Ethnomedicinal, Antimicrobial and Antidiarrhoeal Studies on the Mangrove Plants of the Genus Xylocarpus: A Mini Review

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Abstract

Mangroves being stress tolerant plants possess unique metabolites with significant amount of bioactive compounds which could be isolated and evaluated for possible drug development with suitable biotechnology tools. The mangrove genus Xylocarpus comprises of four species viz. Xylocarpus granatum (Koenig), X. moluccensis (lamk.) and X. mekongensis Pierre and X. rumphii. However, X. rumphii is a less abundant mangrove plant. There have been reports that different species of Xylocarpus are used ethnomedicinally for treatment of various diseases such as fever, malaria, cholera, diarrhoea, swelling of breast, elephantiasis, inflammation, dyslipidemia, pain, hyperglycaemia etc. Recent studies revealed that the extracts from different parts of the plant such as leaves, stem, bark and fruits possess phytoconstituents like alkaloids, glycosides, steroids, limnoids, terpenoids, flavonoids, tannins and other phenolics. Further, it has been established that the different solvent extracts of the plants have exhibited antimicrobial and antidiarrhoeal activities against a number of human pathogens which could be correlated to their phytoconstituents such as flavonoids, alkaloids, limnoids, tannins etc. The present study is aimed at compiling information on phytochemical, pharmacological and ethnomedicinal properties of mangrove plants of genus Xylocarpus, with a view to critically assess the legitimacy of the use of these plants for antimicrobial and antidiarrhoeal activities as well as providing directions for further research.

Keywords: Mangrove; Xylocarpus; Ethnomedicine; Phytochemical; Antimicrobial; Antidiarrhoeal

Introduction

Plants and plant based metabolites are widely used in ethnomedicinal practices around the world. Plants are rich in wide variety of secondary metabolites such as tannins, terpenoids, alkaloids, flavonoids, flananoinds, phenolics, glycosides, saponins, and steroids etc. which have been used for treatment of various diseases for ages. Like any other plant communities, the mangrove plants have also been reported for there ethnomedical uses. Mangroves are the unique plant communities inhabiting the estuarine and intertidal regions of both tropical and subtropical coasts are largely confined to the region between 30° north and south of the equator. These are salt tolerant plant communities comprising of trees, herbs, shrubs and grasses. There are about 39.3 million acres of mangrove forests in the warm coastlines of tropical oceans all over the world distributed in 112 countries and territories [1]. Out of the given total mangrove species and their associates, the number of exclusive or true mangrove species in the world is 68 and they belong to 27 genera. Approximately 55 species of mangroves from 22 genera were distributed in Indian Ocean region [2]. These plants inhabit an extremely challenging environmental abiotic stress condition enumerated by high salinity, water logging condition, high and low tides of water, high temperature, low oxygen, low nutrition, muddy anaerobic soil and strong wind conditions where other plants cannot grow. Along with these abiotic stress factors, the insects and microorganisms and other anthropological condition also contribute a large in developing the biotic stress to these unique plant community. However, these mangrove plants adapted well to these ecological hostile condition by alterations in their physiological processes resulting in the synthesis of novel chemical compounds that offer protection to these plants against various biotic and abiotic stresses mentioned above [3]. A number of these phytocompounds or secondary metabolites have significant pharmacological properties are being used traditionally for treatment of number ailments [4].

For centuries, mangroves have been traditionally used for food (fruits and nectar), feed and medicinal purposes in different parts of the world. They are well known to produce natural metabolites with diverse biological activities. Several mangrove plants viz. Acanthus ilicifolius, Aegiceras majus, Avicennia marina, A. officinalis, Ceriops cadolleana, Excoecaria agallocha, Kandelia rhedii, Nypa fruticans, Rhizophora mangle, R. mucornata and Sonneratia caseolaris are widely used by local medical practitioners in many countries like Africa, South East Asia, South America and Australia including India. These plants are used to cure some diseases like leprosy, elephantiasis, tuberculosis, malaria, dysentery, ulcers and some skin diseases [5]. The mangroves plants are reported to contain some unique class of diverse compounds that includes phorbol esters, phenolics and related compounds, steroids, triterpenes, and their glycosides, tannins, other terpenes and related compounds, flavonoids, tannins, anthocyanins, alkaloids etc [3]. A number of these compounds or secondary metabolites have significant medicinal properties that can be exploited in shaping better human health care needs.

