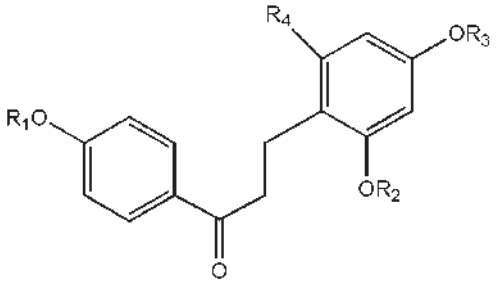


7 -hydroxy -6-methoxy -3 -(4 - hydroxybenzy 1)coumarin



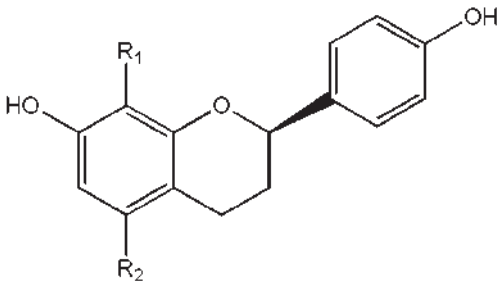
Chalcones

R1=OH R2=H R3=H
2',4'-dihydroxychalcone
R1=OH R2=OH R3=H
2,2',4'-trihydroxychalcone
R1=OMe R2=H R3=OH
2,4'-dihydroxy-2'-methoxychalcone



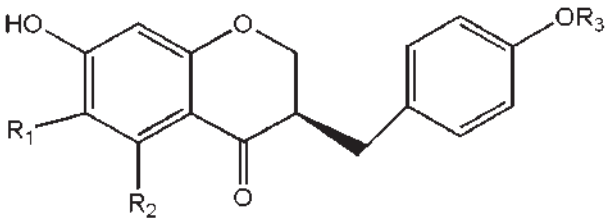
Dihydrochalcones

R1=H R2=Me R3=Me R4=H
4'-hydroxy-2,4-dimethoxydihydrochalcone
R1=Me R2=Me R3=H R4=OMe
4-hydroxy-2,6,4'-trimethoxydihydrochalcone
R1=H R2=H R3=Me R4=H
2,4'-dihydroxy-4-meth-oxydihydrochalcone
R1=H R2=H R3=H R4=H
2,4,4'-trihydroxydihydrochalcone
R1=H R2=Me R3=Me R4=OMe
4,4'-dihydroxy-2,6-dimethoxydihydrochalcone

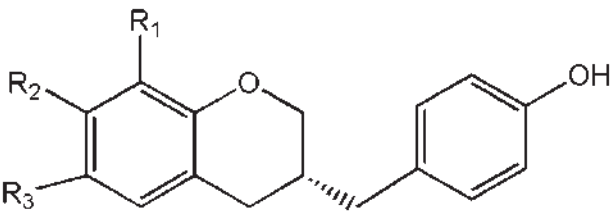


Flavans

R1=Me R2=OMe
(2R)-7,4'-dihy-droxy-5-methoxy-8-methylflavan
R1=Me R2=H
7,4'-dihydroxy-8-methylflavan
R1=H R2=H
7,4'-dihydroxyflavan



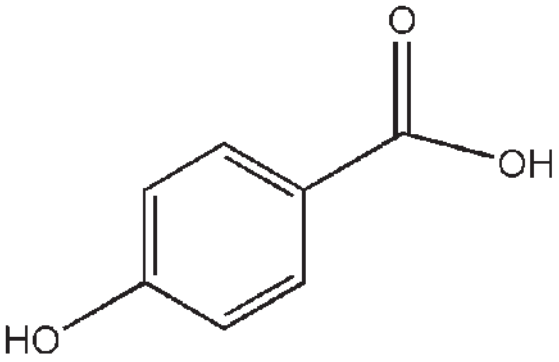
Homoisoflavanones



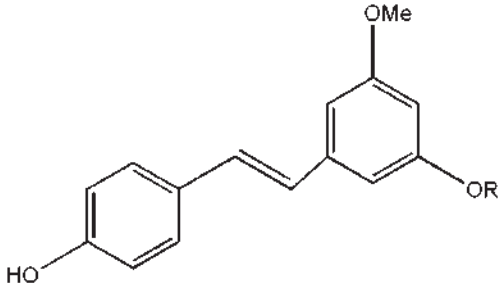
Homoisoflavans

R1=H R2=OH R3=Me
5,7-dihydroxy-4'-methoxyhomoisoflavanone
R1=OMe R2=OH R3=H
5,7,4'-trihydroxy-6-methoxyhomoisoflavanone
R1=H R2=OH R3=H
5,7,4'-trihydroxyhomoisoflavanone
R1=H R2=H R3=H
7,4 -dihydroxyhomoisoflavanone

R1=OMe R2=H R3=OH:
(3R)-6,4'-dihydroxy-8-methoxyhomoisoflavan
R1=H R2=OMe R3=OH
6,4'-dihydroxy-7-methoxyhomoisoflavan
R1=H R2=OH R3=H
7,4'-dihydroxyhomoisoflavan



p-Hydroxybenzoic acid



Stilbenes

R=Me
4'-hydroxy-3,5-dimethoxystilbene
R=H
3,4'-dihydroxy-5-methoxystilbene

Structures of Important and Characteristic Chemical Constituents of *Soymida febrifuga*

Biological activities:

Antioxidant and Anticancer Activities: *S. febrifuga* has been shown to kill human pancreatic cancer cells (Awale et al., 2009; Balachandran and Govindarajan, 2005). The methanol and aqueous extracts of the bark exhibited significant antioxidant and 5-lipoxygenase (5-LOX) inhibitory activities, while the chloroform extract demonstrated stronger anticancer effects against MCF-7, A-431, and HT-1080 cell lines. The hydroalcoholic bark extract showed dose-dependent inhibition of superoxide anion, hydroxyl, and DPPH radicals (Karunasree et al., 2012a & 2012b; Reddy et al., 2008; Vedapriya et al., 2014). Additionally, a 70% ethanol extract at 10 µg/mL selectively killed PANC-1 pancreatic cancer cells under nutrition-deprived conditions (Awale et al., 2009). Compounds like 2',4'-dihydroxychalcone exhibited potent cytotoxicity (PC50 19.0 µM) against PANC-1 cells, and 4'-hydroxy-3,5-dimethoxystilbene showed stronger activity against colon 26-L5 carcinoma cells (IC50 2.96 µM) than the positive control, doxorubicin (IC50 3.12 µM). The bark extract also showed cytotoxic activity against other cancer cell lines, including B16-BL6 melanoma, A549 lung adenocarcinoma, HeLa

cervix adenocarcinoma, and HT-1080 fibrosarcoma (Awale et al., 2009). Methyl angolensate (MA), a compound from *S. febrifuga* root callus, inhibited the growth of T-cell leukemia and chronic myelogenous leukemia cells in a time- and dose-dependent manner, contributing to its anticancer properties (Chiruvella et al., 2008). Additionally, *S. febrifuga* bark & leaves extracts demonstrated significant antioxidant activity through DPPH and nitric oxide scavenging assays, confirming its potential as a source of antioxidants (Bhide et al., 2016; Kindo et al., 2016).

Hepatoprotective Activity: The ethanolic extract of *S. febrifuga* leaves exhibited strong hepatoprotective activity against paracetamol and rifampicin-induced liver damage in animal models (Raviteja et al., 2014).

Antidiabetic Activity: Various column fractions from *S. febrifuga* bark extract showed significant hypoglycemic and antihyperglycemic effects in normal and alloxan-induced diabetic rats. At 200 mg/kg, the 20% chloroform in acetone eluate demonstrated maximum activity comparable to glibenclamide (Chiruvella et al., 2008).

Antibacterial Activity: Acetone and methanol extracts of *S. febrifuga* leaves showed strong antibacterial activity, with maximum inhibition against *Klebsiella pneumoniae* (38 mm) and *Pseudomonas aeruginosa* (37 mm). The water extract also showed notable activity against *Pseudomonas aeruginosa* (35 mm) (Sandhya et al., 2015). The bark extracts showed excellent antibacterial effects against *Bacillus subtilis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Proteus vulgaris*, and *Staphylococcus aureus* (Riazunnisa et al., 2013), and against multi-drug resistant strains of *Porphyromonas gingivalis* and *Prevotella intermedia* (Ninad et al., 2013; Chiruvella et al., 2014d; Paritala et al., 2015*).*

Antifungal Activity: The bark of *S. febrifuga* demonstrated significant inhibition against fungal strains such as *Geotrichum candidum*, *Microsporum canis*, *Trichophyton rubrum*, *Chrysosporium tropicum*, and *Rhizopus stolonifer*, indicating potential use against fungal infections (Bhide et al., 2015; Kindo et al., 2016).

Anthelmintic Activity: Methanol extracts of *S. febrifuga* bark exhibited comparable anthelmintic activity to albendazole when tested on earthworms (Gangurde et al., 2008; Devi, et al., 2021; Pochhi, 2018).

Antifeedant Activity: Isolates from *S. febrifuga* demonstrated potent antifeedant activity against tobacco caterpillar (*Spodoptera litura*) and castor semi-looper (*Achaea janata*), with compounds fissinolide and swietenitin-O showing high antifeedant indices (Yadav et al., 2014).

Patent:

- A process for recovery of natural dye from *Soymida febrifuga bark*, Patent No: 202341007697

Scope of Further R & D: Comprehensive population surveys of *S. febrifuga* have not yet been conducted, and only limited analyses of bark samples exist. Detailed studies on the bark, particularly for its dye potential and phenolic content, are needed for future utilization. This could lead to the discovery of new chemical constituents with pharmaceutical applications. LC-MS/MS profiling should be employed to identify marker compounds for species fingerprinting. Exploring the industrial potential of *S. febrifuga* bark dye for commercial products may open new opportunities. Investigating the bioactive compounds in *S. febrifuga* could reveal untapped pharmacological benefits, warranting further research.

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Sterculia urens Roxb.

Synonyms:
Cavallium urens Schott & Endl.,
Clompanus urens Kuntze, *Kavalama urens* Rafin.

Local/Common/Popular Name(s):
Gulu, Kadaya, Karaya, Katira, Kuteera, Teklej, Semlakatilo, Kullo, Mucara, Ghost Tree, Kovela, Tapsi, India Gum, Bassora Tragacanth, Ghost Tree, Indian Tragacanth, Karaya Tree.

Vernacular Names:
Assamese: Odla; ***Gujarati:*** Kadaayo, kogdol; ***Hindi:*** gulu, karaya, katira, kulu; ***Kannada:*** Kempudale, pinari; ***Konkani:*** pandrukh; ***Malayalam:*** annaanvazhukki, thiiththonti, thonti; ***Marathi:*** kandol, kawali; ***Oriya:*** Gudalo; ***Rajasthani:*** Katila; ***Tamil:*** kutiraippitukkan, centanakku, vellai-puthali; ***Telugu:*** tapasichettu.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Malvales
Family	:	Malvaceae
Genus	:	*Sterculia*
Species	:	*Sterculia urens*

Botanical description: *Sterculia urens* is a medium-sized deciduous tree typically reaching heights of 9 to 15 meters (30 to 50 feet) with a short, crooked trunk supporting a much-branched, rounded crown. The bark is distinctive, appearing greyish-white to red with a shiny texture. It peels off in transparent papery flakes, revealing a smooth, creamy-white underbark that contrasts sharply with the darker surroundings (Darlington et al., 1956). The large, palmately compound leaves measure 23 to 30 cm in length and width resembling a maple leaf with five pointed lobes. These leaves are clustered at the branch ends and with the onset of the dry season turn from green to yellow before falling, leaving the branches bare. The petioles are long and the leaves have a tomentose lower surface with short, thick, tangled hairs, while the upper surface is glabrous. The stipules are caducous and taper to a point (Kala, 2016). The flowers of *S. urens* are small, pedicellate and greenish-yellow arranged in complex branched panicles. The tree is monoecious, predominantly producing bisexual and male flowers with a few female flowers. It exhibits cryptic monoecy and is pollinated by insects with *Apis indica* serving as the primary pollinator (Sunnichan et al., 2004). Flowering occurs after leaf-fall during the dry season with flower clusters forming at the ends of the branches. The fruit is a follicle with 4 or 5 lobes, initially yellow-green, maturing to orange or bright red and covered in fine hairs. Each lobe contains a small, black oval seed. Seeds germinate readily without pre-treatment with seedlings performing best in free-draining loam and sandy soils with a pH of 5.5 to 7.5. The tree has poor tolerance for waterlogged soils and shade (Brady et al., 2002). The wood is soft with pith containing red resin canals.

Distribution: It is distributed widely in India through sub-Himalayan tracts, Gujarat, Rajasthan, Madhya Pradesh, Andhra Pradesh, Uttar Pradesh, Maharashtra and Kerala. In Rajasthan, it occurs in Jaipur, Ajmer, Nagaur, Bara, Jhalawar, Kota, Chittor, Alwar and in Gujarat it is found in Natural Forest of South Gujarat and Ahmedabad, Flora of Shulpaneshwar sanctuary in Gujarat (Regional Centre of BSI, Jodhpur & Indian Biodiversity Portal

records). *S. urens* is a gum-yielding tree native to India, predominantly found in dry deciduous forests and on dry rocky hills across the northern and central regions of the subcontinent (Reid, 2002; Al-Rahman, 2017). It thrives on dried hilltops, exposed ridges, weathered slopes and rock fissures, particularly in soils rich in quartzite, gneiss and schists at altitudes ranging from 300 to 750 meters. The tree is adapted to sub-humid to moderately humid subtropical and tropical climates with long dry seasons. It typically grows in regions where annual temperatures range from lows of 17 to 21°C to highs of 24 to 36°C, with annual rainfall between 300 to 1900 mm and a dry season lasting 6 to 10 months. Optimal gum production is observed in areas with annual rainfall between 700 to 1300 mm (Champion & Seth, 1968).

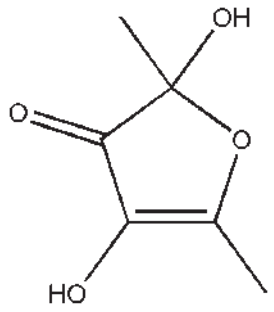
Ethnobotanical Significance: *S. urens*, commonly known as the Karaya Gum tree, has a rich history of use in traditional medicine dating back over 5,000 years. The gum exudate from this tree, known as gum karaya, holds significant market value due to its extensive applications across various industries, including pharmaceuticals, healthcare, food, cosmetics, waste management, paper-textile, composite fiber and leather. In tribal communities, *S. urens* is valued for its indigenous medicinal properties (Davidson et al., 1980; Devi, et al., 2011; Kumar et al., 2016). The gum forms a mucilaginous gel upon contact with water which the body does not digest or absorb. Instead, it swells in the intestine, acting as a laxative and effectively treating chronic constipation. Additionally, gum karaya is applied in powder form to wounds and sores, promoting epidermal growth and aiding in the healing of bedsores (Ganguly et al., 2017; Singh, 2014; Weiping et al.,2000). The bark and leaves of *S. urens* are also used in native medicines. During fieldwork, it was noted that the Katkari tribe consumes the seeds of the tree, particularly during food scarcity. After consuming a handful of seeds, they experienced drowsiness and were able to go without food for several hours. Furthermore, *S. urens* is used in combination with other plants to treat fever and diarrhea (Godbole, 1993; Singh, 2014; Joshi et al., 2016; Dhiman et al., 2019).

Phytochemistry:

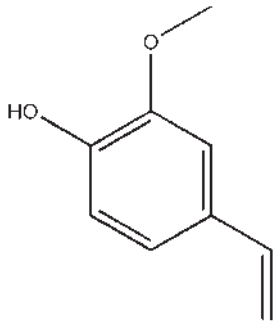
Gum exudates: Glycanorhamno-galacto-uritan (Rao, et al., 1957; Eastwood et al., 1983; Kohajdová et al., 2009), aspartic acid, glutamic acid, valine, leucine, proline, serine (Anderson et al., 1985; Jani et al., 2009; Verbeken et al., 2003).

Seed: Stearic acid, Linoleic acid, Palmitic acid, Eicosadienoic acid, Eicosatrienoic acid (Devi et al., 2011; Galla et al., 2012; Mirhosseini et al.,2012)

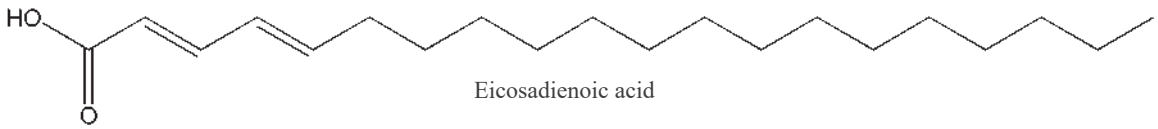
Aerial parts: Phytol; Sucrose; 2, 4-dihydroxy-2, 5-dimethyl-3(2 H)-furan-3-one; 5(2H)-Oxazolone, 4-(phenylmethyl); 2, 3-dihydro-3, 5-dihydroxy-6-methyl-4H-Pyran-4-one; Megastigmatrienone; 2-Methoxy-4-vinylphenol (Nanadagopalan et al., 2015).



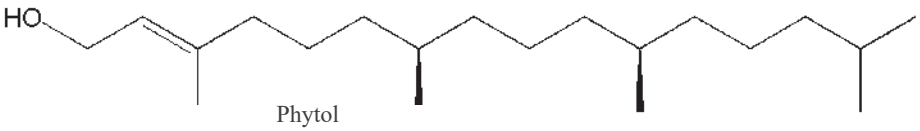
2, 4-Dihydroxy-2, 5-dimethyl-3(2H)-furan-3-one



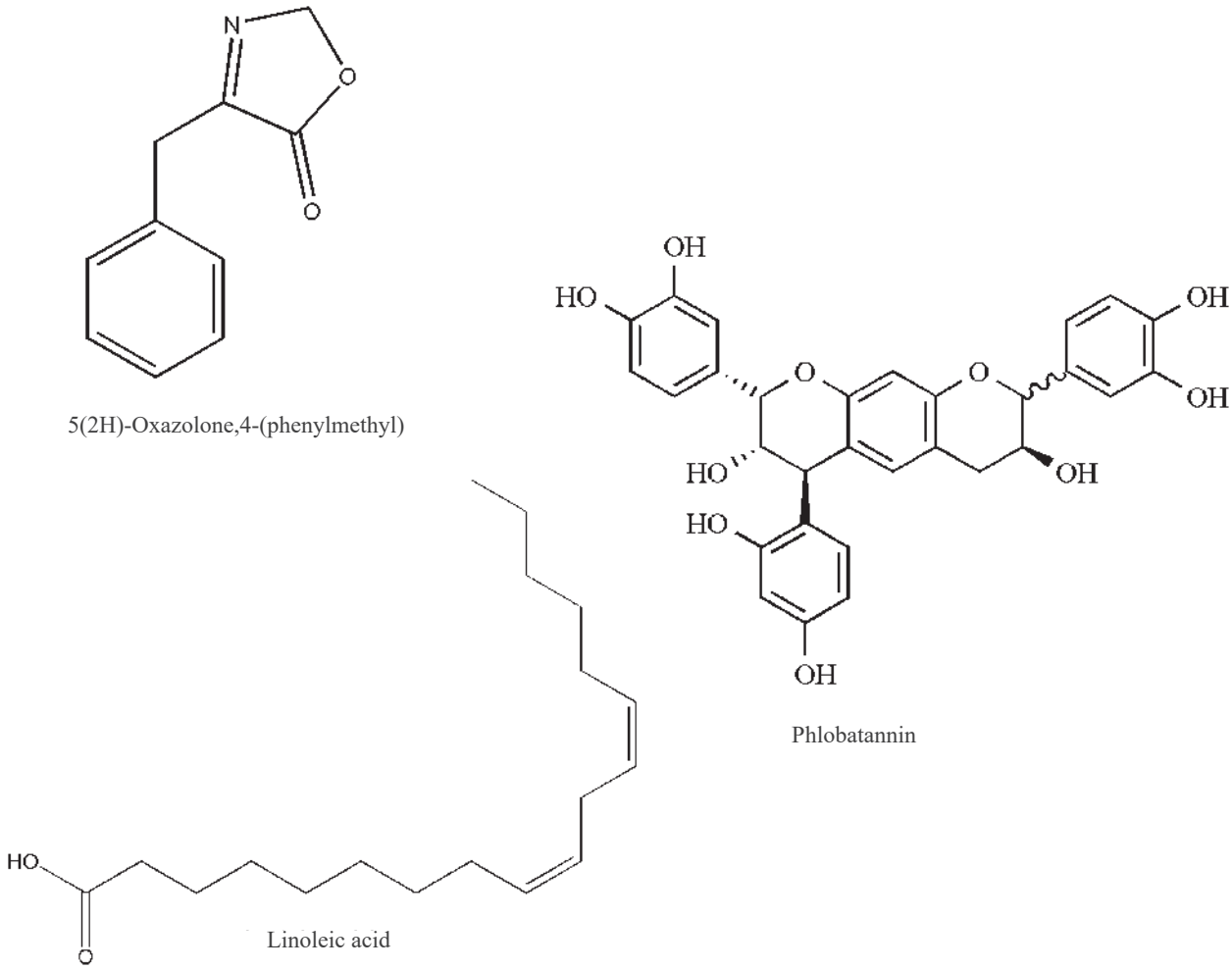
2-Methoxy-4-vinylphenol (2M4VP)



Eicosadienoic acid



Phytol



Structures of Important and Characteristic Chemical Constituents of *Sterculia urens*

Biological Activities:

Antimicrobial Activity: Copper oxide nanoparticles synthesized using karaya gum which acts as both a reducing and capping agent, have shown effective antimicrobial properties against *Escherichia coli* and *Staphylococcus aureus* (Padil et al., 2013). Additionally, the ethanolic extract of *S. urens* leaves has been tested for antibacterial activity using the agar well diffusion method, revealing significant zones of inhibition and indicating potent antibacterial effects (Khadse & Sawant, 2022; Prajapati et al., 2013).

Anti-Urolithiatic Activity: The ethanolic extract of *S. urens* leaves has also been evaluated for its anti-urolithiatic properties using the nucleation assay method. The plant demonstrated potential as an anti-urolithiatic agent, attributed to the presence of phytoconstituents such as flavonoids, alkaloids, and saponins (Devi & Swarnalatha, 2022; Kumar et al., 2011; Upadhyay 2017).

Toxicology: While gum karaya from *S. urens* offers various health benefits, it can also cause complications. The gum swells in the intestine, stimulating the digestive tract but excessive intake may lead to intestinal restriction and other medical issues. It is recommended to drink plenty of water when consuming gum karaya. Moreover, it can reduce the effectiveness of other medications by limiting their absorption so it should be taken at least an hour after other medicines. High doses of gum karaya may also cause diarrhea (Singh et al., 2014).

Patent:

- Gastro retentive formulation with carboxymethylated gum *Sterculia*, Patent No: 202111000642

- Phytochemical analysis and comprehensive evaluation of pharmacological activities, isolation and characterization of bioactive compound from the *Sterculia urens*, Patent No: 202141050693

Scope of Further R&D: *Sterculia urens* is a deciduous tree of the Sterculiaceae family with a rich history of use in traditional medicine. However, there are several areas where further research and development (R&D) could be beneficial. Investigating the nutritional composition of *S. urens* seeds could reveal their potential as a food source both for humans and animals. This research could identify valuable nutrients and promote the use of seeds in diets. The *S. urens* has been traditionally used for various medicinal purposes, modern scientific studies are needed to validate these uses. Research should focus on isolating and identifying bioactive compounds, understanding their mechanisms of action and evaluating their efficacy through clinical trials. In India, it is crucial to advance R&D efforts in conducting clinical trials to explore the potential of *S. urens* in the medical field. This could lead to the development of new therapeutic agents derived from the plant. In addition to its economic importance for tribal communities, the endangered status of *S. urens* necessitates urgent conservation efforts. Strategies should be developed to protect and manage this species to prevent its extinction. Overall, focused R&D on *S. urens* could unlock its potential in nutrition, medicine, and conservation, benefiting both local communities and the broader scientific community.

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Stereospermum personatum (Hassk.) Chatterjee

Synonyms:
Dipterosperma personatum (Hassk.), *Stereospermum caudatum* (DC.) Miq, *Stereospermum colais* (Buch.-Ham. ex Dillwyn) Mabb.

