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Botany, uses, chemistry and bioactivities of mangrove plants IV: *Avicennia marina*

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Introduction

Globally, there are eight species of *Avicennia* with five species (*A. alba*, *A. integra*, *A. marina*, *A. officinalis* & *A. rumphiana*) in East Africa and Indo-Pacific, and three species (*A. bicolor*, *A. germinans* & *A. schaueriana*) in the New World and West Africa (Duke, 2006; Spalding *et al*., 2010). Of these species, the geographical distribution of *A. marina* is the widest, ranging from East Africa, Middle East, South & Southeast Asia to Papua New Guinea, Australia and the North Island of New Zealand. In Australia, three varieties of *A. marina* namely *australasica*, *eucalyptifolia* and *marina* are recognised (Duke, 2006), and in New Zealand, the variety is *resinifera* (Tomlinson, 1986). In a review on the natural products from true mangrove flora: source, chemistry and bioactivities, Wu *et al.* (2008) have included *acutissima*, *anomala*, *intermedia* and *typical* as varieties of *A. marina*. Among the *Avicennia* species, *A. marina* shows remarkable adaptations to a wide range of temperature, tidal inundation, rainfall, salinity and substrate type (Duke, 2006; Maxwell, 2015).

Botany and Uses

Avicennia marina (Forssk.) Vierh. of the family Avicenniaceae is a mangrove tree that can grow more than 10 m in height (Aksornkoae *et al*., 1992; Kitamura *et al*., 1997; Giesen *et al*., 2007). The species produces numerous erect pencil-like pneumatophores with lenticels. The bark is greenish-grey, mottled and peeling in patches. Leaves are elliptic-oblong, pale green on the lower surface with acute to round apex (Figure 1). Inflorescences are a dense spike bearing 8–14 flowers with yellow to orange petals. Flowering may occur throughout the year. Propagules of *A. marina* are greyish-green and heart-shaped with an apex that is rounded or having a short beak.

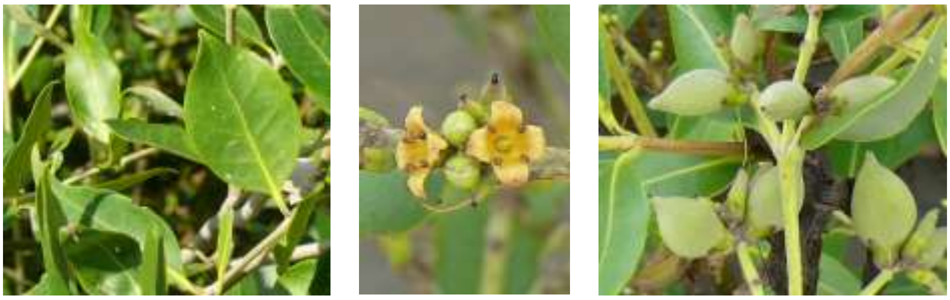


Figure 1 Leaves (left), flowers (middle) and propagules (right) of *Avicennia marina.*

In traditional medicine, the leaves, fruits and bark of *A. marina* are used to treat skin diseases (Fauvel *et al*., 1993) while the stems are used to treat rheumatism, small pox and ulcers (Bandaranayake, 1998). Seeds and seedlings are cooked and eaten as vegetable (Hong & San, 1993; Hu, 2005; Giesen *et al*., 2007).

An important use of mangroves is for livestock fodder and forage. Coastal populations in Gujarat, India, collect the foliage of *A. marina* as fodder for their cattle (Baba *et al*., 2013). Collection is done mostly by the womenfolk (Figure 2). Propagules are also collected and fed to the calves. Livestock owners noted an increase in milk production, which rendered them income gains from increased sale of milk and not having to buy fodder from the market.

