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A REVIEW ON *TECTONA GRANDIS*

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ABSTRACT

Tectona grandis Linn. (Teak) locally known as Sagwan/sagon, belongs to Lamiaceae(Verbenaceae) family, is one of the most valuable timber plant in the world, which is a native to South and Southeast Asia and is renowned for its dimensional stability, extreme durability and hard which is due to its beautiful surface and its resistance to termite and fungal damage even when unprotected by paints and preservatives The main active ingredient compounds that are responsible for these action are tectoquinone, lapachol and deoxylapachol. Naphthoquinones, anthraquinones and isoprenoid quinones are abundant metabolites in teak. In addition to these, teak contains several other phytochemicals such as triterpenoids, flavanoids, steroids, lignans, fatty esters, tannins, proteins, resins, anthraquinone-napthquinone pigments, diterpenes phenolic compounds& dye. Teak is moreover considered as a major constituent in many of the traditional medicines because of the therapeutic potential it is possessed with. Pharmacologically, the plant has been investigated for antioxidant, anti-inflammatory, Antimicrobial, antiarthritic, cytotoxic, anti bacterial, anti tyrosinase, anti diabetic, anti nociceptive, anti termitic, anti-pyretic, cytotoxic, analgesic, hypoglycemic, wound healing and antiplasmodial, hair growth properties, allelopathic activities.This review summarizes the chemistry and pharmacological profile of *Tectona grandis*.

INTRODUCTION

Tectona grandis Linn.(Verbenaceae) is a large deciduous tree. Branchlets are quadrangular, channeled and stellately tomentose. The tree is growing in higher situations, native to central India, Konkan, Western Deccan peninsula, South India and Burma[1]. It is commonly known as sagwan (Hindi), saka (Sanskrit) and teak tree (English)[2, 3]. Teak is a hardwood species of worldwide reputation[4].

Tectonagrandis is a large, deciduous tree reaching over 30 m in height in favorable conditions. Crown open with many small branches; Bark is brown, distinctly fibrous with shallow, longitudinal fissures. The root system is superficial, often no deeper than 50 cm, but roots may extend laterally up to 15 m from the stem Leaves are 30-40 by 15-30 cm, elliptic or obovate acute or acuminate. Upper surface of leaf is rough but usually glabrous and the lower clothed with dense stellate grey or tawny tomentum. The very large, 4-sided leaves are shed for 3-4 months during the later half of the dry season, leaving the branchlets bare. Shiny above, hairy below, vein network clear, about 30 x 20 cm but young leaves up to 1 m long. Flowers are shortly pedicellate with lanceolate bracts at the forks. Flowers small, about 8 mm across, mauve to white and arranged in large, flowering heads, about 45 cm long; found on the topmost branches in the unshaded part of the crown. Fruits are 1-3 cm in diameter, subflobose; pericarp is soft with dense felted stellate hairs[1] Fruit is a drupe with 4 chambers; round, hard and woody, enclosed in an inflated, bladder-like covering; pale green at first, then brown at maturity. Each fruit may contain 0 to 4 seeds. There are 1 000-3500 fruits/kg. This family includes about 236 genera and 6900 to 7200 species (Kuete 2017). The genus Tectona comprises 3 species viz *T. grandis*, *T. hamiltoniana* and *T. philippinensis, T. grandis* (teak) is widely distributed in Bangladesh, Thailand, China, India, and Pakistan. *Tectona hamiltoniana* (Dahat teak) is an endangered local endemic species confined to Burma. *Tectona philippinensis* (Philippine teak) is also

endangered endemic to the Philippines. Teak has worldwide reputation as a quality timber on account of its remarkable physical and mechanical properties, particularly elasticity, strength, durability and decay resistance (Palanisamy et al. 2009).
The generic name comes from 'tekka', the Malabar name for *T. grandis*. The specific name, 'grandis', is Latin for 'large' or 'great'.

Taxonomical classification

Table 1: Taxonomical Classification of *Tectona grandis*

Kingdom	**Plantae**
Superclass	Angiosperms
Division	Eudicots
Class	Asterids
Order	Lamiales
Family	Verbenaceae
Genus	Tectona
Species	grandis

LOCAL NAMES
Bengali - Segun,saigun
Burmese - kyun
English - teak wood,Indianoak,teak tree
Filipino - dalanang,djati
French – teck
German - tiek,Teak(holz) baum
Gujarati - sagach,saga
Hindi - saigun,sagwan,sagun
Indonesian - kulidawa,deleg,jati
Italian - teck
Javanese - deleg,kulidawa
Malay - jati
Nepali - teak,saguan
Sanskrit - bardaru,bhumisah,saka,dwardaru,kharchchad
Sinhala - takku,teaku
Spanish – teca
Swahili - msaji,mtiki
Tamil - tekku,tekkumaram,tek
Thai - sak, mai-sak
Trade name – teak

COMMON SPECIES
Teak belongs to the family Lamiaceae.
There are three species of tectona
1. *Tectona grandis* (common teak) is by far the most important, with a wild distribution in Bangladesh, Sri Lanka, India, China, Pakistan.
2. *Tectona hamiltoniana* (Dahat teak), is a local endemic species confined to Burma, where it is endangered.
3. *Tectona philippinensis* (Philippine teak) is endemic to the Phillipine and is critically endangered according to the IUCN

BIOPHYSICAL LIMITS
Altitude
0.0 - 1200 m,

Mean annual temperature
14-36^{O} C,

Mean annual rainfall
(600)1200 - 2500(4000) mm
Soil type

Their most suitable soil is deep, well-drained, fertile alluvialcolluvial soil with a pH of 6.5-8 and a relatively high calcium and phosphorous content.
The quality of growth, however, depends on the depth, drainage, moisture status and the fertility of the soil. Teak does not tolerate water logging or infertile lateritic soils.

Phytochemical constituents
Root contains lapachol, tectol, tectoquinone, β-sitosterol and a diterpene, tectograndinol[5]. Roots are used in the treatment of anurea and urine retention[6]. The flowers are acrid, bitter and useful in the treatment of bronchitis, biliousness and urinary discharges. Bark is astringent, acrid, sweet and useful in the treatment of bronchitis. The wood is acrid, sedative, anthelmintic, expectorant and useful in the treatment of gravid uterus, piles, leucoderma, dysentery, headache and burning pain over liver region. The ashes of wood applied to swollen eyelids and are said to strengthen the sight. The oil of nuts promotes the growth of hair and removes itchiness of skin. The flowers and the seeds are diuretics[1].

