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Review

Chemical constituents and biological activities of *Chukrasia tabularis* A. Juss. - A review

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***Chukrasia tabularis* A. Juss., commonly known as chickrassy, Burmese almond wood, chittagong wood, lal devdari belongs to the family Meliaceae and is a valuable tree of Asian region. The present review aims to compile the scattered information regarding the chemical constituents, morphological features and medicinal importance of the *C. tabularis.* The different parts of *C. tabularis* (leaves, bark, fruits) are having both ethnobotanical and medicinal significance along with biopesticidal activity. The biological activities of plant are due to the abundance of phenolic compounds including different terpenoids and limonoids. During recent years, bioactivities of extracts and pure compounds isolated from *C. tabularis* have been increasingly investigated. The dire need for such a review arises as the plant is included in the list of threatened species due to its high exploitation for timber utilization.**

Key words: *Chukrasia tabularis*, limonoids, biopesticidal activity, ethnobotanical value, antimalarial activity.

INTRODUCTION

Plants play a dominant role in the introduction of new therapeutic agents as they help to alleviate human ailments. The therapeutic potential including antioxidant, antimutagenic and anticarcinogenic properties of higher plants are due to the presence of secondary metabolites (Ko et al., 2003; Schwab et al., 2000).

The role of secondary metabolites in plant itself is not well understood as these metabolites do not play major roles in physiological functions. But these metabolites are of prime importance for humankind as they prevent the onset of different degenerative diseases by scavenging free radicals and thus preventing chain-reactions mediated damage or binding with catalysts of the oxidative reactions, such as some metal ions (Bazzano et al., 2002; Block et al., 1992; Slemmer et al., 2008). *C. tabularis* A. Juss is one such plant which is rich in secondary metabolites and is being used in ayurveda (Kirtikar and Basu, 1981; Rastogi and Mehrotra, 1993). It is a valuable multipurpose tree species. The plant is a dominant canopy tree in south and south east Asia including India, some parts of China, Malaysia and Thailand. It is also planted in west and South Africa along with Caribbean countries and Costa Rica. *C. tabularis* is distributed in the latitudinal range of approximately 27°N to equator and the altitudinal range of 20 – 1450 m (Ho and Noshiro, 1995). Predominantly, the plant is found scattered in the lowlands areas up to 800 m altitudes with 1400 – 4000 mm rainfall/year. (Streets, 1962; Anon, 1974; Ho and Noshiro, 1995). The above mentioned climatic conditions are the characteristics of evergreen, moist evergreen and mixed deciduous forest. It usually thrives in the areas with unimodal as well as bimodal rainfall regimes. *C. tabularis* tends to colonise disturbed areas and is considered as a pioneer of bare ground including road cuttings in the Malay Peninsula (Mabberley et al., 1995; Csurhes and Edwards, 1998).

NATURAL DISTRIBUTION

In literature, there is no distinct reference to the native place of *C. tabularis*. The species is distributed in a range including India and Nepal, east and southeast of southern China to Indo-China, Combodia, Thailand, Laos, Mayanmar, Bangladesh, Sri Lanka and the Andamans to western Malaysia (Anderson, 1980; Ho and

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Figure 1. Natural distribution of *Chukrasia tabularis* (www.lonelyplanet.com/map/asia).

Noshiro, 1995; Mabberley, 1995; Chen et al., 1997).

In China, Sri Lanka and Vietnam, *C. tabularis* is being domesticated as an agroforestry tree (Bandara, 1999; Kalinganire and Pinyopusarek, 2000). In India, *C. tabularis* occurs in the forests of South India (Maharashtra and Tamil Nadu), hills of Sikkim, grooves of Manipur and grooves of Madras, western Peninsula, Assam, Arunanchal Pradesh, Malabar coast, Malacca, sandoor hills of deccan, western peninsula along the western ghats, west Bengal and the Andaman Islands. The plant is also cultivated in Punjab (Streets, 1962; Brandis, 1971; Anon, 1974; Trimen 1974; Chatterjee and Prakashi, 1997) (Figure 1).

Besides these countries, *C. tabularis* is also introduced in countries including Cameroon, Costa Rica, Nigeria, Puerto Rico, South Africa and United States of America (Streets, 1962; Ho and Noshiro, 1995).

The plant is also known as *Chickrassia tabularis* (A. Juss.) Wight and Arnott (Brandis, 1971); *C. tabularis* is known by several vernacular names including chittagong wood, Burmese almondwood, white cedar, bastard wood and Red Indian wood (Eng.); Surian batu, cherana puteh, repoh, sutnag puteh (Malay); yinma (Burmese); siat-ka, yom-hin (Thai); Hulan hik, hiri kita, kaloti (Sri Lanka) (Brandis, 1971; Appanah and Weinland, 1993; Ho and Noshiro, 1995; Mabberley et al., 1995; Bandara, 1999); Kalinganire and Pinyopusarerk, 2000). In India, the plant is popularly known as lal devdari, agil maleivembu, vedivembu (Tamil); chikrassi (Bengali); boga poma, bogipoma(Asm.), pabba, dalmara, uruli, paruli, agal, madagari vembu kindavepa, akil chuvannagil (Bourdillon, 1908; Brandis, 1921 Anon, 1974; Bakshi et al., 1999). In Indonesia, *C. tabularis* is known as ingol batu whereas in Cambodia, it is known as voryong (Ho and Noshiro, 1995; Clegg, 2000). Tradewise, it is known as Chittagong wood, chikrassy, yinma, yonhim, east Indian mahogany, Indian red wood, white cedar, bastard cedar, Burma almondwood and surian batu (Ho and Noshiro, 1995; Mabberley, 1995). *C. tabularis* is currently preserved as holotype specimen by the Museum national d'Histoire naturelle de Paris, France (Kalinganire and Pinyopusarerk, 2000).

TAXONOMY AND NOMENCLATURE

C. tabularis A. Juss is a tree species belonging to; Division: Tracheophyta; Class: Magnoliopsida; Order: Sapindales; Family: Meliaceae; Sub Family: Swietenioideae and Tribe: Swietenieae.

MORPHOLOGICAL DESCRIPTION

C. tabularis A. Juss is approximately a 40 m tall tree which is branchless for up to 25 – 28 m with large convex buttresses at the top (Figure 2). The bark of the immature tree is smooth but as the plant matures, it turns to rusty brown with deep vertical fissures (Figure 3A). The colour of the bark from inside is reddish-brown or pinkish, the sapwood is straw coloured, whereas the heartwood is yellow to reddish brown in colour. The leaves are 30 - 50 cm long paripinnate having dentate margins with 4 - 6 pairs of opposite or alternate leaflets. A main identification feature of this species is the presence of red coloured leaflets at the top (Anon, 1830; de Condolle, 1878; Anon, 1930; Ho and Noshiro, 1995; Mabberley,

Figure 2. Tree of *C. tabularis* A. Juss.

Figure 3A. Bark of *C. tabularis* A. Juss.

Figure 3B. Leaves of *C. tabularis* A. Juss.

Figure 3C. Inflorescence of *C. tabularis* A. Juss.

Figure 3D. Flowers of *C. tabularis* A. Juss.

1995; Chatterjee and Prakashi, 1997) (Figure 3B).

Flowering of *C. tabularis* normally starts when the tree is 8 - 9 years old and there is profuse flowering after every 2 - 3 years in the month of April and continues until June - July. The flowers are unisexual, small, light yellow in colour and sweet scented in 10 - 30 cm long panicles (Figures 3C, D and E). The fruit is a capsule which is ovoid or ellipsoidal in shape with outer woody and inner stony layers, 2.5 - 5.0 cm in length with 3 - 5 locules. The fruit of *C. tabularis* ripens in January - March and contains 180 - 250 non-endospermic, anemophilous and winged seeds. The wings are almost double in length as compared to the seeds (Figures 3F, G H and I) (Anon, 1830; de Condolle, 1878; Anon, 1930; Ho and Noshiro, 1995; Mabberley, 1995; Chatterjee and Prakashi, 1997).