The genus Xylocarpus consists of ethnomedicinally important mangrove plant species viz. Xylocarpus granatum, X. moluccensis, X. mekongensis, X. rumphii that are used in traditional medicine practices. Extracts of leaves, barks and fruits of these plants have been reported for various ethnomedicinal uses such as fever, malaria, inflation, dysentery, diarrhoea, cholera, abdominal problems, diabetes,
end pneumatophores or root suckers. It has green coloured fruit of on the sandy or rocky bay. The plant has well developed aerial blunt tree that grows generally on the inter-tidal silty but consolidated clay or orange of 5-7 cm in diameter. The X. mekongensis fringes of backwater creeks. They have pointed leaves, deeply serrated is a medium-sized crooked, much branched woody stalk. Almost throughout the year. Diameter of the fruit is up to 20 cm or bark, and abundant red heartwood forming well developed buttresses in distribution and abundance. X. granatum commonly known as a appears to be less common [17]. Out of these four species, X. rumphii belonging to the genus Xylocarpus genuses inhabit sandy and rocky sea-

**Taxonomical Classification**

Kingdom: Plantae
Division: Tracheophyta
Class: Magnoliopsida
Order: Sapindales
Family: Meliaceae
Genus: Xylocarpus
Species: Xylocarpus granatum, X. moluccensis, X. mekongensis

**Botanical Features**

The genus Xylocarpus consists of trees growing around littoral of the tropical Indian Ocean and extending to the Pacific Islands distributed widely in the coastal areas of South-East Asia, Australia and East Africa [15]. The genus Xylocarpus belonging to the family Meliaceae has three distinct species in India viz. Xylocarpus granatum (Koenig), X. moluccensis (lamb.) and X. mekongensis Pierre [16]. However, it has been reported that another species i.e. X. rumphii belonging to the genus Xylocarpus genus inhabits sandy and rocky seashores in the tropics like Sri Lanka, Malaysia and some parts of Australia [17]. Out of these four species, X. rumphii appears to be less common in distribution and abundance. X. granatum commonly known as a ‘cannon ball tree’ is a large spreading medium mangrove tree growing in inter-tidal silty clay soil, with rounded coriaceous leaves, smooth thin bark, and abundant red heartwood forming well developed buttresses surrounding the trunk base. Mature fruits hang on the mother plants almost throughout the year. Diameter of the fruit is up to 20 cm or slightly more, yellowish brown fruit coat, completely round with long woody stalk. X. moluccensis is a medium-sized crooked, much branched ever green tree up to 10 m tall growing generally on the sandy or rocky bay, away from the frequent tidal inundation. They are found on the fringes of backwater creeks. They have pointed leaves, deeply serrated bark and an undistinguished timber. The fruit is the size of a mandarin orange of 5-7 cm in diameter. The X. mekongensis is a medium sized tree that grows generally on the inter-tidal silty but consolidated clay or on the sandy or rocky bay. The plant has well developed aerial blunt end pneumatophores or root suckers. It has green coloured fruit of diameter generally not exceeding 15 cm. The morphological features and distribution of these plants have been summarised in (Table 1).

**Ethnomedicinal Reports**

Ethnomedicine refers to the study of traditional medicinal uses practised by different ethnic groups in concerned with the cultural interpretation of health, diseases and illness. The practice of ethnomedicine involves written documents, experience and knowledge that have been shared from generation to generation [18]. The ethnomedicinal study plays a vital role in drug discovery and anthropological research. It constitutes the scientific backbone for developing active therapeutics based on traditional medicines of different human indigenous societies.

Ethnomedicinal studies on X. granatum have been documented by several researchers. It has been reported that extracts of different parts of X. granatum are used traditionally as relief for fever including malaria, inflammation, dysentery, cholera and other abdominal problems in certain parts of the globe [19,20]. Different extracts of roots, barks [3], fruit seed coat, seed kernels [21] are used to treat cholera and treatment of diarrhoea.

