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New Guinean mangroves – Traditional usage and chemistry of natural products

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With 13 Figures and 4 Tables

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Abstract

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Mangroves belong to those ecosystems that are presently in danger of being extinguished or at best overexploited over most of their distribution range. They are used a.o. as sources of timber of wood for paper and pulp production or for coastal aquaculture. To fully assess their intrinsic value and to maintain their role in coastal protection as well as their high and at some taxonomic levels still largely unknown biodiversity it appears to be useful to look into other potential uses of mangroves. One of these might lie in the fact that they have been used traditionally as sources of non-wood forest products, food and pharmacological agents. In this presentation we combine ethnobotanical and ethnopharmacological aspects of New Guinean mangroves with information on the natural products chemistry of the same species. So far limited attempts have been made to chemically characterise mangroves in New Guinea. Hence most of the chemical data will be taken from other areas.

Introduction

Mangrove forests fringe large parts of the New Guinean coast and form very extensive stands e.g. along the Gulf of Papua, near Lae and Madang and in the Sepik estuary. They also occur elsewhere in smaller stands. A total areal coverage of 4,100 km² has been estimated by BLASCO et al. (2001). Most of the mangrove area is very sparsely populated and almost virgin. The general zonation of the mangrove communities appears to be similar to that of south-east Asia and is dominated by Rhizophoraceae. In the Papuan Gulf, stands of *Rhizophora* spp. and *Bruguiera* spp. are most common and frequently attain large dimensions. An overview of Papua New Guinean mangroves has been given by PERCIVAL & WOMERSLEY (1975).

Traditional uses of mangroves encompass a large variety of applications as summarised in Tab. 1.

Among these uses application of plant parts, extracts or other types of preparations in medical and health care have received relatively little attention in New Guinea. POWELL (1976), in his review of New Guinean ethnobotany, does not mention mangroves except for the use of wood for building purposes. In other mangrove areas considerably more efforts have been devoted to ethnobotanical and ethnopharmacological research (e.g. DRURY 1873, COMBS 1897, WEISS 1973, DAGAR & DAGAR 1986, ALARCON-AGUILARA et al. 1998, PERERA et al. 2001, ZARIDAH et al. 2001, BANDARANAYAKE 2002). In fact, some of the collection of traditional knowledge and usage of mangroves dates back to the beginning of the 20th century and even earlier (e.g. DRURY 1873, PECKOLT 1904, HECKEL 1912, POBEGUIN 1912, QUINONES & PUNCOCHAR 1943, LOUSTALOT & PAGAN 1949).

Mangroves serve as sources of raw material (Tab. 1) including traditionally used dyes (e.g. HEIM & SCHELL 1923, GREENWAY 1941, STEHLÉ 1941). In Papua New Guinea 20,000 tons

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Table 1: Selected traditional uses of mangroves.

species	food use	medical use	other use
Acrostichium speciosum	stems eaten after roasting		axe handles, digging sticks
Avicennia marina	fruit eaten after treatment, cooking flavour, honey	fish stings, ringworms, sores, boils, skin, ulcers, scabies, contraceptive	Shields, charcoal, fuel, construction timber, tanning, wood smoke as mosquito repellent
Brugiera spp.	mangrove worm, hypocotyls after treatment	blood pressure control, eye lotion	Boomerangs, paddles
Camptostemon schultzii		skin sores, scabies, leprosy sores	canoes
Ceriops spp.		malaria symptoms, sores and infections, scabies	spear shafts
Excoecaria agallocha	nectar	fish stings, leprosy	firewood
Lumnitzera spp.	nectar	itch treatment	digging sticks, spears
Nypa fruticans	mud mussels, unripe seeds eaten, sugar, alcohol, vinegar		roof thatching
Rhizophora spp.	roots - famine food, mangrove worm, honey	febrifugal, expectorant, antihemorrhagic, leprosy, sore throat, stomatitis, aphrodosiac, haematuria, skin sores	boomerangs, spears, tanning, timber
Sonneratia alba	nectar	skin disorders	carving
Xylocarpus spp.		Acne, insect bites, dysenteric fever	oil for lamps

Data source: SAENGER et al. (1983), KUNSTADTER et al. (1986), MARSTALLER (1997), www1, www2, www3

of bark were used for tannin production in 1956 (www4), apparently the only estimate available. Besides being source for wood and non-wood products mangrove ecosystems provide a number of important ecological services which include coastal protection, control of riverbank and shoreline erosion and trapping of riverborne particulate material. This role became particularly noticeable after the December 2004 tsunami in SE Asia when mangrove protected coasts showed much less damage than those with no or only degraded mangrove protection (e.g. DAHDOUH-GUEBAS et al. 2005, WEINER 2005).