Table 2: Details of Secondary Metabolites

Secondary Metabolites	Secondary Metabolite	Part of The plant
Phenols and Phenolic Acid	TG1, 2, 3 and 4, Gallic acid Ellagic acid, Acetovanillone, E-isofuraldehyde,3-hydroxy-1-(4-hydroxy-3,5-dimethoxyphenyl)propan-1- one, evofolin A, and syringaresinol	Leaves
Norlignans	Tectonoelin A (or (7Z)-9'nor-3',4,4'-trihydroxy-3-methoxylign-7-ene-9,7'-lactone), Tectonoelin B (or 7Z)-9'nor-3',4,4'-trihydroxy-3,5-dimethoxylign-7-ene-9,7'-lactone), medioresinol, 1-hydroxypinoresinol, lariciresinol, balaphonin.	Stem, leaves, Seed & Wood
Flavonoids	Rutin and quercitin	Leaves
Anthraquinones	Possible anthraquinone moieties for dyeing property	Leaves
Anthraquinones	Possible anthraquinone moieties for dyeing property	Leaves
Glycosoides	Apocarotenoids: tectoionols A and B	Seed, leaves
Steroidal glycoside	beta-sitosterol-beta-D-[4'-linolenyl-6'-(tridecan-4'"-one-1'"-glucuranopyranoside	Seed, leaves
Alkaloids	Quinones: 9,10-dimethoxy-2-methyl anthra-1,4- quinone. 1,4-anthraquinone, tectoquinone, lapachol, dehydro-a-lapachone, tecomaquinone I. Naphthoquinone and anthraquinone derivatives Naphthotectone and anthratectone	Heart wood & Leaves
Steroids	Steroidal compounds, squalene, polylsoprene, cr-tolylmethyl ether, betulinic acid	Heart wood
Fatty esters	7'-hydroxy-n-octacosanoyl n-decanoate, 20'-hydroxy eicosanyl linolenate and 18'-hydroxy n- hexacosanyl n-decanoate.	Stem wood

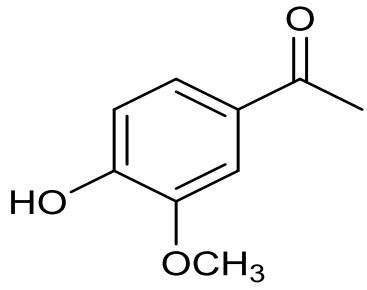
Phytochemical constituents A variety of interesting compounds have been isolated and identified from *T. grandis* Linn. The summarized details of chemical constituents of *T. grandis* Linn. are discussed in Table 3.

Table 3: Preliminary phytochemical screening of *T. grandis*

Name of compound	Test performed	Observation	Ethanol extract	Aqueous extract
Alkaloids	Mayer's	Cream ppt.	+	+
	Hager's	Yellow ppt	+	+
	Wanger's	Reddish brown	+	+
	Dragendroff's	Brown colour	+	+
Carbohydrates	Molisch	Purple ring	+	+
	Fehling's solution	Brick red ppt	+	+
Cardiac glycosides	Legal's	Pink ppt	+	+
	Balget's	Orange colour	+	+
Saponin glycosides	Foam	Foam formation	+	+
Steroids	Salkowski's	Deep red sol.	+	+
Tannins	Lead acetate	White ppt	+	+
	Gelatin (1%)	White ppt	+	+
Proteins and amino acids	Biuret	Violet colour	+	+
	Ninhydrin	Purple colour	+	+
Flavonoids	FCl_3	Yellow colour	+	+

A phytochemical study on the most bioactive extract from *T. grandis* Linn. led to the isolation of two new norlignans, tectonoelin A and tectonoelin B compounds. The chromatographic study of the dichloromethane-water (DCM/H2O) active extract of leaves showed, four phenolic compounds named as acetovanillone[1], Eisofuraldehyde[2], 3-hydroxy-1-(4-hydroxy-3,5- dimethoxyphenyl)propan-1-one[3],

evofolin A[4], and eight lignans, namely, syringaresinol[5], medioresinol[6], 1-hydroxypinoresinol[7], lariciresinol[8], balaphonin[9], zhebeiresinol[10], Tectonoelin A or (7Z)-9'nor-3',4,4'-trihydroxy-3-methoxylign-7-ene-9,7'-lactone[11], Tectonoelin B or (7Z)-9'nor-3',4,4'-trihydroxy-3,5- dimethoxylign-7-ene-9,7'-lactone[12]. The bioactive fractions of teak have seven apocarotenoids, two of which have been isolated for the first time as natural products named as tectoionols A[13] and tectoionols B[14]. The chemical structures were determined through 1D and 2D nuclear magnetic resonance (NMR) experiments and named as 9(S)-4-oxo-7,8- dihydro-b-ionol[15] and 3b-hydroxy-7,8-dihydro-b-ionone[16] have been corrected on the basis of g-HSQC and g-HMBC experiments and three[17-19] are yet to be named. The general bioactivities of isolated compounds have been studied using etiolated wheat coleoptiles[14]. Phenolic compounds like phenolic acids, flavonoids and tannins are important plant metabolites that are important for many pharmacological activities. The isolation of four phenolic compounds named as TG1, TG2, TG3 and TG4 i.e. Gallic acid[20] and ellagic acid[23] (phenolic acids), rutin[21] and quercitin[22] (flavonoids) from the methanol extract of *T. grandis* Linn.The presence of these constituents of teak contributing for the activities by virtue of their different properties like antioxidant, anti-inflammatory, analgesic and antimicrobial activities[15]. The petrol extract of the heartwood of *T. grandis* Linn. afforded a new 9,10-dimethoxy-2-methyl anthra-1,4- quinone[24]. The 1,4-anthraquinone derivative in addition to ether isolated tectoquinone, lapachol, dehydro-a-lapachone, tecomaquinone-I and some unidentified anthraquinones. Previous work on this plant led to the isolation of a number of naphthoquinone and anthraquinone derivatives as well as steroidal compounds, squalene, polylsoprene, cr-tolylmethyl ether, betulinic acid[16]. A new steroidal glycoside identified as beta-sitosterol-beta-D-[4'-linolenyl-6'-(tridecan-4'"- one-1'"-oxy)] glucuranopyranoside and three new fatty esters, 7'- hydroxy-n-octacosanoyl n-decanoate, 20'-hydroxy eicosanyl linolenate and 18'-hydroxy n-hexacosanyl n-decanoate, along with the known compounds n-docosane, lup-20(29)-en-3beta-ol, betulinic acid and stigmast-5-en-3-O-beta-D-glucopyranoside. Their stereo-structures have been elucidated on the basis of spectral data analyses and chemical reactions[17]. Two new quinones, (an isoprenoid quinone, and a dimeric anthraquinone) named naphthotectone and anthratectone, respectively, were isolated from bioactive leaf extracts from *T. grandis* Linn,. Their structures were determined by a combination of 1D and 2D NMR techniques and the bioactivity profile of naphthotectone was assessed using the etiolated wheat coleoptiles bioassay in aqueous solutions at concentrations ranging from 10(-3) to 10(-5)M, as well as the standard target species lettuce, cress, tomato, and onion. The presence of naphthotectone, as the major component in *T. grandis* Linn., suggests that it may be involved in the allelopathic activity previously described for this species, and probably in other defense mechanisms[18].



