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Review Article

MANGROVES: A NOVEL GREGARIOUS PHYTO MEDICINE FOR DIABETES

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ABSTRACT

The current review is a appraisal that gives a general idea of diabetic mellitus, its cure using mangrove plants as herbal drugs. Despite substantial progress in the treatment of diabetes by oral hypoglycemic agents, hunt for newer drugs continues because the existing synthetic drugs have quite a few limitations. The herbal mangrove plants with antidiabetic activity are yet to be commercially formulated as modern medicines, even though the drugs have been acclaimed for their therapeutic properties in the traditional systems of medicine. This chapter highlights diverse mangrove plants available in Indian coastal areas and its antidiabetic activities.

Keywords: Mangrove plants, Herbal drugs, Anti-diabetic activity.

INTRODUCTION

The primordial literature revealed that the diabetes was fairly known and well conceived as an entity in India as "madhumeha". The awareness of system of diabetes mellitus, as the history reveals, existed with the Indians since prehistoric age. Madhumeha is a disease in which a patient passes sweet urine and exhibits sweetness all over the body including sweat, mucus, breath, blood etc[1, 2].

Diabetes mellitus is a metabolic syndrome characterized by inappropriate hyperglycemia caused by a relative or complete deficiency of insulin or by a resistance to the action of insulin at the cellular level. It is the most frequent endocrine disorder, affecting 16 million individuals in the United States and as many as 200 million (approximately 2-7% of the population) worldwide[3]. As the number of people with diabetes multiplies worldwide, the disease takes an ever increasing ratio of national and international health budgets. It is projected to become one of the world's major disablers and killers within the next 25 years. Regions with maximum potential are Asia and Africa, where diabetes mellitus rates could mount to two or three folds than the present rates[4].

DIABETES – AN OVERVIEW

Diabetes has been a experimental model for general medicine. The primary fault in fuel metabolism resulted in prevalent, multiorgan complications that finallycover virtually every system of the body and every specialty of medicine[5, 6]. Such a deficiency results in increased concentrations of glucose in the blood, which in turn damage many of the body's systems, in particular the blood vessels and nerves[7]. The pathogenesis of Insulin Dependent Diabetes Mellitusinvolves environmental causes that may trigger autoimmune mechanisms on genetically susceptible individuals, leading to progressive loss of pancreatic islet β-cells resulting in insulin deficiency. The Non Insulin Dependent Diabetes Mellitus is associated with impaired insulin secretion, obesity, insulin resistance and hereditary disposition in individuals above the age of 40 years [8,9].

Diabetes mellitus is not a solitary disease, but a collection of disorders of varying etiology and pathogenesis that is

characterized by increased fasting and postprandial glucose concentration, insulin deficiency and/ or decreased insulin action and irregularities in glucose, lipid and protein metabolism [10, 11]. In India, about one fifth of the population who lives in metropolitan areas and are over 30 years old and are suffering from both blood pressure and diabetes. According to the new study, the diabetes is more likely to die from colon and breast cancer than those who do not suffer from the condition. The scientists from Colorado School of Public health determined that infants who do not start eating solid food between the ages of four and six months are more likely to develop type 1 diabetes. Measuring the probability of obesity is essential for medical teams and it can help to mitigate the development of type 2 diabetes or pre diabetes in the young.

Long-term complications of diabetes take account of retinopathy with potential loss of vision; nephropathy leading to renal failure; peripheral neuropathy with possibility of foot ulcers, amputations, and Charcot joints; and autonomic neuropathy causing gastrointestinal, genitourinary, cardiovascular symptoms and sexual dysfunction. Patients with diabetes have an increased prevalence of atherosclerotic cardiovascular, peripheral arterial and cerebrovascular disease. Hypertension and abnormalities of lipoprotein metabolism are often found in people with diabetes.

The diabetes mellitus is classified into four major types[12],

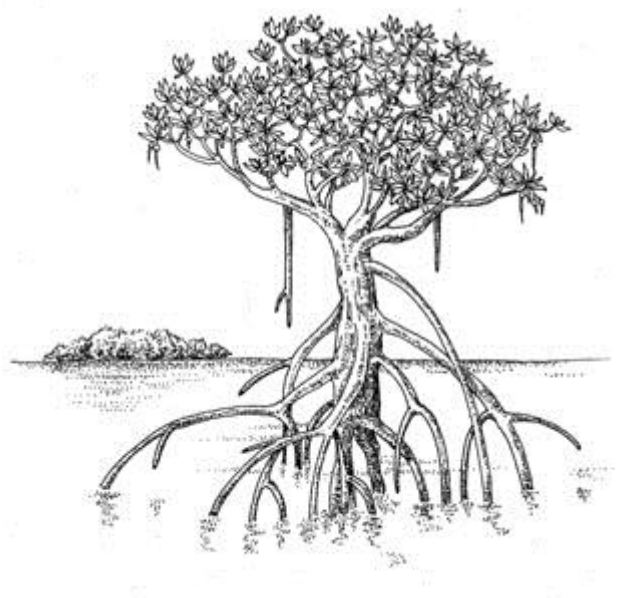
1. Type 1 diabetes (cell destruction, generally leading to absolute insulin deficiency, immune mediated and idiopathic).
2. Type 2 diabetes (may range from principally insulin resistance with relative insulin deficiency to a predominantly secretory defect with insulin resistance).
3. Gestational diabetes mellitus
4. Other specific types (Genetic defect of β–cell function; genetic defects in insulin action; diseases of the exocrine pancreas; endocrinopathies; drug induced, chemical induced; infections; unusual forms of immune mediated diabetes; genetic syndromes associated with diabetes).