CHEMICAL CONSTITUENTS

C. tabularis is a rich source of structurally diversified limo-

Figure 3E. A Flower of *C. tabularis* A. Juss.

Figure 3F. An immature fruit of *C. tabularis* A. Juss.

Figure 3G. Ripened fruit of *C. tabularis* A. Juss.

Figure 3H. Dehiscent fruit of *C. tabularis* A. Juss.

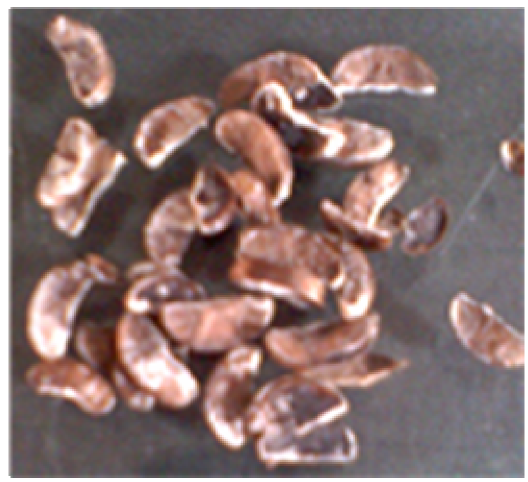


Figure 3I. Seeds of *C. tabularis* A. Juss.

limonoids which are modified triterpenes, having a 4, 4, 8 trimethyl, 17 furanyl steroid skeleton (Roy and Saraf, 2006). The different ring structures within this basic building block and arrangements of other subgroups provide a lot of structural characteristics that have generated interest in this plant (Table 1).

The nature of limonoids is tetranortriterpenoid which are classified on the basis of oxidation of 4 rings (designnated as A, B, C and D in intact triterpene nucleus). The first limonoids isolated from the wood and seeds of *C. tabularis* were a series of the ester derivatives of phragmalin (2, 3, 30-trihydroxy,1, 8, 9-orthoacetate) having a tricyclo ($3.3.1^{2,10}.1^{1,4}$) decane ring system (Connolly et al., 1978) Figure 4. Ragettli and Tamm (1978) isolated phragmalin related C-acyl derivatives of chukrasins from the seeds of *C. tabularis*.

Besides limonoids, the seeds of plant are rich in meliacin esters including 3, 30-Diisobutyrates and 3- isobutyl-

Table 1. Chemical constituents in different parts of *C. tabularis* A. Juss.

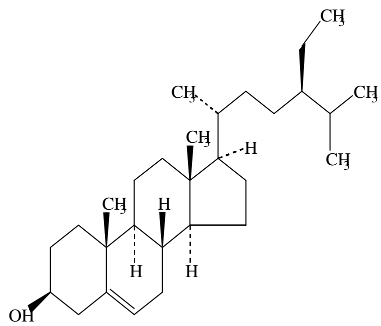
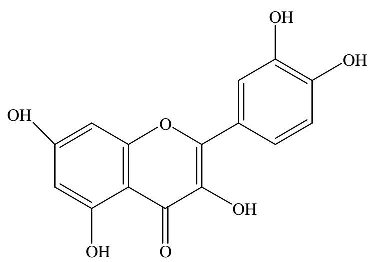
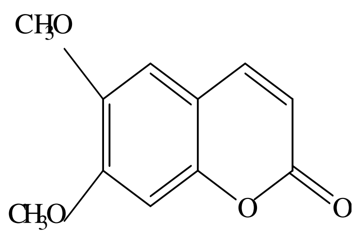
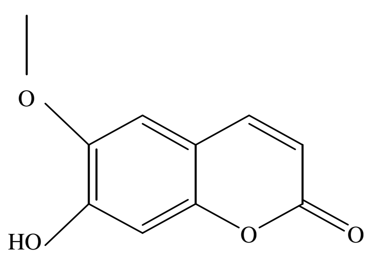
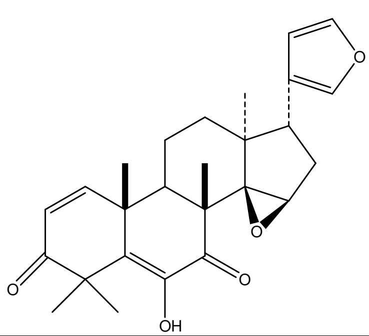
Chemical constituents	Formula	Structure	Extracted from	References
Sitosterol	$C_{29}H_{50}O$		Petroleum extract of Bark	Chatterjee et al. 1974
Quercetin	$C_{15}H_{10}O_7$		Leaves	Rastogi and Mehrotra, 1993
7 dimethoxycoumarin	$C_{11}H_{10}O_4$		Alcoholic extract of Bark	Chatterjee et al. 1974
Scopoletin	$C_{10}H_8O_4$		Alcoholic extract of Bark	Chatterjee et al. 1974
Cedrelone	$C_{26}H_{30}O_5$		Roots	Asolkar et al. 1965

Table 1. Contd

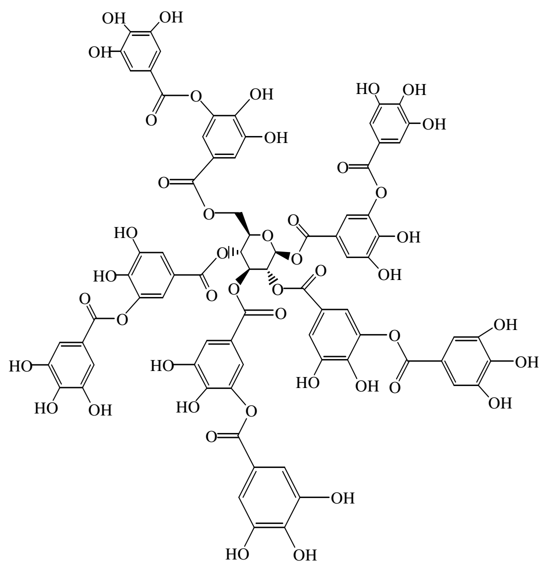
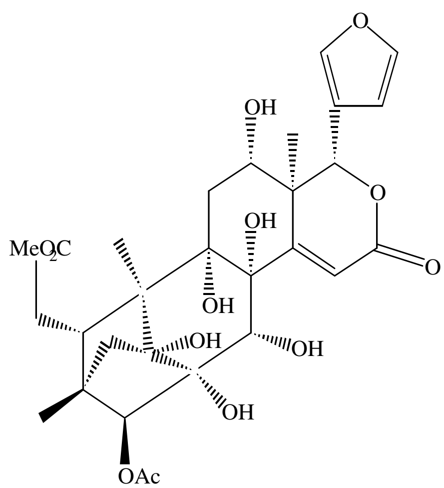
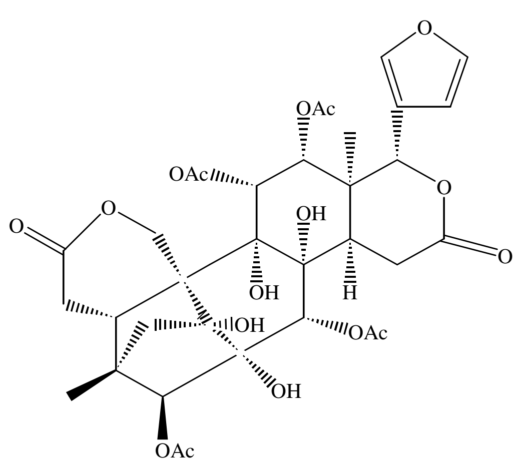
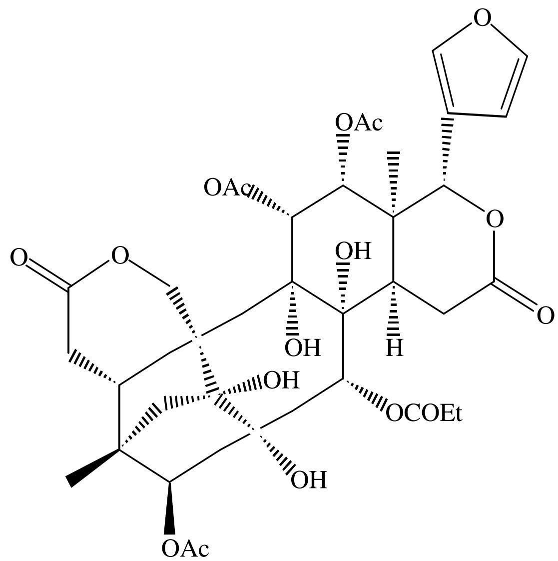
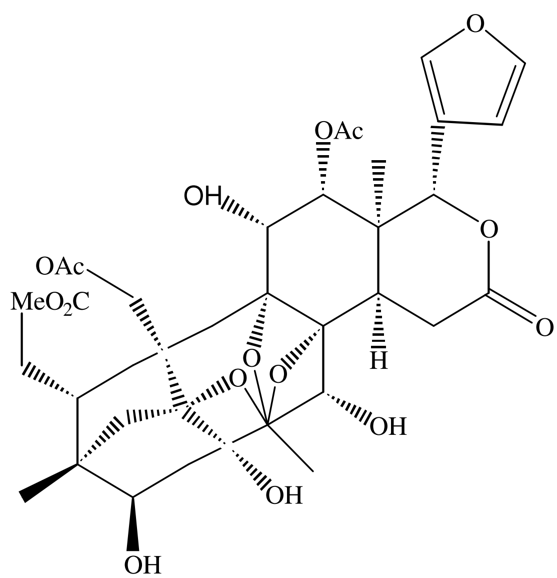
Tannic acid	$C_{76}H_{52}O_{46}$		Leaves and Bark	Rastogi and Mehrota, 1993
Tabulalin	$C_{29}H_{36}O_{13}$		Diethyl ether extract of Root Bark	Nakatani et al. 2004
Tabulalide A	$C_{34}H_{40}O_{17}$		Diethyl ether extract of Root Bark	Nakatani *et al.*, 2004