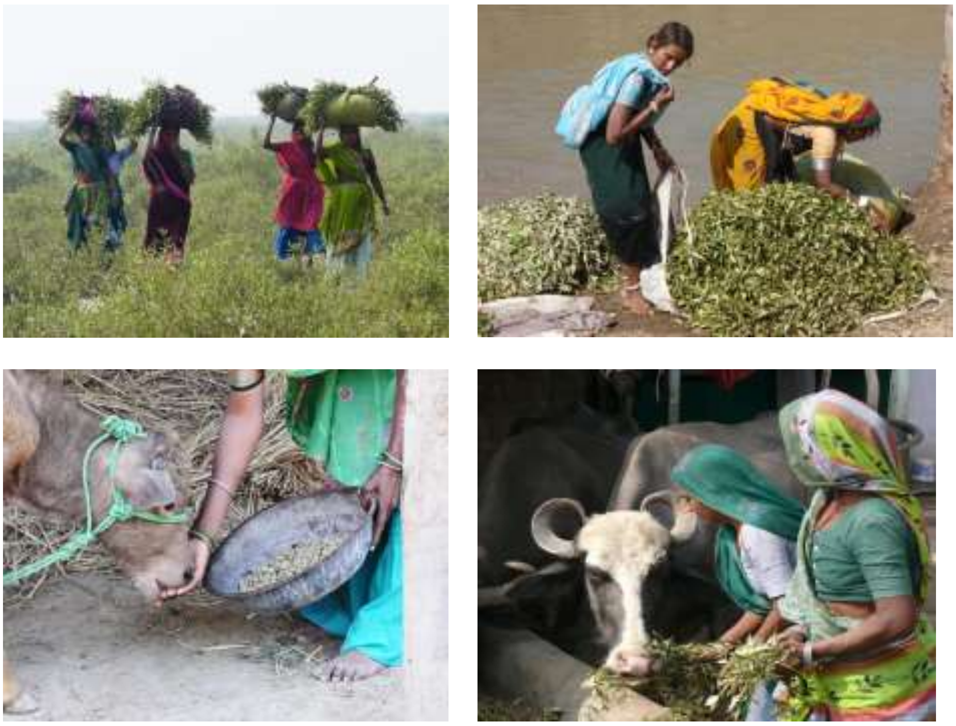
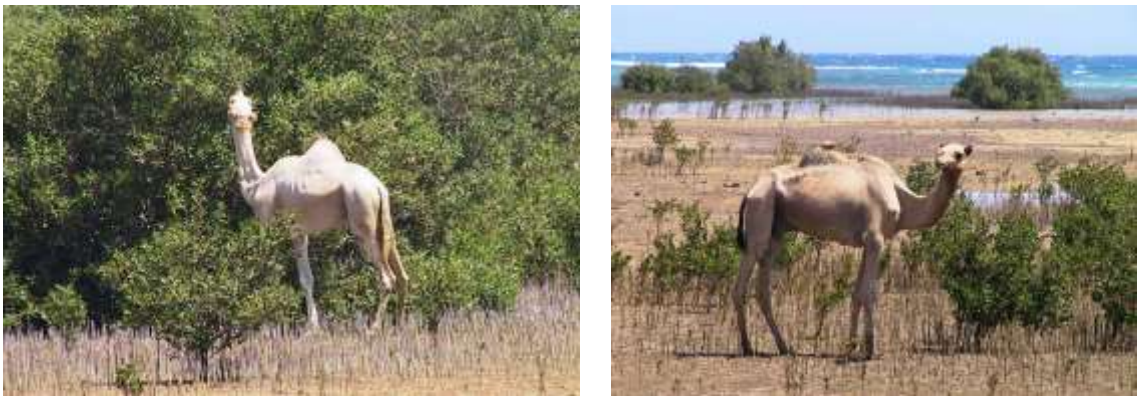


Figure 2 Women in Gujarat collect and wash the foliage of *A. marina* in a nearby river (top row). Back home, the foliage is fed to cattle and propagules to calves (bottom row).

In the Red Sea and Gulf of Aden, *A. marina* mangroves serve as livestock forage for camels (PERSGA, 2004). Figure 3 shows camels grazing foliage of *A. marina* at Nabq Managed Resource Protected Area in South Sinai, Egypt. In the Indus delta of Pakistan, some 16,000 camels and 11,000 cattle feed on mangrove foliage (Khalil, 2000). Camel and cattle browsing in large herds has become a major problem causing degradation of the mangrove stands. A study conducted in South Africa on cattle browsing of *A. marina* trees reported slower and stunted tree growth, and lower frequency of flowering and fruiting (Hoppe-Speer & Adams, 2015).