MEDICINAL PLANTS

Quite a few medicinal plants have been used as dietary add-on and in the treatment of numerous diseases lacking proper understanding of their function. Although phytotherapy continues to be used in several countries, few medicinal plants have received scientific and medical scrutiny. Moreover, a huge number of medicinal plants hold some degree of toxicity. It is reported that one third of medicinal plants used in the treatment of diabetes are considered to be toxic[13, 14].

MANGROVE PLANTS AS ANTIDIABETIC AGENTS

In general, flora of mangrove wetlands are divided into two groups namely, true or exclusive mangrove and associate mangrove species [15]. Traditionally more than 100 numbers of mangroves and mangrove-associated plant used for the treatment of diabetes have been reported, but only a very few number of plants are evaluated and reported scientifically [16].



Recently, the medicinal value of mangroves and associated plants persist to provide priceless therapeutic agents, both in modern medicines and in traditional systems[17]. Also, the ethno pharmacological consequence pointed out the study plant traditionally used for the treatment of rheumatism, painful arthritis, inflammation, asthma, antioxidant, free radical scavenging, anti-inflammatory, antinociceptive, diabetes and hepato-protective actions[18]. Some recent studies showed the medicinal value of mangroves and associated plants persist to provide invaluable treatment modalities, both in modern and traditional systems of medicine[19, 20].

The major families and genus of mangroves having wide medicinal properties are

Acanthaceae (Acanthus hirsutus, Acanthus ilicifolius);

Myrsinaceae (Aegiceras corniculatum);
Avicenniaceae (Avicennia officinalis);
Lecythidaceae (Barringtonia racemosa),
Leguminosae (Caesalpinia mimosoides);
Rhizophoraceae (Ceriops decandra);
Clusiaceae (Calophyllum inophyllum);
Euphorbiaceae (Excoecaria agallocha);
Arecaceae (Nypa fruticans);
Pandanaceae (Pandanus foetidus);
Fabaceae (Pongamia pinnata, Derris scandens);
Tamaricaceae (Tamarix indica);
Convolvulaceae (Ipomoea imperati, I. pes-caprae) and
Sterculiaceae (Heritiera littoralis) [19].

The details regarding the presence of bioactive compounds and medicinal properties in various mangrove plants are interpreted in the table 1.

DIABETES INDUCING AGENT IN ANIMALS

Alloxan is an oxygenated pyrimidine derivative which selectively destroys insulin secreting beta cells in the experimental animals, which results in alloxan diabetes 46. In the present chapter, alloxan is considered as the diabetes inducing agent in experimental animals and blood sugar level increases, since alloxan causes a massive reduction in insulin release, by the destruction of the beta cells of the islets of langerhans and inducing hyperglycemia[3, 47].

SOME IMPORTANT MANGROOVES THAT EXHIBIT ANTIDIABETIC ACTIVITY

Acanthus ilicifolius-

Acanthus ilicifolius, commonly known as Holly-leaved Acanthus, Sea Holly, and Holy Mangrove is a species of shrubs or herbs[20].

Taxonomy

Kingdom	Plantae
Phylum	Tracheophyta
Class	Magnoliopsida
Order	Scrophulariales
Family	Acanthaceae

Common Name: Holy Mangrove

Habitat and Ecology: It commonly grows on the river banks or tidal canal sides or low swampy areas in the mangrove forests and its vicinity.

Systems: Freshwater; Marine

Native: Australia; Bangladesh; Cambodia; China; Hong Kong; India; Indonesia; Macao;Malaysia; Pakistan; Papua New Guinea; Singapore; Sri Lanka; Taiwan, Province of China; Timor-Leste; Viet Nam

Main features: A shrub that grows to 1.5 m tall.

Roots: May develop small prop roots

Leaves: Thick, shiny, waxy, may have prickly edges.

Flowers: In a cluster at the branch tip. The species A. ilicifolius has light violet flowers, while A. ebracteatus has white flowers.

Fruits: Shiny green pods in a cluster

Figure 1:Fruits of Acanthus ilicifolius

Phytochemistry :Two new cyclolignan glycosides, (+)-lyoniresinol 3a-O-β-D-galactopyranosyl-(1→6)-β-D glucopyranoside and (+)-lyoniresinol 2a-O-β-D-galactopyranosyl-3a-O-β-D-glucopyranoside have been reported from aerial parts of A. ilicifolius.A phenylethanoid glycoside (ilicifolioside A) and an aliphatic alcohol glycoside (ilicifolioside B) have been isolated from the aerial parts .Two lignan glucosides, (+)-lyoniresinol 3a-[2-(3,5-dimethoxy-4-hydroxy) benzoyl]-O-beta-glucopyranoside, and dihydroxymethyl-bis (3, 5-dimethoxy-4-hydroxyphenyl) tetrahydrofuran-9(or 9')-O-beta-glucopyranoside have been isolated from the aerial parts [48].