Local/Common/Popular Name(s):
Trumpet Flower.

Vernacular Names:
Hindi: Patiri; ***English:*** Trumpet Flower;
Malayalam: Karingkruna;
Tamil: Paadhalaamaram poopadiri

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Tracheophyta
Class	:	Magnoliopsida
Order	:	Lamiales
Family	:	Bignoniaceae
Genus	:	*Stereospermum*
Species	:	*Stereospermum personatum*

Botanical Description: *Stereospermum personatum* is a tree with brown bark, and its wood is hard, greyish-brown, and marked with dark patches. The flowers are bell-shaped, red with yellow veins, and grow in axillary corymbs. The fruits are elongated, twisted capsules, either tri- or four-sided, and speckled, containing compressed, winged seeds. The leaves are opposite, acute, obovate, and imparipinnate with an acuminate tip. Flowering occurs from April to June at lower elevations and from July to September at higher elevations (India Biodiversity Portal, n.d.).

Distribution: *S. personatum* is distributed across tropical Thailand, Indo-China, Malaysia, the Himalayas, Sri Lanka, and Burma. In Bangladesh, it is found in the forests of Chittagong, Chittagong Hill Tracts, Cox's Bazar, Gazipur, Sylhet, and Tangail. In India, the species grows on deciduous slopes, in semi-evergreen forests, and on hills above 800 meters in elevation (Islam et al., 2016).

Ethnobotanical significance: *S. personatum* is a medicinal plant extensively used in traditional preparations for its diuretic, lithontriptic, expectorant, cardiotonic, aphrodisiac, and appetite-stimulating properties. It is also employed in the treatment of conditions such as dyspepsia, diarrhea, renal and vesical calculi, cough, asthma, hyperdipsia, hemorrhoids, and hyperacidity (Warrier, 1993).

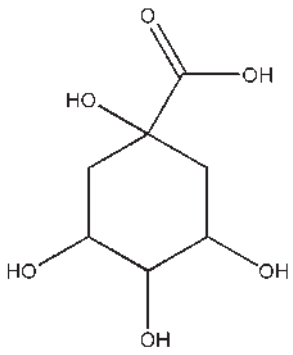
Phytochemistry:

Stem Bark: Sterequinone-A; sterequinone-B; Sterequinone-C; Sterequinone-D; Sterequinone-E; Sterekunthal-B (Kumar et al., 2003; Kumar et al., 2005).

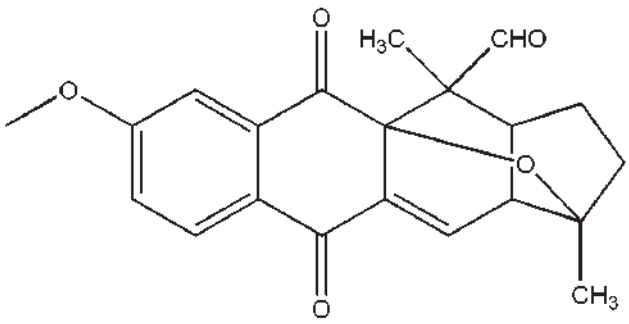
Leaf:1,3,4,5-tetrahydroxyl cyclohexane carboxylic acid; Linoleic acid; Phytol; Octadecamethyl; 3,4-dimethoxy benzamide; Phosphonic acid (Kumar et al., 2003).

Biological Activities:

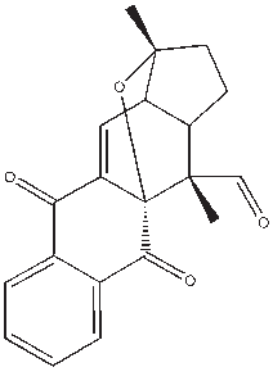
Antimicrobial Activity: The stem bark extract of *S. personatum* showed mild to moderate antimicrobial activity, particularly against gram-positive bacteria, with notable effects on *Sarcina lutea* (13mm inhibition) and gram-negative *P. aeruginosa* (13mm inhibition) (Islam et al., 2010).



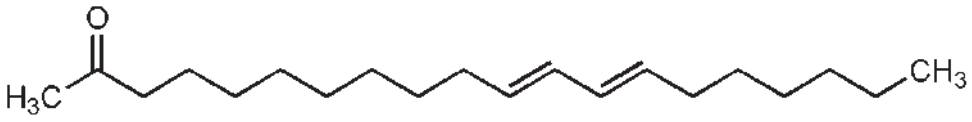
1,3,4,5-tetra hydroxy cyclohexane carboxylic acid



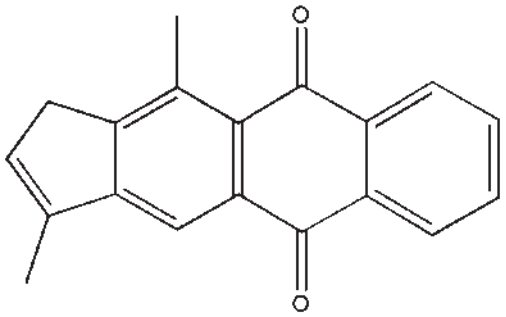
Sterequinone-B



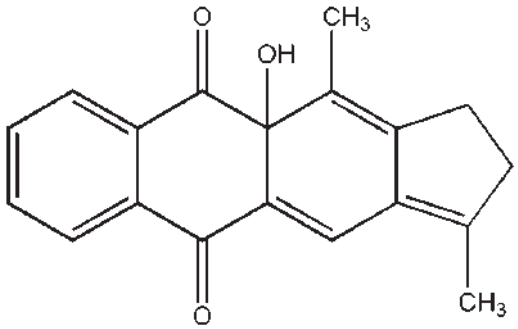
Sterekunthal-B



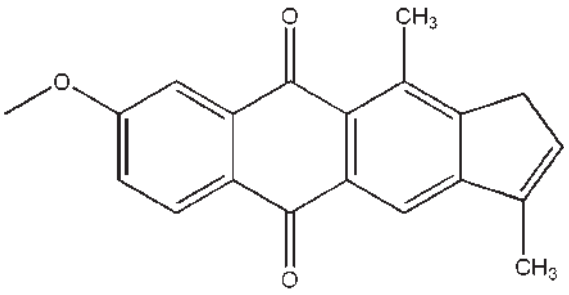
Linoleic acid



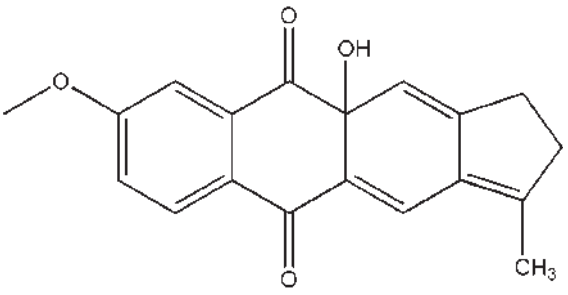
Sterequinone-A



Sterequinone-C



Sterequinone-D



Sterequinone-E

Structures of Important and Characteristic Chemical Constituents of *Stereospermum personatum*

Antioxidant Activity: The compound (-)-Secoisolariciresinol, isolated from dried wood powder of *S. personatum*, exhibited significant antioxidant (DPPH anti-free radical) activity (Rao et al., 2002).

Antidiabetic Activity: The methanol extract of *S. colais* fruit demonstrated anti-diabetic effects in streptozotocin-induced diabetic rats, showing increased liver and muscle glycogen, serum insulin, and reduced fasting blood glucose and glycosylated hemoglobin levels (Imran et al., 2016).

Hypolipidemic Activity: The methanol extract of *S. colais* fruit reduced total cholesterol and serum triglycerides and increased high-density lipoprotein

levels in streptozotocin-induced diabetic rats, indicating hypolipidemic potential (Imran et al., 2016).

Anti-Arthritic Activity: The ethyl acetate extract of *S. colais* showed anti-arthritic effects in animal models, reducing arthritis index and increasing beneficial phytoconstituents (Suseela & Krishnan, 2021).

Analgesic Activity: Methanol, ethyl acetate, and chloroform extracts of *S. personatum* fruits exhibited significant analgesic activity in mice models, including acetic acid-induced writhing and formalin-induced licking (Islam et al., 2018).

Anti-inflammatory Activity: The methanol, ethyl acetate, and chloroform *S. personatum* extracts showed moderate anti-inflammatory effects in carrageenan-induced hind paw edema in mice (Islam et al., 2018).

CNS Depressant Activity: The methanol, ethyl acetate, and chloroform plant extracts also demonstrated significant CNS depressant activity in hole cross and open field tests in mice (Islam et al., 2018).

Patent:

- +-Cycloolivil as antioxidant obtained from *Stereospermum Personatum,* Patent No: KR100750372B1
- (—)-Olivil as antioxidant which is obtained from a new natural source namely *Stereospermum personatum,* Patent No: US6592911B2
- (-)-Secoisolariciresinol as an antioxidant obtained from a new natural source namely *stereospermum personatum,* Patent No: US6489514B1
- A process for isolation of (-) olivil from a new source *Stereospermum personatum*, Patent No: 857/del/2001
- "A process for the preparation of (-)-secoisolariciresinol from a new natural source namely *Stereospermum personatum* useful as an antioxidant", Patent No: 858/del/2001
- A pharmaceutical composition essentially comprising (-)-secoisolariciresinol obtained from *Stereospermum personatum* useful as an antioxidant, Patent No: 861/del/2001

Scope of further R&D: The pharmacological activities of *S. personatum* have established its potential as a versatile medicinal plant, with applications across various therapeutic areas. However, existing studies remain limited, offering only preliminary insights. To fully harness its potential, further research is needed in several key areas. In-depth phytochemical studies are required to isolate and identify additional active compounds, while detailed pharmacological characterization will help elucidate the mechanisms of action and therapeutic efficacy. Additionally, pre-formulation studies are necessary to develop appropriate dosage forms for clinical use, paving the way for its wider application in modern medicine.

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Strychnos potatorum L.f.

Synonyms:
S. poatatorum, Strychnos heterodoxa, Strychnos stuhimannii

Local/Common/Popular Name(s):
Clearing Nut

Vernacular Names:
Sanskrit: Ambuprasadanaphala, Ambuprasadani, Chakshushya, Chhedaniya, Guchhaphala, Kata, Kataka, Katakarenu, Kattha, Khataka, Lekhanatmaka, Payaprasadi, Ruchishya, Ruchya, Rushya, Shlakshna, Shodanatmaka, Tiktamaricha, Tiktaphala, Toyaprasadana; ***Hindi:*** Neimal, Nelmal, Nirmali; ***Marathi:*** Chilbing, Chilhara, Gajara, Nirwali; ***Bengal:*** Nirmali. ***Malayalam:*** Katakam, Tetta, Tettamparap, Titramparala; ***Punjabi:*** Niemali. ***Tamil:*** Akkolam, Ilalam, Kadali, Sillam, Tatta, Tettankottai, Teru; ***Urdu:*** Nirmali.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Gentianales
Family	:	Loganiaceae
Genus	:	*Strychnos*
Species	:	*Strychnos potatorum*

Botanical Description: *Strychnos potatorum* is a medium-sized, glabrous tree reaching 12-13 meters in height. The stem is fluted and covered with thick black or brownish-black bark that forms square to rectangular scales, measuring about 1.32 cm thick, with deep, narrow ridges that easily break off. The branches swell at the nodes. The leaves, about 57 cm long, are nearly sessile, subcoriaceous, ovate or elliptic, acute, glabrous, and shiny, with spuriously three to five nerves, and lateral nerves extending from the midrib's lower part to nearly the tip. The petiole is approximately 2.5 mm long. The flowers are large for the species and form in short, nearly sessile axillary cymes. Peduncles are 0.5 mm long, while pedicels are extremely short. The calyx is around 2 mm long, with five lobes, each about 2.5 mm long, oblong, and acute, with a tuft of hair at the base of each lobe. The ovary is ovoid, glabrous, and tapers into a long style, while the stigma is obscurely two-lobed. The fruit is a shiny, black berry approximately 12 cm in diameter when ripe, containing globose seeds. Flowering occurs in September-October, and fruiting takes place in December (Chatterjee and Pakrashi, 1996; Das, 2008; Kirtikar et al., 1995; Sarin, 1996).

Distribution: *S. potatorum* is found in tropical regions of southern Africa, including Malawi, Zambia, Zimbabwe, Botswana, Namibia, and also in Sri Lanka and Myanmar (Ruby et al., 2011). In India, it is present in West Bengal, as well as in Central and South India, growing at altitudes up to 1200 meters (Singh, 2012).

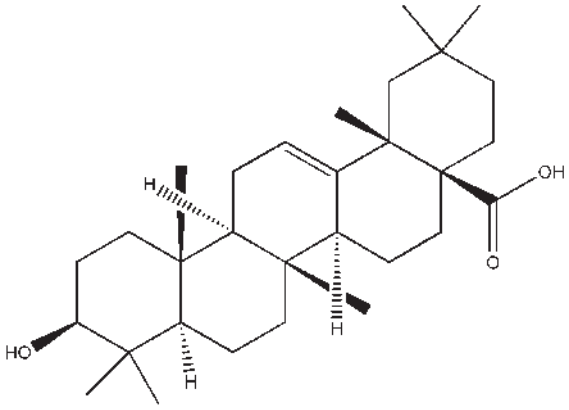
Ethnobotanical significance: The seeds of *S. potatorum* are known for their acrid, alexipharmic, and lithotriptic properties. They are used to treat strangury, urinary discharges, head diseases, and as stomachic and demulcent agents. The seeds are also employed for treating diabetes, diarrhea, gonorrhea, and eye troubles. The roots are used to cure leucoderma, while the fruits are useful for treating eye diseases, thirst, poisoning, and hallucinations. The fruits also possess emetic, diaphoretic, and alexiteric properties. In the Unani system of medicine, the seeds are considered bitter, astringent to bowels, aphrodisiac, tonic, diuretic, and beneficial for liver and kidney complaints, as well as gonorrhea (Ruby et al., 2011; Singh, 2012).

Phytochemistry:

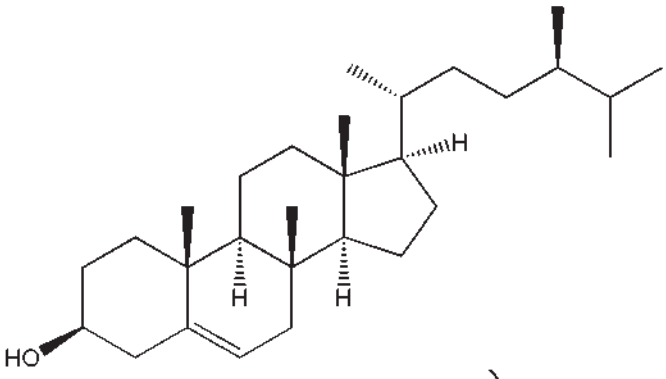
Seeds: β-sitosterol; oleanolic acid; 3β-acetoxy-oleanolic acid (Singh *et al.,* 1977; Singh *et al.,* 1978).

Leaves: Isomotiol, Stigmasterol, β-sitosterol (Mallikharjuna *et al.,* 2009).

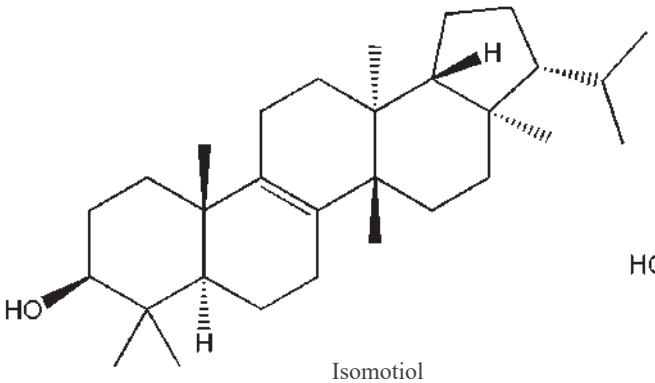
Bark: Stigmasterol, β-sitosterol



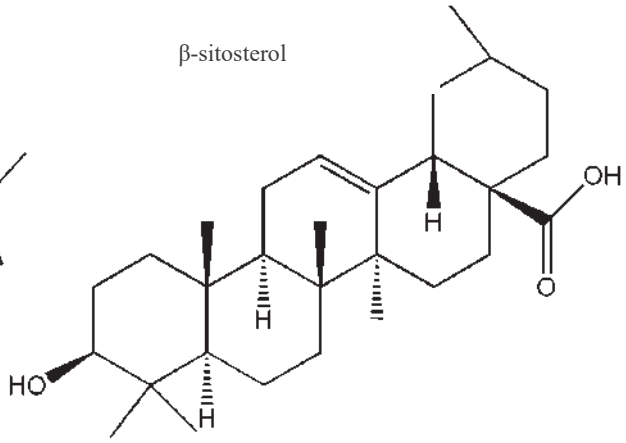
3-β-acetoxy-oleanolic acid



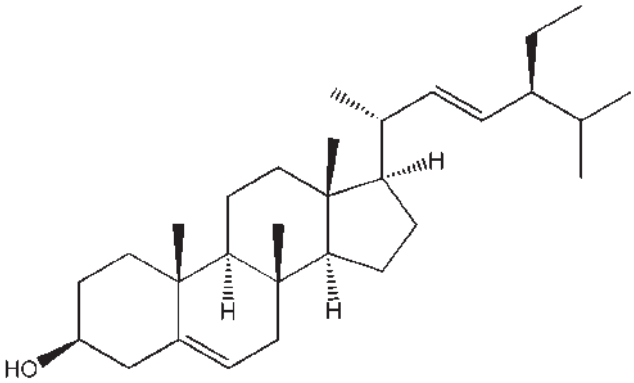
β-sitosterol



Isomotiol



Oleanolic acid



Stigmasterol

Structures of Important and Characteristic Chemical Constituents of *Strychnos potatorum.*

Biological Activities:

Antimicrobial Activity: The alkaloid fractions of *S. potatorum* seeds were tested against pathogenic bacteria, including *Escherichia coli*, showing significant antimicrobial activity (Mallikharjuna et al., 2009).

Antidiabetic Activity: The ethanol extract of *S. potatorum* was found effective in reducing blood sugar levels in alloxan-induced diabetic rats, even at a dose of 100 mg/kg (Bamidele et al., 2014). Additionally, the ethanolic seed extract demonstrated significant antidiabetic activity in

streptozotocin-nicotinamide-induced diabetic rats, improving glucose levels and antioxidant enzyme activity (Mishra et al., 2013). Another study on high-fat diet-fed and streptozotocin-induced diabetic rats showed that a 30-day treatment with the extract at 500 mg/kg improved insulin levels and regulated carbohydrate metabolism (Chandiran et al., 2020). The plant extract was also effective in reducing blood sugar levels in diabetic rats, comparable to glipizide (Biswas et al., 2014). Further, in high-fat-fed, streptozotocin-induced diabetic rats, the seed extract significantly reduced glucose levels and improved antioxidant status (Subramanian, 2020).

Antiarthritic Activity: The aqueous extract and seed powder of *S. potatorum*, administered at 200 mg/kg, showed significant reduction in paw edema in rats, indicating its anti-arthritic properties (Ekambaram et al., 2010; Arya et al., 2011).

Antioxidant Activity: The ethanolic extract of *S. potatorum* demonstrated dose-dependent antioxidant activity in a DPPH scavenging assay, comparable to ascorbic acid, suggesting its potential as a natural antioxidant (Gangwar and Choubey, 2019). Various extracts of the plant also showed significant antioxidant activity in multiple assays, including DPPH, nitric oxide, and hydroxyl radical scavenging (Hareeshbabu et al., 2015).

Toxicology: No toxic effects were observed in vital organs like the liver, kidney, heart, or spleen when treated with the aqueous extract and seed powder of *S. potatorum* for 30 days, indicating its safety for long-term use (Sanmugapriya and Venkataraman, 2006).

Patent:

- Isolation of excipient from *Strychnos potatorum* linn. (nirmali) for preparing pharmaceutical dosage form, Patent No: 710/mum/2013
- In-vitro and in-vivo investigation of anti-diabetic potential of phenolic acids in *Strychnos potatorum* linn. seed extracts, Patent No: 202221015020
- A herbal formulation for prevention and treatment of diabetes and associated complications. Patent No. EP2326338A2
- In this patent, *S. potatorum* was used as one of the species

Scope of Further R&D: *S. potatorum* contains a range of phytochemicals with diverse chemical structures, but limited research has explored their biological activities and medicinal applications. To fully realize its therapeutic potential, further studies are needed to investigate the bioactivity, mechanisms of action, pharmacotherapeutics, and toxicity of these compounds. Although traditional medicine has utilized crude extracts of the plant for centuries, modern drug development requires rigorous research, including proper standardization and clinical trials. While the chemistry of the plant has been studied extensively, additional R&D is essential for its economic and therapeutic advancement.

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Ventilago madraspatana
Gaertn.

Synonyms:
None

Local/Common/Popular Name(s):
Ventilago madraspatana is commonly known as Red creeper.

Vernacular Names:
Hindi: Pitti; ***Kannad:*** Aithaalabeelu; ***Tamil:*** Vempadankodi; ***Telugu:*** Ettasurugudu, Ettashirattalativva, Surlaitige, Surudugudu; ***Odisha:*** Raktapita, Pichali, Petchurimal, Sajumalo, Torida, Petchuri, Raktakhai, Pitchule; ***Sanskrit:*** Dineshvalli, Rakthavalli (Rao et al, 2016).

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Rosales
Family	:	Rhamnaceae
Genus	:	*Ventilago*
Species	:	*Ventilago madraspatana*

Botanical Description: *Ventilago madraspatana*, commonly known as red creeper, is a large, woody, evergreen climber. The bark is dark grey with vertical cracks exposing a vermillion inner surface. Young branches are grey and pubescent, while older branches are dark grey and glabrous. The leaves are pale green, alternate, oblong-lanceolate, elliptic ovate to orbicular, and pubescent beneath when young. They typically have rounded bases, acute or sub-acuminate apices, and crenate margins, with lateral nerves in 4-8 pairs ascending towards the margin. The inflorescences are axillary and terminal panicles, which are minutely grey-pubescent, sometimes with leafy bracts. The yellowish-green flowers, which have an offensive odor, are arranged in terminal or axillary cymose panicles, and are about 5 to 15 cm in length, with a pubescent calyx tube that numbers 3 to 5. Reproduction occurs through pollination, resulting in subglobose nuts that are 5 to 7 mm in diameter, yellow to grey in color, and enclosed in a persistent calyx rim extending to about the middle, with a linear pubescent wing. The seeds are brown, globose, and thin-walled (Nandkarni, 2000; Gamble, 2005; Khare, 2007; Chetty, 2008; Mahmood et al., 2011).

Distribution: *V. madraspatana*, a member of the Rhamnaceae family, is distributed in tropical forests across India. It is found in Bellary district, Karnataka; Yelagiri Hills in Vellore district, and Hoganekkal R.F. in Dharmapuri district, Tamil Nadu; Tirumala Hills in Chittoor district, Gundam R.F. in Kurnool district, and Guvvalacheruvu R.F. in Kadapa district, Andhra Pradesh; as well as in Sambalpur and Mayurbhanj districts of Odisha (Ghosh et al., 2010; Rao et al., 2016). *V. madraspatana* thrives in dry to moist lowland tropical areas, up to elevations of 900 meters. It prefers daytime temperatures between 32 to 40°C, though it can tolerate 10 to 47°C. The species grows best with annual rainfall between 800 to 1,300 mm, tolerating as low as 600 mm and as high as 1,500 mm. It is found in areas with a distinct dry season and prefers well-drained soils, with a pH range of 5.5 to 6.5, but can sustain pH levels from 4.5 to 7.8.