Photos by Emad H. Al-Aidy

Figure 3 Camels grazing foliage of *A. marina* in South Sinai, Egypt.

In a study on the use of mangrove foliage as fodder in Saudi Arabia, results showed that the protein content of *A. marina* leaves (13%) was more than twice that of *Rhizophora mucronata* leaves (6.3%) with comparable values in lipid, carbohydrate and ash contents (Khafaji *et al*., 1993). Protein content in leaves (13%) was 1.9 times higher than stems (7%) and 3.3 times higher than roots (4%).

In New Zealand, cattle in dairy farms located adjacent to mangrove stands would selectively graze on the foliage of *A. marina* (Maxwell & Lai, 2012). Feeding trials showed that the cattle had a strong preference for mangrove foliage used as salt enrichment nutrient (Figure 4). Typically, once the cattle had made their herbage choice, they would consume all the available foliage before feeding on the pasture or hay.

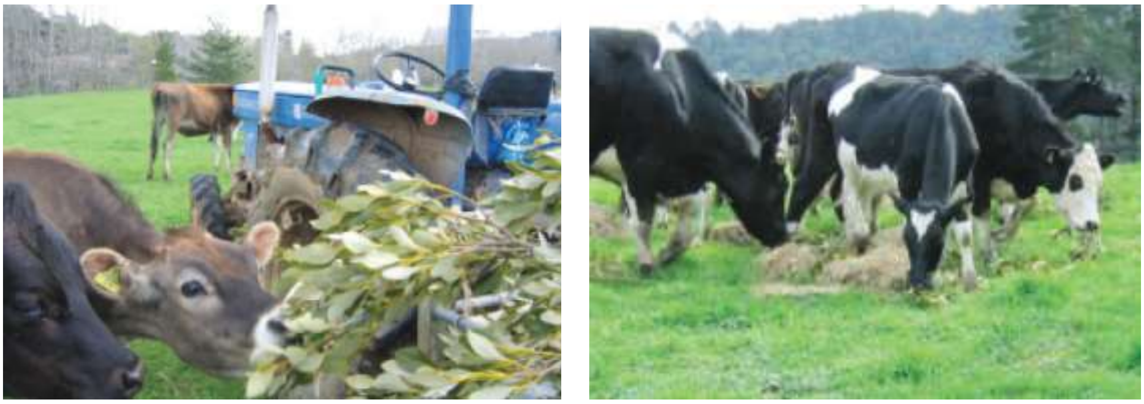


Figure 4 Calves (left) and cattle (right) are particularly fond of feeding on the foliage of *A. marina.*

Avicennia foliage has 0.2–0.3% salt content (Maxwell, 1993). In general, the salt content of mangrove leaves increases with leaf age and succulence (Gray *et al*., 2012). The Na^+ concentration of *A. marina* leaves in Sri Lanka was reported to be 1.4 and 0.6 mmol/g during the high and low tides, respectively (Dissanayake & Amarasena, 2009). Comparable values of 1.3 and 0.8 mmol/g were observed in leaves of *A. officinalis*. A rare and intriguing encounter of rice paper butterflies (*Idea leuconoe*) licking salt exuded from cracked branches of *Bruguiera gymnorhiza* in Iriomote, Japan (Baba *et al*., 2012), reinforces the importance of salt to mangrove fauna.

During the duck-hunting season in New Zealand, hunters would camouflage their boats while waiting for flocks of wild ducks to fly over (Baba *et al*., 2013). This remains an unclassified and irregular use of *A. marina* foliage.

Chemistry

Leaves: Leaf extracts of *A. marina* yielded phenylpropanoid glycosides of acteoside, derhamnosylacteoside and isoacteoside (Fauvel *et al*., 1993), and naphthoquinones, flavonoids, phenolic acids and steroids of avicequinones B & C, 5-hydroxy-4’7-dimethoxyflavone, quercetin, kaempferol, lupeol, betulin, β-sitosterol, ergost-6,22-diene-5,8-epidioxy-3β-ol and *P*-methoxycinnamic acid (Jia *et al*., 2004), and five new iridoids of marinoids A–E (Sun *et al*., 2008).