Table 1. Contd

Tabulalide B	$C_{35}H_{42}O_{17}$		Diethyl ether extract of Root Bark	Nakatani et al. 2004
Tabulalide C	$C_{33}H_{40}O_{16}$		Diethyl ether extract of Root Bark	Nakatani et al. 2004

rate to 30-propionates of phragmalin and 12-acetoxy-phragmalin. The leaves and bark are rich in tabularin (5, 7-dihydroxy-6, 2', 4', 5'-tetramethoxyflavone) and tannic acid. Leaves are reported to have quercetin ($C_{15}H_{10}O_7$), quercetin-3-galactoside and tannic acid in addition to above mentioned metabolites. Roots are known to possess a triterpenoid known as cedrelone. The wood of the plant is reported to be rich in different types of chukrasins and bussein homologues (Rastogi and Mehrotra, 1993).

Chatterjee et al. (1974) isolated sitosterol ($C_{29}H_{50}O$, melting point: 137 - 138°C) from the petroleum extract of bark of *C. tabularis*. They also reported scopoletin ($C_{10}H_8O_4$; melting point: 202 - 203°C) and 6, 7-dimethoxycoumarin ($C_{11}H_{10}O_4$; melting point: 145°C) along with a triterpene melianone ($C_{30}H_{46}O_4$; melting point: 225 - 226°C) from the alcoholic extract of bark of *C. tabularis*.

Purushothaman et al. (1977) isolated tabularin (5, 7-dihydroxy-6, 2', 4', 5'-tetramethoxyflavone) ($C_{19}H_{18}O_8$; melting point: 213 - 214°C) from the hexane extract o f leaves of *C. tabularis*. Ahmed et al. (1978) synthesized tabularin through the oxidative cyclization of the chalcone followed by the removal of the 7-O-benzyl and 5-O-methyl groups in a single step on treatment with boron trichloride under very mild conditions.