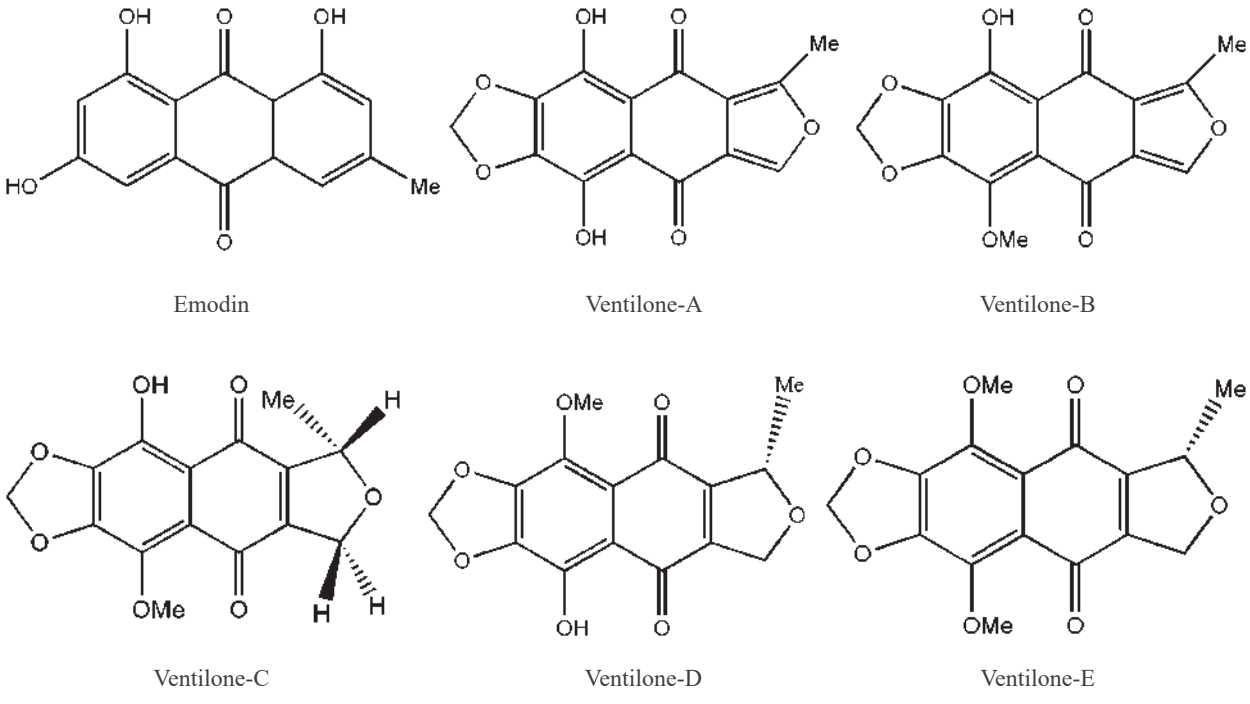
Ethnobotanical Significance: *V. madraspatana* has been traditionally valued for its medicinal properties. The stem bark is used as an appetite

stimulant and in the treatment of gastrointestinal infections, diabetes, certain cancers, and viral infections (Kawade et al., 2015; Sharma et al., 2020). It is also an ingredient in aphrodisiacs (Suthari et al., 2014; Gandagule et al., 2019) and is believed to have healing effects on dyspepsia, colic disorders, leprosy, skin disorders like scabies and pruritus, and general disabilities (Mahmood et al., 2011). A mixture of stem bark powder with gingelly oil is applied externally to treat skin diseases and itching (Chopra, 1969). The root bark is used as a carminative, stomachic, and stimulant, and it is beneficial for conditions associated with kapha, colic flatulence, and erysipelas (Solangaarachchi & Perera, 1993; Bhardwaj et al., 2011). The bark paste is used in the treatment of bone fractures (Panda et al., 2011), and tender branches are utilized for treating vertigo (Jagtap et al., 2019; Basha, et al., 2011). The latex is used to cure edema (Saheb, 2014; Periyasamy & Kaliyaperumal et al., 2015). Additionally, the bark has thermogenic, alexiteric, and tonic properties (Devarinti et al., 2015), and both the bark and leaves are employed in treating malarial fever (Johnson et al., 2015). The seeds are administered to diabetic patients to help lower blood glucose levels (Nandkarni, 2000; Pavani et al., 2012).

Phytochemistry:

Root: Ventinone A, ventinone B, Chrysophanol, physcion, emodin, islandicin, xanthorin, xanthorin-5-methyl ether (Rao et al., 1983), ventilaginone, ventilagol, maderone, cordeauxione, isocordeauxione (Hanumaiah, 1985b), benzisochromanquinones, ventilaquinones A, B, C, D, E, F, G and H (Hanumaiah, 1985a; Charles et al., 1991).

Stem bark: (E)-6-(3,4-dihydroxy-2-methyl-4-(2,6,6-trimethylcyclohex-2-enyl) but-1-enyl)-7-methoxy-2H-chromen-2-one (Kawade et al., 2015)



Structures of Important and Characteristic Chemical Constituents of *Ventilago madraspatana*

Biological Activities:

Antioxidant and Anticancer Activities: Ethanolic and hydroethanolic root extracts of *V. madraspatana* have demonstrated significant antioxidant effects, with increased catalase levels and decreased lipid peroxidation (LPO) and glutathione levels. The ethanolic extract, at a dose of 500 mg/kg, exhibited slightly greater antioxidant activity compared to the hydroalcoholic extract at the same dose (Damayanthi et al., 2015). Additionally, the whole plant's ethanolic extract showed antioxidant and anti-denaturation

activity, with in-vitro studies confirming moderate anti-denaturation and antioxidant effects (Duganath et al., 2010). Hexane root extracts displayed notable free radical and ABTS scavenging activities (Rajesh et al., 2015). Furthermore, ethanolic extracts of the leaves and stems also demonstrated significant antioxidant activity (Gandagule et al., 2019).

Antimicrobial Activity: Various extracts of *V. madraspatana*, including petroleum ether, benzene, ethyl acetate, methanol, and ethanol, were tested against several microorganisms. The methanolic extract showed the highest activity against *Serratia marcescens*, while the petroleum ether extract was most effective against *Proteus vulgaris*. Among the tested solvents, petroleum ether extract exhibited the broadest antimicrobial activity (Packialincy et al., 2013; Periyasamy & Kaliyaperumal et al. 2017). The stem bark of *V. madraspatana*, rich in phytochemicals, demonstrated strong antimicrobial properties. A 100 mg/ml concentration of methanolic extract significantly inhibited *P. vulgaris* with a 13.98 mm inhibition zone. Other bacteria, including *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Klebsiella pneumoniae*, and *Salmonella typhi*, also showed significant susceptibility to the methanolic extract (Kawade et al., 2014). The whole plant exhibited high antibacterial activity, particularly against *Proteus vulgaris* (Lincy et al., 2013). The methanolic root bark extract also displayed potential antimicrobial and antibacterial activities at 60.15 kg/ml (Aparna et al., 2014).

Anti-inflammatory Activity: Physcion and emodin, compounds isolated from the stem bark of *V. madraspatana*, were tested using the carrageenan-induced rat-paw oedema model. These compounds showed a dose-dependent inhibition of nitric oxide (NO•) production by suppressing iNOS protein protein, without affecting macrophage viability. Both compounds reduced oedema volume by 65–68% at a dose of 40 mg/kg, demonstrating a strong in-vivo anti-inflammatory effect. They were also tested against a murine tumor model (Ehrlich ascites carcinoma) and three human cancer cell lines, including A375 (malignant skin melanoma), Hep2 (epidermoid laryngeal carcinoma), and U937 (lymphoma) (Ghosh et al., 2010).

Anti-diabetic Activity: The methanolic extract of *V. madraspatana* leaf powder, at doses of 100, 200, and 400 mg/kg, has demonstrated significant anti-hyperglycemic and anti-hyperlipidemic effects in long-term treatment of STZ-induced diabetic rats. The extract showed the most potent activity at 400 mg/kg, effectively reducing cholesterol, triglycerides (TG), LDL, and VLDL levels, while improving HDL in diabetic rats (Sasikala et al., 2014; Periyasamy & Kaliyaperumal et al., 2017). Additionally, root extracts exhibited anti-diabetic activity, with the methanolic root bark extract showing a 56.25% inhibition of the enzyme alpha-glucosidase (Damayanthi & Satyavati, 2015; Aparna et al., 2014). Furthermore, leaf extracts were found to significantly decrease blood glucose and HbA1C levels and increase serum insulin levels in STZ-induced diabetic albino rats, making it a promising candidate for diabetes treatment (Karauppannan et al., 2020, 2021).

Cardioprotective Effect: Methanolic extracts of the whole plant exhibited a cardioprotective effect against isoproterenol-induced myocardial infarction, indicating potential use in heart-related treatments (Kumar et al., 2010).

Other Pharmacological Activities: The ethanolic extract of *V. madraspatana* has been found to have neuroprotective effects in cerebral ischemia by enhancing the brain's antioxidant defense system. The bark of this plant also has hepatoprotective properties, offering protection against CCl4-induced liver damage. Additionally, the root bark is recognized as a natural antioxidant with hepatoprotective qualities. The stem bark possesses anti-inflammatory and anticancer activities and is also used to treat gout (Periyasamy et al., 2017).

Toxicology: No toxicological studies on *V. madraspatana* have been reported in the literature to date.

Scope of Further R&D: *V. madraspatana*, an evergreen climber from the Rhamnaceae family, has a long history of use in traditional medicine for treating various ailments. Future research should focus on elucidating the specific mechanisms underlying its medicinal properties, such as its appetite-stimulating effects, blood glucose-lowering capabilities, and its potential in treating gastrointestinal infections, cancer, and viral infections. Additionally, comprehensive studies should explore its efficacy in treating conditions like dyspepsia, colic disorder, leprosy, scabies, pruritus, and other skin disorders. Rigorous clinical trials are essential to validate its traditional uses, particularly for diabetes, cancer, and viral infections, which are promising areas for therapeutic development.

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Vitex altissima L.f.

Synonyms:
Vitex alata Willd, *Vitex altissima* L.f. var. *alata* (Willd.), Trimen (Srinivasan, 1987), *Vitex appendiculata* Rottler ex C. B. Clarke, *Vitex latifolia* Wight ex Steud. Nom. Inval, *Vitex zeylanica* Turcz. Nom. Illeg.

Local/Common/Popular Name(s):
Peacock chest tree, Milla (Timber Trade Name)

Vernacular Names:
Hindi: Myrole; ***Assamese:*** Ashoi, Ahoi; ***English:*** Tall chaste tree, Peacock chaste tree, Milla; ***Irula:*** Mehilaimaram; ***Kach:*** Selong-phang; ***Marathi:*** Dhavi-rivthi, Balage; ***Nepali:*** Tin-patte; ***Sylheti:*** Anhui; ***Kannada:*** Balgai, Balgay, Banige Mara, Bharanage, Bharani, Bharaniga, Bulgi, Doddalakkhi, Doddalakki, Hule, Kaadu Naevile, Kaadunekki, Kadunekki, Katnuski, Mailaadi, Mailadi, Mailellu, Maillalu, Mairol, Mairole, Mayiladi, Mayoorolu, Mayurolu, Mirole, Myrole, Nanladi, Naulaadi Mara, Nauldi, Navilaadi, Naviladi, Navladi, Navulaadi, Navuladi, Nerole, Nevaladi, Nowladi, Sampagapala, Sampagepala, SompuKepala, Sompukepala, Tomukki, Torenekki, Tornukki; ***Malayalam:*** Mayila, Attumayila, Mylellu, Myila, Maiyella, Kattumayila, Kattumelan, Mailelou, Mailadi, Maillalu, Mayilati, Mayilella, Mayilelu, Mayilila, Myla, Myladi, Valli; ***Marathi:*** Dhavi-rivthi, Balage; ***Telugu:*** Nevali, Adugu, Ganduparu, Nemiladogu, Busi Chettu, Mayooramu, Mayoorapugandarapu, Mayuramu (for Vitex alata), Mayurapau, Mayurapugandarupa, Mirapagandra, Namiladagu, Nemali Adugu, Nemaliaduga, Nemaliadugu, Nemaliyadugu, Nemiliadagu, Nevalyaduga, Nowlieragu, Nowllieragu; ***Tamil:*** Mayiladi, Maila, Mayilainochi, Mayilaadi, Cakavatitam, Cakavatitamaram, Elilaimayilai, Elilainocci, Kalikarakam, Kalikaram, Kattumayilai, Kattumayilam, Kattuna, Kattunamaram, Kattunocci, Maila, Malyiladi, Mayilaadi, Mayilai, Mayilainochi, Mayilati, Mayilatinocci, Mayilei, Mayili, Talakattinmancalpokki, Tilakam, Titikeyam, Titikeyamaram; ***Others:*** Mailam, Neviladi Kai, Peacock Chaste Tree (Anonymous, 1976; Sivarajan and Mathew, 1996).

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Lamiales
Family	:	Lamiaceae
Genus	:	*Vitex*
Species	:	*Vitex altissima*

Botanical Description: *V. altissima* is a large tree, reaching heights of up to 30 meters. The bark is 10-13 mm thick, greyish-yellow, and scaly. Young shoots are covered with soft, villous hairs, while the branchlets are lenticellate and minutely tomentose. The leaves are compound and opposite, with 3 (rarely 5) sessile leaflets that are lanceolate, elliptic-lanceolate, or oblanceolate. The leaf apex is acuminate, the base is cuneate or acute, and the margin is entire. The upper surface of the leaf is glabrous, while the underside is pubescent or glabrescent along the nerves. The petiole is 3.5-6 cm long, slender, and pubescent, with winged edges in saplings, and auriculate wings at the base. Lateral nerves are pinnate, with 10-16 pairs, and puberulent beneath. The inflorescences form terminal panicles. Flowers are bisexual, white with a blue tinge, and have lanceolate, caducous bracts about 3 mm long. The calyx is densely tomentose, with five short, triangular lobes. The corolla is 5 mm long, two-lipped with an upper lip of 2 lobes and a lower lip of 3 lobes, woolly and ciliate at the edges. There are four stamens, didynamous, with hairy filaments at the base. The ovary is superior, globose, 1 mm

long, with a fulvous-villous apex, 2-4 celled, and contains 4 ovules. The style is filiform with a bifid stigma. The fruit is a smooth, globose, and glabrous drupe, purplish-black, about 5 x 5 mm in size, supported by an enlarged calyx. Seeds are obovate, typically 4 in number (Anonymous, 1976; Matthew, 1983; Vijayasankar et al., 2012).

Distribution: *V. altissima* is a tree species native to regions of East Asia, the Indian subcontinent, and Southeast Asia, including countries like Laos, Indonesia, Papua New Guinea, and Indo-China. It is also found in Pakistan, Bangladesh, Myanmar, Nepal, Bhutan, Sri Lanka, Malaysia, and the Fiji Islands. The species has been cultivated in parts of Europe and the USA (Sivarajan & Mathew, 1996). In India, *V. altissima* is distributed across the Deccan Plateau, Peninsular India, Assam, Arunachal Pradesh, Sikkim, Nagaland, Meghalaya, Manipur, West Bengal, and the Andaman Islands. It is commonly found in the evergreen forests of the Western and Eastern Ghats (Brandis, 1984; Vijayasankar et al., 2012). This large deciduous tree, reaching up to 30 meters in height, typically grows near riversides in deciduous forests and scrub jungles, at altitudes ranging from 40 to 1,100 meters above sea level on laterite and alluvial soils. In higher ranges, it thrives in rocky areas with deep root systems that penetrate rock crevices. *V. altissima* is frequently found in riparian vegetation within sacred groves and on slopes and foothills above 600 meters (Anonymous, 1976; Sivarajan & Mathew, 1996).

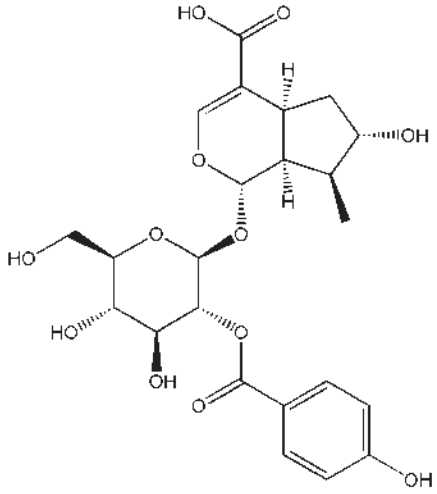
Ethnobotanical Significance: *V. altissima* is a medicinal tree with extensive use in Ayurveda and traditional folk medicine. It is believed to pacify vitiated kapha and vata, and is used to treat a variety of ailments including inflammation, wounds, ulcers, eczema, pruritus, worm infestations, urinary diseases, stomatitis, and conditions related to postpartum recovery (Chaithrika et al., 2019). The bark juice is applied externally to alleviate rheumatic swellings and chest pains (Bose et al., 2014). Additionally, the tree is used to treat stomatitis, cardiac diseases, anorexia, leprosy, worm infestations, rheumatic swellings, and chest pains (Leela et al., 2015). The stem bark is traditionally used for treating ephemeral fever and snake bites. Crushed leaves are applied to wounds and are also used to address skin allergies, as well as snake and scorpion bites, and rheumatism (Santhana Bharathi et al., 2015; Ayyanar, M., & Ignacimuthu et al., 2005). *V. altissima* is employed in the treatment of a wide range of conditions, including stomatitis, cardiac diseases, anorexia, blindness, leprosy, and worm infestations (Parrotta, 2001). The stem bark is specifically used for treating ephemeral fever, snake bites, rheumatic swellings, and chest pains (Pragada & Rao, 2012; Reddy et al., 2008; Yesodharan & Sujana, 2007). Leaves are applied to wounds and are also used for treating skin allergies and rheumatism (Ayyanar & Ignacimuthu, 2009; Narayanan et al., 2011; Rajakumar & Shivanna, 2010). An infusion of leaves, stem bark, and root bark is used to treat malaria and blackwater fever. In the Davanagere district, tribal communities use leaf extract as an antiseptic and in the treatment of wounds, jaundice, and fever.

Phytochemistry:

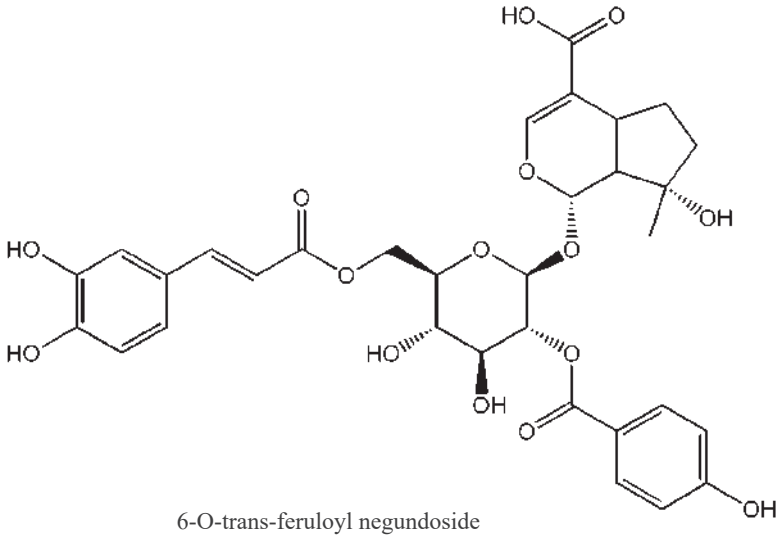
Leaves: Vitexin (Manjunatha *et al.* 2007; Chopra *et al.*, 1956); altissinone; 2''-O-p-hydroxybenzoylorientin; 6'-*O*-*trans*-feruloylnegundoside; 6'-*O*-*trans*-caffeoylnegundoside; 2'-*O*-*p*-hydroxybenzoyl-6'-*O*-*trans*-caffeoylgardoside; 2'-*O*-*p*-hydroxybenzoyl-6'-*O*-*trans*-caffeoyl-8-epiloganic acid; 2'-*O*-*p*-hydroxybenzoyl gardoside; and 2'-*O*-*p*-hydroxybenzoyl-8-epiloganic acid; iridoids; agnuside; and negundoside (Sridhar *et al.* 2005; Ganapaty et al., 2005). 1, 4-dichloro, 4, 6-octadienoic acid; eugenol; germacrene D; caryophyllene; benzene,1-(1,5-dimethyl-4-hexenyl)-4-methyl, [S-(R*, S*)]; 1, 3-Cyclohexadiene; 5-(1, 5-dimethyl-4-hexenyl)-2-methyl; α-Caryophyllene; 1,6,10-Dodecatriene, 7,11-dimethyl-3-methylene-[Z], dodecanoic acid, 3-Pyridine carboxylic acid; 6-amino d-mannose; tetra decanoic acid; 1, 2-benzene dicarboxylic acid; butyl octyl ester; n-hexadecanoic acid; hexadecanoic acid ethyl ester; Phytol, 9, 12-octadecadienoic acid [Z, Z]; octadecanoic acid, squalene (Janakiraman *et al.*, 2012).

Biological Activities:

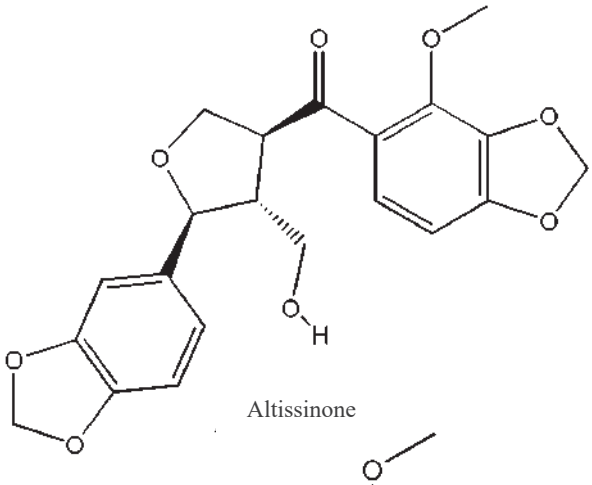
Antibacterial Activity: The methanolic extract of *V. altissima* leaves exhibits antibacterial properties against both Gram-positive and Gram-negative bacteria. It has shown significant activity against Gram-positive bacteria such as *Bacillus cereus*, *Bacillus subtilis*, *Bacillus pumilus*, *Micrococcus luteus*, and *Staphylococcus aureus*. However,



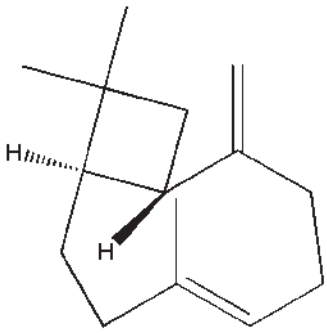
2'-O-p-hydroxybenzoyl-8-epiloganic acid



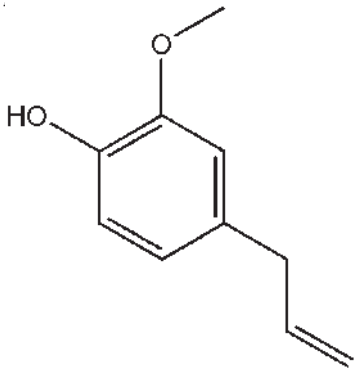
6-O-trans-feruloyl negundoside



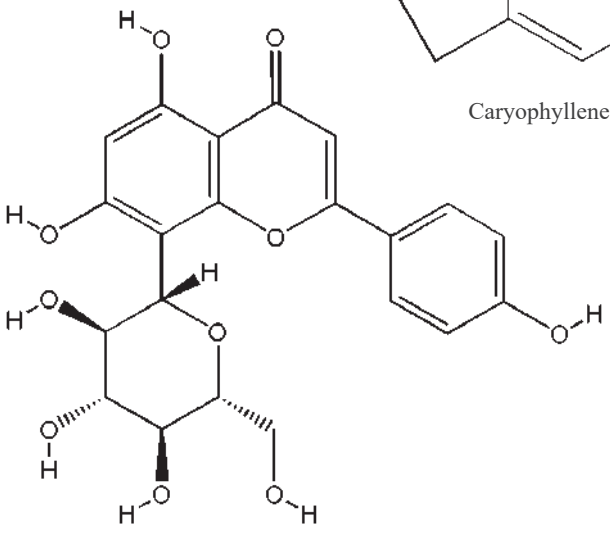
Altissinone



Caryophyllene



Eugenol



Vitexin

Structures of Important and Characteristic Chemical Constituents of *Vitex altissima*

the extract is less effective against Gram-negative bacteria, including *E. coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Proteus vulgaris*, *Salmonella typhimurium*, *Shigella flexneri*, and *Shigella sonnei* (Kannathasan et al., 2011). The aqueous ethanolic extract of *V. altissima* leaves has demonstrated potent antibacterial activity against *Klebsiella pneumoniae*, *Escherichia coli*, *Staphylococcus mutant*, *Serratia marcescens*, and *Vibrio cholerae*. Even at low concentrations, the hydro-alcoholic extract effectively inhibits *E. coli* and *Staphylococcus mutant* (Leela et al., 2015). The ethyl acetate extract of *V. altissima* has shown the highest activity against *Bacillus subtilis*

(Irulandi et al., 2017). Overall, the antimicrobial activity of *V. altissima* was evaluated against several bacteria, revealing a higher zone of inhibition for *Klebsiella pneumoniae* (1.25), *Escherichia coli* (1.0), *Staphylococcus mutant* (0.95), *Serratia marcescens* (0.7), and *Vibrio cholerae* (0.65). Moderate inhibition was observed for *Salmonella typhi* (0.6) and *Pseudomonas aeruginosa* (0.6), while low inhibition was noted for *Proteus mirabilis* (0.55) and *Bacillus cereus* (0.5) (Leela et al., 2015).