Aerial parts: From aerial parts of *A. marina*, two new flavonoids of luteolin 7-*O*-methylether 3’-*O*-β-D-glucoside and its galactoside analogue along with known luteolin 7-*O*-methylether, chrysoeriol 7-*O*-glucoside and isorhamnetin 3-*O*-rutinoside were identified (Sharaf *et al*., 2000). Two new and one known iridoid glucosides together with triterpenoids and flavonoids of acteoside, isoacteoside, syringaresinol, 5,7-dihydroxy-3’,4’,5’-trimethoxyflavone, betulinic acid, betulin, lupeol, indolyl-3-carboxylic acid, avicequinone C and kaempferol were also isolated (Feng *et al*., 2006, 2007).

Twigs: Naphthoquinones isolated from the twigs of *A. marina* by Han *et al*. (2007) included avicennones A–G, avicequinones A & C, avicenols A & C, and stenocarpoquinone B.

Fruits: Methyl palmitate (42%) is the predominant components of the essential oil from fruits of *A. marina* (Huang *et al*., 2009). The fruit extract afforded three new phenylethyl glycosides of marinoids J–L, and a new cinnamoyl glycoside of marinoid M (Gao *et al*., 2014).

Bioactivities

Antimicrobial activity: Avicequinones A & C, stenocarpoquinone B, and avicennones E & F from the twigs of *A. marina* exhibited significant antimicrobial activity against four *Mycobacterium* species, *Staphylococcus aureus* and *Candida albicans* (Han *et al*., 2007). Leaf extracts of *A. marina* displayed antibacterial activity against *Escherichia coli*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae* and *S. aureus* with the methanol extract being the most effective followed by ethyl acetate extract (Devi & Rajkumar, 2013).

Cytotoxic activity: The mixture of avicennones E–F, avicequinone C and stenocarpoquinone B from the twigs of *A. marina* also showed strong antiproliferative activities against L-929 mouse fibroblast and K562 human leukemia cell lines (Han *et al*., 2007). Tested against BT-20 human breast cancer cells, luteolin 7-*O*-methylether 3’-*O*-β-D-glucoside and luteolin 7-*O*-methylether from the aerial parts of *A. marina* showed moderate cytotoxicity (Sharaf *et al*., 2000). The leaf extract of *A. marina* displayed cytotoxicity against MCF-7 and MDA-MB 231 breast cancer cells *via* apoptosis (Momtazi-borojeni *et al*., 2013; Esau *et al*., 2014). A phenethylol and sesquiterpenoid isolated from an endophytic fungus *Penicillium* sp. FJ-1 of *A. marina* were reported to inhibit Tca8113 and MG-63 human cancer cells (Zheng *et al*., 2014). Similarly, brocazines isolated from *Penicillium brocae* MA-231 of *A. marina* also showed cytotoxic activity against tumour cell lines (Meng *et al*., 2014).

Maxwell (1971) observed that tannin-polyphenols exuded from *A. marina* leaves inhibited the maturation of *Culex* mosquitoes and Primavera *et al.* (2004) reported that smoke from dried branches act as mosquito repellent. A dietary administration of aqueous leaf extract of *A. marina* (1% and 4%) improved the immune status and survival rate of clown fish challenged with *Vibrio alginolyticus* after six and eight weeks (Dhayanithi *et al*., 2015). A toxicological study conducted on leaf extracts of *A. marina* in rats showed that oral doses up to 4.0 g/kg for three consecutive days did not affect either body or liver weights (Ali & Bashir, 1998).

Other biological and pharmacological activities of *A. marina* included anti-bacteriophage (Khafagi *et al*., 2003), anti-viral (Zandi *et al*., 2009; Namazi *et al*., 2013; Behbahani *et al*., 2013), anti-arthritis (Gandomani & Malatib, 2014a) and antinociceptive (Gandomani & Malatib, 2014b) properties.

Conclusion

Of the *Avicennia* species, *A. marina* has the widest geographical distribution, and shows remarkable adaptations to a wide range of temperature, tidal inundation, rainfall, salinity and substrate type. From being a fodder and forage for camels and cattle, *A. marina* has progressed to become a medicinal plant with anticancer, mosquito larvicidal, mosquito repelling, immuno-protective, anti-bacteriophage, anti-viral and anti-arthritis properties.

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