They are important feeding, shelter, breeding and nursery grounds for coastal fish and crustacean species thereby providing and sustaining the livelihood for coastal communities. Mangrove ecosystems act as buffers for terrestrial organic and inorganic nutrients as well as inorganic sediments thus playing a vital role in the health of seaward coral reefs. With an estimated global area of ~18×10^6 ha (SPALDING et al. 1997) they are important carbon sinks and hence have an influence on the global and regional climates. In addition mangroves are used extensively for recreation and (eco)tourism activities.

In view of the fact that mangrove areas are rapidly declining due to a.o. coastal aquaculture such as shrimp ponds or clear-cutting for e.g. paper and pulp production (e.g. KELLEHER et al. 1995, VALIELA et al. 2001, THORNTON et al. 2003) attempts to collect traditional knowledge on these plant species is an urgent necessity (MILES et al. 1999). In the present communication we review published information on the use of New Guinea mangroves as pharmaceutical agents combining this, where possible, with chemical information obtained from other mangrove regions. Although a total of 37 mangrove species has been reported to occur in New Guinea the review will focus on the dominant species only (Tab. 2). Due to its economic importance the mangrove palm will be addressed also.

For a number of species considered below data on triterpenoids and steroids have been presented by GHOSH et al. (1985), MISRA et al. (1984, 1985), HOGG & GILLAN (1984) and RAFII et al. (1996). UV-absorbing phenolic compounds have been found by LOVELOCK et al. (1992) without, however, a detailed chemical characterisation of these. Information on hydrocarbons and wax esters has been provided by HOGG & GILLAN (1984), MISRA et al. (1986, 1987) and RAFII et al.

Table 2: Dominant mangrove species in New Guinea considered in this review.

Aegiceras corniculatum (Mysinaceae)
Avicennia marina (Avicenniaceae)
Bruguiera gymnorhiza (Rhizophoraceae)
Bruguiera parviflora (Rhizophoraceae)
Excoecaria agallocha (Euphorbiaceae)
Lumnitzera racemosa (Combretaceae)
Rhizophora mucronata (Rhizophoraceae)
Rhizophora mangle (Rhizophoraceae)
Xylocarpus granatum (Meliaceae)
Nypa fruticans (Palmae)

(1996). In a study of lipid composition in relation to salinity stress OKU et al. (2003) noted the predominant occurrence of sterol esters among polar lipids, sterols, triacyl glycerols, wax esters, sterol esters and several unknown compounds.

PREMANATHAN and co-workers (PREMANATHAN et al. 1992, 1993, 1994a, b, 1995, 1996) tested a number of Indian marine plants, among them several mangrove species, for antiviral activity against Newcastle disease, vaccinia, Semliki Forest, encephalomyocarditis and hepatitis viruses. Bark extract of *Rhizophora mucronata* and leaf extract of *Bruigiera cylindrica* were highly effective against all viruses tested.

PREMANATHAN et al. (1996) reported anti-HIV activity of mangrove bark and leaf extracts to be effective against infected MT4 cells. Five extracts (bark of *Rhizophora mucronata* and leaves of *Excoecaria agallocha, Ceriops decandra, Rhizophora apiculata, Rhizophora lamarckii*) completely inhibited the virus adsorption to the cells. Later the same group identified a polysaccharide from the leaf of *R. apiculata* as active agent (PREMANATHAN et al. 1999). Except for bulk carbohydrate composition no further attempts were made towards a structural characterisiation.

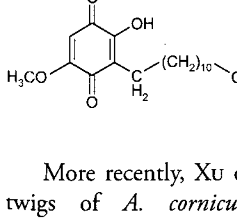
The chemistry of floral scent of a number of mangrove species has been investigated by AZUMA et al. (2002). A total of 61 compounds were found these being a.o. fatty acid and carotenoid derivatives or terpenoids. The chemical profiles of individual species appear to be unique ranging from only two compounds in *Kandelia candel* to 25 in *Nypah fruticans*. All compounds characterised have been found before in floral scents of other angiosperms.