Table 1. Contd

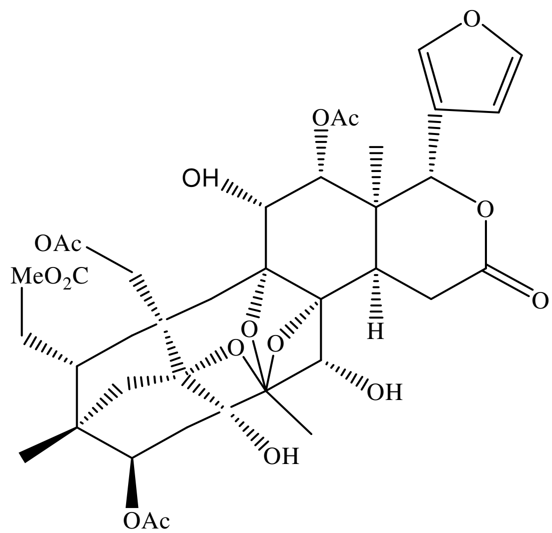
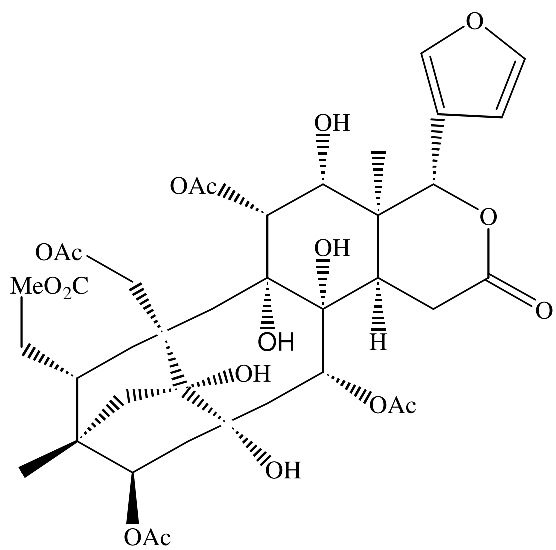
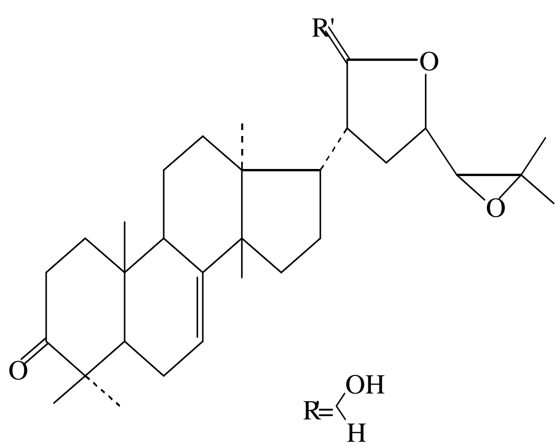
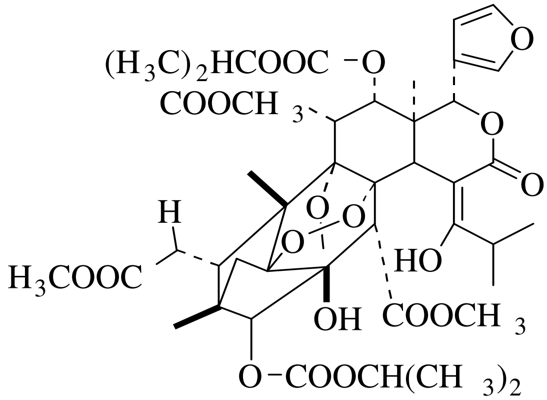
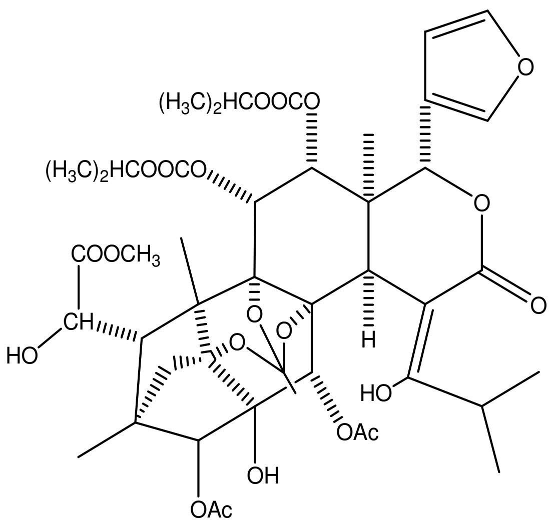
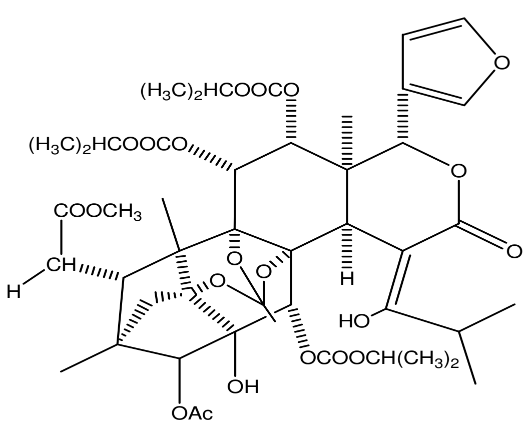
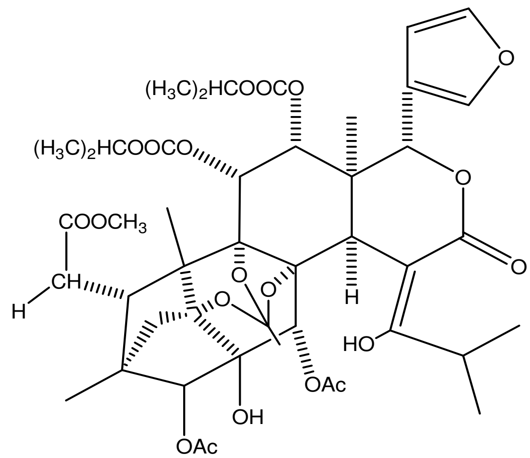
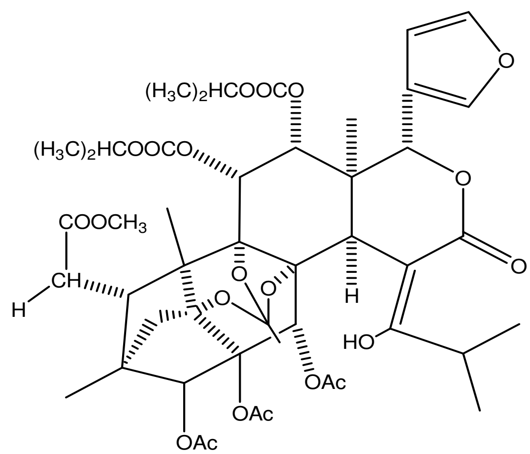
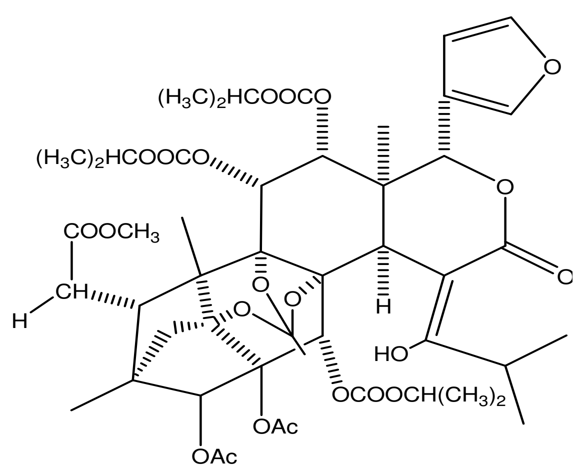
Tabulalide D	$C_{35}H_{42}O_{17}$		Diethyl ether extract of Root Bark	Nakatani et al. 2004
Tabulalide E	$C_{35}H_{44}O_{18}$		Diethyl ether extract of Root Bark	Nakatani et al. 2004
Melianone	$C_{30}H_{46}O_4$		Alcoholic extract of bark	Chatterjee et al. 1974

Table 1. Contd

Bussein Homologue	$C_{44}H_{58}O_{20}$		Timber	Rastogi and Mehrota, 1993
Chukrasin A	$C_{45}H_{58}O_{21}$		Seeds, Wood	Ragettli and Tamm, 1978; Rastogi and Mehrota, 1993
Chukrasin B	$C_{47}H_{62}O_{21}$		Seeds, Wood	Ragettli and Tamm, 1978; Rastogi and Mehrota, 1993

Nakatani et al. (2004) isolated 6 phragmalin limonoids from the diethyl ether extract of root bark of *C. tabularis* collected at Xian tan, China. The phragmalins include tabulalin ($C_{29}H_{36}O_{13}$) possessing an α – β unsaturated lactone structure and 5 tabulalides (A - E) having novel 19-oxygenated structures. The compounds were isolated using droplet countercurrent chromatography (DCCC) and reversed phase HPLC. The tabulalide A ($C_{34}H_{40}O_{17}$),

Table 1. Contd

Chukrasin C	$C_{45}H_{58}O_{20}$		Seeds, Wood	Ragettli and Tamm, 1978; Rastogi and Mehrota, 1993
Chukrasin D	$C_{47}H_{60}O_{21}$		Seeds, Wood	Ragettli and Tamm, 1978; Rastogi and Mehrota, 1993
Chukrasin E	$C_{49}H_{64}O_{22}$		Seeds, Wood	Ragettli and Tamm, 1978; Rastogi and Mehrota, 1993

tabulalide B ($C_{35}H_{42}O_{17}$), tabulalide C ($C_{33}H_{40}O_{16}$), tabulalide D ($C_{35}H_{42}O_{17}$) and tabulalide E ($C_{35}H_{44}O_{18}$) were obtained as white amorphous powders. Tabulalides A and B were having characterstics C-7/C-19 lactone