Antidiabetic Use: A single oral dose of 200 and 400 mg/kg of the eyhanolic root extract was evaluated for anti-diabetic activity in alloxan-induced diabetic rats. Dosage of 200 and 400 mg/kg of the extract significantly decreased blood glucose levels in diabetic rats after 5 h, 3 hr respectively in acute study and 1st day in sub-acute study. The histopathological study has shown better regeneration of β cells at both doses of extract. The obtained results have shown that the Acanthus ilicifolius root ethanolic extract

Table 1: Chemical constituents and medical properties of true mangroves Plant

Name	Part used as medicine	Chemical Constituents	Medicinal properties	References
Acanthus ilicifolius	Bark,Fruits, Leaves, Roots	Alkaloids, long chain alcohols, steroids, sulphur, triterpenes, saponins	Analgesic,anti-inflammatory, blood purifier, antidiabetic,anti-viral, etc.	20; 21; 22; 23; 24 ; 25
Bruguiera conjugata	Stem, Bark	Sulphur containing alkaloids	Antidiabetic	26; 27; 28
Bruguiera cylindrica	Fruits,Roots Leaves	Alkaloids, tannins	Antidiabetic	29; 26
Bruguiera parviflora	Bark	Phenolic compounds	Anticancer, antidiabetic	29; 30
Bruguiera rumphii	Bark and Leaves	Tannins, triterpenes	Antidiabetic	29
Bruguiera sexangula	Bark	Phenolics, steroids, alkaloids, tannins	Anticancer, antidiabetic	29; 31.
Ceriops roxburghiana	Whole plant	Gibberellins, Procyanidins	Antiucler, antidiabetic	30; 32.
Dalbergia ecastophyllum	Bark	Chalcones, steroids, isoflavanoids	Antidiabetic	33; 34.
Excoecaria agallocha	Whole plant	Alkaloids, tannins, phorbol esters, polyphenols,	Uterotonic, purgative, antidiabetic	26, 35.
Heritiera macrophylla	Leaves	Carotenoids, tannins	Antidiabetic	36.
Kandelia candel	Whole plants	Alkaloids, tannins, saponins, polyphenols	Antidiabetic	29; 37.
Kandelia rheedii	Bark, Fruits and Leaves	Steroids, triterpenes	Antidiabetic	29; 38
Nypa fruiticans	Leaves and Fruits	Acetic acid, ethanol	Antidiabetic, treatment for snake bite	29; 39.
Rhizophora conjugata	Bark	Anthocyanins, steroids, tannins, triterpenes	Antidiabetic	38.
Rhizophora gymnorrhiza	Bark	Anthocyanins, Anthocyanidins, tannins, steroids	Antidiabetic	38.
Rhizophora mangle	Bark and Leaves	Tannins, triterpenes	Antidiabetic	29; 40.
Rhizophora racemosa	Flowers and Leaves	Tannins, steroids	Antiviral, antidiabetic	29; 35.
Rhizophora stylosa	Leaves, roots and seeds	Inositols, steroids	Antiviral, antidiabetic	41; 42
Salicornia brachiata	Leaves and Stems	Steroids, triterpenes	Antiviral, antidiabetic, toothache	29; 43.
Sonneratia ovata	Fruits	Steroids	Stop bleeding, antidiabetic	29; Bhosle et.al, 1976.
Xylocarpus granatum	Bark	Alkaloids, steroids, limonoids, tannins, triterpenes	Treat fever, malaria, cholera and antidiabetic	29; 38.
Xylocarpus moluccensis	Bark, Fruits	Limonoids, xyloccensins	Treat fever, malaria, naphrodisiac and antidiabetic	29; 45.

shown the presence of flavonoids, alkaloids, terpenoids, tannins and steroids and also has a potent anti-diabetic activity in wistar rats further investigation is required by using the purified compound to evaluate and isolation of the phytochemicals responsible for the anti-diabetic activity of ethanolic extract of Acanthus ilicifolius root[49].

Ceriops decandra-

A small to medium-sized straight, columnar, evergreen tree, under favourable conditions reaching up to 35 m in height and the trunk up to 35 cm in diameter with short basal buttresses.

Taxonomy

Kingdom	Plantae
Phylum	Tracheophyta
Class	Magnoliopsida
Order	Rhizophorales
Family	Rhizophoraceae

Synonym: Ceriops roxburghiana

Habitat and Ecology: This species is found in the intermediate estuarine zone in mid to high intertidal regions. It has a maximum tolerance of salinity at 67 ppt and a salinity of optimal growth at 15 ppt 50. This is a slow-growing species, and can be tolerant of extreme environmental conditions.

Systems: Marine

Native: Bangladesh; India; Malaysia; Myanmar; Thailand

Main features: A 2 to 3 m tall shrub forming small butteresses.

Roots: May develop small prop roots

Leaves: simple and opposite.

Flowers: di-to tri-chotomous in condensed axillary cymes; hypocotyle 9-15 cm long, sharply ridged

Fruits: one celled one seeded. Forms thin knee-like pneumatophorh.