Gallotannins from some mangrove species which have been traditionally used as tanning agents (e.g. HILLIS 1956) show marked interspecific concentration differences and pronounced seasonal variations (RAVI & KATHIRESAN 1990).

Aegiceras corniculatum

From the bark of the species a compound has been isolated that is used as piscicide (5-*O*-methylembelin; **1**; GOMEZ et al. 1989).

The desmethylated compound embelin (**2**, n = 10) exhibits orange colour but is otherwise according to HENSENS & LEWIS (1966) without biological activity. On the other hand, antifertility effects of embelin isolated from *Embelia ribes* has been described (KRISHNASWAMY & PURUSHOTHAMAN 1980a, b). Both embelin and 5-*O*-methylembelin (**1**) are potent inhibitors of hepatitis C virus protease (HUSSEIN et al. 2000). Rapanone (**2**, n = 12) exhibits mild antioxidant and potent anti-inflammatory action (OSPINA et al. 2001).



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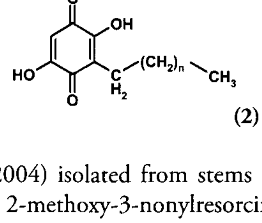
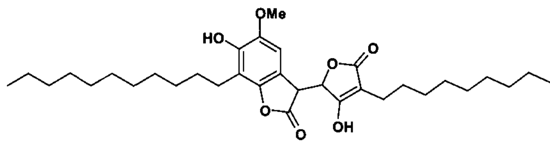


(2)

More recently, XU et al. (2004) isolated from stems and twigs of *A. corniculatum* 2-methoxy-3-nonylresorcinol, 5-*O*-ethylembelin, 2-*O*-acetyl-5-*O*-methylembelin, 3,7-dihydroxy-2,5-diundecylnaphthoquinone, 2,7-dihydroxy-8-methoxy-3,6-diundecyldibenzofuran-1,4-dione, 2,8-dihydroxy-7-methoxy-3,9-diundecyldibenzofuran-1,4-dione and 10-hydroxy-4-*O*-methyl-2,11-diundecylgomphilactone (**3**). 5-*O*-ethylembelin and 5-*O*-methylembelin exhibited activity against HL-60, Bel7402, U937, and Hela cell lines.



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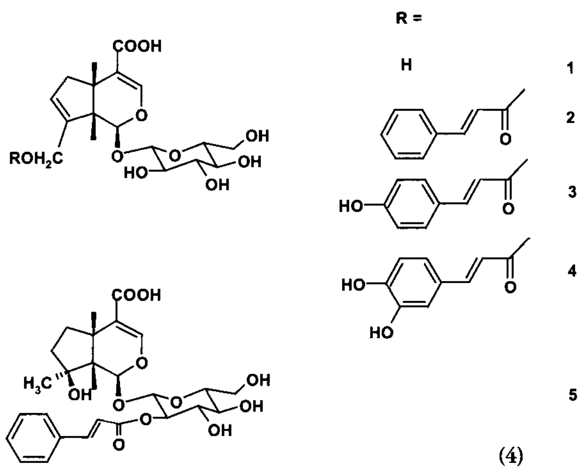
Avicennia marina

Roots of this species are used in New Guinea to ease pain from fish stings. The pneumatophores are chewed and the resulting pulp is put on the sting. In other parts of the world leaves are used as aphrodisiac and to alleviate tooth ache. Astringent effects have been ascribed to this species. *Avicennia* is a good bee plant giving an excellent honey.

Tannins (RAJANGAM 1988, RAVI & KATHIRESAN 1990), triterpenoids (BELL & DUEWELL 1961, RAFII et al. 1996), flavonoids (SHARAF et al. 2000), iridoids [**4**; cinnamoyl (**4.2**), *p*-coumaryl (**4.3**) and caffeoyl (**4.4**) derivatives of geniposidic acid (**4.1**) and the cinnamoyl derivative of mussaenosidic acid (**4.5**), SHAKER et al. 2001] and phytoalexins **5.1** – **5.4** (SUTTON et al. 1985) have been found in *A. marina*.