Table 1. Contd

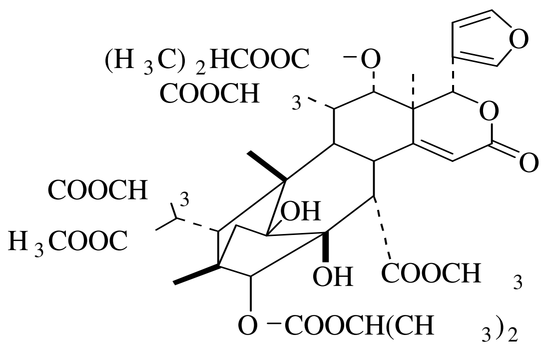
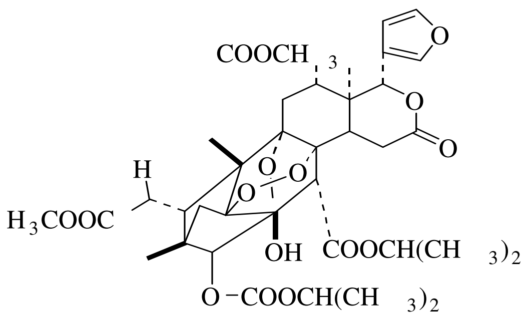
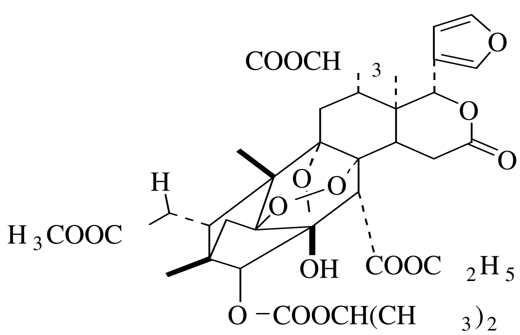
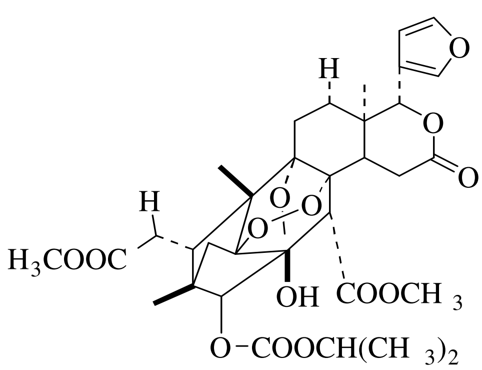
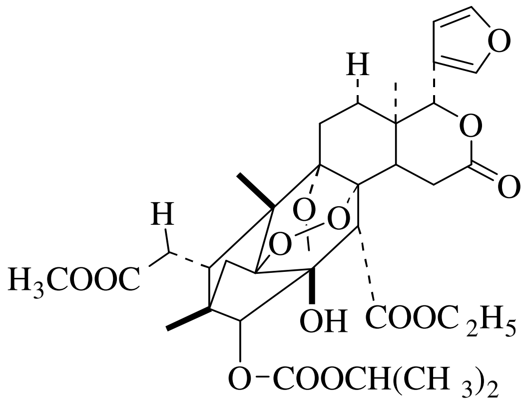
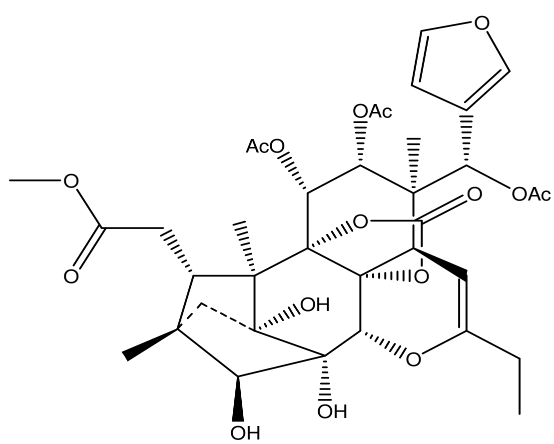
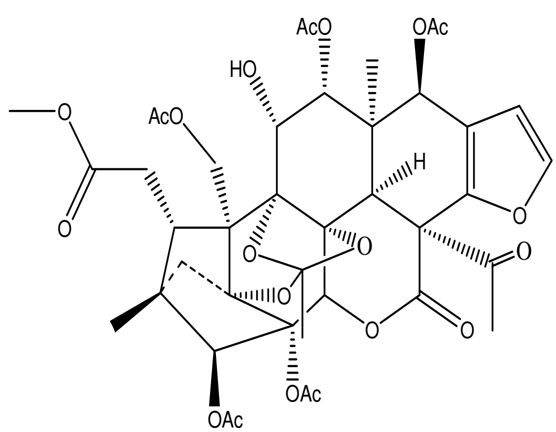
Tabularin	$C_{41}H_{52}O_{19}$		Hexane extract of leaves and bark	Purushothaman et al. 1977
12-acetoxyphragmalin 3,30 Diisobutyrates	$C_{39}H_{54}O_{16}$		Seeds	Rastogi and Mehrota, 1993
12-acetoxyphragmalin 3, isobutyrates-30-propionates	$C_{38}H_{52}O_{16}$		Seeds	Rastogi and Mehrota, 1993
Phragmalin 3,30 Diisobutyrates	$C_{34}H_{44}O_{14}$		Seeds	Rastogi and Mehrota, 1993

Table 1. Contd

Phragmalin 3, isobutyrates-30-propionates	$C_{35}H_{46}O_{14}$		Seeds	Rastogi and Mehrota, 1993
Chuktabrin A	$C_{36}H_{44}O_{16}$		Twigs and Leaves	Zhang et al., 2008
Chuktabrin B	$C_{41}H_{46}O_{20}$		Twigs and Leaves	Zhang et al., 2008

bridge, whereas Tabulalide C - E were having 19-acetoxy functional group. The compounds Tabulalide C and D contained a 1, 8, 9-orthoacetate group. Fan et al. (2007) isolated 4 phragmalin ortho esters, namely tabularisins A - D from the seeds of *C. tabularis* collected from the Hainan Island of China. These compounds represent a

Table 1. Contd.

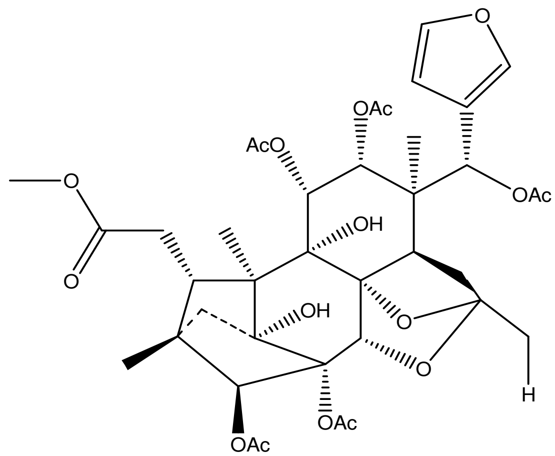
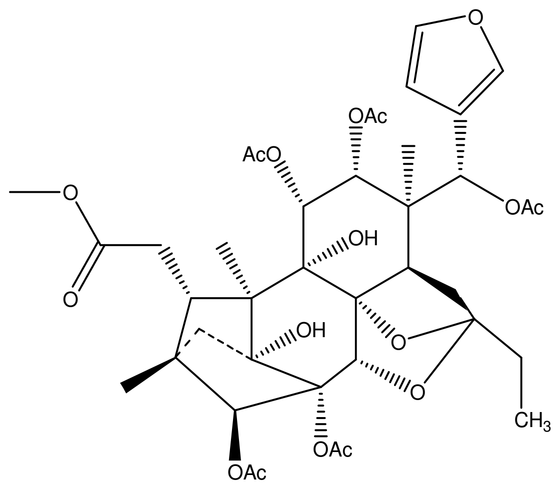
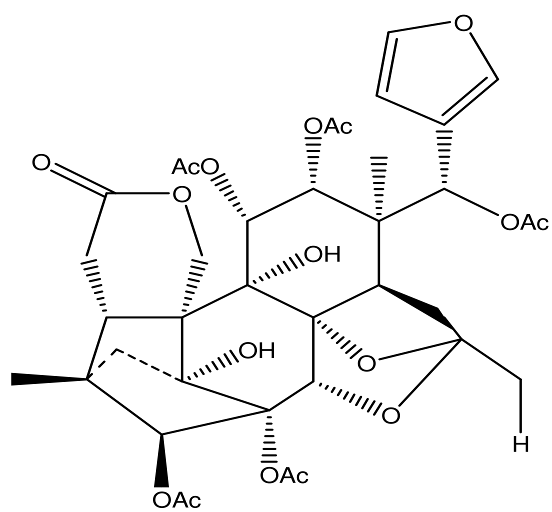
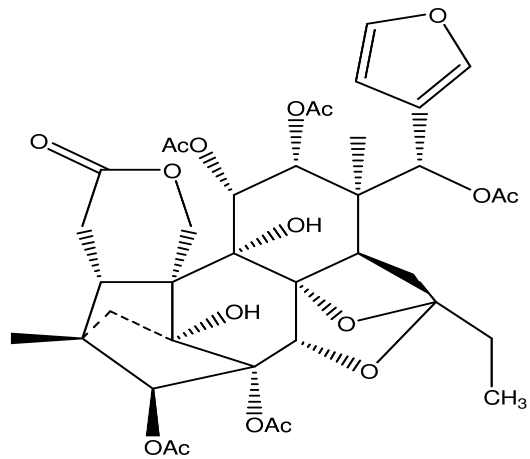
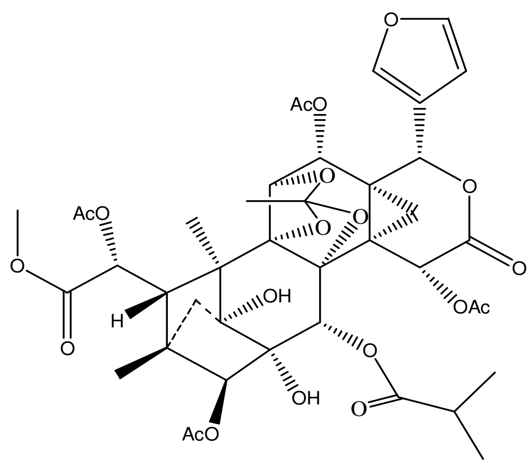
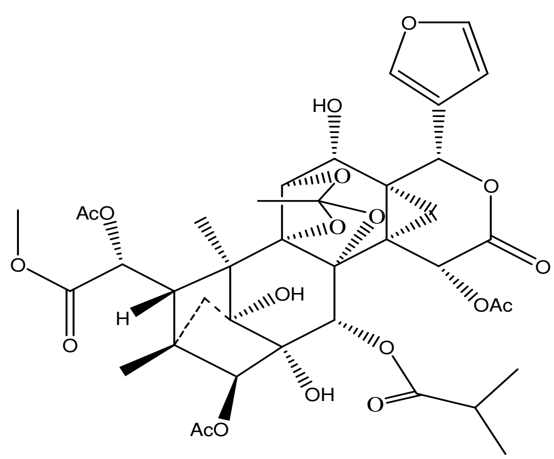
Chuktabularin A	$C_{38}H_{48}O_{17}$		Stem Bark	Zhang et al., 2007
Chuktabularin C	$C_{39}H_{50}O_{17}$		Stem Bark	Zhang et al., 2007
Chuktabularin B	$C_{37}H_{44}O_{17}$		Stem Bark	Zhang et al., 2007