Branches: thick

Figure 1: Ceriops decandra leaves

Phytochemistry: A few chemical investigations on C. decandra from different parts of India and the globe revealed the presence of diterpenoids, triterpenoids and lignins, 51, 52, 53, 54 & 55 remarkably little studies on the chemistry and the biological activity of the species from Indian or Bangladeshi Sundarbans have been reported till date. Study by (Ghosh et al.1985) revealed significant contents of lipids, sterols and triterpenes from the leaves of C. decandra from Indian Sundarban region. The study also revealed the sterol and triterpene composition of the leaves of the species.Misra et al.198756 reported the hydrocarbon and wax ester profile from the leaves of this species from Indian Sundarban along with six other species of mangroves.

Uses: The extract of the mangrove plant C. decandra exhibits promising antidiabetic activity.The mangrove plant Ceriops decandra is reportedly rich in lignins with proven anti-oxidant activity. Alloxan, a β-cytotoxin, induces chemical diabetes in a variety of experimental animals by damaging insulin secreting β-cells, which results in insulin-dependent diabetes mellitus. There are also a number of other plants that reportedly possess antihyperglycemic activity and have an insulin-stimulatory effect including Eugenia jambolana, Gymnema yunnanese, Boerhaavia diffusa and Tinospora cordifolia 57 and 58.

Sonneratia alba-

This large and beautiful tree is commonly seen, usually on the seaward side of the mangroves. It is considered the most widely distributed Sonneratia species. A pioneer species, it colonises newly formed sandy mud flats in sheltered estuaries and coastal areas. It is intolerant to long periods of exposure to freshwater.

Taxonomy

Kingdom	Plantae
Phylum	Tracheophyta
Class	Magnoliopsida
Order	Myrtales
Family	Lythraceae

Common names: 'berembang' in Malaya, 'mangrove apple' in English, and 'Mangrovenapfel', "Pagatpat" in the Philippines

Habitat and Ecology: This species is found in the low-intertidal zone. It is intolerant of long periods of freshwater,

and prefers high salinity. It is a pioneering species that is fast growing, but has low seed-viability. In the low intertidal zone, it can be the dominant species along with A. marina, forming a tree line along the seaward margin of its range. It prefers soils of consolidated mud and sand. This species can grow to 30 m in height[59].

Systems: Terrestrial; Marine

Native: Australia; Brunei Darussalam; Cambodia; China; Comoros; India; Indonesia; Japan; Kenya; Kiribati; Madagascar; Malaysia; Mayotte; Micronesia, Federated States of ; Mozambique; Myanmar; New Caledonia; Palau; Papua New Guinea; Philippines; Seychelles; Singapore; Solomon Islands; Somalia; Sri Lanka; Taiwan, Province of China; Tanzania, United Republic of; Thailand; Tuvalu; Vanuatu; Viet Nam59 .

Main features: Tree 3-30m tall.

Bark: cream to light grey, finely fissured. Thick underground cable roots spread out from the trunk. These bear sturdy conical pneumatophores (25cm to 1m tall). But the tree may lack pnematophores if it grows on a solid substrate.

Leaves: nearly circular or spoon-shaped (5-12.5cm) tapering at the base, thick and leathery. Young leaves are pale green with faint tinge of pink at the leaf 'tip'. The leaves are arranged opposite one another.

Flowers: large (10cm diameter) with 6 petals narrow white often inconspicuous, and many long white stamens that are pink at the base, forming a powder-puff shape. Stiff cup-shaped calyx with sepals broadly triangular and reddish on the inside. According to Giesen, the flowers are pollinated by hawk-moths, birds and fruit-eating bats.

Fruit: Somewhat pear-shaped (5-7cm) leathery. The tips of the calyx lobes bend back towards the stalk. Seeds white, flattened, tiny, buoyant (due to air-filled tissues in the seed) [60]

Figure 2: Sonneratia alba leaves

Antidiabetic Use: The leaf extract of the mangrove plant, Sonneratia alba was evaluated for its antidiabetic activity comparable to glinclamide and identified the specific molecule that shows such property using several chromatographic techniques and proton – Nuclear magnetic resonance spectrometry. The molecular markers are said to be similar among the closely related species of the mangrove groups. Some studies showed that this plant has tremendous blood glucose attenuating activity because it has reduced significantly the sugar level by amount 19% during the first 6 hours and reduced further to 67% after 12 hours [61, 62].

Uses as food: Leaves may be eaten raw or cooked. The ripe fruit are eaten by people from Africa to the Malays and Javanese, and are said to taste like cheese. In Eastern Africa the leaves are used a camel fodder.

Other uses: Sonneratia is used for firewood, but is not the preferred mangrove tree for this purpose. Although it produces a lot of heat, it also produces a lot of ash and salt. The heavy timber is resistant to shipworm and pests and is used for building boats, piling and posts for bridges and houses.

Traditional medicinal uses: Sonneratia caseolaris is used in poultices for cuts, bruises (Burma) and sprains and swellings. Ripe fruit are used to expel intestinal parasites (Malay) and half-ripe fruit for coughs.

Sphaeranthus indicus -

Sphaeranthus indicus Linn. is a medicinal plant widely used in Indian traditional system of medicine for curing various ailments63. It grows in rice fields, dry waste places and cultivated lands in tropical parts of India. It is distributed throughout India, Sri Lanka, Africa and Australia from sea level to 1200 m altitude 64.