Antioxidant Activity: The methanolic extract of *V. altissima* leaves exhibits the highest antioxidant activity and reducing power, while the lowest activity is observed in hexane and cold extracts (Latha et al., 2007). Iridoid glucosides isolated from the ethyl acetate extracts of the leaves also demonstrate potent antioxidant activity (Sridhar et al., 2004). Among the different extracts, methanol and chloroform extracts show the most significant antioxidant activity (Sharma et al., 2015).

Anticancer Activity: Phytochemical analysis of *V. altissima* leaf extract identified 22 bioactive compounds with potential anticancer properties. These compounds were evaluated using bioinformatics tools, revealing a range of binding energies from -4.67 kcal/mol to -18.47 kcal/mol. The compound 3,7,11,15-Tetramethyl-2-hexadecen-1-ol showed maximum effectiveness against the BCL-2 protein, while 1,6,10-Dodecatriene, 7,11-dimethyl l-3-methylene-[Z] was most effective against HER2. These compounds, present in *V. altissima*, indicate potential use in cancer treatment without adverse side effects (Naganathan et al., 2016). Additionally, an eco-friendly synthesis of SnO2 nanoparticles using *V. altissima* extract demonstrated significant cytotoxic effects on the MCF-7 cancer cell line, further proving its anticancer potential (Bhavana et al., 2019).

Wound Healing Activity: The ethanol leaf extracts of *V. altissima* have shown significant wound healing properties, as evidenced by increased wound contraction, skin breaking strength, granulation tissue dry weight, hydroxyproline content, and reduced epithelialization period and breaking strength of granulation tissue (Manjunatha et al., 2007).

Anti-inflammatory and Analgesic Activity: The ethanol extract of *V. altissima* stem bark demonstrated significant dose-dependent anti-inflammatory and analgesic properties in vivo. When tested at 150 and 450 mg/kg body weight, it showed effectiveness in carrageenan-induced rat hind paw edema and acetic acid-induced vascular permeability in mice, comparable to the reference drug indomethacin (Sivaranjani et al., 2018). The ethyl acetate extract of *V. altissima* leaves also exhibited significant anti-inflammatory activity in rats using the paw edema model, attributed to the presence of non-polar compounds. Triterpene acids such as corosolic acid (80%), epicorosolic acid (79%), ursolic acid (70%), maslinic acid (72%), and euscaphic acid (55%) showed moderate 5-lipoxygenase enzyme inhibitory activity at a dose of 500 µM, compared to the control, nordihydroguaiaretic acid (70%, 100 µM) (Sridhar et al., 2005). Additionally, the crude methanolic extract at higher concentrations showed significant anti-inflammatory activity in the carrageenin-induced paw edema model in rats (Bose et al., 2014; Sunitha et al., 2020).

Renoprotective Activity: The methanolic extract of *V. altissima* bark was evaluated for its renoprotective effects against cisplatin-induced renal damage in Wistar rats. The extract was found to attenuate oxidative stress by enhancing endogenous antioxidant levels and reducing lipid peroxidation. A higher dose of the extract helped maintain the normal histopathological integrity of the kidneys (Vedula et al., 2022).

Scope for further R&D: *V. altissima*, a deciduous tree in the Lamiaceae family, is recognized for its traditional medicinal uses. To deepen our understanding of its therapeutic potential, further research is essential. Key areas of focus should include a comprehensive phytochemical analysis to identify and isolate novel bioactive compounds responsible for its medicinal effects. Investigating the specific mechanisms of action of *V. altissima* compounds in treating conditions such as inflammation, wounds, ulcers, allergies, and joint pain is crucial. Additionally, preclinical studies, including well-designed animal models, are needed to evaluate the safety and efficacy of both extracts and isolated compounds. This research will bridge the gap between traditional knowledge and modern science, advancing the therapeutic applications of *V. altissima*.

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Vitex negundo L.

Synonyms:
Agnus-castus negundo (L.) Carrière, *Vitex agnus-castus* var. *negundo* (L.) Kuntze, *Agnus-castus incisa* (Lam.) Carrière, *Vitex agnus-castus* var. *negundo* (L.) Kuntze, *Vitex agnus-astus* var. *negundoides* Kuntze, *Vitex arborea* Desf. *Vitex chinensis* Mill., *Vitex elmeri* Moldenke, *Vitex gracilis* Salisb., *Vitex incisa* Lam., *Vitex incisa* var. *heterophylla* Franch., *Vitex laciniata* Schauer, *Vitex leucoxylon* Blanco, *Vitex negundo* f. alba C.P'ei, *Vitex negundo f.albiflora* H. W. Jen & Y. J. Chang, *Vitex negundo* var. *heterophylla* (Franch.) Rehder, *Vitex negundo* var. *incisa* (Lam.) C.B.Clarke, *Vitex negundo* var. *macrophylla* Moldenke, *Vitex negundo* var. *negundo, Vitex sinuate* Medik., *Vitex spicata* Lour., *Vitex trifolia* var. *foliolis obtuse crenatis* Lam.

Local/Common/Popular Name(s):
Shivari, Nirgundi, Five-leaved chaste tree.

Vernacular Names:
Telugu: Vaavili; ***Tamil:*** Nirkundi, Vellai-nochi; ***Hindi:*** Shivari, Nirgundi; ***Malayalam:*** Vellanocchi, Indranee, Karunacci; ***Kannada:*** Nkkilu, Lakkigida, Nekka, Nakkigida; ***Punjab:*** Shwari; ***Assam:*** Aslok; ***Bengal:*** Nirgundi, Nishinda; ***English:*** Five leaved chaste trees; ***Gujarati:*** Nagod; ***Marathi:*** Nirgundi; ***Punjabi:*** Sambhalu, Banna; ***Sanskrit:*** Nirgundi.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Lamiales
Family	:	Lamiaceae
Genus	:	*Vitex*
Species	:	*Vitex negundo*

Botanical Description: *Vitex negundo* is a woody, aromatic, deciduous shrub or small tree, commonly known as the five-leafed chaste tree or monk's pepper. It typically grows between 2-5 meters in height, with slender, quadrangular branchlets. The leaves are palmately arranged with five lanceolate, acute leaflets, measuring 4-10 cm in length. The terminal leaflet has a longer petiole compared to the lateral ones. The undersides of the leaves are hairy, and both ends of the leaflets taper to a point. Flowers of *V. negundo* are bluish-purple, arranged in axillary or terminal panicles that can reach up to 30 cm in length. The fruit is a black, succulent drupe, around 5-6 mm in diameter, containing four seeds. In central India, the plant flowers from June to December, with fruiting occurring from September to February. The species also has a strong, deep root system that produces numerous suckers (Meena et al., 2011).

Distribution: *V. negundo* is widely distributed across India, Sri Lanka, Afghanistan, tropical Africa, Madagascar, China, and the Philippines (Kirtikar et al., 2008). In India, it occurs in Bengal, southern regions, and Burma (Nadkarni, 2002). It thrives in waste areas, near villages, riverbanks, moist regions, and deciduous forests (Sharma et al., 2005). The plant is found from coastal regions to the subtropical Western Himalayas, the Andaman Islands, and in drier zones, especially

in Karnataka and Tamil Nadu, where it grows both wild and cultivated. *Vitex* typically reaches heights of 3 to 9 feet but can grow up to 20 feet when cultivated. It prefers light, well-drained loamy soil and can withstand temperatures as low as 10°C. The plant is commonly planted as a hedge between fields and is not grazed by cattle. It ascends up to 1,500 meters in altitude across much of India.

Ethnobotanical Significance: *V. negundo* has been mentioned in ancient texts like the *Charaka Samhita*, Ayurveda, Unani, and traditional Chinese medicine. It is widely used for various medicinal and ritualistic purposes. Herbal shoes made from its wood are used to treat rheumatism, a practice seen in Chhattisgarh. The branches of *V. negundo* and *Diospyros melanoxylon* are believed to possess magical powers, used by Oroan tribes to ward off evil spirits and protect crops (Gupta, 1991). In historical warfare, soldiers wore *Cardiospermum halicacabum* creepers, while the defending army used *V. negundo* flowers (Swamy, 1973). The leaves are also used traditionally to repel insects; dry leaves are placed with garments to prevent insect damage, burned to keep mosquitoes away, and used to repel bedbugs (Ghosh, 2000; Pal & Jain, 1998). Various traditional uses include fumigating *V. negundo* leaves for repelling mosquitoes (Tarafdar, 1983), medicinal benefits, using leaf extracts as insect repellents in rice fields, and applying leaf extracts to treat crop pests in states like Himachal Pradesh, Tamil Nadu, and Gujarat (Lal & Verma, 2006; Tarafdar & Raichaudhuri, 1991; Arora et al.,2011). Additionally. fumigation with a mixture of nigundika, guggul (*Commiphora wightii*), and oil cake are used in the treatment of wind diseases and production of shoots (Sadhale, 1996) and in elephant diseases (Sadhale and Nene, 2004). The Oraon and Korwa tribes of Raigarh, Madhya Pradesh, use the leaf juice mixed with seeds of *Trachyspermum ammi* (ajwain) to treat stomach trouble in cattle and conjunctivitis (Maheswari, et al., 1991). The plant is used to treat various cattle diseases, including diarrhea and foot-and-mouth disease, and its extracts are used for postnatal care to reduce swelling of the uterus. The plant is effective in treating ailments like sciatica, muscle swelling, and respiratory disorders. The seeds and roots are used in traditional medicine to treat eye diseases, skin conditions, and digestive issues (Ambasta, 1986; Nadkarni, 2002). Additionally, *V. negundo* has applications in reproductive health and as a cooling remedy for pitta-related disorders like liver complaints and fever (Warrier et al., 1995). Traditional practices utilize a decoction of *V. negundo* and neem leaves to treat fever in cows. Ground *Vitex* leaves mixed with ingredients such as *Leucas aspera,* bottle gourd, mustard, and sesame oil have been used to cure various cattle diseases (Lal and Verma, 2006). In Telangana, farmers feed *Vitex* leaves with coconut and bananas to treat foot and mouth disease (Khan, 2006). In Gujarat, feeding *Vitex* leaves helps control diarrhea in animals (Bhimsen, 1995). The leaves also relieve swelling in livestock, with postnatal care benefits for animals (Pal and Jain, 1998). The leaves of *Vitex negundo* are traditionally used in combination with other ingredients to treat digestive diseases in horses (Ayangarya, 2006; Jadhav et al., 2005). Additionally, they serve as a refrigerant for cattle, providing relief in cases of heat stress (Ali, 1999), and are also employed in treating colic in buffaloes (Shah and Khan, 2006). Dried *V. negundo* leaves are burned to repel mosquitoes and insects around livestock. In regions such as Himachal Pradesh and Madhya Pradesh, *Vitex* branches are used to sweep paddy fields to protect crops from harmful insects (Tarafdar and Raichaudhuri, 1991). The leaf extract with buttermilk is used by the tribals for control of rice leaf folder, brinjal leaf beetle, tomato fruit borer, groundnut cutworm, and storage pests such as the rice weevil (Ahuja, *et al.,* 2000). Additionally, the plant leaves are used for the rejuvenation treatment (Kayakalpa) along with *Azadirachta indica, Ecliptaalba, Sphaeranthus indicus,* and *Carum copticum* (syn. *Trachyspermum ammi*) (Patkar, 2008). In traditional medicine, *Vitex* is used to treat sciatica, digestive problems, gonorrhea, and swelling of muscles. It is also beneficial for postnatal care as it helps the uterus return to its normal size and reduces swelling. The leaves are used to improve digestion, increase sexual power, and reduce common ailments such as cough, fever, and spleen inflammation (Balkishan, 2008). A decoction of the leaves with long pepper is also effective for catarrhal fever and headaches (Nadkarni, 2002). The seeds of *Vitex* are used to reduce swelling and treat spermatorrhea, particularly when mixed with dry ginger and milk (Kirtikar et al., 2008). Vitex seeds are used in regulating the menstrual cycle, treating eye, skin diseases and leprosy. The roots are considered a tonic, febrifugal,

expectorant, anodyne, have diuretic properties, and are used to treat dyspepsia, colic, rheumatism, and boils (Sensarma, 1998). The roots have tonic, febrifuge, and expectorant properties and are used to treat dyspepsia, colic, and rheumatism (Nadkarni, 1994). A tincture of the root bark is also used to treat irritability of the bladder and rheumatism (Ambasta, 1986). *Vitex negundo* holds significant value in traditional medicine for both human and veterinary care, offering remedies for a wide range of conditions.

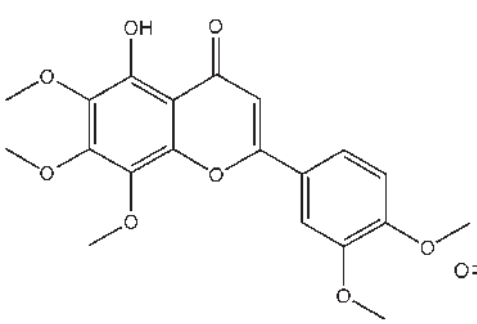
Phytochemistry:

Leaves: Luteolin-7-glucoside; casticin; iridoid glycoside; vitamin C; carotene; benzoic acid; β-sitosterol; C-glycoside (Chawla, et al., 1991; Leopold et al., 1998); 2-p-hydroxybenzoyl mussaenosidic acid; 6'-p-hydroxybenzoyl mussaenosidic acid (Dayrit et al., 1994; Basu et al.,1944; Kuo et al., 1989); negundoside ($C_{23}H_{28}O_{12}$); nishindaside ($C_{15}H_{24}O_9$); 5,3-dihydroxy-7,8,4-trimethoxy flavanone; 5,3-dihydroxy-6,7,4-trimethoxy flavanone; 5,3'-dihydroxy-6,7,4'-trimethoxy flavone; 3',4',5,5',6,7,8-heptamethoxyflavone; 3-O-desmethylartemetin; Vitedion A; 5-O-desmethylnobiletin, 4', 5, 7-trihydroxy-30 -O-β-D-glucuronic acid-600-methyl ester (Gautam et al., 2008; Sathiamoorthy, et al., 2007; Krishna et al., 2002).

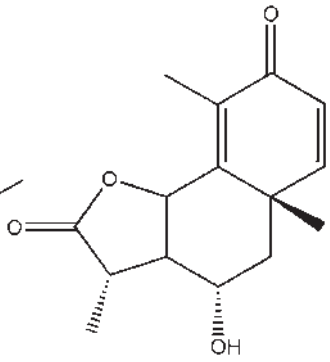
Roots: Furanoeremophilane (Haq et al., 2004).

Stem bark: Leucoanthocyanidins; leucoanthocyanidins-7-O-rhamno-glucoside; 6-C-glycosyl-5-O-rhamnopyranosyl trimethoxy wogonin; acerosin-5-glucoside monoacetate; 6β-glucopyranosyl-7-hydroxy-3',4',5',8-tetramethoxy flavone-5-O-α-L-rhamnopyranoside; 3',7-dihydroxy-4',6,8-trimethoxy flavone-5-O-(6''-O-acetyl-β-D-glucopyranoside); 3,3',4',6,7-pentamethoxyflavone-5-O-(4''-O-β-D-glucopyranosyl)-α-L-rhamnopyranoside; 4,5,7-trihydroxyflavone-8-(2''-caffeoyl-β D-glucopyranoside); 3,5,5,7-tetrahydroxy-4-methoxyflavone-3-O-(4''-O-β-galactopyranosyl) galactopyranoside (Gupta et al., 1973; Li et al.,1987).

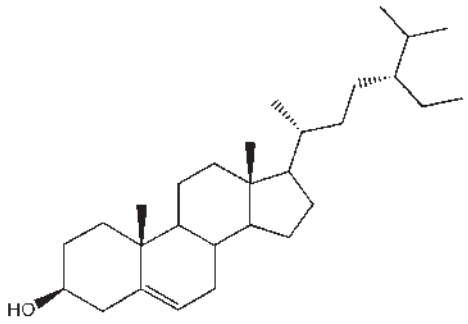
Seeds: 5-oxyisophthalic acid; vitex triterpene ($C_{30}H_{50}O_8$); 5β-hydro-8,11,13-abietatrien-6α-ol; lanostan-8,25-dien-3β-ol; 3β-acetoxyolean-12-en-27-oic acid; 2α,3α-dihydroxyoleana-5,12-dien-28-oic acid; 2β,3α-diacetoxyoleana-5,12-dien-28-oic acid; 2α,3β-diacetoxy-18-hydroxyoleana-5,12-dien-28-oic acid; artemetin; 6-hydroxy-4-(4-hydroxy-3-methoxyphenyl)-3-hydroxymethyl-7-methoxy-3,4-dihydro-2-naphthaldehyde (Chawla et al., 1992).



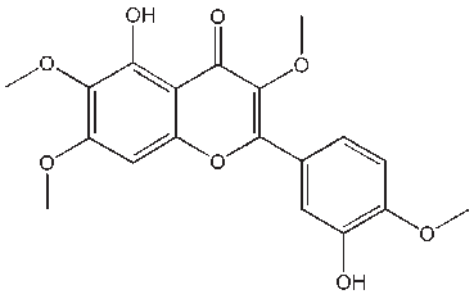
5-O-desmethyl nobiletin



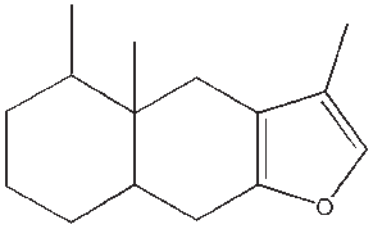
Artemisin



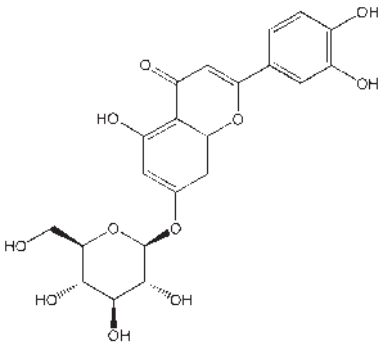
β-sitosterol



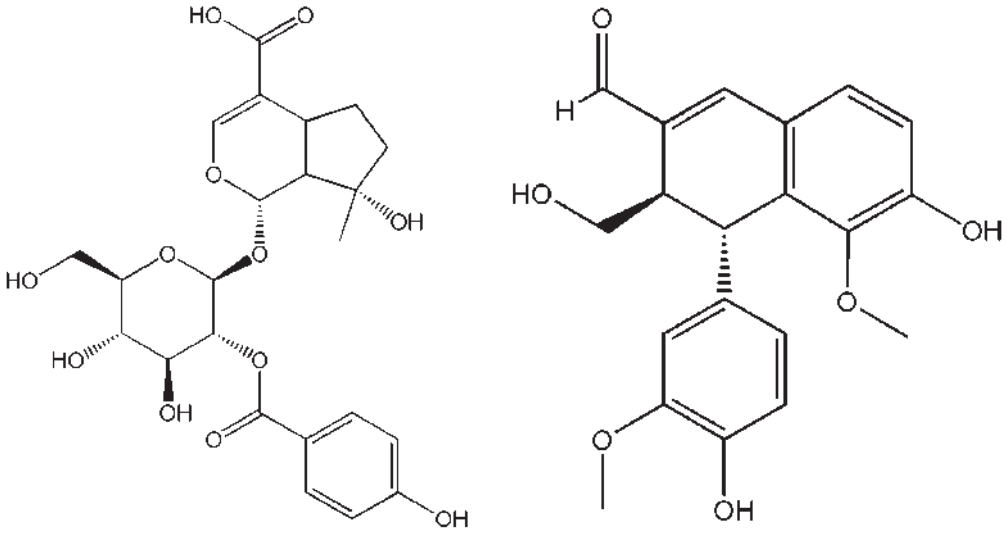
Casticin



Furanoeremophilane



Luteolin-7 -glucoside



Negundoside Vitedoin A

Structures of Important and Characteristic Chemical Constituents of *Vitex negundo*

Biological activities:

Anti-inflammatory and Analgesic Activity: The leaf extract of *V. negundo* has been shown to prevent carrageenan-induced and formaldehyde-induced rat paw edema, confirming its anti-inflammatory potential. Studies report that *V. negundo* extracts exhibit significant anti-inflammatory effects in both acute and sub-acute inflammation. The plant's anti-inflammatory activity has been extensively studied by several researchers (Sharma and Singh, 1980).

Antioxidant activity: *V. negundo* contains Vitedoin A, a potent antioxidant (Ono et al., 2004). Its extracts reduce levels of superoxide dismutase, catalase, and glutathione peroxidase in Freund's adjuvant-induced arthritic rats (Devi, 2007). The plant's antioxidant properties, attributed to flavanones, vitamin C, and carotene, help combat oxidative stress by reducing lipid peroxidation. These effects are mainly due to phenolic compounds such as flavonoids, phenolic acids, tannins, and phenolic diterpenes (Ambasta, 1986). Studies show that *V. negundo* exhibits strong scavenging activity against ABTS radical cations in a dose-dependent manner (Rao et al., 1977), as well as DPPH radicals, likely due to its polyphenols and flavonols (Rabeta and Nabil, 2013).

Anti-cancer Activity: Studies have shown that *V. negundo* extracts do not affect stomach tissue, even at toxic doses, though dose-dependent changes were observed in the heart, liver, and lung tissues (Tandon and Gupta, 2004). The leaf extracts demonstrated cytotoxic effects on COLO-320 tumor cells (Smit et al., 1995). Additionally, chloroform extracts from the leaves were toxic to human cancer cell line panels (Diaz et al., 2003). Compounds such as vitexicarpin, artemetin, and penduletin isolated from *V. negundo* were tested against human HepG2 and MCF-7 cell lines, showing increased reactive oxygen species production, induction of apoptosis, and activation of caspase3/caspase8 pathways (Vo et al., 2022).

Drug potentiating ability: *V. negundo* extracts have been reported to enhance the effects of various drugs. These include anti-inflammatory agents like ibuprofen and phenylbutazone (Tandon and Gupta, 2006), analgesics such as meperidine, aspirin, morphine, and pethidine, as well as sedative-hypnotics like pentobarbitone and diazepam (Gupta et al., 1997), and chlorpromazine (Gupta et al., 1999). The extracts also potentiate anti-convulsive agents such as diphenylhydantoin and valproic acid.

Anticonvulsant Activity: The petroleum ether and butanol leaf extracts of *V. negundo* have shown protective effects against electroshock seizures, while the root extract demonstrated minimal activity. The petroleum ether extract of the root was effective only against leptazole-induced convulsions, whereas

the methanolic leaf extract provided significant protection against both strychnine and leptazole-induced convulsions (Tandon and Gupta, 2006). Additionally, the ethanolic leaf extract exhibited anticonvulsant properties and potentiated the effects of 10 standard anticonvulsants, potentially reducing their dosage and associated side effects (Mahalakshmi et al., 2010).

Hepatoprotective Activity: Negundoside and Agundoside from *V. negundo* have demonstrated hepatoprotective effects. The plant extract reduces serum bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), and total protein (TP) levels in liver damage cases. Leaf extracts were effective against liver damage induced by d-galactosamine, tubercular drugs, and carbon tetrachloride (Tandon et al., 2008). Additionally, the ethanolic leaf extract showed hepatoprotective activity against thioacetamide-induced liver injury in Sprague Dawley rats, restoring abnormal biochemical parameters to near-normal levels, similar to the effects of the standard drug, Silymarin. Histopathological analysis supported these findings (Kadir et al., 2013).