Antiviral activity has been tested a.o. in this species (PADAMAKUMAR & AYYAKKANNU 1994). The use of methanol extracts of *A. marina* and *Rh. mucronata* leaf against root-infecting fungi and root-knot nematodes in tomatoes has also been described by MEHDI et al. (2001).

A decoction of *Rh. mangle* was found to have significant anti-hyperglycemic effects (ALARCON-AGUILARA et al. 1998).



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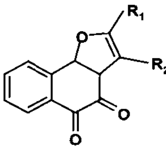


(5)

1	R1 = H	R2 = OH
2	R1 = H	R2 = H
3	R1 = C (OH) $(CH_3)_2$	R2 = H
4	R1 = H	R2 = OAc

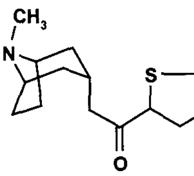
Bruguiera spp.

The seed of *Bruguiera* species germinates while still on the tree. The embryo is consumed as food not only in Melanesia (New Guinea, Solomons, New Caledonia and the Loyalty Islands), but also in Micronesia, in Yap and in the Palaus.

Loder & Russell (1966) described the occurrence of brugine (**6**) in the bark of *B. sexangula*. This compound has been ascribed antitumour activity. Other tropine alkaloids present include esters of ethanoic, propanoic, butanoic, methylpropanoic, 2-methylbutanoic or 3-methylbutanoic, and benzoic acids (Loder & Russell 1969).

From the root and bark of *B. gymnorhiza* the terpenoid compounds (7) have been isolated by Subrahmanyam et al. (1999) together with other diterpenes. Steviol represents the early stages of 13-OH gibberellin biosynthesis in higher plants (Bearder & Sponsel 1977). This was the first isolation of steviol in free state from a natural source. From *B. gymnorhiza* fruits several gibberellins have been isolated (Ganguly & Sircar 1974). Laphookhieo et al. (2004) found a series of triterpenoid taraxerol derivatives in the fruits of *B. cylindrica* of which *Z*-feruloyltaraxerol and 3*R*-*Z*-coumaroyltaraxerol showed weak cytotoxicity against the NCI-H187 cell line.

Han et al. (2004) isolated three new ent-kaurane diterpenoids and one new ent-beyerane diterpenoid together with nine known ent-kaurane diterpenoids from *B. gymnorhiza*. Of particular interest is the chlorine containing compound 17-chloro-13,16-*β*-dihydroxy-*ent*-kauran-19-al (**8**).



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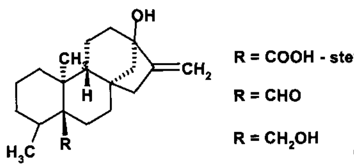

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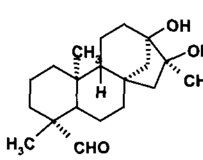
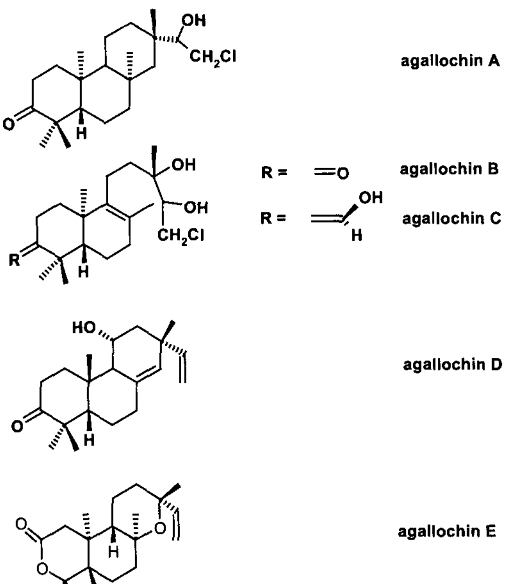


(8)

Excoecaria agallocha

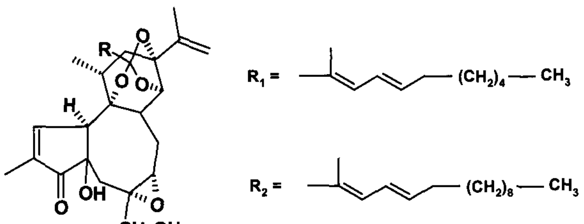
In New Guinea the white sap is used to ease pain from fish stings while the sap from leaves and young shoots is employed for penis enlargement and is said to prolong sexual stimulation. The sap reputedly provokes skin cancer (Marstaller 1997) and contact with it may lead to, at least temporary, blindness, as the common name blind-your-eye mangrove suggests (see e.g. Drury 1873). The soot from green branches has been used for tattooing as it is particularly fine-grained (Rau 1985).