X. mekongensis, another species of the genus Xylocarpus has been reported to have ethnomedicinal uses. The bark and pneumatophore of X. mekongensis possess antimalarial, antiarrhythmia and antinociceptive activities [3,22,23]. Traditionally X. mekongensis is used as an astringent and in the treatment of fever, dysentery, diarrhoea [24]. The kernel root of this plant also reported for their anti-inflammatory properties [25].

Yet another species of the genus Xylocarpus i.e. X. moluccensis is also used in traditional medicinal practices as reported by several studies. The fruit and bark of X. moluccensis is used in the treatment of fever, malaria, antiarrhythmia, antiemic, elephantiasis and swelling of the breast etc. [3]. An ointment prepared from seed ash of the plant X. moluccensis along with sulphur and coconut oil is used for treatment of itch [24]. The ethnomedicinal uses of the different species of the Xylocarpus plants have been summarized in (Table 1).

**Phytochemical Constituents**

The mangrove plants that belong to the genus Xylocarpus have shown enormous ethno medicinal potential; however, few reports are available about their active principles responsible for their biological activities. The presence of alkaloids, flavonoids, monoterpenes, tetratriterpenoids, tetratriterpenoids, limonoids, phenolic acids, steroids etc. has been reported in the leaves, stem bark and fruits of these plants [3,19]. Numerous alkaloids have been reported in the barks, roots and fruits extracts of X. granatum [26]. Four alkaloids viz. N-methyl flindersine, chelerythrine, dihydrochelerythrine, acetonid dihydrochelerythrine were isolated from the root barks of X. granatum [27]. Besides, its fruits also contain many alkaloids like xylolgranatinin, granatoin [28-30]. Flavonoids like catechin, epicatechin, kaempferol, 3-O-β-D-glucoside are also found in different parts (bark, fruits and leaves) of the plant X. granatum [19,28,31]. Similarly, the bark of X. moluccensis is reported to contain flavonoids like catechin and epicatechin [19]. X. granatum seeds are rich source of limonoid xylocarpin [32] and hispidol B [26].

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The different species of X. mekogenensis in different extracts of X. mekogenesis. Compounds like xyloccensin, xylocarpin are reported in X. mekogenesis. X. pentamer, procyanidin hexamer, procanidin decamer and procyanidin B1, procyanidin B3, procyanidin trimer, procyandinin B1, procyanidin hexamer, procyanidin pentamer, procyanidin hexamer, procyanidin decamer and procyanidin undecamer [19]. However, very few compounds are reported in X. mekogenesis. Compounds like xylocarpin, xyloccensin are reported in different extracts of X. mekogenesis [3,43]. The different species of the genus Xylocarpus along with their major phytoconstituents and bioactivity are summarized in (Table 2).

### Table 1: Botanical features, distribution and ethnomedicinal uses of Xylocarpus plants.

| Mangrove species | Features | Occurrence | Ethnomedicinal uses |
|------------------|----------|------------|---------------------|
| X. granatum      | Plant: Small to medium-sized, glabrous, evergreen tree Leaf: Paripinnate, the leaves have 1 or 2 pairs of leaflets. The leaflets are characteristically obovate with a rounded apex. The lamina is gradually tapering towards the thick, distinct petiolule. The lamina is coriaceous with a shining surface. Bark: Trunk surface is pale, smooth with its thin bark peeling off in flakes or patches Fruit: large, globose up to 20–30 cm across. Flowers: Small in axillary few-flowered cymose panicles, 4–7 cm long. Root: Erect, conical leaf bases are present but the horizontal cable roots develop into ribbon-like root system. | East Africa, South east Asia, India, Bangladesh, Burma, Ceylon Malaya and Indonesia | Bark: cholera, fever, malaria, diarrhea Leaves: microbial, diarrhoea Fruits: hyperglycaemia, dyslipidemia, diarrhoea |
| X. moluccensis   | Plant: Moderate-sized trees (5-20m in height) with well-developed woody trunk Leaf: Leaflets ovate Bark: Bark longitudinally fissured, smooth, with the bark peeling in thick dark brown narrow strips Fruit: Subglobous up to 10 cm across, with 10–15 pyramidal seeds. Flowers: The inflorescence 10 cm long. The flowers are creamy white with an attractive orange red disc Root: Horizontal cable roots produce vertical, conical, laterally compressed knee roots or pneumatophores which may grow up to 30 cm tall. | Coastal region of India, Bangladesh, Burma, Ceylon Malaya and Indonesia | Bark: fever, malaria, astrinquent, febrifuge, dysentery, diarrhoea. Leaves: bacterial, cancer and inflammation Fruits: aphrodisiac, cure for elephantiasis and swelling of the breasts, anticarcinoid. Hyperglycaemia and dyslipidemia |
| X. mekogenensis  | Plant: Tree 5-20m tall Leaf: Paripinnate, the leaves have 1, 2 or 3 pairs of leaflets. The leaflets are ovate or oblong with a pointed or blunt tip. The surface of the lamina is flat. Bark: Trunk surface is rough, brown, fissured with the bark peeling in thick dark brown narrow strips. Fruit: Subglobous up to 10 cm across, with 10–15 pyramidal seeds. Flowers: The inflorescence 10 cm long. The flowers are cream white with an attractive orange red disc Root: Horizontal cable roots produce vertical, conical, laterally compressed knee roots or pneumatophores which may grow up to 30 cm tall. | Bengal, Burma, the Andaman’s, the Malay Peninsula and Archipelago, Australia, Fiji and Africa | Bark: malaria, diarrhoea, antinociceptive activities, inflammation and oxidant Fruits: elephantiasis, preventing swelling of the breast |