Table 1. Contd

Chuktabularin D	$C_{38}H_{46}O_{17}$		Stem Bark	Zhang et al., 2007
Tabularisin A	$C_{41}H_{48}O_{20}$		Seeds, Twigs and Leaves	Fan et al., 2007; Zhang et al., 2007
Tabularisin B	$C_{39}H_{46}O_{19}$		Seeds, Twigs and Leaves	Fan et al., 2007; Zhang et al., 2007

new class of phragmalins having a cyclopropanyl ring. Tabularisins A and B were the first reported phragmalins with an 8, 9, 11-ortho esters. Tabularisin A was a phragmalin type limonoid with 18° of unsaturation of which, 12°

Table 1. Contd.

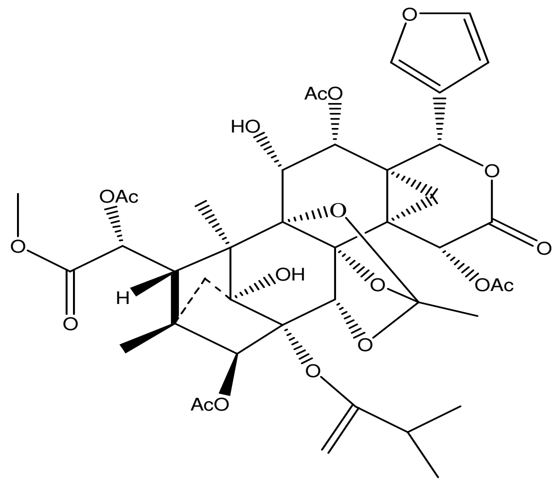
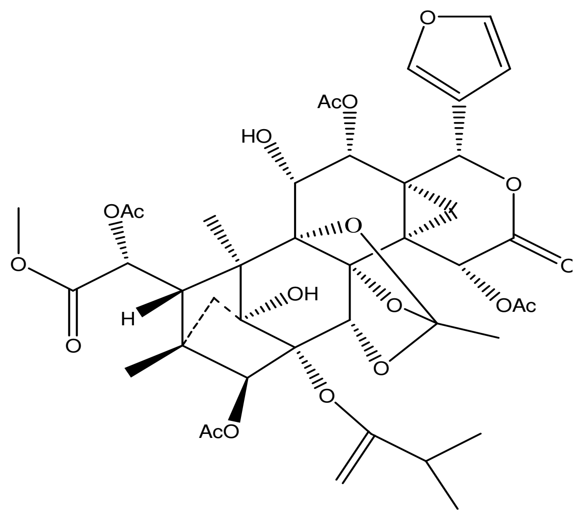
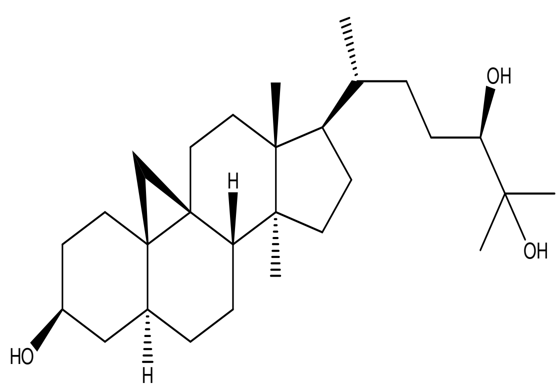
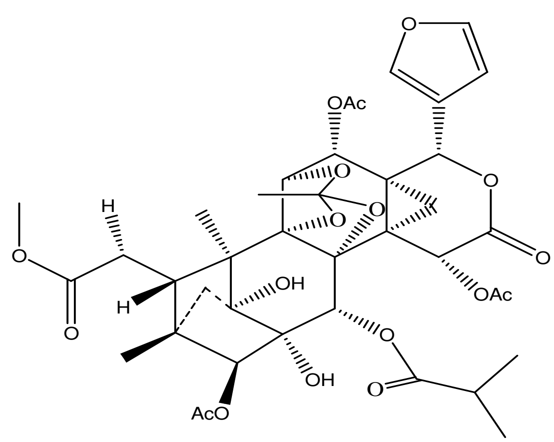
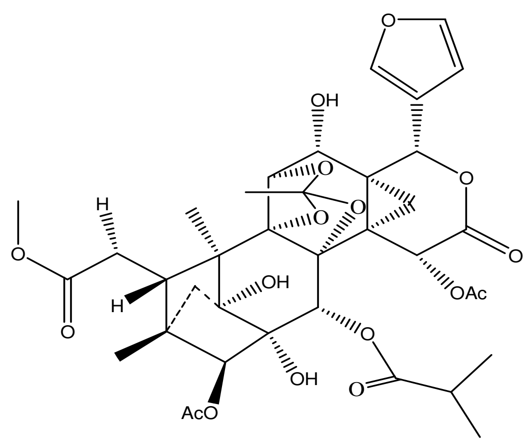
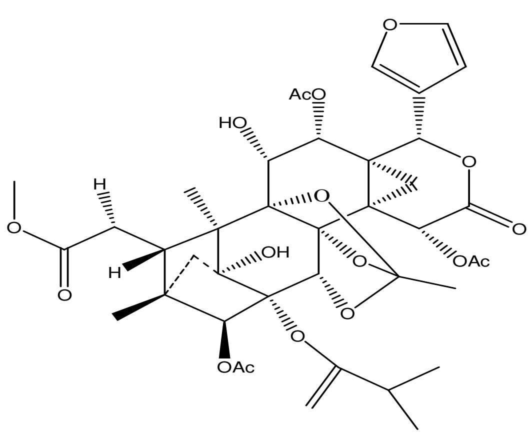
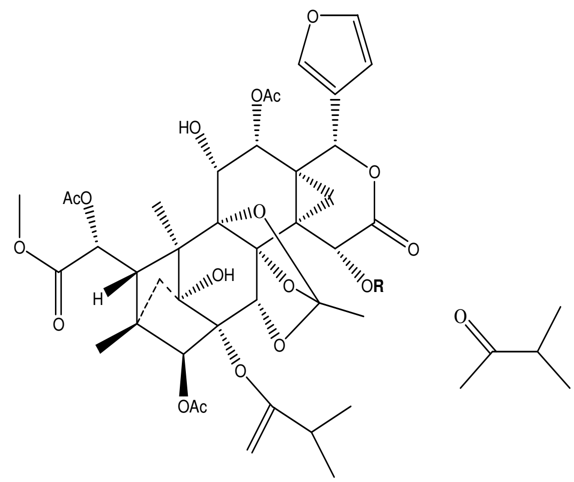
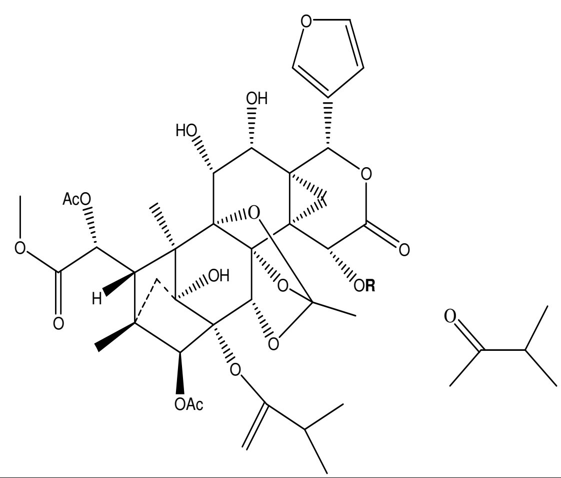
Tabularisin C	$C_{41}H_{48}O_{20}$		Seeds, Twigs and Leaves	Fan et al., 2007; Zhang et al., 2007
Tabularisin D	$C_{37}H_{44}O_{17}$		Seeds	Fan et al., 2007
(24*R*)-28,29-Dinor-cycloartane-3*β*,24,25-triol	$C_{28}H_{48}O_3$		Twigs and Leaves	Zhang et al., 2007