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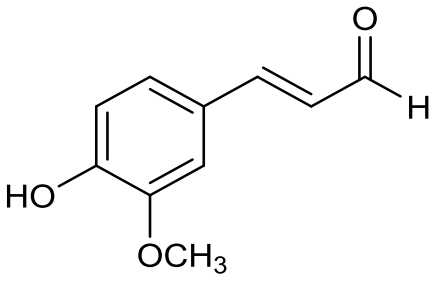

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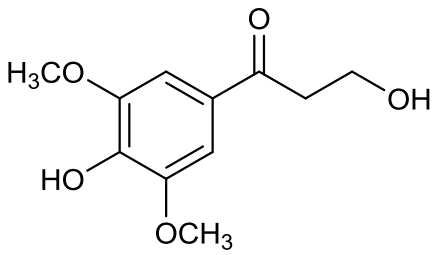

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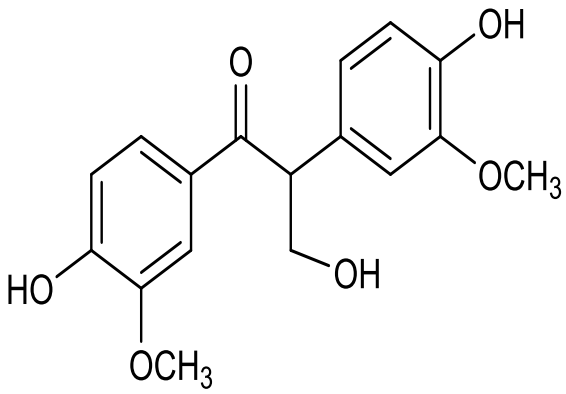
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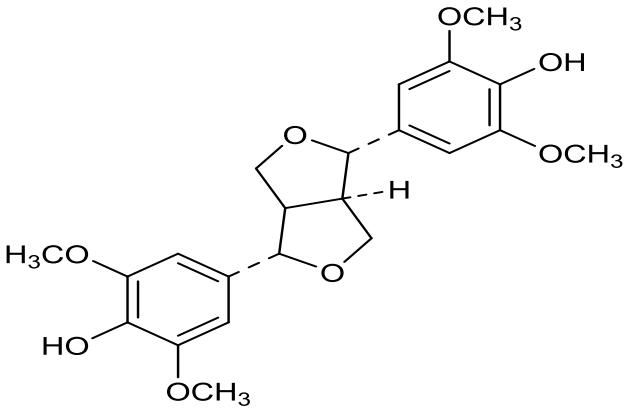
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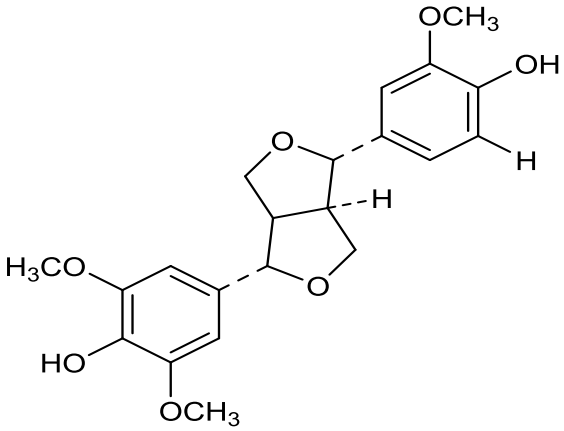
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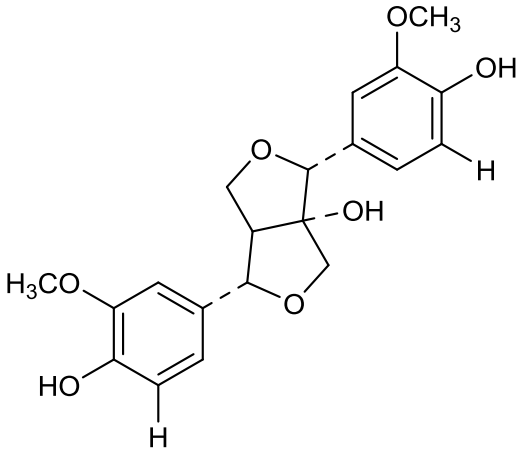
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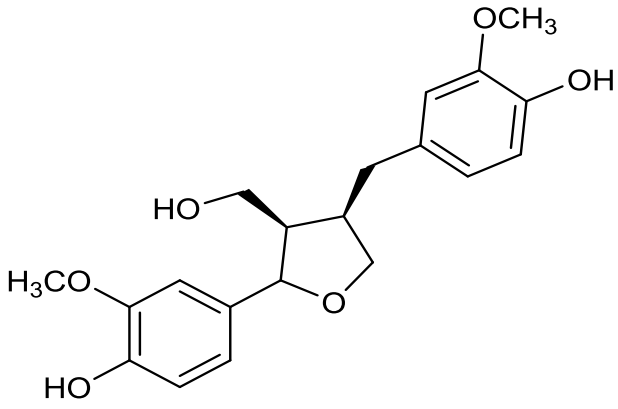
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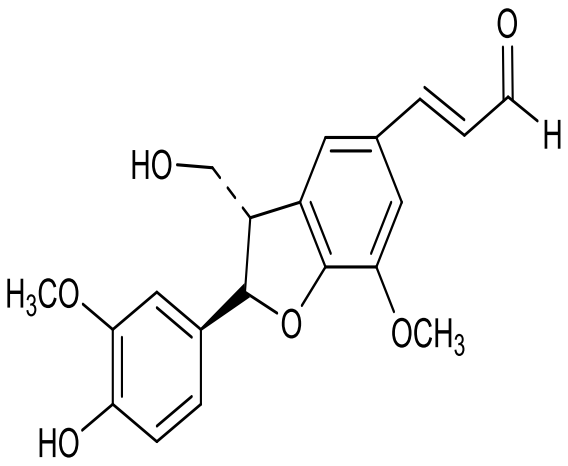
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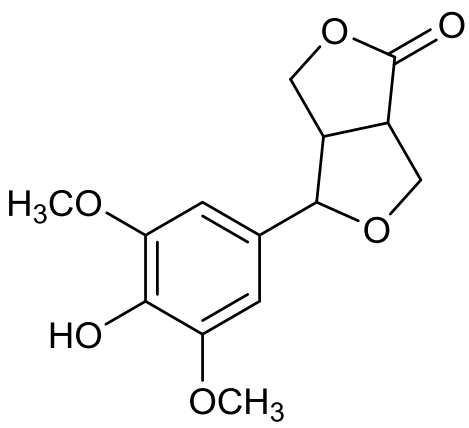
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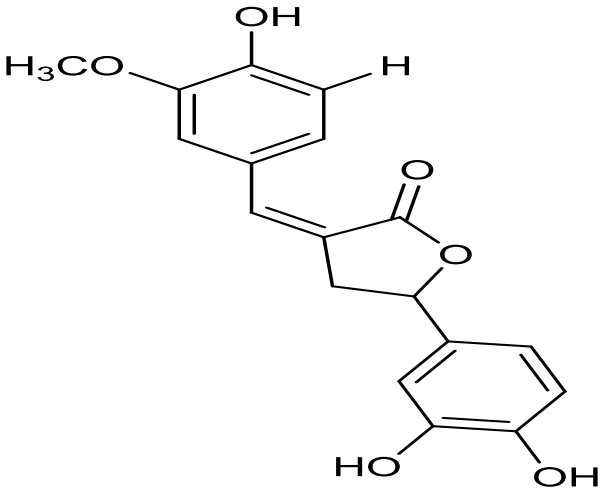
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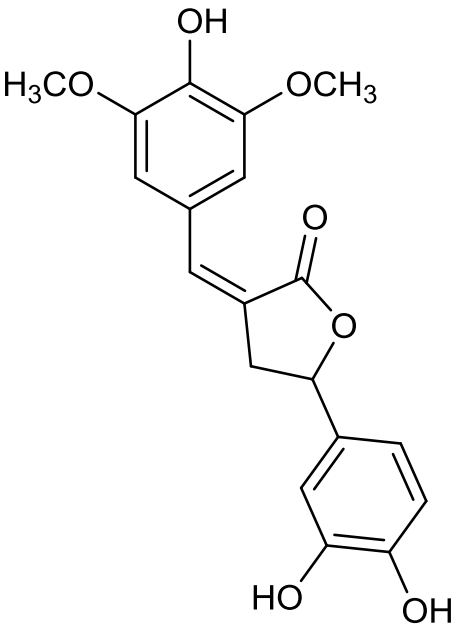
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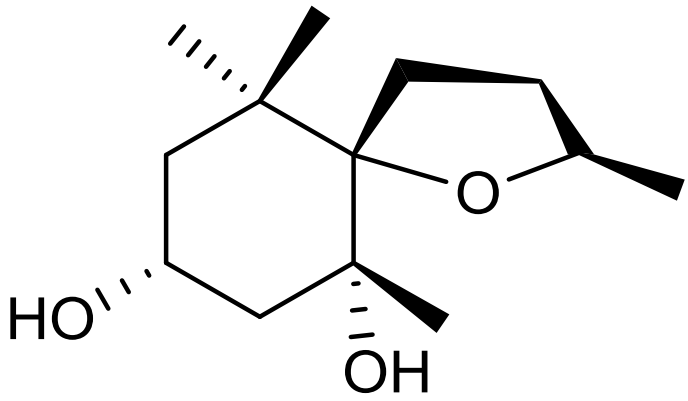