Taxonomy

Kingdom	Plantae
Phylum	Tracheophyta
Class	Magnoliopsida
Order	Asterales
Family	Compositae

Synonyms: Sphaeranthus hirtus Willd. and Sphaeranthus mollis Roxb.

Common names: Munditika, Mundi, Shravani, Bhikshu, Tapodhana, Mahashravani, Shravanahva, Shravanashirshaka.

Habitat and Ecology: It is an annual found growing in wet areas, occasionally temporarily submerged. Common in and around irrigation ditches and rice fields and considered as a weed. Grows from the plains to 800 m.

Systems: Terrestrial; Freshwater

Native: Australia (Northern Territory, Queensland); Bangladesh; Bhutan; Ethiopia; India (Andaman Is., Andhra Pradesh, Bihar, Goa, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh, West Bengal); Lao People's Democratic Republic; Lesotho; Madagascar; Malaysia (Peninsular Malaysia); Myanmar (Myanmar (mainland)); Nepal; Somalia; South Africa; Sri Lanka; Swaziland; Thailand; Viet Nam.

Morphology: The herb S. indicus is much branched, strongly scented, and annual erect with branched tappering roots tap roots[65]. Odor of herb is slightly aromatic but disappears on long storage.

Stems: are cylindrical with toothed wings.

Leaves: are sessile, decurrent, 2–7 cm long, 1–1.5 cm wide, obovate-oblong, rounded or subacute, glandular-hairy, spinous-serrate or dentate, narrowed at the base and greenish-brown in color.

Flowers: are borne in terminal, solitary, globose, clusters of heads. Heads of flowers are purple, bracts are short slender and acuminate. In each head, the outer flowers are females, few or many, fertile, the central flowers bisexual, fertile or sterile, involucre narrow, bracts paleaceous, spathulate, acute, ciliate; receptacle small, naked. Corolla of female flowers are purple, slender, tubular, minutely two to three toothed; corolla of hermaphrodite flowers are purplish white, tubular or funnel-shaped, four to five toothed, anther-base sagittate, auricles acute or tailed, style-armed, filiform, sometimes connate.

Fruits: are oblong and have compressed achenes in which pappus is absent.

Figure 3: *S. indicus* plant

Microscopic Characters:

Leaf: The leaf is dorsiventral and shows abundant trichomes of varying types on both the epidermis. Simple trichomes are three to four celled, thick walled and measure 130.8–145.2 µm in length and 29.0–43.5 µm in width. Trichomes are straight/knee shaped, with a swollen base and with collapsed cell at the middle or at the apex. Midrib shows three to four collateral vascular bundles associated with a group of sclerenchymatous cells on either side[65].

Figure 4: (T.S.) of leaf of S. indicus

Stem: The stem shows cork with two to three layers of parenchymatous cells covered with papillose cuticle having trichomes and can be distinguished by thepresence of a discontinuous ring of lignified pericyclic fibers and a well-developed ring of bicollateral vascular bundle.

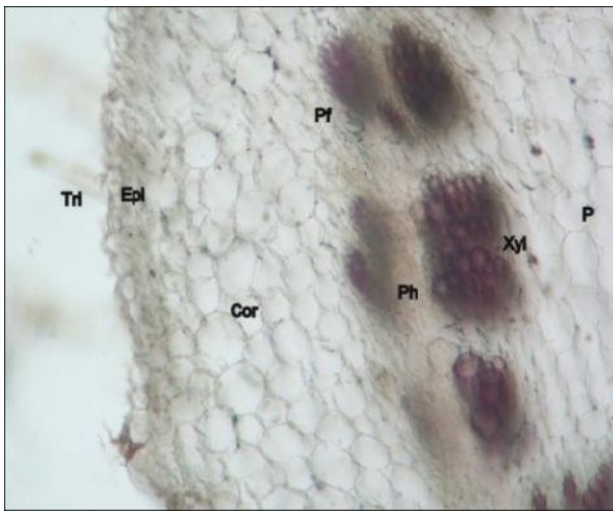


Figure 5: T.S. of stem of S. indicus

Root: The root shows on its outer side metaderm, a typical brown colored tissue. It consists of suberized cells, arranged irregularly and forms a protective layer. Radial groups of pericyclic fibers and few stone cells are seen alternating with radially arranged secretory canals in the secondary cortex. Phloem is parenchymatous and radially arranged. Medullary rays are pitted, lignified and about two to five seriate.

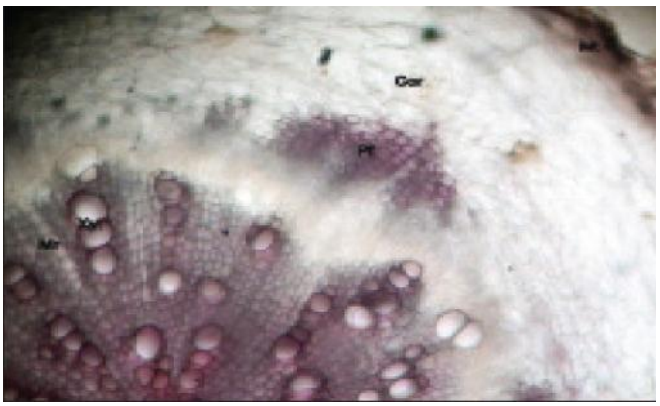


Figure 6: T.S. of root of S. indicus

Parts used: Whole plant, seeds, flowers and roots.