Anti-filarial Activity: The ethyl acetate extract of *V. negundo* leaves exhibited dose-dependent anti-filarial activity against the *Setaria cervi* parasite. The inhibitory concentration was determined to be 0.16 mg/mL, as shown through motility inhibition and MTT reduction assays (Sahare, et al., 2008; Sahare and Singh, 2013).

Antibacterial Activity: The ethanol extract of *V. negundo* leaves demonstrated significant antibacterial activity against *Escherichia coli* (ATCC 25922), *Staphylococcus aureus* (ATCC 25923), and *Klebsiella pneumoniae* (ATCC 27736) using the well diffusion method (Deogade et al., 2016; Kumruzzaman et al., 2013). The methanol extract exhibited strong antibacterial effects, both in vitro and in vivo, against *Vibrio cholerae*, *Vibrio parahaemolyticus*, *Vibrio mimicus*, *Escherichia coli*, *Shigella* spp., and *Aeromonas* spp., as evaluated through disc diffusion, viable bacterial cell count, and minimum inhibitory and bactericidal concentrations (Kamruzzaman et al., 2013).

Anti-eosinophilic Activity: An aqueous subfraction of *V. negundo* leaves was shown to reduce bronchial hyperresponsiveness and serum bicarbonate levels in egg-albumin-induced asthma in guinea pigs, indicating anti-eosinophilic activity (Patel and Deshpande, 2013).

Other Activities: *V. negundo* exhibits various biological activities beyond its primary uses. The aqueous extract of the plant is known for its laxative effect, while its leaf extract has shown potential hypoglycemic activity by inhibiting alpha-amylase. Its CNS depressant properties have been demonstrated, as it enhances sleeping time when used in conjunction with pentobarbitone sodium, diazepam, and chlorpromazine in mice (Gupta et al., 1997). Methanolic root extracts have been effective in countering the lethal effects of venom from *Vipera russellii* and *Naja kaouthia* (Alam et al., 2003). Additionally, aqueous leaf extracts showed toxicity towards lepidopteran pests such as *Spodoptera litura* and *Helicoverpa armigera*. The flavonoid-rich seed fraction disrupted the later stages of spermatogenesis in dogs and affected male reproductive function in rats, suggesting anti-androgenic properties (Bhargava, 1989). However, these findings contrast with the traditional use of *V. negundo* as an aphrodisiac (Hegde and Hebbar, 2009). Furthermore, ethanolic extracts of the plant demonstrated estrogen-like activity, making it a candidate for hormone replacement therapy.

Toxicology: An acute toxicity study of ethanolic leaf extract in albino rats found it to be practically non-toxic, with an LD50 of 7.5 g/kg body weight. No histomorphological changes were noted in the stomach, though dose-dependent changes were observed in the heart, liver, and lung (Tandon and Gupta, 2004).

Commercial Products: The leaf extract of *V. negundo* is an ingredient in skincare products like pimple creams.

Patent:

- Dermatological or cosmetic compositions containing a polyphenol-enriched extract of *Vitex negundo*, Patent No: US20190008757A1
- Analytical method for identifying *Vitex negundo* honey and syrup adulterated Vitex negundo honey, Patent No: CN107192770B
- Compound *Vitex negundo* capsule, preparation method and uses thereof, Patent No: CN100394949C

- Inhibiting melanogenesis with essential oils extracted from *Vitex negundo* linn leaves, Patent No: TWI465259B
- Production method *for Vitex negundo* bean curd products, Patent No: CN101057646A
- A kind of production method of *Vitex negundo* var cannabifolia coltsfoot flower health tea, Patent No: CN109007154A
- *Vitex negundo* leaf tea wine brewing method, Patent No: CN104987981A
- Application of *Vitex negundo* extract in preparation of medicine for preventing or treating necrotic enteritis, Patent No: CN114984111A
- Preparation method of *Vitex negundo* leaf caffeine, Patent No: CN104381548A
- Plant enzyme beverage containing garden *Vitex negundo*, Patent No: CN113115877A
- Application of *Vitex negundo* extract in preparation of animal growth promoting feed, Patent No: CN115486493A
- *Vitex negundo* soup fumigation lotion and preparation method thereof, Patent No: CN114533829A
- *Vitex negundo* repair liquid and preparation method and application thereof, Patent No: CN111631990A
- Processing method of *Vitex negundo* leaf composite tea vinegar, Patent No: CN105969632A
- Method for extracting small-molecule pectin from aqueous extract of *Vitex negundo* Linn leaves, Patent No: CN113698508A
- Centrifugal separation type *Vitex negundo* leaf purification device and process, Patent No: CN115444136A
- Plant enzyme beverage containing garden *Vitex negundo*, Patent No: CN113016964A
- *Vitex negundo* callus induction method, Patent No: CN112741001B
- *Vitex negundo* linn leaf extract and preparation method as well as application thereof, Patent No: CN104586700A
- Preparation method of *Vitex negundo* seed enzyme used as chicken drinking water, Patent No: CN110800879A
- Method for preparing emerald bean jelly from dry powder of *Vitex negundo* leaves, Patent No: CN112841614A
- Twig propagation method of *Vitex negundo*, Patent No: CN110558067A
- *Vitex negundo* young stem callus induction device, Patent No: CN112741000B
- Seed collecting and seedling culturing method of *Vitex negundo* L., Patent No: CN105493847A
- *Vitex negundo* young stem callus induction device, Patent No: CN112741000B
- Seed collecting and seedling culturing method of *Vitex negundo* L., Patent No: CN105493847A
- Preparation method of *Vitex negundo* linn volatile oil, Patent No: CN103571613A
- Storage device for *Vitex negundo* medicinal material, Patent No: CN215347735U
- Method for preparing *Vitex negundo* leaf extract, Patent No: CN111195302A
- Method for utilizing *Vitex negundo* var ineica scrap to culture pholiotaadiposa, Patent No: CN104478547A
- *Vitex negundo* softening treatment liquid, Patent No: CN104960054A
- Jingtiao (Vitex negundo L. Var. heterophylla (Franch) Rehd) leaf tea beverage and its production process, Patent No: CN1196415C
- Insecticidal composition containing natural celastrus angulatus and natural *Vitex negundo* and application thereof, Patent No: CN103315006B
- Health-care mattress with *Vitex negundo* seed, Patent No: CN2316943Y
- Process of making sweetened lagundi (*Vitex negundo*)- calamansi juice, patent no: ph22020000155u1
- Process of making lagundi (*Vitex negundo*) ointment, patent no: ph22020000151u1
- Health-care sole with *Vitex negundo* seed, Patent No: CN2316947Y
- Efficient *Vitex negundo* seed treatment agent, Patent No: CN104938532A
- *Vitex negundo* plant named 'Little Madame', Patent No: USPP27192P3
- Process of making lagundi (*Vitex negundo*) tea, patent no: ph22020000146u1

- *Vitex negundo* particle and detection method and application of fingerprint thereof, Patent No: CN116298001A
- Fly fumigating killing incense containing *Vitex negundo* ingredients and production method thereof, Patent No: CN105767017A
- Rapid propagation method for test-tube plantlets of negundo chaste tree, Patent No: CN112493137B
- Rooting powder containing garden negundo chaste tree, Patent No: CN112741118A
- Vitex mosquito-repellent incense, Patent No: CN104472593A
- Drop pills of negundo chaste tree and preparation method thereof, Patent No: CN100542569C
- *Vitex negundo* L. seed processing method, Patent No: CN104956808A
- Special matrix for potted gardening negundo chaste tree, Patent No: CN112673927A
- Preparation method and application of negundo chaste tree fruit total lignans, Patent No: CN105796764B
- Dried-fruit *Vitex negundo* honey capable of invigorating stomach and preparation method thereof, Patent No: CN104304882A
- Method for keeping fruits and vegetables fresh by using extract of folium viticis negundo, Patent No: CN114365761A
- Cuttage method for rootstocks of garden negundo chaste tree, Patent No: CN110612822A
- Lagundi (*Vitex negundo*), Tanglad (*Cymbopogon citrates*) And Ginger Herbal Syrup, Patent No: Ph22013000337u1
- A Composition Of Herbal Candy From Lagundi (*Vitex negundo*) Extract, Patent No: PH22016000996Y1
- A solid beverage containing fructus *Vitex negundo*, Patent No: CN113016972A
- A Process Of Producing Herbal Candy From Lagundi (*Vitex negundo*) Extract, Patent No: PH22016000997Y1
- Anaerobic power generation and gas supply station with *Vitex negundo* woven and film lined structure, Patent No: CN105385573A
- Anti-Inflammatory Liniment With Lagundi (*Vitex negundo*) Extract As Active Ingredient, Patent No: PH22010000626Y1
- Seed collecting and seedling culturing method of *Vitex negundo* L., Patent No: CN105493847A
- Dermatological Or Cosmetic Compositions Containing A Polyphenol-Enriched Extract Of *Vitex negundo*, Patent No: Wo2017129779a1
- *Vitex negundo* root extract and preparation method and application thereof, Patent No: CN107693423A
- *Vitex negundo* test-tube plantlet rapid propagation method, Patent No: CN112493137A
- Method for propagating tender branches of *Vitex negundo*, Patent No: CN110558067A
- Vitex Plant Named 'WHIT L', Patent No: US2016219775P1
- Horticultural *Vitex negundo* bactericide, Patent No: CN112753718A
- Medicinal Uses Of *Vitex negundo* Linn, Patent No: 761/Mum/2003
- Novel Compound Isolated From *Vitex negundo* Useful For The Treatment Of Rheumatoid Arthritis, Patent No: 620/Mum/2009
- A composition comprising of glycyrrhiza glabra extract, and *Vitex negundo* extract and uses thereof, patent no: 1475/che/2015
- Compounds from *vitex nigundo* for enhancing antibiotic activity and overcoming drug resistance, patent no: 1464/del/2015
- "Evaluation of *Vitex negundo* and *Tecoma stans* plant for behavioral and neuropharmacological activity and process of extraction thereof", Patent No: 202121000298
- Nanoparticle-based antiseptic cream (ocivitex) from *Vitex negundo* and *Ocimum sanctum,* patent no: 202241067515

Scope of further R&D: *Vitex negundo*, a deciduous shrub or small tree from the Verbenaceae family, is widely recognized for its medicinal properties and traditional use across cultures. Future research should focus on the detailed study of its chemical compounds and their potential therapeutic applications. Specific areas of interest include its effects on chronic diseases, neurological disorders,

and metabolic syndromes, with an emphasis on understanding the underlying mechanisms. Well-designed clinical trials are essential to evaluate the safety and efficacy of *V. negundo* extracts in humans. These studies will not only validate its traditional uses but may also lead to the development of new pharmaceutical treatments.

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Woodfordia fruticosa
(L.) Kurz

Synonyms:
Grislea punctata Buch.-Ham. ex Sm., *Grislea tomentosa* Roxb., *Lythrum fruticosum* L., *Lythrum hunteri* DC.

Local/Common/Popular Name(s):
Fire- Flame Bush.

Vernacular Names:
India: ***Hindi:*** Ban-mahendi, Dhai, Dhatuki, Dhaura; ***Sanskrit:*** Agnijwala Kannada Bela, Taamra pushpin, Daathakee Kusumka; ***Malayalam:*** Tamarpushi, Tatire, Tatiripushpi; ***Tamil:*** Dhathari-jagri, Dhattari; ***Telugu:*** Dhaarhupushpika, Dhaathaki; ***Tibetan:*** Dha-ta-ke, Me-togdatakki; ***Urdu:*** Guldhawa; ***Gujarati:*** Dhaavadi Bengali Dhai, Dawai, Dhaiphul; ***Marathi:*** Dhalas, Dhayati, Dhadva; ***Punjabi:*** Dhavi Farsi Dhaava; ***Oriya:*** Dhobo, Jaliko, Harwari; ***Bihar:*** Dhai, Dawai; ***Jammu and Kashmir:*** Thwai Nepali Dhangera.

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Myrtales
Family	:	Lythraceae
Genus	:	*Woodfordia*
Species	:	*Woodfordia fruticosa*

Botanical Description: *Woodfordia fruticosa* is a fully grown leafy shrub, reaching up to approximately 3.5 meters in height, characterized by broad, spreading branches and fluted stems. The young shoots are cylindrical, covered in fine white pubescence, while the bark is smooth and cinnamon-brown. The leaves are arranged oppositely or sub-oppositely. The plant's bright red flowers are numerous, densely clustered in axillary paniculate-cymose formations on short glandular pubescent pedicels. The calyx is long and striated, featuring glandular dots, with a small campanulate base and a slightly curved long bright red tube that narrows above the included capsule. The petals, longer than the calyx teeth, are narrowly linear and taper to a fine point at the apex. The fruits are small ellipsoid, membranous capsules that dehisce irregularly, breaking the calyx near the base. Seeds are minute, brown, shiny, and smooth-angular with an obovate shape (Das et al., 2007). During the flowering stage, *W. fruticosa* takes on a twiggy, formless appearance as the leaves shed, and the plant becomes enveloped in red due to its small, tube-like flowers, which can grow individually or in clusters along branches and side twigs. Each flower features a narrow tube with a curved greenish base, supported by a short stalk. The tube swells slightly before dividing into narrow, pointed lobes, revealing a group of long stamens inside. The entire flower, including the stamens, is less than 2 cm in length. The fruit is surrounded by withering sepals and develops into an oblong capsule. The leaves, dull and harsh with a dark green upper surface and a paler underside, grow in whorls of three or opposite arrangements. Occasionally, the leaves feature small black glands on the underside (Singh et al., 2014).

Distribution: *W. fruticosa* is widely distributed across Southeast and Far East Asia, including countries like Sri Lanka, China, Malaysia, Indonesia, Japan, and Pakistan, as well as in Tropical Africa. In India, the plant is commonly found throughout the country, ascending to altitudes of around 1500 meters. Its presence is notable in northeastern regions, such as Tenga and Salari to Nafra in the East Kameng district of Arunachal Pradesh,

Kawlkuth areas in Mizoram, and the northern parts of West Bengal near South Sikkim. Additionally, it occurs in the Gangetic plains (Shanker & Rawat, 2013; Kirtikar & Basu, 1935; Syed et al., 2013).

Ethnobotanical Significance: *W. fruticosa*, commonly known as Dhatki or Fire Flame Bush, holds significant importance in traditional Ayurvedic medicine (Saoji et al., 1972; Chopra et al., 1956: Atal et al., 1982; Kumar et al., 2016). All parts of the plant are therapeutically valuable, but the flowers are especially prized in herbal medicine due to their high demand in both local and international markets. According to Ayurvedic texts, Dhatki has a variety of medicinal properties, including being pungent, acrid, toxic, alexiteric, and anthelmintic. It serves as a uterine sedative and is effective in treating ailments such as thirst, dysentery, leprosy, erysipelas, blood diseases, leucorrhoea, and toothache. It is also used to suppress Kapha and Pitta doshas. Dhatkipushpa, the flower, is frequently employed in treating dysentery, irritable bowel syndrome, rheumatism, dysuria, and hematuria due to its astringent properties **(**Dey, 1984; Das et al., 2007; Uday et al., 2014).

Phytochemistry:

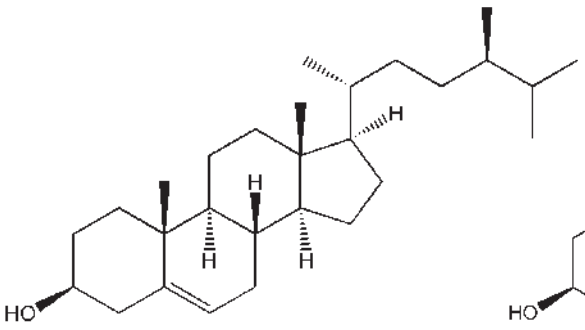
Stem: Octacosanol; β-Sitosterol; Norbergenin; Gallic acid; Bergenin; Norbergenin (Desai et al., 1971; Kalidhar et al., 1981; Kadota et al., 1990).

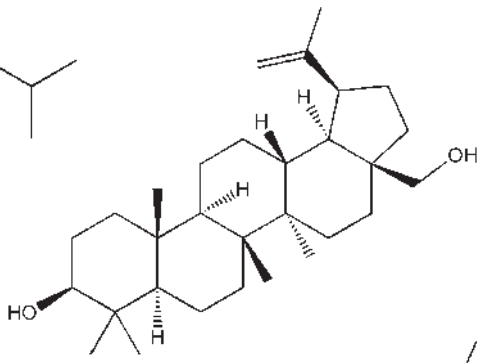
Flowers: Octacosanol; β-Sitosterol; Chrysophanol-8-O-glucopyranoside; Hecogenin; Meso-inositol; Ellagic acid; Chrysophanol-8-O-D-glucopyranoside; 3-Rhamnoside; 3-β-L-Arabinoside; 3-O-β-D-Galactoside; Naringenin 7-Glucoside; Kaempferol 3-O-glucoside; Pelargonidin 3, 5-Diglucoside; 1, 2, 3, 6-tetra-O-galloyl-β-D-Glucose; 1, 2, 4, 6-tetra-O-galloyl β-D-glucose; 1, 2, 3, 4, 5-Penta-O-galloyl-β-D-glucose; Tellimagrandin; Gemin D; Heterophyllin A; Oenothein B (Nair et al., 1976; Chauhan et al., 1979a; Chauhan et al., 1979b**;** Yoshida et al., 1989a; Yoshida et al., 1990).

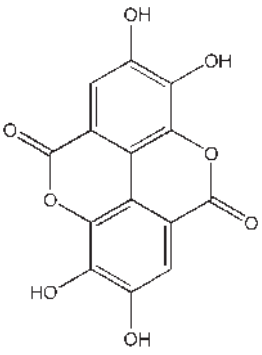
Leaves: β-Sitosterol; Lupeol; Betulin; Betulinic acid; Oleanolic acid; Ursolic acid; Ellagic acid; Gallic acid; Lawsone; 3-β-L-Arabinoside; 3-O-α-L-Arabinopyranoside; 3-O-β-D-Xylopyranoside; 3-O-(6''–galloyl)-β-D-glucopyranoside; 3-O-(6''-galloyl)-β-D-galactopyranoside; 3-O-β-D-Galactoside; 3-O-α-L-Arabinopyranoside; 3-O-(6''-galloyl)-β-D-galactopyranoside; Woodfordins A-C; Woodfordin D; Oenothein A; Isoschimawalin A; Woodfordins E-I; Woodfructicosin (Nair et al., 1976; Kalidhar et al., 1981; Dan and Dan, 1984; Kadota et al., 1990).

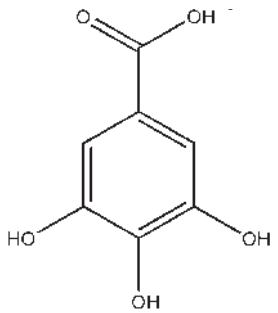
Biological Activities:

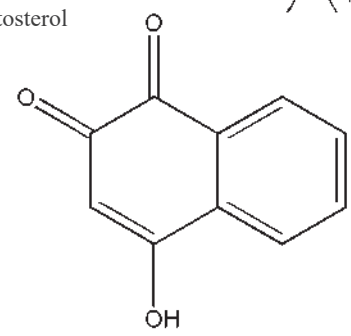
Anti-tumor Activity: Woodfordin C, a macrocyclic dimeric hydrolyzable tannin isolated from the dried flowers of *W. fruticosa*, has demonstrated significant inhibition of DNA topoisomerase II *in vitro*, as well

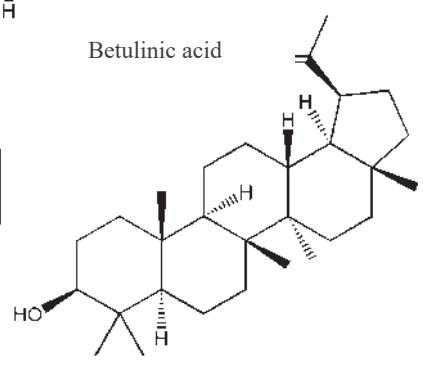

β-sitosterol

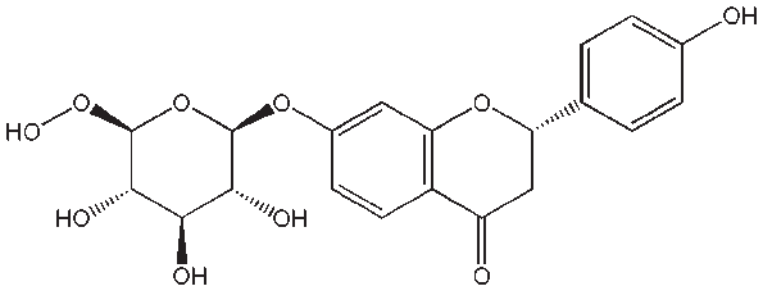

Betulinic acid


Ellagic acid

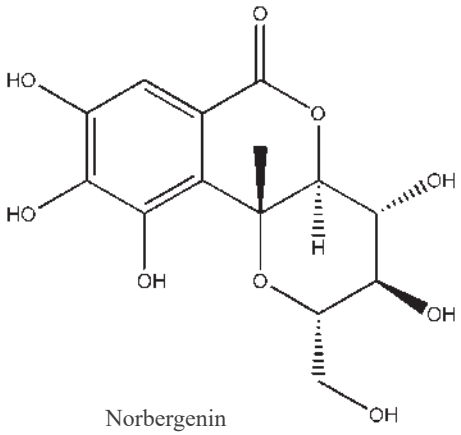

Gallic acid


Lawsone

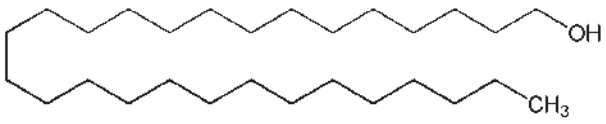

Lupeol



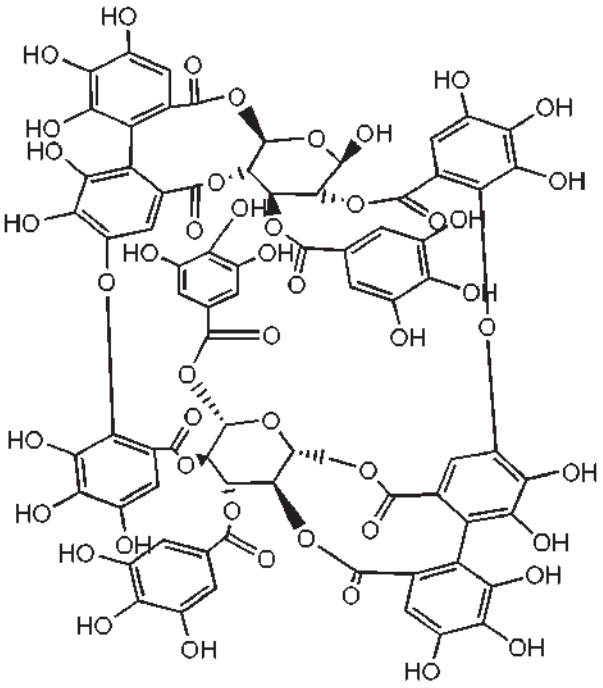
Naringenin 7- glucoside



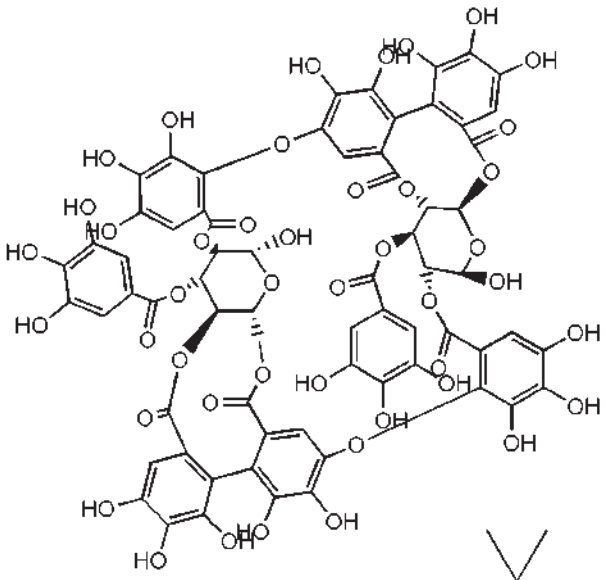
Norbergenin



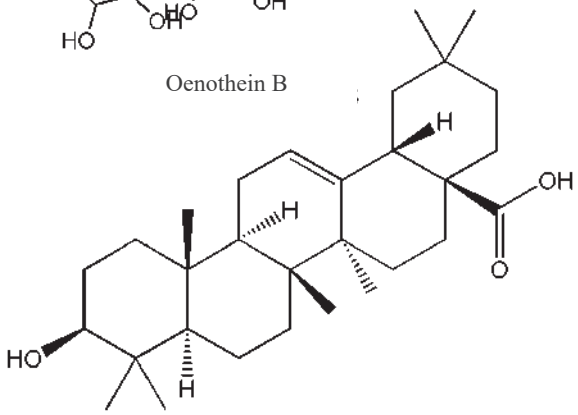
Octacosanol



Woodfordin C



Oenothein B



Oleanolic acid

Structures of Important and Characteristic Chemical Constituents of *Woodfordia fruticosa*

as anti-tumor activity *in vivo* (Yoshida et al., 1990). Additionally, Oenothein B, another key constituent of *W. fruticosa* flowers, has been shown to inhibit both 5-alpha-reductase and aromatase, enzymes linked to tumor growth. Based on this evidence, *W. fruticosa* is suggested to possess anti-tumor properties (Lesuisse et al., 1996).