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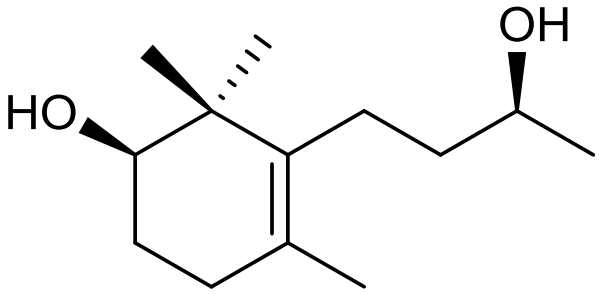

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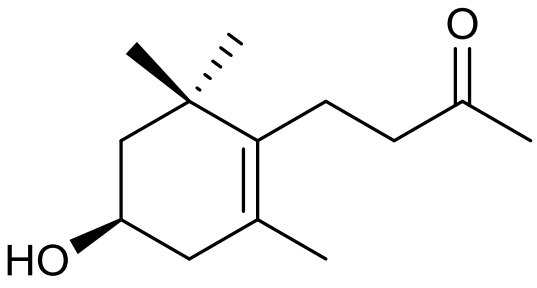

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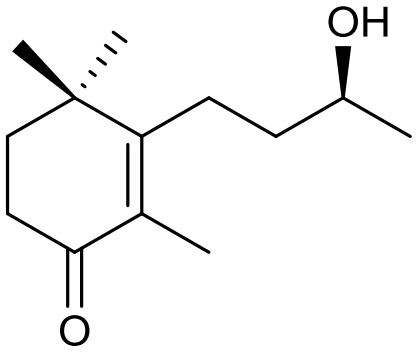

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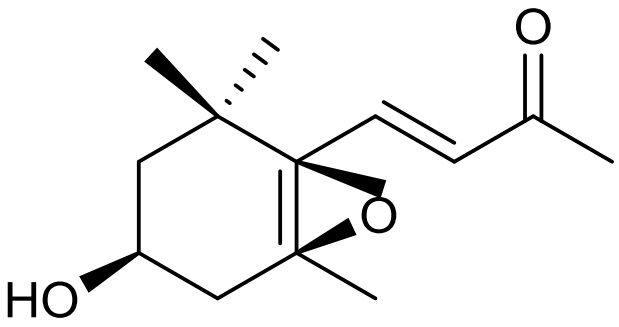

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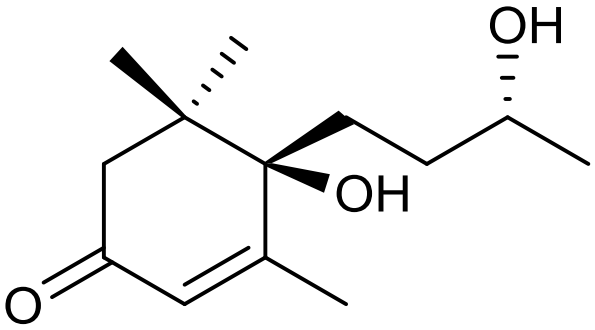

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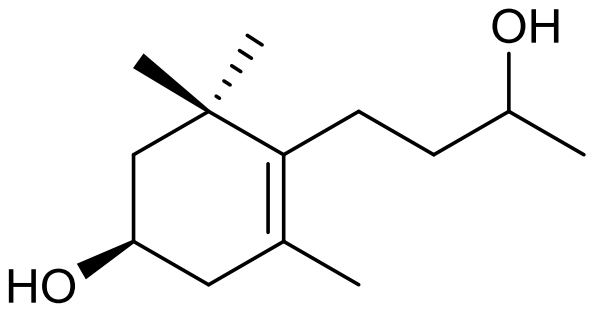

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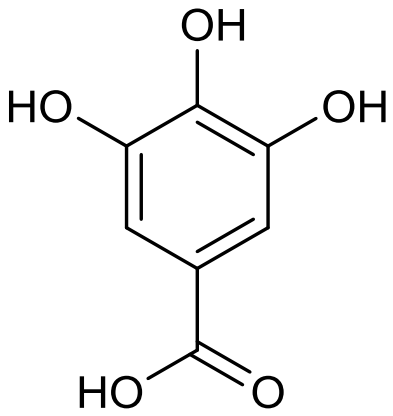

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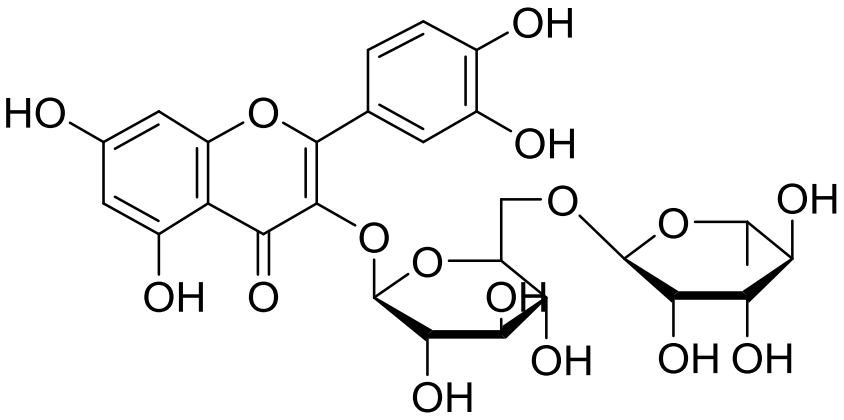