Phytochemistry: A sesquiterpene lactone, 7-hydroxyeudesm-4-en-6,12-olide, and a sesquiterpene acid, 2-hydroxycostic acid, along with the known compounds, β-eudesmol and ilicic acid, have been isolated from the acetone extract of S. indicus66. Three 7-hydroxyeudesmanolides and two sesquiterpenoids, cryptomeridiol and 4-epicryptomeridiol, have been isolated from this plant67.Eudesmanoids such as 11α,13-dihydro-3α,7α-dihydroxy-4,5-epoxy-6β,7-eudesmanolide, 11α,13-dihydro-7α-acetoxy-3β-hydroxy-6β,7-eudesm-4-enolide and 3-keto-β-eudesmol have been isolated from S. indicus [68]. A bicyclic sesquiterpene lactone has been isolated from petroleum ether extract of aerial parts of S. indicus69.

Ethnobotonical Claims: All the parts of the S. indicus have medicinal uses. In Ayurvedic system of medicine, the whole herb is used in insanity, tuberculous glands, indigestion, bronchitis, spleen diseases, elephantiasis, anaemia, pain in the uterus and vagina, piles, biliousness, epileptic convulsions, asthma, leukoderma, dysentery, vomiting, urinary discharges, pain in the rectum, looseness of the breasts, hemicranias 63. The whole herb is used in ayurvedic preparations to treat epilepsy and mental disorders.Hot water extract of the herb is used as an anthelminitic, as a diuretic, as a fish poison [70, 71]and as an aphrodisiac [72]. In unani, the herb is used as a tonic, laxative, emmenagogue, and also it increases the appetite, enriches the blood, lessens inflammation, cools the brain and gives luster to the eye, is good for sore eyes, jaundice, scalding of urine, gleet, biliousness, boils, scabies, ringworm in the waist, diseases of the chest. The plant is traditionally used for diarrhea [73]. The entire plant is used as an emmenogogue[74]. Hot water extract of the entire plant is used for glandular swelling of the neck and for jaundice [75].

Antihyperglycemic activity

- The 50% ethanolic extract of plant was reported to have hypoglycemic activity76. Antihyperglycemic effect of alcoholic extract of S. indicus was evaluated in the nicotinamide (120 mg/kg, i.p.) and streptozotocin (60 mg/kg, i.p.) induced diabetes in rats. Fasting plasma glucose levels, serum insulin levels, serum lipid profiles, magnesium levels, glycosylated hemoglobin, changes in body weight and liver glycogen levels were evaluated in normal and diabetic rats. Fasting normal rats treated with the alcoholic extract of S. indicus showed significant improvement in oral glucose tolerance test. Oral administration of S. indicus for 15 days resulted in a significant decrease in blood glucose levels and increase in hepatic glycogen and plasma insulin levels[77].
- The cytotoxic action of alloxan is mediated by reactive oxygen species, with a simultaneous massive increase in cytosolic calcium concentration, leading to a rapid destruction of beta cells. Experimental studies reveals that the petroleum ether extracts from Sphaeranthus indicus flower head (50, 100 and 200 mg/kg) orally administered produced a significant decrease in the blood glucose level in alloxan-induced diabetes rats. It also proves the traditional claim to S. indicus for its anti-diabetic activity [78,79].

Terminalia catappa-The tree with many names

Figure 7: Terminalia catappa tree

Tropical-Almond or Terminalia catappa is a 30 to 55-foot-tall, deciduous tree which forms a symmetrical, upright silhouette in youth with horizontal branches reaching 35 feet in width. The branches are arranged in obvious tiers, giving the tree a pagoda-like shape. As the tree grows older, the crown spreads and flattens on the top to form a wide-

spreading vase shape. Botanically Terminalia catappa (ter-mih-NAIL-ee-uh kuh-TAP-uh) it is not related to the edible almond. No doubt the tree gets it common name from the seed pods which look like large unshelled three-inch almonds and from the seed/kernel which resembles almonds.

Taxonomy

Kingdom	Plantae
Phylum	Spermatophyta
Class	Dicotyledonae
Order	Myrtales
Family	Combretaceae

Synonyms (discarded names): Phytolacca javanica, Terminalia procera

Common names: Due to its origin in tropical Asia, this species is known in English under names such as Indian almond, Bengal almond, Singapore almond, Malabar almond, Talisay almond, and of course Tropical almond. The names Sea almond, Wild Almond and Umbrella tree are also used. Throughout its native and introduced ranges in the tropics, it is known under a wide range of national or local names, e.g. Ketapang, Ebelebo and Zanmande.

Habitat and Ecology: T. catappa is a characteristic species of tropical beach forests, especially raised sandy beaches above high tide, but also rocky shores, and sometimes on the edges of mangrove swamps [80, 81]. It may also grow as a pioneer on denuded or disturbed lands up to 300 m altitude [81, 82]. In French Polynesia, it seems to have replaced the indigenous T. glabrata [83]. In Vanuatu, occasional apparently wild trees in the forest are likely remnants of former settlements or gardens [84].