### Table 2: Phytochemical constituents and bioactivity of Xylocarpus species.

| Xylocarpus species | Major Phytoconstituents | Bioactivity | Compounds Isolated | References |
|--------------------|-------------------------|-------------|--------------------|------------|
| X. granatum        | Alkaloids, Steroids, Tannins, Triterpenes, Limonoids, Flavonoids, Sapornins | Antimicrobial, Antifilarial, CNS-depressant activity, Antidiabetic, Antiinflammatory, Antimicrobial, Antiallergic, Antimicrobial, Antinociceptive, Antioxidant, Antifungal, Antiperoxidative, Antioxidant | 4-hydroxybenzoic acid, ethyl 3,4-dihydroxybenzoate, xylogranarin, granatoin, N-Methyltrypoline, β-Sitosterol, β-D-glucoside | [6-7], [14], [26-27], [33], [36-37], [40], [44-52] |
| X. moluccensis      | Alkaloids, Steroids, Tannins, Triterpenes, Proanthocyanidins, Flavonoids, Limonoids | Antiepileptic, Antioxidant, Antiradical, Antimicrobial, Antiinflammatory, Antioxidant Activity, Antileptic activity, Antioxidant activity, Antiperoxidative, Antioxidant | Procyanidin decamer, procyanidin hexamer, Catechin, epicatechin, procyanidin B1, B3, procyanidin trimer, procyanidin pentamer, procyanidin hexamer, procyanidin decamer procyanidin undecamer | [1], [13], [19], [53-55] |
| X. mekogenensis     | Tannins, Sapornins, Flavonoids, Alkaloids, Steroids | Antibacterial, Antioxidant Activity, Antineoplastic, Antioxidant activity, Antiperoxidative, Antioxidant | Xylocarpin, xyloccensin | [8-9], [56-58] |

stigmasterol, sitosterol, 28-isofucosterol. Seeds and fruits of this plant contain some important sterols like ergosterol peroxide, β-sitosterol fatty acid esters [42]. The bark of X. granatum is reported to contain procyandin B1, procyanidin trimer and pentamer. Similarly, bark of X. moluccensis are rich sources of variety of proanthocyanidins like procyanidin B1, procyanidin B3, procyanidin trimer, procyandin pentamer, procyanidin hexamer, procyanidin decamer and procyanidin undecamer [19]. However, very few compounds are reported in X. mekogenesis. Compounds like xylocarpin, xyloccensin are reported in different extracts of X. mekogenesis [3,43]. The different species of the genus Xylocarpus along with their major phytoconstituents and bioactivity are summarized in (Table 2).

### Antimicrobial and Anti diarrhoeal Activities of Xylocarpus Sp.

#### Antimicrobial activity

The phytochemicals as remedy for various ailments including microbial infections have been known for centuries which form the basis for their use in ethnomedicinal practices around the world [59]. Recently, the indiscriminate use of antibiotics has led to the emergence of multidrug resistant microbial strains; hence the search for novel antimicrobial compounds is the need of the hour.