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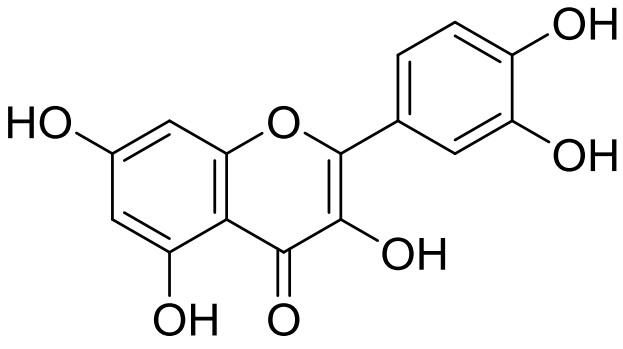

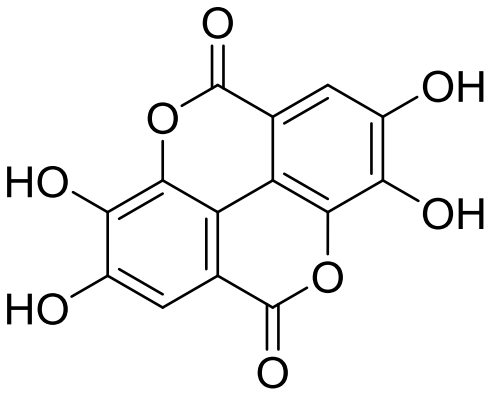

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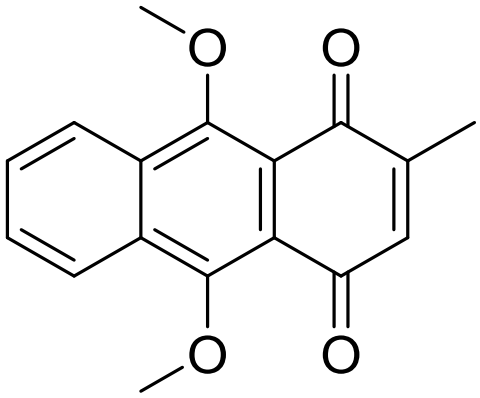

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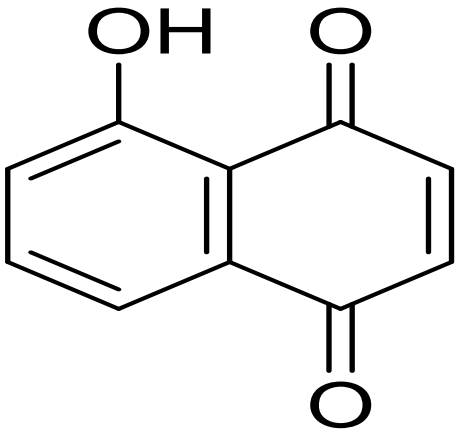

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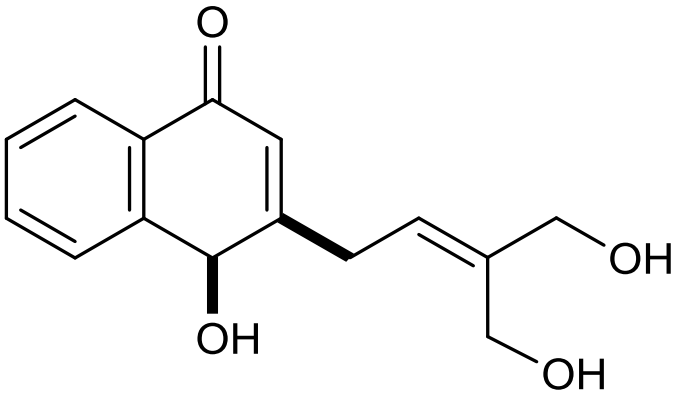

26.

Pharmacological activities

In the recent years, the use of herbal products has been increasing worldwide. Herbal source have always been striking basis of drugs. On the other hand, intricate ways of molecular interactions and bioactivity mechanisms of the extracts or their bioactive constituents provide a challenge to the scientists. *T. grandis* Linn. displays a wide range of pharmacological activities and a brief overview of its pharmacological activities are also presented in this article.

PHARMACOLOGICAL PROFILE

Antioxidant activity

Antioxidant activity of leaf, bark and wood of Hexane, chloroform, ethyl acetate and methanol extracts was checked with 1, 2-diphenyl 1-picryl hydrazil (DPPH) and ABTS+ free radical. Ethyl acetate extract of wood showed very high activity with 98.6 % inhibition against DPPH and ABTS+ free radicals. The antioxidant activity of *T. grandis* Linn. with its crude ethanol extracts by H2O2 scavenging activity, DPPH and FRAP assay proved its potential[6]. Another study examined the antioxidant activity of *T. grandis* Linn. leaf extracts employing four in vitro assay systems, i.e., Total phenolic content, reducing power, Super oxide radical scavenging activity, Inhibition of H2O2 induced erythrocyte haemolysis method, in order to understand the usefulness of this plant as a foodstuff as well as in medicine[7]. The

plant extracts of 17 commonly used Indian medicinal plants were examined for their possible regulatory effect on nitric oxide (NO) levels using sodium nitroprusside as an NO donor in vitro. *T. grandis* Linn. shows potential scavenging activity among all other plant extracts[8].

The antioxidant potential activity of the defatted 90% methanol extract of *T. grandis* as well as its derived fractions was determined via eye-detected semiquantitatively via a rapid DPPH staining-TLC technique. Each diluted sample was applied as a TLC layer that was stained with DPPH solution. This method depends up on the inhibition of the accumulated of oxidized products and the generation of free radicals was inhibited via the addition of antioxidant and masking of the free radicals (Soler-Rivas, 2000; El-Sayed et al., 2011). Initial faint spots appeared and weak spots could be observed in sample row, and the appearance of white spots has potential value for the indirect evaluation of the different tested fractions (Chang et al., 2002). These white spots with strong intensity appeared quickly at the concentration of 0.50 mg/ml of each extract, ascorbic acid was used as a positive control. Results revealed that, all the tested extracts showed promising activity but the n-BuOH extract showed the potent activity followed by the EtOAc. These results revealed that all the tested extracts react positively with DPPH and these reactions based on the ability of these extracts/fractions as free radical scavenging compounds. The wider diameter as well as high color intensity of the resulting dots (spots) indicates the high radical masking activity of the tested fractions (Dong-Jiann Huang et al., 2005; El-Sayed et al., 2011).

The antioxidant property of the *Tectona grandis* leaves, conferred upon by the presence of high amounts of tannin may also be responsible for pro-healing action of the extract (Mrityunjoy Majumdar, 2007).

Several concentrations ranging from 25-250 µg/ml of the ethanolic extract of *Tectona grandis (TG)* was tested for antioxidant activity in different in-vitro models. It was observed that free radicals were scavenged by the *TG* in a concentration dependent manner in all the assay viz DPPH; H2O2 scavenging activity, reducing power activity, were found to be 37.5, 32.0 and 190.0 µg/ml concentration respectively. On a comparative basis the extract showed better activity in DPPH· radicals with IC50 value of 37.5 µg/ml. However the extract also showed encouraging response in quenching H2O2 radicals with IC50 value of 32.0 µg/ml, and reducing power assay showed 50 % reduction at 190.0 µg/ml concentration.(Pharmacologyonline 3: 296-305 (2008) Ghaisas et al).