Native distribution: Terminalia catappa has a natural distribution from Seychelles through India, the Andamans and adjacent islands, and throughout Southeast Asia (Myanmar, Thailand, the Malay Peninsula, Vietnam, the Phillipines, Indonesia) to Papua New Guinea and Northern Australia as far south as the Tropic of Capricorn. It is also found throughout the South Pacific Region including the Solomon Islands, Vanuatu and Fiji; as well as the high archipelagos of Polynesia and Micronesia but is possibly an aboriginal introduction to the eastern parts of this range [85]. The species is also found on China (within the Guangdong and Yunnan provinces), Taiwan, Cambodia, and New Caledonia (USDA, ARS, 2010)

Native habitat: Terrestrial (Coastal Forest), Shoreline (Mangrove Forest; Sandy Beach; Rocky Beach)

Morphology: The tree is often characterized by horizontal branches that are divided repeatedly into tiered whorls. Each tier is 3 to 6 feet apart, usually on a single erect trunk. The leader shoot may extend more than once a year. Usually a medium sized tree to about 50 feet tall. It can reach a height of 80 feet with a trunk diameter of 1 to 2 feet; these often have slight buttresses. The gray to dark gray-brown bark is fairly smooth and thin, becoming slightly fissured with age. Young fast growing trees have open crowns and discernable whorls of branches. Mature older trees have a flattened crown of medium density and less discernable branch tiers[86].

Trunk: The trunk is often buttressed, with grey bark that is slightly fissured[86].

Leaves: The leaves are alternate and crowded together near the ends of the twigs in terminal rosettes. Petioles areshort, under 1 inch, and stout. Leaf blades are thick and big, as much as 15 inches long and 6 inches wide. They are obovate, with smooth margins, and are abruptly short-pointed or rounded at the apex. New leaves have a covering of soft, appressed, brown hairs.

Figure 8: Early leaves of *Terminalia catappa*

Mature leaves are glabrous (shiny) above and very finely pubescent below. They are leathery, and dark green. They turn shades of bright yellow, red and purple before falling in the winter. The trees are briefly bare during that time. In some environments they may lose their leaves twice a year[86].

Flowers: Flowers are arranged on long slender racemes up to 6 inches long. They are 0.16 to 0.24 inches across,white or cream-colored, five-lobed. They are termed inconspicuous but are easily seen when the tree is in full bloom. One or more racemes appear at the ends of twigs. Flowers are of two kinds, male and perfect. Both types occur on a single tree, usually with the perfect flowers at the base of the raceme and male flowers directly above. Flowers of both types are greenish-white or light brown. Normally they appear in early summer and fruits follow quite late in the year. Plants usually commence flowering and fruiting within 2 to 3 years after transplanting, but this can vary with site and genotype[86].

Figure 9: The inflorescence is a long, thin, raceme

Figure 10: Fruits of Tropical Almond

Fruits: Fruits are drupes about the size and shape of an almond fruit but with a slight wing. They are 2 inches or more long and 1 inch across. Full-sized fruits are at first green and turn red, brown, or yellow at maturity.When young, the fleshy fibrous pulp surrounding the large seed is edible and sweet and slightly sourthereafter. Inside the husk there is a light brown, thick, hard stone that contains an almond-like kernelthat is also edible. In some areas, flowering and fruiting may occur throughout the year. The fruits float but the flesh rots readily and the seeds soon germinate[86].

Leaf microscopic characters:

Midrib: The T.S. of midrib shows dorsiventral structure and a distinct biconvex out line in the basal regions where as in the apical region becomes Plano convex. The T.S. (Figure 12) show single layered epidermis covered with thick cuticle. Epidermal cells of the ventral side and dorsal side are rectangular in shape and distinct thinking on radial walls. Some of the epidermal cells on the ventral sides elongate to form covering trichomes show mostly pointed end. Beneath the epidermal cells on both the sides the layers of collenchymatous cells is wider towards the ventral side which is 3-4 layers. Followed by collenchyma cells is the 6-7 layers of parenchymatous cells with angular thickening. Some of the parenchyma cells contain dark reddish brown matter in cells and rosette of calcium oxalate crystal. Next to parenchymatous layer is 1-2 layer thick walled sclerenchyma cells and groups of stone cells scattered in between. Arc-shaped vascular strands where xylem surrounded by upper and lower side by phloem. Xylem consist of metaxylem and protoxylem with protoxylem facing towards the upper epidermis. Air cavity is present in parenchymatous pith. Few thick wall cells are scattered in pith.

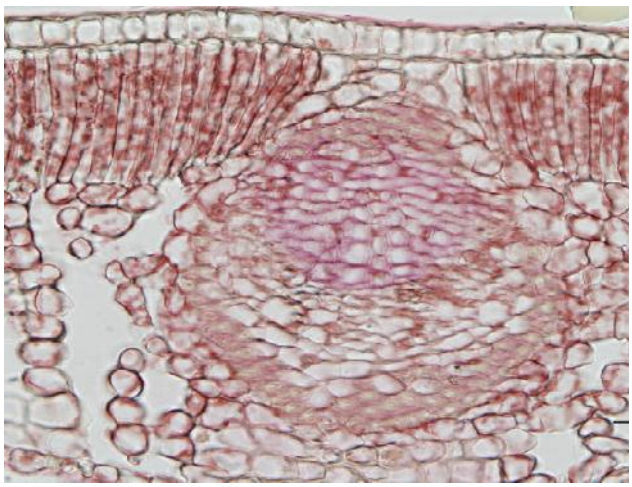


Figure 11: T.S of Terminalia catappa leaf

Lamina: TS of lamina shows single layered epidermis composed of radially elongated cells. Palisade is single layered cylindrical cells. Mesophlyll composed of loosely arranged spongy parenchyma cells .Some of the cells in the mesophyll region shows presence of calcium oxalate crystals. Vascular tissue consists of phloem at the centre and xylem around.