Anti-asthmatic and Anti-inflammatory Activity: The flower extract of *W. fruticosa* has shown anti-asthmatic effects through broncho-protection, bronchorelaxation, anti-inflammatory, antioxidant, and mast cell stabilization properties. These effects are attributed to the presence of polyphenols and saponins in the flower extracts (Hiralal et al.,

2014). Additionally, in a separate study, various leaf extracts of *W. fruticosa* were evaluated for in vitro anti-inflammatory activity using the egg protein denaturation method, demonstrating significant anti-inflammatory potential (Tiwari et al., 2021).

Anti-microbial Activity: The ethanolic extract of *W. fruticosa* flowers demonstrated significant antimicrobial activity against *Staphylococcus aureus* (MTCC 3160), *Klebsiella pneumoniae* (MTCC 3384), *Pseudomonas aeruginosa* (MTCC 2295), *Salmonella typhimurium* (MTCC 1254), and *Candida albicans* (MTCC 183). Streptomycin and amphotericin were used as reference antibiotics (Najda et al., 2021). Additionally, antimicrobial assays using agar-well diffusion revealed that flower samples of *W. fruticosa* exhibited stronger antimicrobial activity than leaf samples when tested against *Staphylococcus aureus*, *Micromonospora* sp., *Staphylococcus epidermis*, *Zymomonas mobilis*, *Alternaria solani*, and *Fusarium culmorum* (Grover et al., 2014).

Anti-psoriatic Activity: The ethanolic extract of *W. fruticosa* flowers was evaluated for anti-psoriatic activity using complete Freund's adjuvant and formaldehyde-induced psoriasis models in Swiss albino mice. The study revealed that ointments containing 0.05% and 0.1% (w/w) of the extract exhibited anti-psoriatic potential in a dose-dependent manner (Srivastava et al., 2016).

Hypoglycemic Activity: The flower extract of *W. fruticosa* was orally administered to alloxan-induced diabetic mice to evaluate its hypoglycemic effects. The results indicated that the extract exhibited dose-dependent hypoglycemic activity and showed synergistic effects when combined with glyburide (Bhatia & Khera, 2013).

Anti-diabetic Activity: The aqueous extract of *W. fruticosa* leaves and stem bark was investigated in both normal and alloxan-induced diabetic rats. It effectively reduced elevated blood glucose levels and increased body weight in diabetic rats. The antidiabetic activity was attributed to the presence of saponins and flavonoids, which may enhance insulin sensitivity or stimulate insulin secretion (Beck & Namdeo, 2015). Additionally, the methanolic flower extract of *W. fruticosa* demonstrated significant antidiabetic activity by promoting beta-cell regeneration in alloxan-treated diabetic rats (Rawal & Gupta, 2017).

Antioxidant Activity: The antioxidant activity of *W. fruticosa* flowers was evaluated in albino rat models where lipid peroxidation was induced by carbon tetrachloride in male Sprague-Dawley rats. After the experimental period, the levels of lipid peroxidation products and the antioxidant status of the liver and kidneys were assessed. The administration of the flower extract, along with carbon tetrachloride, restored the antioxidant activities of superoxide dismutase, catalase, glutathione transferase, and glutathione peroxidase, which were decreased in the carbon tetrachloride-treated rats (Rajesh & Latha, 2013). Additionally, the flower and leaf extracts of *W. fruticosa* were tested for antioxidant activity using the DPPH scavenging assay and reducing power test. The flower parts exhibited superior antioxidant activity compared to the leaf samples (Grover et al., 2014).

Nootropic Activity: The nootropic potential of *W. fruticosa* flowers was assessed in a scopolamine-induced mouse model of Alzheimer's disease. The ethanolic extract demonstrated significant improvements in learning and memory, indicating its efficacy as a nootropic agent. This activity is attributed to the presence of bioactive phytoconstituents such as flavonoids and glycosides (Sareetha et al., 2021).

Wound Healing Activity: The wound healing effects of *W. fruticosa* flowers were investigated using methanolic and aqueous extracts incorporated into an ointment base in rat models. Both extracts exhibited substantial wound-healing activity, likely due to the presence of tannins, which are known to promote tissue repair and regeneration (Sonawane et al., 2020).

Toxicity: An acute oral toxicity study of *W. fruticosa* stem extract in Albino Wistar rats revealed no mortality or adverse effects, indicating that the extract is safe for consumption within the tested dosage range.

Commercial Products: The flower extract of *W. fruticosa* is utilized in various skincare products. It is a key ingredient in hand creams, night creams, and facial sheet masks, valued for its therapeutic properties and benefits for skin health (Search Results - *Woodfordia fruticosa*, n.d.).

Patent:

- Anti peptic ulcer activity of an extract of a plant flower *W. fruticosa*, Patent No: US20060040005A1
- Rapid propagation method for *W. fruticosa* tissue culture, Patent No: CN104285800A
- *W. fruticosa* (L.) Kurz cuttage seedling cultivating method, Patent No: CN106106098A
- Applications of different "yeasts" isolated from flowers of *W. fruticosa* (Linn.) In the process of fermentation of asava and arishta, Patent No: 150/mum/2012
- *In vivo* anti-fungal activity, spectrophotometric analysis, and molecular characterization of *W. fruticosa* leaf against candida isolates in patients with uncontrolled diabetes mellitus, Patent No: 202241000299

Scope of Further R&D: The current knowledge of *W. fruticosa* is fragmented, with insufficient systematic surveys of its population and challenges in seed germination due to limited viability. Addressing these issues through exploration of macro and micropropagation techniques is essential for conservation efforts. The flower of *W. fruticosa* is crucial in Ayurvedic formulations, yet detailed analyses of its medicinal properties and potential pharmaceutical applications are limited. Additionally, its vibrant orange/red flowers are utilized in dyeing fabrics, presenting opportunities for the pharmaceutical, cosmetics, and textile industries. Despite this, there is a lack of comprehensive information on its chemical constituents. Conducting thorough extraction and LC-MS/MS profiling is necessary to identify key marker compounds and establish a chemical fingerprint for the species. Research into the use of *W. fruticosa* flower dye in commercial products could reveal significant industrial applications. Overall, these insights underscore the need for further studies to explore and harness the full potential of *W. fruticosa*, particularly regarding its bioactive compounds and their applications.

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Wrightia tinctoria
(Roxb.) R.Br.

Synonyms:
Nerium tinctorium Roxb, *Wrightia laciniata* A. DC. *Wrightia timorensis* Miq, and *Wrightia tinctoria* subsp.

Local/Common/Popular Name(s):
Sweet Indrajao, Pala indigo plant and Dyers's oleander.

Vernacular Names:
Hindi: Dhudi, Hat, Kura, Kurchi, Kureya, Karva-indarjau; ***English:*** Ivory tree, Easter tree, Pala indigo, Sweet Indrajao; ***Marathi:*** Kala kuda; ***Bengali:*** Kurchitita-indarjau, Dhudi; ***Tamil:*** Vepali

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Gentianales
Family	:	Apocynaceae
Genus	:	*Wrightia*
Species	:	*Wrightia tinctoria*

Botanical Description: *Wrightia tinctoria* is a small to medium-sized deciduous tree, growing up to 18 m in height and 20 cm in diameter, with characteristic green lines along its stem and a milky-white resin. The bark is smooth, corky, and pale grey. Leaves are simple, opposite, and decussate, measuring up to 10 cm in length and 5 cm in width. The young leaves exhibit a bluish hue with crimson nerves. The flowers are white, fragrant, and measure 1-5 cm in length, arranged in lax dichasia cymes about 5 cm long. The fruit is a slender green follicle, up to 50 cm in length and 0.5 cm in diameter, found in pendulous pairs, coherent only at the tip. Seeds are linear with pointed ends, light yellowish-grey, measuring 1.2-1.8 mm in length, and are capped with tufts of white silky hairs. The tree sheds its leaves in winter, with new foliage emerging in spring. Flowering occurs from April to June, with peak fruiting in August (Brown, 1810).

Distribution: *W. tinctoria* is found across Asia, Africa, and Australia, and is endemic to Australia, India, Myanmar, Nepal, and Vietnam. In India, its distribution ranges from Rajasthan to Madhya Pradesh and across Peninsular India, ascending to an altitude of 1200 meters in the hills (Brown, 1810).

Ethnobotanical Significance: In Karnataka and Tamil Nadu, *W. tinctoria* is commonly known as the "jaundice curative tree" due to the effectiveness of its young leaf juice in treating jaundice. The fresh leaves are pungent and, when crushed, can be placed in a decayed tooth cavity to alleviate pain. Leaf juice is also used as a remedy for snake bites and is valued for its febrifuge, stomachic, and tonic properties (Patil et al., 2013). In Siddha medicine, the plant is frequently used to treat psoriasis and other skin conditions. Leaves are soaked in coconut oil and exposed to sunlight for a day before application for psoriasis treatment (Thas, 2008). The oil made from fresh leaves in combination with coconut oil exhibits analgesic, anti-inflammatory, and antipyretic properties, which contribute to its effectiveness in treating psoriasis (Krishnamurthi et al., 1981).

Phytochemistry:

Leaves: Lupeol; α- and β-Amyrin; Indigotin; Indirubin; Tryptanthrin; Isatin; Rutin; β-Sitosterol; Triacontanol; Myristic acid; Palmitoleic acid; Palmitic acid; Stearic acid; Behenic acid; Arachidic acid (Rao et al., 1966; Ramchandra, 1993).

Flowers: Hexadecanoic acid; 15-methyl-2-mercaptopropanoic acid; Pentadecanoic acid; 3-methyl-3-butanoic acid; Disilanone (Jain & Bari, 2010).

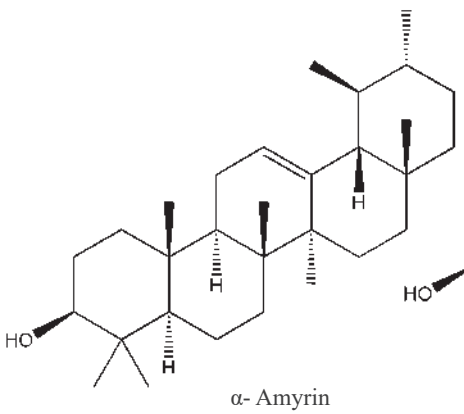
Stem: Lupeol; Stigmasterol; Campesterol (Jain & Bari, 2010).

Bark: Lupeol; α- and β-Amyrin (Bigoniya et al., 2006; Rangaswami & Rao, 1963).

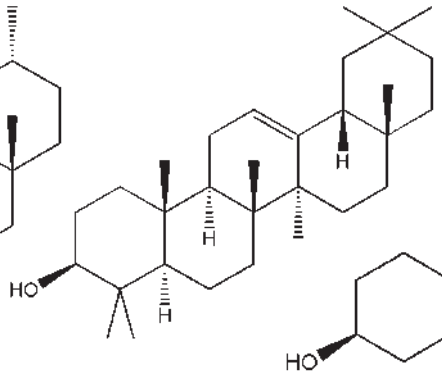
Seeds: Lupeol; Chlorogenic acid; Dihydrocanaric acid; Glycerol; Erythritol; Thritol; D-galactose; D-mannose; 14 α-Methyl Zymosterol; Desmosterol; Clerosterol; 24-Methylene-25-Methyl Cholesterol; 24-Dehydropollinastanol; 24-Methyl Cholesterol; 24-Methylene Cholesterol; 24-Ethyl Cholesterol; 24-Ethyl 22 E-dehydrocholesterol; Isofucosterol; Cholesterol; Palmitic acid; Stearic acid; Behenic acid; Arachidic acid (Akihisa et al., 1988; Bigoniya et al., 2006; Rangaswami & Rao, 1963; Srivastava et al., 2010; Subramanian et al., 2005).

Mature seed pods: α- and β-Amyrin; Lupeol; Ursolic acid; Oleanolic acid; Isoricinolic acid; β-Sitosterol (Rao et al., 2019).

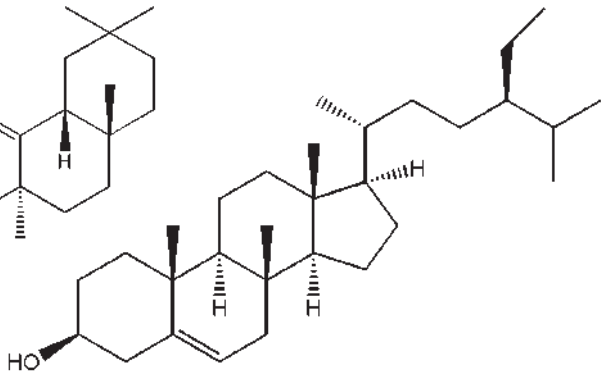
Immature seed pods: α- and β-Amyrin; Cycloartenone; Cycloeucalenol; Wrightial; β-Sitosterol (Rao et al., 2019).



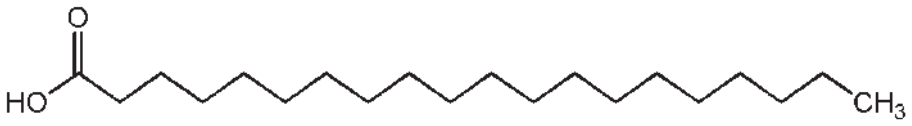
α- Amyrin



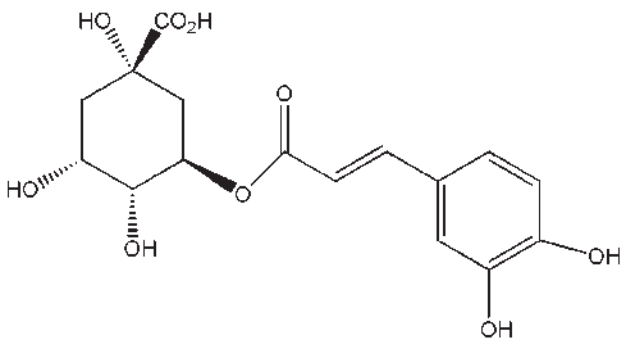
β-Amyrin



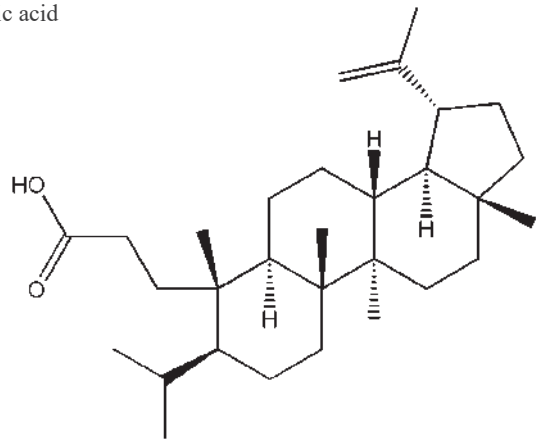
β-Sitosterol



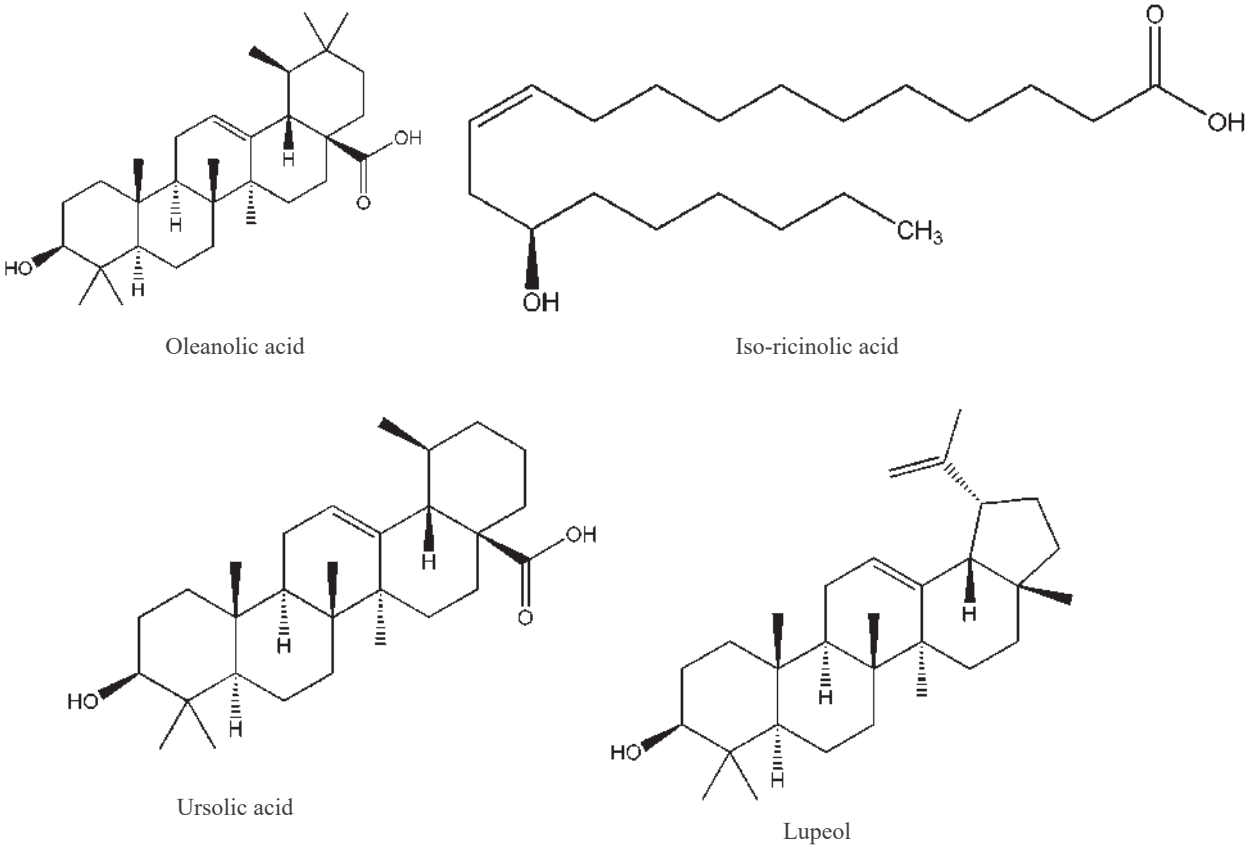
Arachidic acid



Chlorogenic acid



Dihydrocanaric acid



Oleanolic acid

Iso-ricinolic acid

Ursolic acid

Lupeol

Structures of Important and Characteristic Chemical Constituents of *Wrightia tinctoria*

Biological Activities:

Antibacterial Activity: *W. tinctoria* leaves have demonstrated strong antibacterial activity against *Staphylococcus* and *Bacillus* species (Ranjani et al., 2012). The chloroform, ethanol, and methanol extracts of *W. tinctoria* were tested against *Escherichia coli*, *Bacillus subtilis*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* using the disc diffusion method, showing significant antibacterial effects (Vedhanararyanan et al., 2013). Additionally, callus extracts of *W. tinctoria* exhibited higher antibacterial activity against *E. coli*, *S. aureus*, *P. aeruginosa*, and *B. subtilis*, with methanol extract showing the strongest effects (Geetha et al., 2014). Further studies also confirmed that methanol extract had superior antibacterial activity against *S. aureus* and *E. coli* compared to other extracts, using Streptomycin citrate as a reference (Patil et al., 2015).

Anti-lipolytic Activity: The methanol extract and its fractions from the dried seeds of *W. tinctoria* were evaluated for anti-lipolytic activity. Rats treated with the crude methanol extract showed a significant reduction in plasma triglyceride levels after 3 hours compared to untreated groups. Among the fractions, the n-hexane fraction exhibited the highest lipase inhibitory activity, indicating that the seeds possess potent anti-lipolytic properties (Patel and Kumar, 2020).

Hepatoprotective Activity: The methanolic extract of *W. tinctoria* leaves was tested for hepatoprotective activity against D-galactosamine-induced liver damage in albino rats, with silymarin as a reference drug. The extract significantly reduced serum levels of ALT, AST, ALP, and total bilirubin, indicating its hepatoprotective potential. The combination of silymarin and *W. tinctoria* extract further enhanced protection against liver toxicity (Dixit et al., 2015).

Anti-inflammatory Activity: The hexane, methanol, and aqueous extracts of *W. tinctoria* leaves were evaluated for anti-inflammatory activity using carrageenan-induced paw edema in animal models.

The methanolic extract exhibited significant anti-inflammatory effects (Patil et al., 2013).

Anti-fungal Activity: Herbal formulations containing active constituents from *W. tinctoria* demonstrated significant inhibition against *Pityrosporum ovale* and *Candida albicans*. Additionally, the woody stems of the plant were found effective against non-dermatophytic fungi (Jain and Bari, 2009; Krishnamoorthy and Ranganathan, 2000).

Anti-viral Activity: The methanol extract of *W. tinctoria* leaves showed anti-viral activity against the hepatitis C virus in the Huh 5.2 cell line, which exhibits persistent viral replication (Sathyanarayanan et al., 2009; Selvam et al., 2010).

Antioxidant Activity: The methanolic extract of *W. tinctoria* was evaluated for antioxidant activity using the DPPH method. The extract demonstrated a free radical scavenging capacity comparable to standard antioxidants, likely due to the presence of terpenes, flavonoids, vitamin E, and other phytoconstituents (Khan et al., 2021).

Larvicidal Activity: Crude aqueous and petroleum ether extracts of *W. tinctoria* fruits and leaves were evaluated for their larvicidal activity against the filarial vector *Culex quinquefasciatus*. The aqueous fruit extract exhibited the highest larvicidal activity compared to other extracts (Sakthivadivel et al., 2014).

Anthelmintic Activity: Alcoholic and aqueous extracts of *W. tinctoria* leaves were tested for anthelmintic activity against *Raillietina spiralis* and *Ascaridia galli*. The extracts showed significant dose-dependent anthelmintic effects, as measured by worm paralysis and death times (Rajalakshmi and Harindran, 2013).

Anti-asthmatic Activity: The ethanol extract of *W. tinctoria* leaves was evaluated for anti-asthmatic activity in albino Wistar rats. It exhibited significant, dose-dependent anti-asthmatic activity, possibly through histamine inhibition (Khan and Ansari, 2018).

Anti-cancer Activity: Ethanol, petroleum ether, and ethyl acetate extracts of *W. tinctoria* stem bark was assessed for anti-cancer activity using Dalton's lymphoma ascites and Ehrlich's ascites carcinoma models. All extracts demonstrated significant anticancer effects (Chaudhary et al., 2017).

Toxicity: *W. tinctoria* has shown a safe and tolerable toxicological profile, making it an ideal candidate for further exploration in treating various diseases (Oviya et al., 2015).

Commercial Products: The leaf oil and bark extract of *W. tinctoria* are used in skincare products such as lip balm and creams (Search Results - *Wrightia tinctoria*, n.d.).