Phytochemicals possessing antimicrobial activities can provide an alternative source as the natural products contains diversified chemical compounds that can be exploited scientifically for development of novel...
drugs. In this respect, mangrove plants can play a very important role as they offer a very rich source of valuable bioactive compounds and thus merit serious consideration for the discovery of novel drugs having antimicrobial properties. The antimicrobial properties of the mangrove plants have been recently attracted the researchers’ worldwide since the mangrove plants possess strong antimicrobial compounds (viz. flavonoids, tannins, terpenoids, coumarins, alkaloids, lectins) that may act against a broad range of disease causing microorganisms. Patra and Mohanta [60] have reported the antimicrobial activities in several mangrove plants that include Avicennia marina, A. officinalis, Brugiera gymnorrhiza, B.conjugate, B. sexangula, C. odorata, Ceriops decandra, Exoecaria agallocha, Heritiera littoralis, Rhizophora apiculata, R. mucronata, X. granatum.

The mangrove plants of genus Xylocarpus exhibited promising antimicrobial activities and are also reported for possession of several unique antimicrobial compounds. Several studies have shown that the bark, leaves and fruit extracts of the plant X. granatum exhibited effective antimicrobial activities against several Gram positive and Gram negative bacteria. The ethanol, petroleum ether, chloroform, carbon tetrachloride [10] and methanol [61,62] extracts of stem of X. granatum exhibited antimicrobial activity against various microbes like Staphylococcus aureus, S. epidermis, Shigella boydii, Proteus sp., Escherichia coli, Streptococcus pyogenes, Bacillus subtilis. Similarly, Rao and Chaitanya [47] reported the antibacterial and antifungal activities of ethanolic extracts of leaf and stem (100 mg/ml and 300 mg/ml) of X. granatum. It has been suggested that different parts of the mangrove plant X. granatum exhibit antimicrobial properties which may be due to the presence of phytoconstituents such as alkaloids, flavonoids, tannins etc. [63]

Another species of the genus Xylocarpus, i.e. X. moluccensis also possessed promising antimicrobial properties as reported by various studies. The different parts like barks [7], pneumatophores [54], fruit husk [64], leaves [56] of X. moluccensis exhibited considerable antibacterial activity against a wide range of both Gram positive and Gram negative bacterial strains that include E. coli, Enterobacter aerogenes, Pseudomonas aeruginosa, Salmonella typhi, S. boydii, S. dysenteriae, S. flexneri, S. sonneli, Staphylococcus aureus, Staphylococcus epidermidis, S. pyogenes and Vibrio cholera, Klebsiella pneumoniae, Enterobacter aerogenes and Pseudomonas aeruginosa.

Amongst the three species of Xylocarpus, X. mekongensis have been least reported for its antimicrobial activities. However, Ahmed et al. [65] reported the antibacterial activity of different solvent extracts of bark of X. mekongensis against various bacterial strains viz. Vibrio cholera, S. flexneri, S. boydii, Salmonella typhi, S. paratyphi and S. aureus. The ethyl acetate and chloroform extracts of bark showed relatively higher antibacterial activity amongst the different solvent extracts studied. The details of the antimicrobial compounds from the different Xylocarpus species are described in (Table 3).

The antibacterial property [66,67] of the different species of the mangrove genus Xylocarpus can be attributed to the presence of different secondary metabolites like flavonoids, saponins, polyphenols. Some important antimicrobial phytochemicals isolated from the mangrove plants of genus Xylocarpus have been included in (Figure 1).