Table 1. Contd

Tabularisin E	$C_{39}H_{46}O_{18}$		Twigs and Leaves	Zhang et al., 2007
Tabularisin F	$C_{37}H_{44}O_{17}$		Twigs and Leaves	Zhang et al., 2007
Tabularisin G	$C_{39}H_{46}O_{18}$		Twigs and Leaves	Zhang et al., 2007

were occupied by 7 ester were occupied by 7 ester carbonyls, 1-ortho-acetate and a β-furyl ring and the remaining 6° required a hexacyclic core. The tabularisin A was obtained as colourless plates with molecular formula of $C_{41}H_{48}O_{20}$, [melting point: 292 – 294°C (decomposed)] as established by HREIMS and ^{13}C NMR. Tabularisin B was obtained as a white amorphous solid with molecular formula $C_{39}H_{46}O_{19}$. It was a 12-O-diacetyl derivative of tabularisin A. Tabularisin C was also a phragmalin analog with an ortho acetate group and was obtained as colour-

Table 1. Contd

Tabularisin H	$C_{43}H_{52}O_{20}$		Twigs and Leaves	Zhang et al. 2007
Tabularisin I	$C_{41}H_{50}O_{19}$		Twigs and Leaves	Zhang et al. 2007

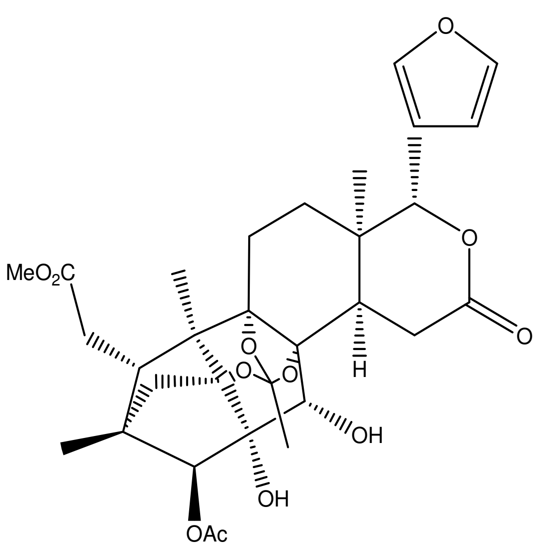


Figure 4. Structure of Phragmalin

D was obtained as a white amorphous solid having molecular formula, $C_{37}H_{44}O_{17}$.

In a subsequent study, Zhang et al. (2007a) isolated 4 novel 16-norphragmalin type limonoids and chuktabularins A - D from the ethanolic extract of stem bark of *C. tabularis* collected from Xishuangbanna, China. These chuktabularins have characteristic unprecedented skeletons with a biosynthetically extended C2 or C3 unit at C-15 forming a unique 2, 7-dioxabicyclo [2.2.1] heptane system. These compounds were isolated using silica gel and C-18 reversed phase silica gel chromatography and purified by semipreparative HPLC. Chuktabularin A was obtained as white amorphous powder having molecular formula $C_{38}H_{48}O_{17}$, whereas the molecular formula of chuktabularin B was $C_{37}H_{44}O_{17}$. Chuktabularin C and D with molecular formula of $C_{39}H_{50}O_{17}$ and $C_{38}H_{46}O_{17}$ as determined by HREIMS showed the presence of one more CH_2 unit than those of chuktabularin A and B respectively.

In continuing research, Zhang et al., (2007b) isolated 5 new limonoids, Tabularisins D-I and dinorcycloartane along with 3 known compounds, tabularisins A - C from an ethanolic extract of the twigs and leaves of *C. tabularis* var. velutina collected in Xishuangbanna, Yunnan Province, China. These compounds were obtained as white amorphous powders. Along with these limonoids, Zhang et al., (2008) isolated chuktabrins A and B from the ethanolic extract of the twigs and leaves of *C. tabularis*. Chuktabrin A was obtained as colourless crystals having molecular formula, $C_{36}H_{44}O_{16}$. The compound has characterstic unprecedented 1, 3-dioxolan-2-1 and a 3, 4-dihydro-2H-pyran formed via an ether bond between C-30 and C-1' in the biosynthetically extended C-3 unit at C-15. Zhang et al., 2008 isolated chuktabrin B as white amorphous powder and assigned it a molecular formula of $C_{41}H_{46}O_{20}$ on the basis of HREIMS at m/z 858.2604. Chuktabrin B has an unprecedented polycyclic skeleton with a biosynthetically extended C-2 unit (acetyl) at C-15.

ECONOMIC IMPORTANCE

C. tabularis is a timber plant, the wood of which is used in decorative paneling and to make musical instruments. The timber of the plant is also used in high grade cabinet work, furniture and flooring. Besides this, the plant is used for carving, cooperage, for making paper pulp, propellers, for making railway sleepers, ship, boat building, packing boxes and also for general construction (Aggarwal, 1986; Kalinganire and Pinyopusarek, 2000). The bark and leaves of plant also contain high valued commercial gums and tannins (22%) for which it is used in tanning industry. The flowers are known to contain red and yellow dye (Aggarwal, 1986). In Ayurveda, the bark and leaves of this plant are mentioned of having great medicinal properties as antipyretic and antidiarrheal activities (Kirtikar and Basu, 1981). The twig and bark extract of *C. tabularis* are reported to have antifeedent activity against Pieris rapae (cabbage white butterfly) and third instar larvae of Spodoptera littoralis (Boisd.) respectively due to which it might be used as natural insecticide (Kalinganire and Pinyopusarek, 2000; Nakatani et al., 2004; Abdelgaleil and Aswad, 2005).

The plant is grown as shade tree along with coffee plantation and is also domesticated for agroforestry. It is used for commercial purposes as green manure (Rai, 1985; Kalinganire and Pinyopusarek, 2000).

ETHNOBOTANICAL/ETHNOMEDICAL VALUE

C. tabularis is a dominant tree of Konthoujam Lairembi (a sacred grove of Manipur) with an importance value index (IVI) of 1.61. These sacred groves are the seat of biodiversity. Here the plant is vernacularly known as Tairenmanbi and its young leaves and bark are taken orally for the treatment of various diseases including fever. The preferred route of its consumption is oral (Khumbongmayum et al., 2005). Burkill (1966) has also reported its use in the treatment of fever.