Patent:

- A unique sustainable construction material extracted from *W. tinctoria* seed fiber and analyzing its properties thereof, Patent No: 202041019727
- Synthesis of nickel oxide nanoparticles using *W. tinctoria* leaf latex, Patent No: 202141015906
- Development of nanoparticle formulation using methanolic extract of *W. tinctoria* for anti-microbial therapy, Patent No: 202231051950

Scope of Further R&D: *W. tinctoria*, commonly known as dyer's oleander or Pala indigo plant, holds significant traditional value, especially in medicine. However, limited scientific research exists on this species, highlighting the need for further investigation. Key areas of research include documenting traditional uses across cultures, conducting comprehensive phytochemical analyses to identify and quantify compounds from different plant parts, and performing bioassays to assess biological activity, toxicity, and safety profiles. Additionally, exploring its potential industrial applications, such as in natural dyes and bio-based materials, is crucial. *W. tinctoria*'s phytoremediation properties also warrant research into its effectiveness in wastewater treatment. A thorough investigation of these aspects could reveal the full potential of *W. tinctoria* in scientific, medicinal, and industrial contexts.

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Xanthium strumarium L.

Synonyms:
Xanthium spinosum, Xanthium ambrosioides, Xanthium americanum Walter.

Local/Common/Popular Name(s):
Rough Cocklebur, Clotbur, Common Cocklebur, Large Cocklebur, Woolgarie Bur, Ditch Bur, Sheep Bur, Bur Thistle, Abrojo, Adhisishi, Badagokhru, Bhakra, Chotadhatura.

Vernacular Names:
Marathi: Dumundi, Dutundi, Sankeshwara, Shankeshwar, Duthundi; ***Sanskrit:*** Arishta, Bhulagna, Brahma-Dundi, Chanda, Gokshuru, Itara, Mangalyakamalini, Medhya, Pitapushpi, Raktapushpi, Sarpakshi; ***Tamil:*** Marhe-Matta, Marlu-Mutta, Marlumutta; ***Telugu:*** Maraluteege, Maruluthige, Thalnoppi; ***Kannada:*** Maralumathi

TAXONOMIC CLASSIFICATION

Kingdom	:	Plantae
Phylum	:	Streptophyta
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Order	:	Asterales
Family	:	Asteraceae
Genus	:	*Xanthium*
Species	:	*Xanthium strumarium*

Botanical Description: *Xanthium strumarium* is a much-branched annual herb that can grow up to 2 meters tall. It features a short, stout, hairy stem that is brownish or reddish-brown, often with red spots and is ribbed and roughly hairy but lacks spines. The stems are either round or slightly ribbed with a purple-speckled appearance and short white hairs scattered across the surface. The leaves are simple, broad-ovate to triangular, 3-5 lobed and dull green with toothed margins. They have short bristly hairs on both sides with the upper surface being darker and prominently 3-veined with purplish veins. The leaves are large broad, light to bright green and arranged alternately with irregular lobes and egg-shaped fruit clusters nestled around the stem. The leaves also have inconspicuous teeth, are about 5-15 cm long, often three-lobed, with prominent veins, long petioles, and a scabrous texture on both sides. The plant produces creamy or yellowish-green, unisexual flowers that are arranged in terminal and axillary heads. These flowers appear in the leaf axils or terminally on branches, arising between the leaf petioles and stems and at the ends of the erect stems. The fruits are obovoid, enclosed in a hardened involucre with two hooked beaks and hooked bristles. *Xanthium strumarium* flowers from July to October and the seeds ripen between August and October.

Distribution: *X. strumarium* is a globally widespread species found in various regions across the world. In Asia, it is native to China and extensively distributed across Northeast China, Southwest China, North China, East China and South China. The plant is also prevalent in Russia, Iran and several states in India including Assam, Bihar, Odisha, Madhya Pradesh, Maharashtra, Uttar Pradesh, Telangana and Andhra Pradesh. Additionally, it is found in North Korea and Japan. Beyond Asia, the plant can be found in North America and Argentina, reflecting its adaptability to a wide range of environmental conditions (Nel et al., 2004; Oksanen et al., 2016). *X. strumarium* often forms dense, mono-specific stands, typically found in low-lying riparian areas, agricultural fields, waste places, roadsides and along riverbanks in warmer regions (Marwat et al., 2010).

Ethnobotanical significance: *X. strumarium* holds significant ethnobotanical value and is used as a medicinal herb across various cultures in Europe, China, Indo-China, Malaysia and America. The entire plant, particularly the roots and fruits are utilized in traditional medicine. In Ayurveda, it is known for its cooling, laxative and tonic properties and is used to treat a variety of ailments such as leucoderma, biliousness, insect bites, epilepsy and fever. It is also believed to enhance appetite, memory, voice and complexion. Native American tribes use the plant to alleviate constipation, diarrhea and vomiting. In traditional Chinese medicine, it is a remedy for headaches, cramps, limb numbness, ulcers and sinus problems. Additionally, *X. strumarium* is considered effective in treating long-standing cases of malaria (Chopra et al., 1986) and has been used as an adulterant for *Datura stramonium*. An infusion of the plant has been employed to treat rheumatism, kidney diseases and tuberculosis and internally for allergic rhinitis, sinusitis, urticaria, catarrh, rheumatoid arthritis, constipation, lumbago, leprosy and pruritis (Moerman et al., 1998). Historically, the plant has been applied to scrofulous tumors, ulcers, boils and abscesses (Foster et al., 1990). The paste of green spiny fruits is used to treat migraines and the juice from leaves and fruits is believed to be effective against smallpox. The roots are used in cancer treatment (Chopra et al., 1986). In China, the burs serve as a tonic, diuretic and sedative. A decoction of the root is used to treat high fevers and leucorrhoea and to help expel the afterbirth. The seeds which yield a semi-drying edible oil(30-35%) resembling sunflower oil, are used for bladder infections, herpes and erysipelas. In Assam, young floral tops and leaves are boiled and eaten as a pot-herb. Despite its medicinal uses, the plant is suspected of being poisonous but the toxic substances are removed **by** washing and cooking (Chopra, 1945). The water-soluble toxic substance is extensively used for treating sinus congestion (Dharmananda, 2003).

Phytochemistry:

Aerial parts: Xanthinin; Xanthumin; Xanthatin; Xanthostrumarin; Atractyloside; Carboxyatractyloside; Xanthanol; Isoxanthanol; Xanthinosin; 4-Oxo-bedfordia acid; Hydroquinone; Xanthanolides (Willaman et al.,1970; Malik et al., 1992; Marco et al., 1993; Winters et al., 1969; Minato et al., 1965); Caffeoylquinic acids; α, and γ-Tocopherol (Molina-Torres & Martinez, 1991); Thiazinedione (Ma et al., 1998; Qin L., et al., 2006); Diacetyl Xanthumin; 11α,13-dihydroxanthatin; 4β, 5β-Epoxyxanthatin-1α, 4α-Endoperoxide,1β, 4β, 4α, 5α–Diepoxyxanth-11(13)-en-12-oic acid; 8-Epixanthatin; 2-Epixanthumin; and 8-Epi-Xanthatin-5β-epoxide (Ahmed et al., 1999).

Essential oil*:* d-Limonene; d-Carveol; α-Ionone; Terpinolene; β-Caryophyllene; p-Cymene (Habibi et al., 2004; Cole et al., 1980).

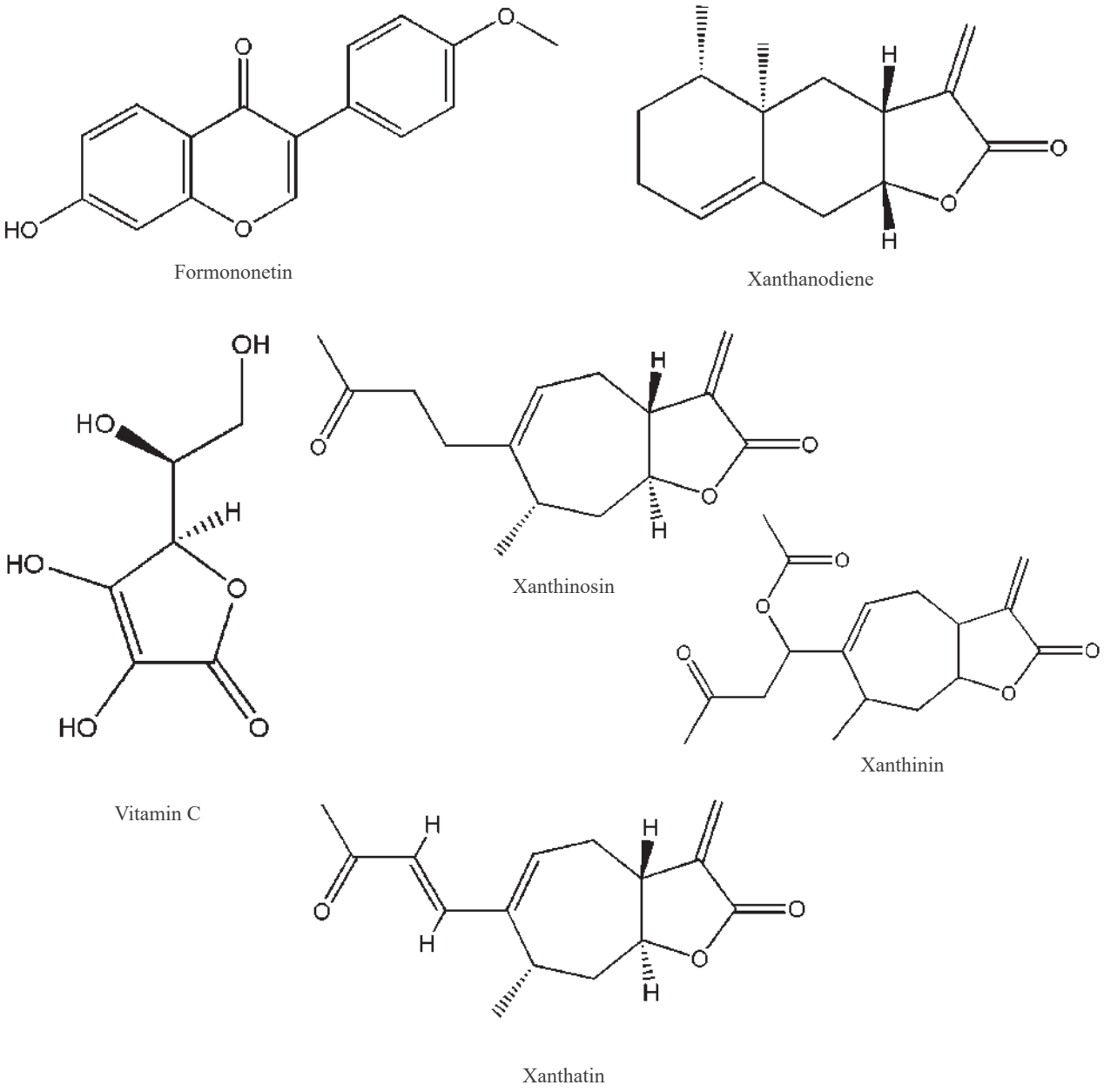
Seeds: Hydroquinone, Choline; Iodine (Chopra et al., 1986; Chopra et al., 1945); Oleic acid; Linoleic acid; Palmitic acid; Stearic acid; Behenic acid; Capric acid; Lauric acid; Myristic acid; Palmitic acid (Bhargava et al., 1960-61); β-Selinene; Phytol; Xanthanodiene; Isoalantolactone; 2-Hydroxytomentosin; Tomentosin; Isoguaiene (Rastogi & Mehrotra, 1970-79; 1980-84).

Fruits: Vitamin C; 7-Hydroxymethyl-8,8-dimethyl-4,8-dihydrobenzol [1,4] thiazine-3,5-dione-11-O-β-d-glucopyranoside (Han Tet al., 2006); 2-Hydroxy-7-Hydroxymethyl-8,8-dimethyl-4,8-dihydrobenzol [1,4] thiazine-3,5-dione-11-O-β-d-glucopyranoside; 7-Hydroxymethyl-8,8-dimethyl-4,8-dihydrobenzo [1,4] thiazine-3,5-dione; 7-hydroxymethyl-8,8-dimethyl-4,8-dihydrobenzol [1,4] thiazine-3,5-dione-(2-O-caffeoyl)-β-d-glucopyranoside; ferulic acid; formononetin and ononin (Han et al., 2006); glucose; fructose; sucrose; organic acids; phosphatides; potassium nitrate; β-sitosterol; γ-sitosterol; strumaroside (Bhakuni et al., 1971; Craig et al., 1976; Bisht & Singh, 1979).

Leaves: Amino-n-butyric acid; arginine; aspartic acid; cysteine; glutamic acid; methionine; proline; tryptophan (Bisht et al., 1978; Mondal et al., 1998).

Biological Activities:

Antibacterial Activity: The plant extract has demonstrated antimicrobial activity against various pathogens, including *Proteus vulgaris*, *Staphylococcus aureus*, *Bacillus subtilis*, *Candida albicans* and *Candida pseudotropicalis* (Jawad et al., 1988). An alcoholic solution of xanthinin, at concentrations of 0.01–0.1% showed strong antibacterial effects against gram-negative bacteria and fungi (Little et al., 1950). Further studies revealed that the ether-neutral extract of



Structures of Important and Characteristic Chemical Constituents of *Xanthium strumarium*

X. strumarium exhibited the strongest inhibitory effects against eight strains of gram-positive bacteria, six strains of gram-negative bacteria, and *Cryptococcus neoformans*. Additionally, the essential oil of *X. strumarium* was found to have significant in vitro antibacterial activity against Shiga toxin-producing *E. coli* O127:H7, particularly during the late exponential and stationary phases of the bacterial life cycle (Rad et al., 2016).

Anti-inflammatory Activity: The methanol extract of *X. strumarium* has been assessed for its anti-inflammatory properties in lipopolysaccharide-stimulated murine macrophage-like RAW264.7 cells, human monocyte-like U937 cells, and an LPS/D-galactosamine-induced acute hepatitis mouse model. The results indicated that the plant possesses notable anti-inflammatory activity (Hossen et al., 2016).

Antitumor Activity: The antitumour activity of *X. strumarium* has been demonstrated through various studies. Two xanthanolide sesquiterpene lactones, 8-epi-xanthatin and 8-epi-xanthatin-5β-epoxide, isolated from the leaves have shown significant inhibition of human tumor cell proliferation in vitro,

including A549 (non-small cell lung), SK-OV-3 (ovary), SK-MEL-2 (melanoma), XF498 (CNS), and HCT-15 (colon) cells. These compounds also inhibited the farnesylation of human lamin-B by farnesyl transferase in a dose-dependent manner (Oudhia *et al*., 2001; Oudhia & Dixit, 1994; Rodriguez *et al*., 1976; Kim *et al*., 2003; Kupchan et al., 1971). Further research on the antitumor activity of *X. strumarium* extracts and their purified compounds revealed that XE-N-S1 exhibited the most potent activity against HeLa cells. For HepG2 cells, XE-N-S1 and XE-N-S3 were particularly effective while XE-N and XE-N-S1 demonstrated good activity against HT29 cells. XE-N-51 showed high activity against Saos2, NCI H522, NCI H1703, and Clone M3 cells and XE-N-S3 was the most effective against LN CAP cells. When comparing the toxicity of these extracts and compounds with existing antitumor agents, XE-A, XEA-A and XEA-B had the lowest toxicity, with XE-B being less toxic than etoposide. However, XE-N-S1 and XE-N-S3 were more toxic than etoposide and XE-A-S3 exhibited toxicity between that of etoposide and cisplatin (Kim et al., 2003). Additionally, the extract of *X. strumarium* was analyzed for antitumor activity against cultured HeLa cells using the MTT assay in a dose- and time-dependent manner. The extract inhibited the growth and proliferation of HeLa cells by inducing cell death, DNA fragmentation, and increasing the number of apoptotic cells post-treatment (Vaishnav et al., 2015).

Anticancer Activity: The plant extract has shown potential anticancer activity in vitro against a panel of human cancer cell lines, including breast (MCF7), renal (TK10) and melanoma (UACC62). The extract was screened by the National Cancer Institute (NCI) against 60 human cancer cell lines revealing promising anticancer properties across several cancer types including leukemia, melanoma and cancers of the lung, colon, kidney, ovary, CNS, breast and prostate (Fouche et al., 2008). Additionally, the stem and leaf extract of *X. strumarium* was tested for anti-cancer activity on HepG2 cancer cells using acridine orange-ethidium bromide dual staining. After 60 hours of treatment, the extract induced apoptosis evidenced by cell shrinkage and the formation of apoptotic bodies, demonstrating significant anti-cancer potential (Ly et al., 2021).

Anti-ulcerogenic Activity: Xanthatin a compound derived from *X. strumarium* exhibits significant gastric protective activity. In animal studies, xanthatin showed strong inhibitory effects on gastric lesions induced by 0.6 N HCl and 0.2 N NaOH, reducing ulceration by 58–96% at doses ranging from 12.5 to 100 mg/kg in rats. The presence of a non-hindered 4,5-unsaturated carbonyl group in xanthatin appears to be crucial for its gastric cytoprotective effects (Favier et al., 2005).

Antitussive Activity: The extract of *X. strumarium* has been found to possess antitussive properties comparable to codeine phosphate, a standard antitussive drug. At doses of 100 and 200 mg/kg (administered orally), the extract significantly inhibited the cough reflex by 39.75% and 65.58%, respectively, over a 2-hour period (Mandal et al., 2005; Dong *et al*., 2002).

Antifungal Activity: *X. strumarium* exhibits potent antifungal activity attributed to compounds like terpenes, d-limonene, and d-carveol (Bisht *et al*., 1978). A key antifungal compound identified in the plant is “diacetyl xanthumin” (4-oxo-1(5), 2, 11, (13)-xanthatriene-12, 8-olide). Fresh sap from the plant, when diluted 50-fold, effectively controlled disease incidence in both pot and field trials. Additionally, crude extracts of the plant inhibited mycelial growth and zoospore germination of *Phytophthora drechsleri*, the pathogen responsible for atractylis rot, at concentrations of 12.5 and 15.6 µg/ml, respectively (Dong et al., 2002). The plant’s leaf extract also shows strong antifungal activity against *Fusarium moniliforme* (Kishore et al., 1982; Parveen et al., 2017). In a study using hexane, ethyl acetate and alcoholic extracts of the leaves, the hexane extract demonstrated significant inhibition against *Candida albicans, Aspergillus niger, Pseudomonas aeruginosa* and *Staphylococcus aureus* at a concentration of 200 µg/disc. The ethyl acetate extract was effective against *A. niger*, *S. aureus* and *Escherichia coli* at the same concentration, while the alcoholic extract only inhibited *S. aureus* (Amerjothy et al., 2007). Moreover, the plant has shown substantial potency against *Cryptococcus neoformans* and various Candida species with low toxicity to brine shrimp. The presence of 4,5-dihydroxyl groups in the quinic acid moiety is essential for antifungal activity and adding a free amino group further enhances the

inhibitory effect against Aspergillus fumigatus (Ma et al., 2007).

Hypoglycemic Activity: *Xanthium strumarium* demonstrates significant hypoglycemic activity in animal studies. The plant showed a potent ability to lower blood sugar levels in rats (Favier et al., 2005; Kupiecki et al., 1974). Specifically, the antihyperglycemic effects of caffeic acid and phenolic compounds found in the fruit of *X. strumarium* were investigated. In diabetic rats, both those with streptozotocin-induced diabetes and insulin resistance, intravenous injection of caffeic acid led to a dose-dependent reduction in plasma glucose levels. Interestingly, this effect was not observed in normal rats, suggesting an insulin-independent mechanism of action for caffeic acid. Furthermore, caffeic acid was found to reduce the rise in plasma glucose levels in insulin-resistant rats undergoing a glucose challenge test. Additionally, caffeic acid enhanced glucose uptake in isolated adipocytes in a concentration-dependent manner. This increase in glucose utilization likely contributes to the observed lowering of plasma glucose levels (Hsu et al., 2000).

Antimitotic Activity: *X. strumarium* may contain antimitotic components. In studies using the microtubule-tubulin system isolated from mammalian tissue, both whole and partially separated chemical constituents of the plant effectively inhibited tubulin polymerization, suggesting potential antimitotic activity (Menon et al., 2001).

Neuropharmacological Activity: *X. strumarium* exhibits central nervous system (CNS) depressant activity. Rodents treated with the plant extract showed significant behavioral changes, including reduced spontaneous motility, prolonged pentobarbitone-induced sleep and suppressed exploratory behavior and avoidance responses. These findings suggest that the plant has notable neuropharmacological effects (Mandal et al., 2001; Rastogi & Mehorotra, 1960-69).

Antitrypanosomal and Antimalarial Activities: *X. strumarium* has demonstrated both antitrypanosomal and antimalarial properties. In vitro studies revealed that a 50% ethanolic extract of *X. strumarium* leaves exhibited significant trypanocidal activity across various concentrations (5, 50, 500, and 1000 µg/ml). In vivo, the extract prolonged the survival of *Trypanosoma evansi*-infected mice at dosages of 100 and 300 mg/kg, administered intraperitoneally, although higher doses (1000 mg/kg) proved toxic (Talakal et al., 1995). Additionally, aqueous and methanolic extracts of the plant showed antiplasmodial activity, effectively inhibiting the growth of the chloroquine-resistant *Plasmodium falciparum* strain FCR-3 with EC50 values below 10 µg/ml (Tran et al., 2003).

Antioxidant and Hydrophobic Activities: The antioxidant properties of *X. strumarium* were assessed through various extract fractions using cross-linking assays on lens proteins. Crude, chloroform ($CHCl_3$) and ethyl acetate (EtOAc) extracts displayed approximately 10% antioxidant activity while water extract showed no effect (Lee et al., 2001). In further studies, the butanol extract exhibited the highest antioxidant activity among several tested extracts (hexane, ethyl acetate, n-butanol and water) likely due to the presence of phenolic compounds such as tannins, flavonoids, and polyphenols, which are known for their reactive oxygen species (ROS) scavenging and chelating abilities (Kang et al., 2003).

Repellent and Insecticidal Effects: *X. strumarium* extracts have been investigated for their repellent and insecticidal properties. Under laboratory conditions, diluted extracts of the fruits and leaves exhibited a strong repellent effect though their insecticidal activity was relatively low. Field studies confirmed the repellent efficacy of a 1/6 concentration of fruit extract against both adult and larval stages of the Colorado Potato Beetle. This repellent effect is attributed to toxic components in the plant including hydroquinone and xanthatin, which are known to repel insects (Cetinsoy et al., 1998; Harada et al., 1985).

Anti-Arthritic Activity: The fruit of *Xanthium strumarium* demonstrated significant anti-arthritic effects including suppression of paw swelling and arthritic scores in rats. It also reduced TNF-α and IL-1β levels while increasing IL-10 suggesting its potential as an anti-arthritis agent. The extract also lowered COX-2 and 5-LOX levels with phenolic acid derivatives identified as active components (Lin et al., 2014).

Anti-Allergic Activity: Caffeoylxanthiazonoside, isolated from the fruits of *X. strumarium*, exhibited

anti-allergic properties in rodent models. It reduced nasal symptoms and IgE levels in rats with allergic rhinitis indicating its potential for treating allergies (Peng et al., 2014).

Anti-Leishmanial Activity: The leaf extract of *X. strumarium* showed significant anti-leishmanial activity against *Leishmania major* comparable to the reference drug amphotericin B. It achieved an infection rate of 51% and a multiplication index of 57% (Ahmadi et al., 2021).

Toxicology: *Xanthium strumarium* is toxic to mammals primarily due to the presence of carboxyatractyloside, a sulfated glycoside found in the seeds and early seedling stages. While mature plants are generally considered non-toxic, cases of toxicosis have been reported in cattle that ingested mature plants with burs. High carboxyatractyloside content, especially in the spines, poses risks, particularly in products used in traditional medicine (Witte et al., 1990; Dharmananda et al., 2003; Cole et al., 1980; Al-Qura'n, 2005).

Ingesting *X. strumarium* can lead to severe side effects including depression, vomiting, abdominal pain, weakness and convulsions, potentially resulting in death within 6 to 96 hours. The plant can cause hypoglycemia and hepatic damage attributed to the disruption of oxidative phosphorylation, a critical process for cellular energy metabolism. Toxic ingredients such as sesquiterpene lactones, contribute to symptoms like vomiting, weakness, tremors and convulsions. Acute hepatic necrosis and other severe symptoms have been observed in pigs which experienced hypoglycemia and elevated liver enzyme levels following ingestion (Mei et al.,2003; Yin et al., 2008; Stuart et al., 1981; Roussakis et al., 1994; Masvingwe & Mavenyengwa,1998).