Petiole: TS of petiole shows single layered epidermis .Epidermal cells on both sides a strong thickening on their radial wall. Epidermal cells are followed by 3-4 layers of collenchyma cells. Collenchyma cells are bigger towards the plane region compared to the dorsal side. Followed by collenchymatous layer is the continuous layer of parenchyma composed of 5-6 layers. Some of the collenchymas cells shows presence of rosette calcium oxalate crystals .Central region of petiole is occupied by arc shaped vascular strands showing xylem surrounded by phloem on upper and lower side. Air cavity is absent in pith region of petiole[87].

Ethnobotanical Uses:

Food (Fruit & Vegetable): The fruit pulp is edible and the kernel has a flavour similar to almonds, hence the common name.

Medicinal: The leaves are also used as a topical treatment for rheumatic joints (in Indonesia and India), a decoction of the bark is used as a treatment for dysentery (Southeast Asia).

Others: The leaves and bark are used in tanning and dyeing.

Antidiabetic use:

- Methanolic and aqueous extracts of Terminalia catappa fruit exhibited significant antihyperglycemic activities in alloxan-induced diabetic rats. These extracts showed im-provement in parameters like body weight and lipid profile as well as regeneration of beta-cells of pancreas and so might be of value in diabetes treatment4.
- Some studies indicated that Terminalia catappa fruit extracts have good antidiabetic activity. Methanol and aqueous extracts of T. catappa exhibited significant anti-hyperglycemic activities in alloxan induced hyperglycemic rats without significant change in body weight. The animals can also improve the condition of diabetes as indicated by parameters like body weight and lipid profile along with serum creatinine, serum urea, and serum alkaline phosphatase. These extracts showed improvement in parameters like body weight and lipid profile as well as regeneration of beta cells of pancreas and so might be of value in diabetes treatment [4, 88].

Other uses: Indian almond is a multipurpose tree.

- The bark and leaves and sometimes roots and green fruits are locally used for tanning leather and provide a black dye, used for dyeing cottons and rattan and as ink.
- The timber is of good quality and is used for house and boat building. It is susceptible to termites.
- The seed is edible and considered delicious, and contains a pale odourless oil, similar to almond oil. The oil is employed medicinally as a substitute for true almond oil to relieve abdominal inflammations, and, cooked with the leaves, in treating leprosy, scabies and other skin diseases.
- The flesh of the fruit is also edible, but is often fibrous and not tasty in spite of the pleasant smell. The tree is often planted in avenues and gardens as a shade tree. It is very well suited for this purpose because of its pagoda-like habit, with long, horizontal branches and large leaves.
- The leaves have a sudorific action and are applied to rheumatic joints.
- The tannin from bark and leaves is used as an astringent in dysentery and thrush.
- It is also regarded as diuretic and cardiotonic and is applied externally on skin eruptions

CONCLUSION

Thus, the chapter highlights the importance of the mangrove plants and its antidiabetic activity. The potency of herbal drugs is significant and they have negligible side effects than the synthetic antidiabetic drugs. There is increasing demand by patients to use the natural products with antidiabetic activity. In recent times there has been renewed interest in the plant remedies. Plants hold definite promises in the management of diabetes mellitus.

Further, Photo-micrographical data in some studies reinforce healing of pancreas, by mangrove plant extracts, as a plausible mechanism of their antidiabetic activity. This chapter laid the foundation to study the active compounds of such anti diabetic mangrove plants that are responsible for the hypoglycemic activities. Mangroves and associated plants provide a wide domain for therapeutic application in recent years, most yet to be explored.

The pharmaceutical properties of mangrove trees provide a wide domain for medical use, requiring further studies for possible drug development. Medicines are reviewed by various research works done in India regarding the common uses of mangroves. This suggests the existence of "Parallel knowledge" in different disciplines with regards to screening of anti diabetic mangrove plants. The mode of action of anti

diabetic activity of mangrove plant extract is varies with each type of plants and its parts.

In recent years, screening of mangrove plants for a variety of biological activities is gaining importance. Mangroves are biochemically unique, producing a wide array of novel natural products. Mangrove and mangrove associates contain biologically active anti diabetic, anti inflammatory and anti microbial compounds. Mangrove forests, though essentially common and widespread, are highly threatened. Local societies along with their knowledge about the mangrove also are endangered, while they are still under represented as scientific research topics. So there is a great need to conserve the mangrove forests. With this literature we have tried to give some knowledge on the utilization patterns, and mangrove plants with broad spectrum medicinal and anti diabetic activity, which could be fused together to arrive at an innovative compounds for tackling diabetic oriented problems. Care must be taken in the development of such innovative compounds are ecologically safe and economically viable by performing a role in protection and also prevent the risk of development of novel compounds to cure this insulin deficient disorder.

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