Chemically *E. agallocha* is one of the better characterised mangrove species. Chlorinated terpenoid compounds (agallochins A – E, **9**) have been described by Anjaneyulu & Rao (2000), Anjaneyulu et al. (2002a) and Konishi et al. (1996). In addition leaf material was found to contain taraxerol, friedelin, epitaraxerol, *β*-sitosterol and taraxerone while *β*-amyrenyl acetate, *β*-amyrin and *β*-sitosterol were found to be present in the wood (Hui & Sung 1968).



(9)

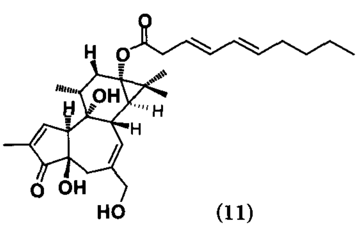
The piscicidal compounds (**10**) isolated from the twigs and bark of *E. agallocha* (Ohigashi et al. 1974) differed in their acitivity, the compound with the longer aliphatic side chain exhibiting the highest fish-killing activity.



(10)

12-Deoxyphorbol-13-(3E,5E-)decadienoate (**11**) exhibits inhibition of HIV replication in vitro but is also a potential tumour promotor (Erickson et al. 1995).

Konishi et al. (1998) examined 17 diterpenes from the resinous wood of *E. agallocha* for their anti-tumour-promoting activity of which ent-3*β*-hydroxy-15-beyeren-2-one (**12**) was highly effective .



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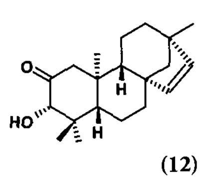


(12)

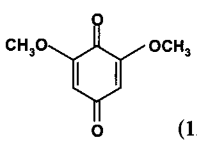
Lumnitzera racemosa

In Papua New Guinea the bark chewed with young betelnut is used for (self)sterilisation (RAU 1985).

Rhizophora spp.

No information is available on traditional use of these species in New Guinea except for the use of tannins providing dyes for the inside of canoes and boats with high preservative quality (GREENWAY 1941, HEIM & SCHELL 1923). Stem extracts of *Rh. mucronata* have been used elsewhere to treat constipation and to cure fertility related and menstruation disorders. *Rh. mangle* bark and bark resin have been used as a native remedy for leprosy, elephantiasis, asthma, diarrhea, dysentery, and to treat lesions of various kinds (MORTON 1965)

A large number of terpenoids occur in Rhizophora species (e.g. ANJANEYULU & RAO 2001, ANJANEYULU et al. 2000, 2002b, WILLIAMS 1999). Insecticidal (KABARU & GICHIA 2001, THANGAM & KATHIRESAN 1997, WILLIAMS 1999), antiviral (PADAMAKUMAR & AYYAKKANNU 1994, PREMANATHAN et al. 1999) and antimicrobial (MELCHOR et al. 2001, ROJAS HERNANDEZ & COTO PEREZ 1978) activities have been found in extracts of different plant parts. Compared to other species tested *Rh. mangle* showed only little activity against fungal skin infections (CACERES et al. 1993). In extracts of *Rh. apiculata* heartwood 2,6-dimethoxy-*p*-benzoquinone (**13**) was the only constituent which exhibited activity against fungi, bacteria and boll weevils although a.o. steroids, long-chain carboxylic acids and alcohols have been found to be present (KOKPOL et al. 1993).



(13)

The occurrence of *p*-chinoid compounds in mangroves is noticeable (see structures **1** and **2**) and might provide leads for detailed searches in other mangrove species.

Effects on gastric ulcers of a lyophilised aqueous extract from red mangrove bark have been investigated in rats. The treatment increased mucus content this being accompanied by a proportional increase in proteins (PERERA et al. 2001).

A polysaccharide extracted from the bark of *Rh. mucronata* was found to inhibit adsorption of Human Immunodeficiency Virus to test cells (PREMANATHAN et al. 1999).