Allergic reactions are also reported particularly during the plant's pre-fruiting stage in autmn. The plant has been linked to airborne contact dermatitis with patch tests showing a high degree of hypersensitivity. Cross-sensitivity with *Parthenium hysterophorus* has been noted suggesting similar antigenic components (Kirtikar, 1981; Chopra, 1958; Shivpuri & Dua, 1963; Pharmacopoeia Commission of PRC, 1988; Pasricha et al., 1990; Mahajan et al., 1996; Bajaj et al., 1996).

Patent:

- Highest calorific value biodiesel from Cocklebur (*Xanthium Strumarium*) seed oil., Patent No: 202121062100
- Process for isolation of compounds from plant *Xanthium Strumarium*, Patent No: 202221039570
- A soap composition for atopic dermatitis containing fermented extract of *Xanthium strumarium* l. and preparation method thereof, Patent No: WO2009008656A2
- Method for making *Xanthium strumarium* polysaccharide and cosmetics containing the same, Patent No: KR101769032B1
- Composition for prevention and treatment of arthritis comprising herbal mixture extract of *Xanthium strumarium* Linne, rehmanniae radix preparata and acanthopanacis cortex, Patent No: KR20090011140A
- Composition for stimulating germination of *Xanthium strumarium* seed, Patent No: JPH1087413A
- Composition for promoting regeneration of skin including *Xanthium strumarium* and methods for manufacturing the same, Patent No: KR101286388B1
- Cosmetic composition for inhibiting secretion of sebum comprising an extract of *Xanthium strumarium*, Patent No: KR20110022131A
- Method for producing an extract of *Xanthium strumarium* and application to cigarette, Patent No: JP2014057574A
- Composition comprising an extract of combined crude drug including *Xanthium strumarium* L. for preventing and treating inflammatory disease or allergic disease, Patent No: KR101469325B1
- Method for preparing biodiesel from *Xanthium strumarium*, Patent No: CN103131541A
- Method for isolating and purifying *Xanthium strumarium* L. extract having antimicrobial and antitumor activity and the use of the extract, Patent No: KR100536618B1
- Manufacturing method of *Xanthium strumarium* extracts which is useful to skin disease and its *Xanthium strumarium* extracts, Patent No: KR20160024516A

- Composition for improving oral inflammation including *Xanthium strumarium* and extract of Sward bean as an effective ingredient and preparing method thereof, Patent No: KR20210047451A
- Compound showing apoptosis-inhibitive effect purified from *Xanthium strumarium*, Patent No: KR100641867B1
- Composition for preventing or treating liver cancer comprising fraction of *Xanthium strumarium* extract, Patent No: kr20200106331a
- Composition for anti-inflammatory comprising a *Xanthium strumarium* extract as an active ingredient, Patent No: kr20220104928a
- A composition for relieving allergic rhinitis comprising a mixture of *xanthium strumarium*, magnoliae flos, elm'srootskin, luffa and chrysanthemum indicum flowers fermented product, Patent No: kr20190048122a
- Cosmetic for improving skin wrinkle comprising polyphosphate of fermented *Xanthium strumarium*, Patent No: kr101280483b1
- *Xanthium strumarium* and pine tar ointment, Patent No: cn108969553a
- Manufacturing method of *Xanthium strumarium* extracts which is useful to skin disease and its *Xanthium strumarium* extracts, Patent No: kr20160024516a
- *Xanthium strumarium* and pityrol ointment, Patent No: cn108969676a
- Cosmetic composition for inhibiting secretion of sebum comprising extract of *Xanthium strumarium*, Patent No: kr20110022131a c
- Contact lens preservatives containing *Xanthium strumarium* l. Extracts as effective constituent, Patent No: kr100791244b1
- Method for making *Xanthium strumarium* polysaccharide and cosmetics containing the same, Patent No: kr101769032b1
- Composition for stimulating germination of *Xanthium strumarium* seed, Patent No: jph1087413a
- Method for producing extract of *Xanthium strumarium* and application to cigarette, Patent No: jp2014057574a

Scope of further R&D: *Xanthium strumarium*, despite being an aggressive and widespread weed, holds significant potential for phytoremediation. However, its cultivation and application require controlled growth conditions to prevent its invasive spread. Comprehensive analyses have revealed a rich array of phytochemical constituents and a wide range of pharmacological activities. Moving forward, future research should focus on in vitro and in vivo studies coupled with clinical trials to validate the traditional uses of this plant through evidence-based phytotherapy. Given the herb's remarkable multi-activity profile, particularly its anti-tumor and anti-cancer effects, research should prioritize the quantification of individual bioactive constituents and the assessment of their pharmacological activities in humans. This approach will help to unlock the full therapeutic potential of *X. strumarium*, demonstrating that its value extends far beyond its weed-like appearance. Additionally, previous reports have highlighted the plant's toxicity to mammals when ingested, underscoring the need for thorough toxicological studies. These studies are crucial to ensuring the safety of *X. strumarium*, particularly if it is to be developed for medicinal applications. By addressing these aspects, researchers can better understand the risks and benefits associated with this plant, paving the way for its safe and effective use in therapeutic contexts.

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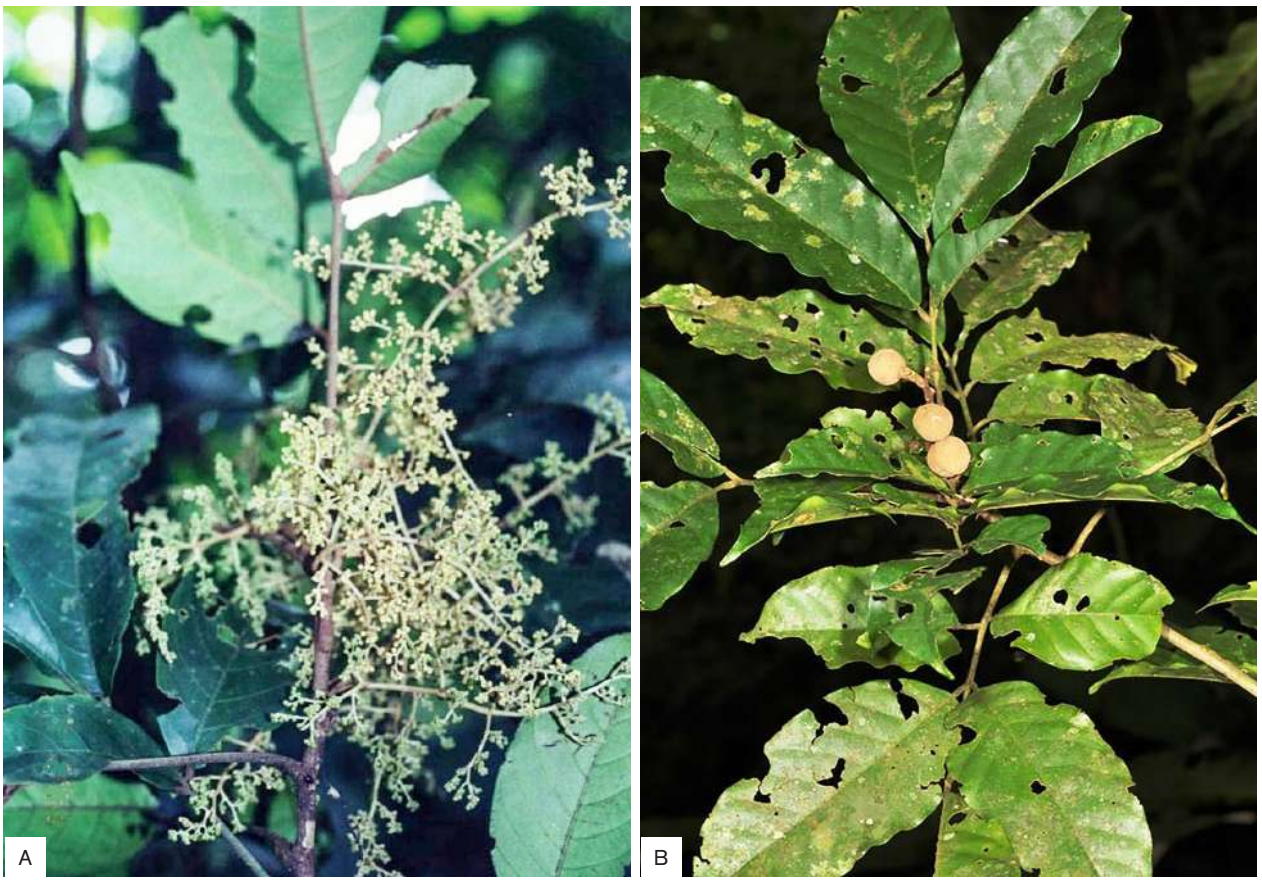
Adenanthera pavonina L. : **A.** Tree; **B.** Seeds



Aglaia edulis (Roxb.) Wall. : **A.** Flowers; **B.** Fruits

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Alangium salviifolium (L.f.) Wangerin : **A.** Flower; **B.** Fruits

Amoora wallichii King. : **A.** Leaves; **B.** Tree

Anogeissus acuminata (Roxb. ex DC.) Wall. ex Guill. & Perr.: **A.** Flowers; **B.** Tree

Anogeissus pendula Edgew. : **A.** Flowers; **B.** Tree

A

B

Arnebia euchroma (Royle ex Benth.) I.M.Johnst.: **A.** Plant; **B.** Roots

A

B

C

Balanites aegyptiaca (L.) Delile : **A.** Fruits; **B.** Tree with Fruits; **C.** Tree

Buchanania axillaris (Desr.) Ramamoorthy : **A.** Fruits; **B.** Bark colour and Gum; **C.** Tree

Canarium strictum Roxb. : **A.** Leaves; **B.** Trunk; **C.** Tree

Carallia brachiata (Lour.) Merr. **A.** Tree; **B.** Fruits

Careya arborea Roxb.: **A.** Bark; **B.** Tree

Cassine glauca (Rottb.) Kuntze : **A.** Flowers; **B.** Tree

Cinnamomum cecidodaphne Meisn. : **A.** Leaves; **B.** Tree

Citrullus colocynthis (L.) Schrad. : **A.** Plant; **B.** Fruits

Cupressus torulosa D.Don ex Lamb.: **A.** Seed Cones; **B.** Needles **C.** Tree

Cyperus rotundus L. : **A.** Tree; **B.** Rhizomes

Dysoxylum malabaricum Bedd. ex C.DC. : **A.** Flower; **B.** Fruits; **C.** Tree

Garcinia morella (Gaertn.) Desr.: Tree

A

B

C

Gardenia gummifera L.f.: **A.** Gum; **B.** Trunk; **C.** Tree

Holarrhena antidysenterica Wall.: **A.** Flowers; **B.** Fruits

Juniperus indica Bertol.: **A.** Leaves and berries like cones; **B.** Stem

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Juniperus polycarpos K.Koch.: **A.** Berries-Like cones; **B.** Tree

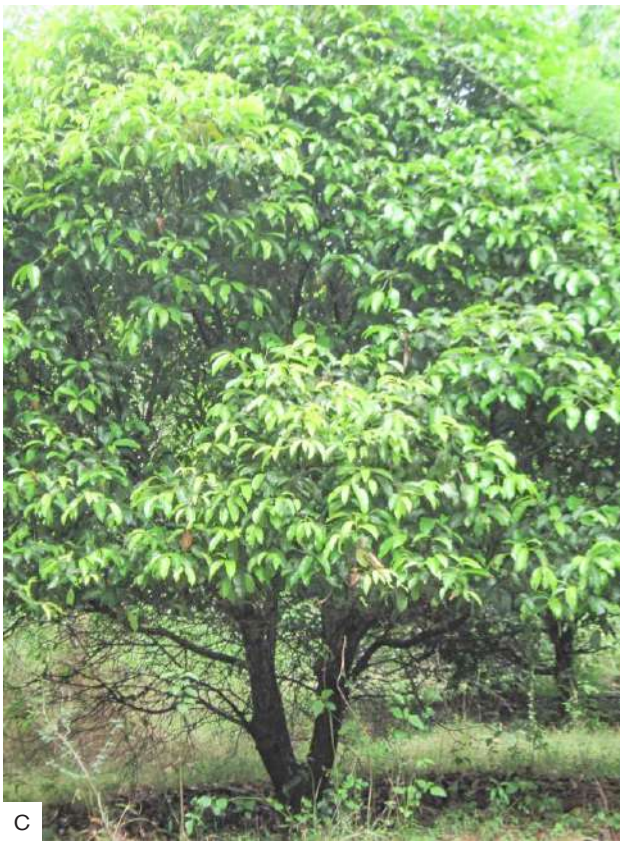
Litsea cubeba (Lour.) Pers.: **A.** Fruits; **B.** Leavs; **C.** Tree

Mallotus nudiflorus (L.) Kulju & Welzen.: **A.** Fruits; **B.** Seeds; **C.** Tree

Mallotus philippensis (Lam.) Müll.Arg.: **A.** Fruits; **B.** Seeds; **C.** Tree

A

B

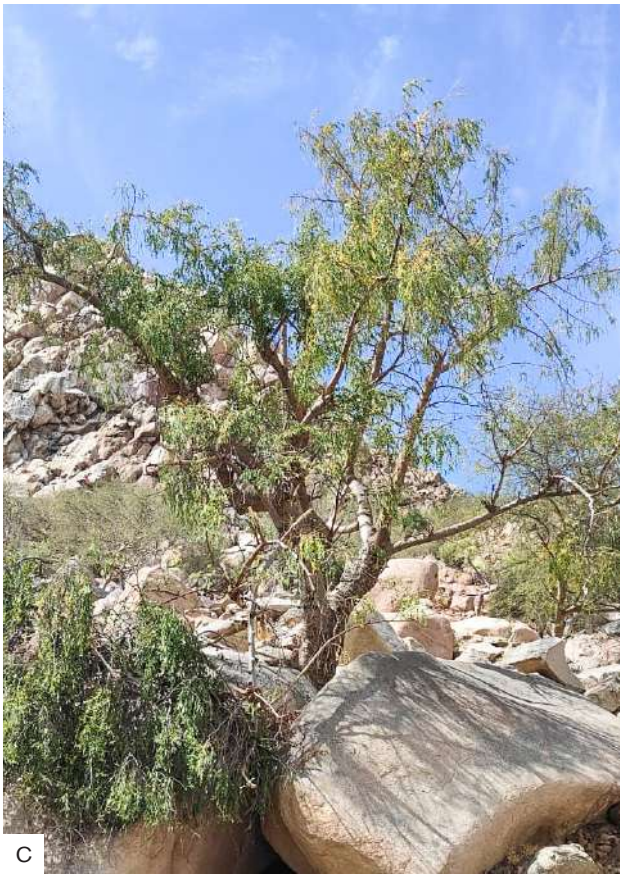


C

Mimusops elengi L.: **A.** Flowers; **B.** Fruits; **C.** Tree

A

B



C

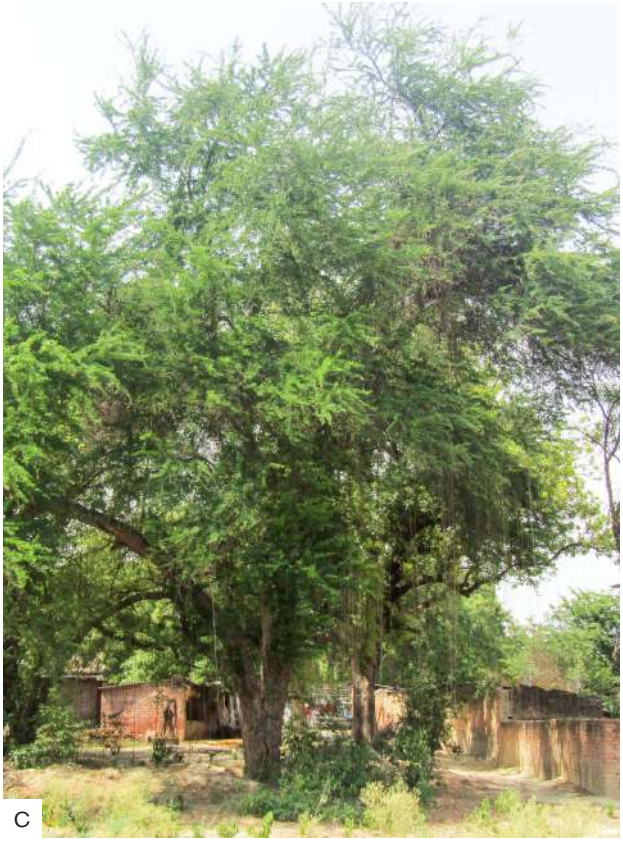
Moringa oleifera Lam.: **A.** Flowers**; B.** Leaves; **C.** Tree

Neolitsea pallens (D.Don) Momiy. & H.Hara. : **A.** Fruits; **B.** Leaves; **C.** Tree

Oroxylum indicum (L.) Kurz. : **A.** Fruits; **B.** Tree

A

B



C

Pithecellobium dulce (Roxb.) Benth.: **A.** Flowers; **B.** Fruits; **C.** Tree

A

B

C

Prinsepia utilis Royle.: **A.** Fruits; **B.** Seeds; **C.** Plants

Pterocarpus santalinus L.f.: **A.** Trunks; **B.** Tree

Punica granatum L.: **A.** Flowers; **B.** Peels; **C.** Plant

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Samanea saman (Jacq.) Merr.: Tree

A

B

C

Sapindus emarginatus Vahl: **A.** Fruits; **B.** Seeds; **C.** Tree

Sapindus trifoliatus L.: **A.** Fruits; **B.** Flowers

Schima wallichii (DC.) Korth.: **A.** Flowers; **B.** Tree


A


C


B


D

Simmondsia chinensis (Link) C.K.Schneid.: **A.** Male Flowers; **B**. Seeds **C.** Plant **D.** Fruits


A


B

Skimmia laureola (DC.) Decne.: **A.** Flowers; **B.** Plant

Soymida febrifuga (Roxb.) A.Juss.: **A.** Bark; **B**. Tree

Sterculia urens Roxb.: **A.** Gum; **B.** Tree

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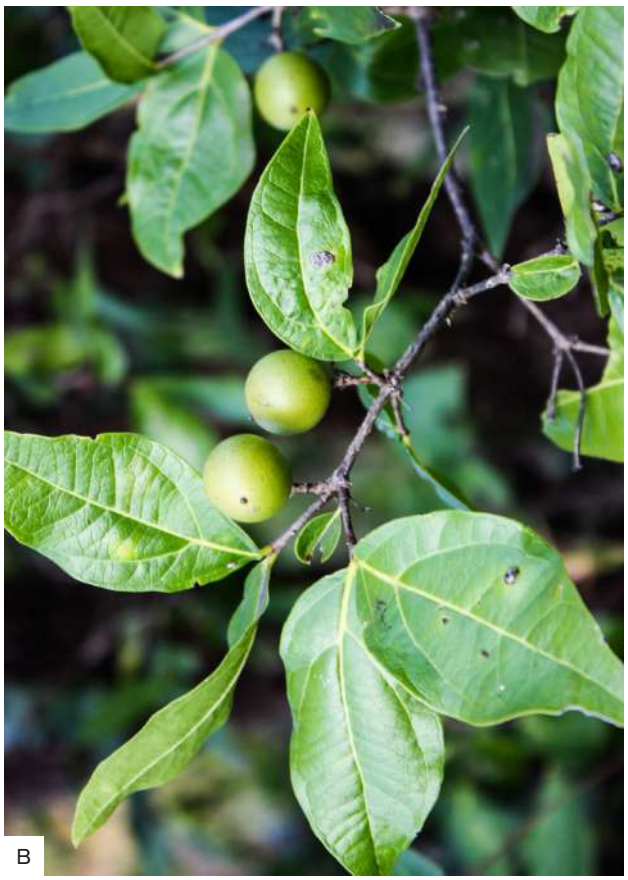
Stereospermum personatum (Hassk.) Chatterjee.: **A.** Flowers; **B**. Fruits; **C.** Tree



Strychnos potatorum L.f.: **A.** Flowers; **B.** Furits

Ventilago madraspatana Gaertn.: **A.** Plants; **B**. Stem

Vitex altissima L.f.: **A.** Flowers; **B.** Tree

A

B

C

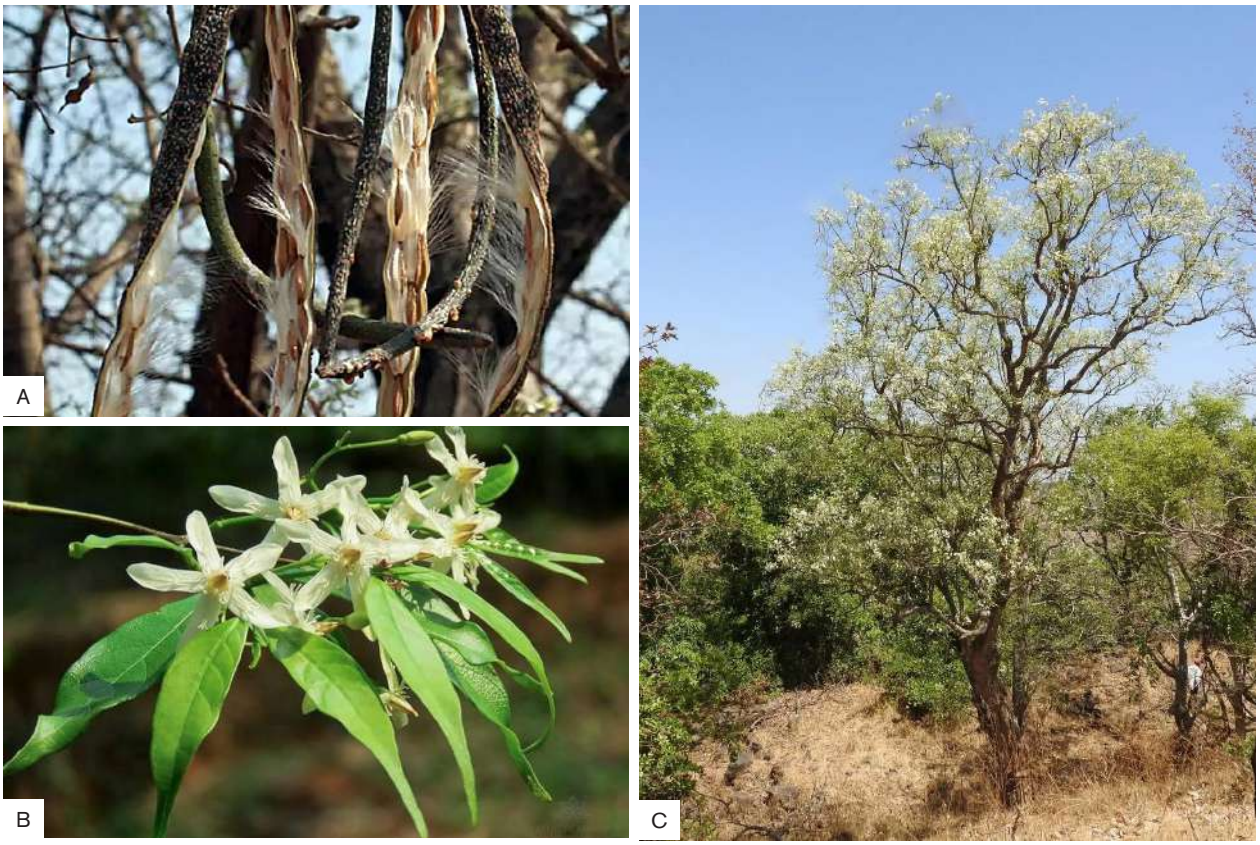
Vitex negundo L.: **A.** Leaves and Flowers; **B**. Seeds **C.** Plants

A

B

C

Woodfordia fruticosa (L.) Kurz.: **A.** Leaves and Flowers; **B**. Seeds **C.** Plants



Wrightia tinctoria (Roxb.) R.Br.: **A.** Fruits; **B**. Leafs and Flowers **C.** Plants

Xanthium strumarium L.: **A.** Flowers; **B**. Fruits **C.** Plant

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(Indian Council of Forestry Research & Education, Dehradun)
P.O.: New Forest, Dehradun-248006,
(Uttarakhand), India

Printed at Shiva Offset Press, Dehradun, Ph. 0135-2715748