In another work, *Rajkumar S Bagali et. Al,* stated that several concentrations ranging from 10-1000 µg /ml of the ethenolic extract of bark of *Tectona grandis* tested for their antioxidant activity by DPPH model. It has been observed that free radicals were scavenged by the *Tectona grandis* bark ethenolic extract in a concentration dependent manner in this DPPH assay (Table 2).The ethenolic extract of bark of *Tectona grandis* showed DPPH radical scavenging activity with an IC50 value of 211 µg /ml when compared with Standard BHT (Butylated hydroxytolune) IC50 value of 107 µg /ml.

Antioxidant activity of the plant was assessed using DPPH radical scavenging activity, ferric reducing antioxidant power, ABTS radical scavenging activity, and Linoleic acid test. The results were expressed as IC50 value which is the concentration of the plant required to scavenge 50 % of the free radicals present in the system. IC50 value is inversely related to the antioxidant activity of the extracts, hence the lower the IC50 value the higher the percentage inhibition on free radicals. Extracts with IC50 value ranging between 10 and 50µg/mL are considered to possess strong antioxidant activity (Phongpaichit, 2007). DPPH stable free radical method is a reliable way to measure the antioxidant activity of plant extracts (Koleva et al., 2002; Suresh et al., 2008). Natural antioxidants available in plants are in charge of inhibiting or preventing the detrimental effects of oxidative stress. The pronounced effect of *Tectona grandis* on DPPH radical scavenging is thought to be due to their hydrogen donating ability. Also, the result of the FRAP assay showed high potential of the extract in reducing ferric tripyridyltriazine (Fe3+- TPTZ) complex to ferrous tripyridyl triazine (Fe2+- TPTZ) which is evident in the IC50 value obtained. Similarly, the extract was highly able to scavenge the radical-cation ABTS + produced by the oxidation of 2,2′-azinobis-63-ethylbenzothiazoline-6-sulphonate which is a good indication of antioxidant activity. Linoleic acid test evaluates the inhibitory effect of a compound or a mixture on the oxidation of β-carotene in the presence of molecular oxygen (O2). Hence, in this study, the plant displayed high inhibitory effect. These antioxidant activities suggest that this plant may be very useful in the management and treatment of various maladies. Phytochemical components of plants act as primary antioxidants. It is believed that phytochemicals may be effective in combating or preventing disease due to their antioxidant effect. The strong antioxidant property possessed *Tectona grandis* are mainly due to the presence of the identified phytochemicals such as flavonoid, alkaloids, phenol, tannins and glycoside. Similarly, terpenoids, play important role in controlling metabolism and also perform protective role as antioxidants (Soetan, 2008).

Anti inflammatory activity

The ethanolic & acqueous extracts of stem bark of *T. grandis* given by oral route in rat showed significant dose-dependent analgesic and antiinflammatory activities ($p<0.001$) at doses of 100, 300 and 500 mg/kg. Both ethanolic and acqueous bark extracts at 500 mg/kg exhibited significant activity within 15 min which lasted up to 120 min while the higher dose of the same extract showed significant activity after 30 min which gradually decreased after 60 min. Aqueous and ethanol extracts of *T. grandis* had an antiinflammatory effect at 100, 300 and 500 mg/kg, respectively. The acqueous extract had higher antiinflammatory potential than indomethacin, while the activity of the ethanolic extract was approximately similar with that of indomethacin. The Aqueous extract was more active than the standard product, paracetamol (for analgesic) and indomethacin (for antiinflammation) ($p<0.001$) but this activity was less important for the ethanolic extract, at the dose of 500 mg/kg.

Study has shown that the aqueous extract of the bark of the *T. grandis* (200 and 400 mg/kg, p.o.) possess a significant ($p<0.001$) anti-oedematoganic effect on paw oedema induced by carrageenan compared to vehicle treated animals. Since carrageenan induced inflammation model is a significant test for anti-inflammatory agent acting by the mediators of acute inflammation[31]. The results of this study showed that *T. grandis* can be effective in acute inflammatory disorder.

Related previous work by Asif (2011) reported significant dose-dependent anti-inflammatory activities of *T. grandis* stem bark aqueous and ethanol extracts in vivo on carrageenaninduced rat paw oedema. A comparative anti -inflammatory study of *T. grandis* flowers in vivo (Ramachandran et al., 2011) and leaves in vitro (Javalgikar et al., 2019) using similar model also indicated significant activity.

Antibacterial activity

Preliminary study on antibacterial activity of crude extract from leaf, bark and wood showed chloroform extract of leaf to be most promising. Out of the four cultures tested, it showed good activity against S. aureus (14 mm) and K. pneumoniae (8 mm) at the highest concentration checked (500 µg). Methanol extract of leaf and ethyl acetate extract of wood was also able to show fairly good activity against gram positive and negative species. On comparison, only chloroform extract of leaf was able to produce activity even at least concentration tested. The result supports previously reported data on antimicrobial activity of aqueous extract of teak against *S. aureus* and *K. Pneumonia*.[16] But a detailed study on different extracts of leaf has not been carried out so far. Antifungal and antibacterial activity of saw dust, wood and bark of teak along with the compounds identified has been reported earlier[17-18]. As plant leaves are site of synthesis for different class of compounds, the chance of finding bioactive novel compounds will also be high. According to reviews, extracts or phytochemicals showing activity against gram positive and negative organisms are rare. So the presence of a compound(s) with broad spectrum activity against both types of organisms has to be explored by further purification.

The antibacterial effect of this extract was found to be comparable to the antibacterial activity exhibited by conventional antibacterial cream, Silver Sulphadiazine (SSD). On considering antibacterial activity of *Tectona grandis* leaf extract exhibit a better antibacterial activity against pathogens from burn injuries. Regarding *Tectona grandis*, though it showed inhibition irrespective of the species studied, the efficiency is found to be very much less in Salmonella typhi MIC studies. It reveals that about 0.125± 0.02 mg/ml of *Tectona grandis* leaf extract was required for inhibition of growth for Proteus vulgaris to other species (0.030- 0.07 mg/ml).(K G Purushotham* & L Sankar Int J Pharm Bio Sci ; www.ijpbsonline.com)

The research study revealed that characterize of inhibitory mechanism in *T. grandis* Linn. bark and to determine its effectiveness against Listeria monocytogenes and methicillin resistant Staphylococcus aureus (MRSA) by employing disc diffusion method. The study also investigated the antibacterial compound is 5-hydroxy-1,4- naphthalenedione (Juglone)[25] by gas chromatography-mass spectrometry, and 1H and [13]C NMR analysis[19]. Later, another research study investigated that, Juglone has been found to be inhibitory to oral pathogens, notably Streptococcus mutans, Streptococcus sanguis, Porphyromonas gingivalis and Prevotella intermedia[20,21]. Another study showed the synergistic in-vitro antibacterial activity to formulate new cost effective antimicrobial agent for multi-drug resistant organisms, based on the synergistic activity of Tetracycline with methanol extract of *T. grandis* Linn.. The Minimum Inhibition Concentration (MIC) of methanol extract in combination with Tetracycline using 9 different Gram-positive and Gram-negative bacteria and those are associated with various forms of human infections. It shows maximum synergistic activity against different bacteria both Gram-positive and Gram-negative species. The higher synergistic rate was achieved against Salmonella typhimurium (MTCC 98), Klebsiella pneumonia (MTCC 432), and lowest synergistic shows against Pichia pastoris (MTCC 34), Escherichia coli, (MTCC 729). No synergistic activity was observed in Citrobacter freondii (MTCC 1658)[23]. The antibacterial activity was also tested for leaf, bark and wood extracts of *T. grandis* Linn. against Staphylococcus aureus (ATCC 25923),

Klebsiella pneumoniae (ATCC 700603), hospital strains of Salmonella paratyphi and Proteus mirabilis by disc diffusion assay[24].