### Antidiarrhoeal activity

According to WHO census for developing nations, diarrhoea remains a major cause of infant mortality and morbidity [68]. Though various drugs are available for treatment of diarrhoea still numerous side-effects (e.g. abdominal discomfort, dry mouth, nausea, constipation and headache) are associated with these drugs. In comparison to conventional drugs, numerous herbal antidiarrhoeal remedies from various medicinal plants are available having lesser side effects and better efficacy. The bioactive compounds from these plants exert their antidiarrhoeal activity by decreasing the gastrointestinal motility as well as the secretions in vivo [69]. Phytoconstituents like tannin, tannic acid, flavonoids, alkaloids, sesquiterpenes,  

| Plant name | Plant part (s) used | Test method | Compounds identified | References |
|------------|--------------------|-------------|----------------------|------------|
| X. granatum | Ethanol extract of stem bark, methanolic extracts of rootlet and shoot | Agar disc diffusion method | Xyloccensin, procyanidin B3, catechin, epicatechin, procyanidin B1, procyanidin trimer, procyanidin pentamer, xylocarpin, N- methylflindersine xylogranatins A-D | [10], [19], [27], [48], [61], [65-66] |
| X. moluccensis | Hexane, Benzene, Chloroform, Ethyl Acetate, Methanol, Acetone, Ethanol and Water extracts of leaves and stem; methanol extract of fruit husk; ethanol extracts of the pneumatophores | Agar disc diffusion method | flavonoids, alkaloids and glycosides | [56], [63-64] |
| X. mekongensis | methanol, ethyl acetate and chloroform extracts of bark | Agar disc diffusion method | Saponins, tannins, flavonoids | [56] |

Table 3: Antimicrobial activities of Xylocarpus species.

![Figure 1: Structure of some antimicrobial phytoconstituents reported from Xylocarpus sp.](Image)
diterpenes, terpenes and terpenoids are present in many plants that may contribute to antidiarrhoeal activity. As part of the continuing research on antidiarrhoeal activity, mangroves plants have not been left out. Different mangrove species like *Carapa moluccensis*, *C. obovata*, *H. littoralis*, *R. apiculata*, *R. mangle*, *X. garantum*, *X. moluccensis* and *X. mekongensis* have been reported to exhibit antidiarrhoeal activity [3].

It has been reported that the extracts of different parts of two *Xylocapus* species such as *X. granatum* and *X. moluccensis* are traditionally used for treatment of diarrhea. The ethanolic bark and leaves extracts of *X. granatum* showed antidiarrhoeal activity in number diarrhoeal animal models. They were found to exhibit significant antidiarrhoeal activity in a dose dependent manner [62]. The purging indices and percent purging indices for bark extracts of *X. granatum* were reported to be 32.09, 22.75% (500 mg/kg) and 14.07, 10.30% (1000 mg/kg) and for leaves extract as 51.56, 40.66% (500 mg/kg) and 17.62, 28.83% (1000 mg/kg) respectively. The decreased percent purging indices represent the potential antidiarrheal activity of bark and leaf extracts. In another experiment, the methanol extracts of *X. granatum* bark has been reported for their antidiarrhoeal activities in experimental castor oil and magnesium sulphate induced by diarrhoeal mice. The methanol extract showed dose-dependent antidiarrhoeal activity in both models at 250 and 500 mg/kg dose as evident by reduced number of faeces and total number of diarrhoeic faeces. The anti-diarrhoeic activity of these extracts may be due to antisecretory mechanism, decreased water reabsorption or delayed gastrointestinal transit [11]. Lakshmi et al. [70] also reported that fruit seed coat of *X. garantum* showed promising antidiarrhoeal activity at 500 mg/kg dose level in castor oil induced diarrhoeal mice model. The ethanol extracts of the fruit on further fractionation leads to isolation of many bioactive molecules [71] like gedunin, photogedunin, palmitic acid as listed in (Table 4).

Another species of the mangrove plant that belongs to the *Xylocapus* genus i.e. *X. moluccensis* is also reported for it’s antidiarrhoeal activities. The methanol bark extracts of *X. moluccensis* exhibited significant antidiarrhoeal activity in castor oil and magnesium sulphate induced diarrheal mice models at 250 and 500 mg/kg doses [21,22]. Structures of some important antidiarrhoeal compounds isolated from *Xylocapus* plants have been included in (Figure 2).

### Possible Mechanism of Action

Although there are very few reports are available on the on the isolated compounds from the *Xylocapus* species, but assumptions can be made about the possible mechanism of action of these mangrove isolates on their antibacterial and antidiarrhoeal activities. The *Xylocapus* plants are known for the occurrence of a characteristic compound called limonoids that have a wide spectrum of biological activities, particularly insecticidal action [72]. Some of the other phytochemical compounds such as glycosides, saponins, tannins, flavonoids, terpenoids, and alkaloids are also reported to have antimicrobial activity [63,73]. The phytochemical screening of these *Xylocapus* plants have shown the presence of diverse class of compounds like alkaloids, terpenoids, tannins, glycosides, saponins, steroids, coumarins etc. which may be responsible for its antimicrobial activities against a wide range of microbes including Gram positive and Gram negative bacteria, yeast, fungi [60].