Extracts from four *Rhizophora* species showed protection times of 33 to 70 minutes against mosquitoe attacks (*Aedes aegypti*) with *Rh. apiculata* stilt root extract being the most effective (THANGAM & KATHIRESAN 1993).

Xylocarpus granatum

The bark of this species has been used in New Guinea to provide a dye that gives a maroon colouring to grass skirts (RAU 1985). Elsewhere fruits have been used to soothe aching muscles and limbs and, together with chalk, to treat skin disorders.

KOKPOL et al. (1996) describe the presence of limonoids in *Xylocarpus* fruits. Similar tetraterpenes have been found in *X. moluccensis*, a plant which constitutes an integral part of the Fijian traditional medicine (e.g. ALVI et al. 1991, MULHOLLAND & TAYLOR 1992, TAYLOR 1983).

Nypa fruticans

The mangrove palm has widespread use among mangrove dwellers and appears to be the most versatile higher plant species growing in the mangal. The leaves are used for roof thatching while young leaves provide cigarette wrappings. The sap is an important source for sugar, alcohol and vinegar (DALIBARD 1999, MARTIN 1999). The white endosperm of the fruit can be eaten raw, cooked or preserved in syrup. The young shoots, decayed wood and leaves are used in Southeast Asia as cure for herpes, toothache and migraine (MARSTALLER 1997). A more exotic application of *N. fruticans* extract, i.e. its effect on the inhibition of zinc corrosion, has been tested by ORUBITE-OKOROSAYE & OFORKA (2004).

Apparently so far no attempts have been made to characterise the chemistry of secondary metabolites of the mangrove palm despite of its economical importance. The only study reported in the literature is that of AZUMA et al. (2002) on floral scent compounds (see above).

Ethnopharmacological application of plants in New Guinea

To illustrate the wide variety of plants, among them mangroves, that are used for similar medical purposes two fields of

Table 3: Herbals used in New Guinea in reproductive processes.

species	**use as/for**
Ocimum basilicum (Labiateae)	aphrodisiac
Avicennia marina (Avicenniaceae)*	aphrodisiac
Rhizophora sp. (Rhizophoraceae)*	aphrodisiac
Excoecaria agallocha (Euphorbiaceae)*	penis enlargement
Avicennia marina (Avicenniaceae)*	long-term contraceptive
Solanum moszkowskii BITTER. (Solanacee)	contraceptive
Zingiber officinale ROXB. (Zingiberacedae)	contraceptive
Flemingia strobilifera (Legimuminosae)	contraceptive
Terminalia catappa (Combretaceae)	sterilisation
Hibiscus rosa-sinensis L. (Malvaceae)	abortion
Medinilla crassiveria (Melastomataceae)	proceptive
Ficus nasuta Summerh. (Moraceae)	fertility increase
Lindsaya repens (Lindsayaceae)	boychild
Cerbera floribunda (Apocynaceae)	childbirth assistance
Dodonaea viscosa (L.) Jacq. (Sapindaceae)	lactation increase
Pandanus tectorius var. *novo-guineensis* (Pandanaceae)	treatment of gonorrhoea
Ocimum basilicum (Labiateae)	treatment of gonorrhoea

Data source: WOODLEY 1991, MARSTALLER 1997
* = mangrove species

Table 4: Herbal malaria cures in New Guinea.

species	preparation/usage
relief of symptoms	
Uvaria rosenbergiana (Annonaceae)	stem sap
Plectanthrus congestus (Labiatae)	fresh water soaking, bath
Barringtonia asiatica (Barringtoniaceae)	crushed inner bark + water
Sterculia L. sp. (Sterciliaceae)	crushing, water, bath
treatment	
Alstonia scholaris (Apocynaceae)	infusion of dried bark
Alsonia spectabilis (Apocynaceae)	dto., scraped bark + water
Scaevola sericea (Goodeniaceae)	removal of leaf epidermis, chewing
Pterocarpus indicus (Leguminosae)	leaf
Maclura cochinchinensis (Moraceae)	stem sap
Embelia palauensis (Myrsinaceae)	freshly squeezed stem sap
Psidium guajava (Myrsinaceae)	leaf
Gouania Lam. sp. (Rhamnaceae)	stem sap
Mussaenda ferruginea (Rubiaceae)	stem sap
Amomum aculeatum (Zingiberaceae)	sap from beating bark with a stick

Data source: WOODLEY 1991

application will be illustrated in the following – human reproductive processes (Tab. 3) and malaria treatment (Tab. 4).