A disc diffusion method was used to determine bacterial inhibition by teak bark extracts. Thus, the Listeria and MRSA cultures were grown overnight at room temperature in Fraser broth (Oxoid) and tryptone soya broth (TSB; Oxoid), respectively. Lawns of L. monocytogenes and MRSA were prepared using 0.1 ml volumes of overnight broth cultures on MLSM and TSA respectively. These broth cultures contained c. 108 cells ml)1 . Then, 1, 2, 3 and 5 µl volumes of purified extract, which corresponded with 1.7, 3.4, 5.1 and 8.5 mg of bark, were pipetted onto 6 mm diameter Whatman (Maidstone, UK) filter paper discs, airdried, and placed on the bacterial lawns before incubation at 37ºC overnight. Comparisons were made with identical quantities of Juglone (Sigma, Poole, UK). Antibacterial activity was recorded when zones of clearing were observed. Purified material from silica TLC Bio-assay plates (Nunc, Hereford, UK) was examined to determine the presence of bioactive compounds (after Austin and Billaud 1990). Thus, the TLC sheet was placed on top of MLSM or TSA, as appropriate, and incubated at 4ºC for 3 h to allow antimicrobial compounds to diffuse into the medium. These were overpoured with 100 ml of molten cooled MLSM or TSA seeded with 1 ml of an overnight broth culture, which cultures contained c. 10^8 cells ml^{-1} of L. monocytogenes or MRSA. After incubation at 37ºC for 18 h, 5.0 ml of 10% (w/v) tetrazolium (sodium salt; Sigma) was added, and the presence or absence and precise location of zones of clearing were recorded. Spots in the TLC, considered to contain antimicrobial compounds, were scraped into solvent, i.e. ethyl acetate, and inhibition re-affirmed by antibiogrammes (Austin and Billaud 1990).

The antibacterial activity was performed by disc diffusion method were checked against Staphylococcus aureus, Staphylococcus epidermidis and Propionibacterium acnes was modified by Tendencia (2004). Bacterial were culture in Mueller-Hinton Broth, MHB (2 ml) and incubated at 37°C for 18-24 hours. Adjust turbidity by normal saline solution (0.85%) and determine by spectrophotometry the optical absorbance to 0.08-0.13 at 625 nm. Then, swab culture on Mueller-Hinton Agar (MHA) and dry the surface for 3-5 minutes. The crude extracts were dissolved in methanol and solutions were dropped on paper disc (500 µg/disc), place paper disc on MHA and incubated for 18-24 hours. After that measure the diameter of inhibition zone and gentamicin was used as a positive control and methanol was used as a negative control. The antibacterial activity from fresh and fallen leaves extracts by disc diffusion method against S. aureus, S. epidermidis and P. acnes with concentration at 500 µg/disc. The diameter of inhibition zone showed that fresh (13.90±0.91mm) and fallen (13.45±0.70 mm) leaves extracts from Phrae, fresh leaves (12.45±0.30 mm) from Sukhothai, fresh leaves from Chaingmai (11.23±0.79 mm) and fallen (11.68±0.73 mm) leaves from Lampang at Thongphaphum silviculture research station good activity against S. aureus. Fresh (13.11±0.51 mm) and fallen (14.31±0.6 mm) leaves extract from Phrae, fallen (13.78±0.51 mm) leaves extract from Lampang and fallen (11.62±0.43 mm) leaves extract from Khonkaen at Thongphaphum silviculture research station inhibited growth of S. epidermidis. Fresh (14.01±0.22 mm) leaves extract at Thongphaphum silviculture research station, fallen (13.32±0.82 mm) leaves extract from Lampang at Pitsanulok, silviculture research station, fresh leaves extract from Sukhothai at Thongphaphum silviculture research station inhibited growth of P. acnes reported.

The addition of teak leaf extract showed antibacterial activity on Escherichia coli ATCC 25922 and Staphylococcus aureus ATCC29213 proven by the formation of clear zone diameter 0.12cm-1.26cm and 0.14cm-1.37cm. other research showed that teak leaf extract added on edible film caused inhibition of *Eschericia coli* and *Staphylococcus aureus; Psedomonas aeruginosa, Proteus mirabilis, Salmonella typhimurium, Klebsiella pneumoniae, Escherichia coli* and *Serratia marcescens*[121]. Teak leaf extract has antibacterial activity against *Escherichia coli*[120]. Antibacterial contained by edible films containing teak leaf extract more effect on *Staphylococcus aureus* ATCC 29 213 compared against *E.coli* ATCC 25922. This is caused by the structure of the cell wall of Gram-positive bacteria such as *Staphylococcus aureus* is simpler than the cells of Gramnegative bacteria, *Escherichia coli*, so cause antibacterial easier entry into cells of gram-positive bacteria. Grampositive bacteria have a cell wall of different sensitivity to antibiotics, physical and enzyme treatment compared with gram-negative bacteria which Gram-positive bacteria more sensitive than Gram-negative antibacterial[122]. In order antibacterial effect on Gram-negative bacteria, antibacterial must penetrate the outer membrane of bacterial sheath advance. After that, the antibacterial entry through the cell wall and reaches past the periplasmic enzyme serine protease.The enzyme responsible for the biosynthesis of the cell wall[123]. Carrageenan with the concentration of 7% and 20% leaf extract resulted in the largest inhibition zone. The higher the concentration of leaf extract the higher the antibacterial antibacterial activity, meaning that the bacteria will be killed faster when higher concentrations of antibacterial given[120]. Phenol is a major component in teak leaf extract as antibakteri. Fenol can be damaged by oxidation. The efectiveness of oxidation depending on the amount of O2 in the air and the material properties of carrageenan[6] transmission of O2, as the small molecule of carrageenan fill a void in polymer matrix