Diarrhoea is usually a result of gastrointestinal infection, which can be caused by a variety of bacterial, viral and parasitic organisms. Further, disturbances in the transport of electrolytes and water in the intestines give rise to diarrhoea leading to increased luminal osmolarity, increased electrolyte secretion, decreased electrolyte absorption and deranged intestinal motility causing a decreased transit time [73]. Studies on *X. granatum*, and *X. moluccensis* revealed that these plants are rich in potential antidiarrhoeal bioactive compounds like tannins, tannic acid, flavonoids, alkaloids, sesquiterpenes, diterpenes, terpenes and terpenoids [21] that can be utilized in antidiarrhoeal drug development [69]. The complex content of chemicals derived from these plants may have multiple targets of action and might therefore have several potential effects against diarrhoeal disease. The involvement of synergistic effects of astringent and antibacterial effect in combination with decreased intestinal movements might be responsible for their antidiarrhoeal potentials.

| Plant name | Plant part(s) used | Test method | Compounds identified | References |
|------------|-------------------|-------------|----------------------|------------|
| *X. granatum* | Ethanol extract of stem bark, leaves and fruits | • Castor oil induced diarrhoeal model | Gedunin, Photogedunin, Palmitic acid, Flavonoids, tannins, saponins, anthraquinone | [11], [61], [70] |
| *X. moluccensis* | Methanol extracts of bark | • Magnesium sulphate-induced diarrhoea models. • Gastrointestinal motility model • The disc-diffusion method | Flavan-3-ols and procyanidins | [21], [22] |
| *X. mekongensis* | NR | NR | NR | NR |

Table 4: Antidiarrhoeal activities of *Xylocapus* species.

![Figure 2: Structure of some antidiarrhoeal phytoconstituents reported from *Xylocapus* sp.](image)
Future Prospects and Conclusion

The mangrove plants inhabit a unique ecological habitat exemplified by various stress conditions like high salinity, water logging, low oxygen condition, light stress, low nutrition conditions are reported to be biochemically unique and possess several bioactive compounds. Compounds isolated from the mangrove species have the potential to act as lead compounds for drug discovery. The different mangrove species of *Xylocarpus* possess significant pharmacological activities which can be pharmacologically exploited. These plants have shown promising therapeutic applications in treatment of various ailments particularly in microbial infection and diarrhoea as reported by various ethnomedicinal and experimental studies. Even though extracts from mangroves and mangrove-associated species possess therapeutically activity moieties against a number of diseases, the specific metabolites responsible for these bioactivities are remained to be elucidated.

The bioactive compounds isolated from mangrove plants like *Xylocarpus* have advantages over the conventional medicines as the ethnomedicinal studies suggested that the diversified chemical content from these plants have multiple targets of action and might therefore have several potential therapeutic effects against diarrhoeal diseases. The involvement of synergistic effects of astringent and antibacterial effect of these plant extracts in combination with decreased intestinal movements may play vital role for their anti diarrhoeal potentials. However, safety, adverse effects and toxicity assays of these plant products has to be carried out in order to have a basis of these mangrove plant species to be recommended as phytomedicines useful against diarrhea. Though many plants have been used in folklore medicine worldwide, recently, extracts from mangroves and their associated species have been proven to possess antimicrobial activities against a number of human, animal and plant pathogens.

The information presented in this review clearly indicates that the different mangrove species of *Xylocarpus* viz. *X. granatum*, *X. moluccensis* and *X. mekogenesis* possess pharmacologically active compounds such as alkaloids, flavonoids, limonoids, terpenoids, phenolic glycosides etc. having enormous therapeutic potential in alleviating a number of ailments. However, bioactivity guided isolation of these phytoconstituents is needed to establish the activity-structure relationship that may reveal the bioactive compounds responsible for different pharmacological activities in general and antimicrobial and antidiarrhoeal activities in particular.

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