BIOLOGICAL ACTIVITIES

Interest in phytomedicine has exploded in the last few years and about 500 different plant species are used as key ingredients and many are still being collected from the wild (Mendelsohn and Balick, 1995). *C. tabularis* bark has got a reference in Ayurveda and its bark has been used traditionally in China and India as an antipyretic, astringent, antidiarrheal and anti-influenza drug (Kirtikar and Basu, 1981; Chen et al., 1997; Bencao, 1999). As astringents, the bark decoction heals stretch marks and other scars. Mild astringent solutions are used to relief minor skin irritations as those resulting from superficial cuts, insect bites, allergies e.t.c.

It has been found that the 50% ethanolic extract of stem bark of *C. tabularis* has an effect on respiration, makes CVS active and was also spasmolytic along with having diuretic properties. The plant is also used in the treatment of skeletal fractures (Ekanayake, 1980; Bakshi et al., 1999). The seed extracts of *C. tabularis* exhibited haemagglutinating activity against human and other animal erythrocytes (Roy and Bhalla, 1981). In order to further explore the biological activity of *C. tabularis*, first step was made by MacKinnon et al. (1997) who tested a series of 60 extracts of 22 plants from the family Meliaceae for their activity against *Plasmodium falciparum* causal organism of malaria, using both chloroquine sensitive and chloroquine resistant strains. It has been found that the extracts of leaves of *C. tabularis* showed the highest activity against chloroquine sensitive strains along with *Azadirachta indica* and *Cedrela salvadorensis*, whereas the leaves of *C. tabularis* showed the highest activity against the chloroquine resistant strains. The presence of limonoids particularly limonoid genudin is responsible for their significant anti-malarial activity (Deck et al., 1998; Schwikkard and Heerden, 2002). The leaves of the plant are reported to have anti-oxidant activity (Kaur et al., 2008).

Nagalakshmi et al. (2001) reported the anti-bacterial and anti-fungal activities of different extracts (Petroleum ether, benzene, chloroform, ethyl acetate and methanol) of *C. tabularis* using disc diffusion method along with the determination of minimum inhibitory concentration (MIC) against bacteria (*Bacillus subtilis* MTCC 121, *Staphylococcus aureus* MTCC 737, *Pseudomonas aeruginosa* MTCC 1688, *Escherichia coli* MTCC 1687, *Proteus vulgaris* MTCC 1771 and *Klebsiella pneumoniae* MTCC 109) and fungi (Candida albicans MTCC 183, *Aspergillus fumigatus* MTCC 1811, *Aspergillus niger* MTCC 1344 and *Fusarium oxysporum* MTCC 1755). The methanolic, ethyl acetate and petroleum ether extracts were found to inhibit the growth of 7, 6 and 3 of the 10 used microorganisms respectively. Nagalakshmi et al. (2001) found that in terms of MIC, the methanolic and ethyl acetate ex-

Table 2. Antifeedant activity of limonoids isolated from *C. tabularis* on *Spodoptera littoralis* (leaf disc choice bioassay).

Compound	Antifeedent (%)	
	500 μg/ml	1000 μg/ml
Tabularin	12.3 ^{fg}	20.6 ^{gf}
Tabulalide A	9.6 ^{fgh}	11.6 ^{h}
Tabulalide C	12.5 ^{gf}	29.1 ^{e}
Tabulalide D	14.8 ^{f}	17.3 ^{g}
Tabulalide F	3.0 ^{i}	3.1 ^{i}

Antifeedant percentages within a column followed by the same letter are not significantly different ($P < 0.05$, based on the LSD test). Table adopted from Abdelgaleil and Aswad (2005).

tracts were effective against *P. aeruginosa* and *A. fumigatus*, whereas petroleum ether extract was effective against *A. niger* as well as *A. fumigatus*.

BIOPESTICIDAL ACTIVITY

Phenolic compounds act as natural pesticides, providing plants with resistance to pathogens, parasites, and predators (Ames et al., 1990; Stoewsand, 1995; Salad, 1998). Limonoids are such compounds and being tetranotriterpenoid in nature, they are included in the category of phenols. These compounds occur in abundance in the plants belonging to family meliaceae. Abdelgaleil and Nakatani, 2003; Nakatani et al., 1981, 1984, 2000; Nakatani, 1999 and Saad et al., 2003 isolated several types of compounds (limonoids) as insect antifeedent from the members of meliaceae family.

In a leading step to their research, Nakatani et al. (2004) further isolated 6 new phragmalin limonoids (tabulalin and tabulalides (A - E)) from the root bark of *C. tabularis* using droplet countercurrent chromatography (DCCC) and reversed phase HPLC. The antifeedent activity of isolated compounds was further analyzed by Nakatani et al. (2004) using conventional leaf disk method given by Wada and Munakata (1968) against the third instar larvae of *Spodoptera littoralis* (Boisd.). Furthermore, the antifeedent activity was also studied by Abdelgaleil and Aswad (2005) against third instar larvae of cotton leaf worm, Spodoptera littoralis (Boisd.) by using leaf disc choice bioassay given by Kubo and Nakanishi (1977). In their analysis, they reported that tabulalin and tabulalide D were strongly active at 500 with 50 ppm concentration corresponding to concentration of ca.1 μg/leaf/cm^2 (Table 2). The antifeedent activity was found to be comparable to many other liminoids from the meliaceae plants (Abdelgaleil et al., 2000; Huang et al., 1995; Mootoo et al., 1996). The other compound under investigation showed weak activity at 1000 ppm while tabulalide C was not active at the same concentration.

ANTI-OXIDATIVE PROPERTIES

In recent years, *C. tabularis* has been explored for its anti-oxidative properties. It has been found that the methanolic extract/fractions of *C. tabularis* leaves were very much effective in scavenging free radicals (2, 2' diphenyl-1-picryl hydrazyl radical, hydroxyl radicals, generated *in vitro*, using Haber Weiss reaction mixture) either by electron or hydrogen donation. The plant extracts were also having reduction ability as determined in reducing power assay. The plant was reported to rich in phenolic and flavonoid contents and there has been found a close correlation between the total flavonoid, total phenolic content and anti-oxidant activity (Kaur et al., 2008).

In a recent study, it was found that the different extract/fractions of *C. tabularis* were helpful in minimizing the peroxyl radical mediated damage to the polyunsaturated fatty acids (Kaur et al., 2009). Due to this property the plant may play a potential role in preventing food spoilage arising due to lipid peroxidation. Also the bark of plant is rich in dyes, so it might be used as food additive. The inhibitory action of plant extract/fractions on lipid peroxidation is due to its secondary metabolites which might act as chain-breaking electron donors (by reducing $ROO^{\cdot}$), by chelating metal ions (as these ions help to initiate the reaction), or acting as chain-breaking electron acceptors (by oxidizing $R^{\cdot}$) (Aherne and O'Brien, 1999).

PRESENT STATUS

Most of the pharmaceutical industries and wooden Industries are highly dependent on wild trees for the supply of raw materials in order to extract medicinally important compounds and for timber. Due to a lack of proper cultivation practices, destruction of plant habitats, illegal and indiscriminate collection of plants from these habitats, many medicinal plants are severely threatened. *C. tabularis* A. Juss is one such plant which is included in IUCN red list (2006) of threatened species. So, today there is a dire need to focus on the cultivation of plant along with the exploration of its medicinal properties.

Conclusion

Recent reports on *C. tabularis* indicated that the plant is rich in a variety of limonoids and could be used as natural pesticide, insecticide along with other members of family Meliaceae. Limonoids are known to play an important role in the prevention of onset of degenerative diseases. The protective properties of these phytochemicals are due to their capability to scavenge free radicals, chelate metal ions and neutralizing the effect of harmful chemicals. The survey of literature reveals that the insecticidal properties of Azadirachta indica A. Juss are due to the presence of limonoids. Limonoids help in the eradication of harmful pests as they are having insecticidal, antifeedent and growth inhibitory activities as they effect on the developmental stages of insects. Also a lot of work is being carried out to explore the biological activities and the possible use of plant extracts/pure compounds in order to treat various ailments.

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