Table 4 does not list any mangrove species in use against malaria in New Guinea although applications have been reported from other regions. The bark of *Rh. mangle* has been used as a substitute for quinine to alleviate fever (MORTON 1965). THANGAM & KATHIRESAN (1992, 1997) report on the larvicidal activity of *R. apiculata* extracts on mosquitoes. *Ceriops tagal* extracts are reportedly astringent and hemostatic and have been used as a folk remedy for malaria and sores (DUKE & WAIN 1981).

Discussion

In view of the fact that a large number of plants has been used traditionally for treatment of the same illness the question arises "What are the common principles of the different plant species used for a single purpose?" Can they be related to common chemical structures of the active compounds or related to a similar mode of action? In view of the fact that the plants listed in Tabs. 3–4 belong to different families which also grow under different environmental conditions it appears somewhat unlikely that similar chemical compounds will be synthesised.

One explanation may be that superficial resemblance of plant parts gives rise to the ascribed effects. This must, however, be seen in the context of non-medicinal influences, i.e. the role of magic in traditional healing practice (see e.g. MARKS 1987, BALÉE 1999) and the associated psychosomatic effects.

It should also be considered that especially older ethnobotanical literature might not be up to the taxonomic standards of the discipline. Thus, in some cases a reappraisement of this information might become necessary employing established procedures (e.g. MARTIN 2004).

In addition the chemistry of traditional preparations needs to be considered, e.g. the actions of saliva enzymes, of lime, of "traditional salt" (itself being a plant preparation) and of temperature (extraction, preparation) as well as the extraction agent (fresh, rain, marine waters) may change the chemical composition of extracts and of active compounds.

Synergistic action needs also to be taken into consideration, e.g. berberine isolated from rhizomes of *Berberis aristata* exhibits antimicrobial and antifungal activity. When used in conjunction with santonin its activity increases (SINGH et al. 2001). Similarly, when berberine was used together with 5′-methoxyhydnocarpin-D, which is itself inactive, a marked increase in antimicrobial activity was noted (TUMA 2002).

The list of reported uses and phytochemicals of the mangrove species growing in New Guinea is long but as yet still incomplete. The present review gives an overview of selected phytochemical investigations carried out so far and the pharmacological properties of secondary metabolites. From this it should be possible to identify a number of species which should be investigated in greater detail than previously done.

However, our understanding of the ecological conditions under which secondary metabolites of interest in e.g. pharmacological applications are synthesised by mangroves is still far from being comprehensive. The role of microorganisms in the production of secondary metabolites still remains to be elucidated in greater detail, i.e. symbiotic or parasitic interactions with host plants which might induce metabolite production.

Genoptypic variations need to be considered as needs seasonality or interannual variability in secondary metabolite production. Secondary metabolites may also be produced depending on the developmental stage of the plant.

Besides this variability inherent in the plant material to be investigated the formation of artefacts during sample work-up should also be taken into consideration. This has been described for alkaloids (e.g. SULAIMAN et al. 1998, THEN et al. 2000), flavonoids (e.g. BORGEZ-ARGAEZ et al. 2000), terpenoids (e.g. GROMOVA et al. 1982, CHAKRAVARTY et al. 1987, HOLST et al. 1994) and steroids (e.g. KOBAYASHI et al. 1992, MILKOVA et al. 1997), both for plant and animal sources.

The techniques and the extraction agents used also play a vital role in determining extract composition. MAHASNEH & EL-OQLAH (1999) e.g. found that 1-butanol extracts of various plants showed higher antimicrobial activities than either petrol ether, ethanol or aqueous extracts. Traditional techniques such as Soxhlet extraction need to be compared to modern ones such as supercritical CO_2, microwave or room temperature-ultrasonically aided extraction techniques.

Conclusions

From the information presented above it can be concluded that mangroves might become sources of important new pharmacological agents. However, comprehensive ethnobotanical and ethnopharmalogical surveys, activity-guided search for natural products and establishment of activity – structure relations still have to be carried out. In addition, mangrove-associated fungi, ferns and other macrophytes, e.g. epiphytic parasites, as well as mangrove-dwelling animals should also be taken into consideration as sources of new chemical compounds and biologically active principles.

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