so as to minimize O2 that affected the oxidized phenols. The hydrophobic nature of O2 and hydrophilic structure carrageenan resulted in O2 difficult to penetrate the polymer carrageenan[124], so phenol in the network are better protected if the edible film[125]. Average inhibition zone diameter of edible film formed from varies carrageenan concentration with addition of varies teakleaf extract concentration. Teak bark is effective against *Listeria monocytogenes* and methicillin resistant *Staphylococcus aureus*. The antibacterial compound of teak leaf is 5-hydroxy-1, 4- naphthalenedione (Juglone)[126]. This compound has been found to be inhibitory to oral pathogens, *notably Streptococcus mutans, Streptococcus sanguis, Porphyromonas gingivalis and Prevotella intermedia*[127, 128].
Another study showed the synergistic in-vitro antibacterial activity to formulate new cost effective antimicrobial agent for multi-drug resistant organisms, based on the synergistic activity of Tetracycline with methanol extract of teak. Other research shows maximum synergistic activity against different bacteria both Gram-positive and Gram-negative species. The higher synergistic rate was achieved against Salmonella typhimurium (MTCC 98), Klebsiella pneumonia (MTCC 432), and lowest synergistic shows against Pichia pastoris (MTCC 34), Escherichia coli (MTCC 729). No synergistic activity was observed in Citrobacter freondii (MTCC 1658)[120]. The antibacterial activity was also tested for leaf, bark and wood extracts of teak against *Staphylococcus aureus* (ATCC 25923), *Klebsiella pneumoniae* (ATCC 700603), hospital strains of *Salmonella paratyphi* and *Proteus mirabilis*[129].

Antimicrobial activity of *Tectona grandis* of both pure and hybridi variety were evaluated by using disc diffusion method against different pathogenic bacteria. The observation was taken after 24 hours and following results were obtained.The results of pure and hybrid variety taken separately. In pure variety of *Tectona grandis* the Staphylococcus aureus showed the maximum antimicrobial activity ZOI=4mm while, *Salmonella typhi* showed ZOI=3mm and minimum antimicrobial activity was shown by *Bacillus cereus* ZOI=2mm while *Escherichia coli* showed no antimicrobial activity. In comparison with the work conducted by Purushotham and Sankar (2013)[115] it was observed that *Tectona grandis* leaves extract prepared using chloroform showed antimicrobial activities against *Staphylococcus aureus, Escherichia coli* and *Salmonella typhi*. The efficiency of *Salmonella typhi* was very less. Purushotham et al. (2010) tested four plant extract and only *Tectona grandis* leaves showed inhibition, leaves were extracted using methanol which showed high antibacterial activity against *Mycobacterium tuberculosis* even at low concentration. The result suggested that presence of active compounds at high concentration like tectoleafquinone, tectoquinone, juglone, naphthaquinone, beulinac acid could be the reason. In other study Krishna and Nair (2010) reported that plant extract obtained using chloroform shows activity against *Staphylococcus aureus*. They further reported that only leaves extract prepared using chloroform showed antibacterial activity at low concentration. Since leaves of the plant are the site for the synthesis of bioactive compounds and therefore they have high concentration of active compounds in leaves and hence they showed antibacterial activity in the leaves. Nayeen and Karvekar (2011) suggested that some phenolic compounds like gallic acid, ellagic acid, rutin, sitosterol, quercetin etc from the leave extract of *Tectona grandis* are responsible for its anti – allergic, anti – microbial, anti – oxidant, cardioprotective and vasodilator effect. In hybrid variety of *Tectona grandis* the *Staphylococcus aureus* showed the maximum antimicrobial activity ZOI=9mm while, *Salmonella typhi* showed ZOI=5mm and minimum antimicrobial activity was shown by *Bacillus cereus* ZOI=3mm while *Escherichia coli* showed no antimicrobial activity. It can be assumed that hybrid plant have some genetic modification that lead to the more antimicrobial activity in hybrid plant as compared to pure variety of *Tectona grandis*. In comparative way of both pure and hybrid variety of *Tectona grandis*, it concluded that hybrid variety of plant showed more antiit might be microbial activity as compared to pure variety of plant. Like *Staphylococcus aureus* in hybrid plant extract showed ZOI=9mm whereas in pure variety it showed ZOI=4mm. Likewise *Salmonella typhi* in hybrid plant extract showed ZOI=5mm whereas in pure variety it showed ZOI=3mm. Same *Bacillus cereus* in hybrid plant extract showed ZOI=3mm while in pure variety it showed ZOI=2mm. The common thing between the two is that in both plant extract (pure and hybrid) antimicrobial activity was absent in *Escherichia coli* (gram negative bacteria). It might be due the complex cell wall of E.coli that makes this bacteria resistant against antimicrobial compounds. It can be said that highest ZOI was shown by Staphylococcus aureus followed by *Salmonella typhi* and *Bacillus cereus* respectively in both hybrid and pure varieties of *Tectona grandis*and no antimicrobial activity in Escherichia coli.

Anti termite activity

Subterranean termites were collected from an active wild colony of *Reticulitermes speratus*. The colony was maintained in a dark room at 28°C and 80% relative humidity (RH) until use. A petri dish (diameter 9 cm, height 2 cm) containing 20 g moistened and sterilized sea sand was used as a container test. Paper disc (diameter 8 mm; Whatmann International) were impregnated with

chloroform solution containing each of the test fractions. The treatment retention was 5 % (w/w) per disc and 3 duplicates were applied for each sample. After drying at 60^{O}C for 2 hours, followed by drying in a vacuum dessicator for 24 hours, they were put on a petri dish. The control discs were impregnated with chloroform only and dried with the same manner. Fifty worker *Reticulitermes speratus* Kolbe termites were introduced into the petri dish. The petri dishes were placed in a dark chamber at 27^{O}C and 80 % relative humidity. After 10 days the disc were taken out, dried in the same manner and the weight loss was determined. Mortality was calculated based on the surviving number of termites; Deoxylylapachol was detected in the n-hexane soluble extracts, however, it explained relatively little the variation in termite antifeedancy of teak bark.

Antipyretic activity by Brewer's yeast induced pyrexia Method

The antipyretic activity was assessed in male albino rats using paracetamol as a reference standard. The subcutaneous injection of yeast distinctly amplified the rectal temperature and the mean increment recorded was 1.24–2 ◦F after 18 hr of administration. The fall of temperature in test groups was statistically significant and it is in a dose dependent manner compared to the reference standard. Since the pattern of reducing temperature for the test sample was almost similar to that of standard, suggesting the antipyretic activity may be by interfering the prostaglandin production and other inflammatory mediators like cytokinines. From the pharmacological activity results, it can be affirmed that the seeds acquired considerable anti pyretic activity in adult Wistar rats in a dose dependent manner for the selected animal model.

Cytotoxic activity

Brine shrimp lethality test (BSLT) Brine shrimp cytotoxicity assay has been considered as primary screening bio-assay for anticancer activity. Brine shrimp assay is suggested to be a convenient probe for the pharmacological activities in medicinal plant extracts (Mayerhof et al., 1991). BST bioassay can be successfully used as a cheaper, reliable and quicker tool for isolating the biologically active fractions especially anticancer agents from the natural sources (Pathak et al., 1988). In the present study, extracts of *T. grandis* plant were evaluated by the brine shrimp lethality bioassay using the procedure (Meyer et al., 1982). Basing on the brine shrimp toxicity data, the n-BuOH extract showed the most potent toxic effect at LC50 = 15.84 µg/mL, followed by defatted 90% MeOH extract which showed cytotoxicity at LC50 = 79.43 µg/ mL, 90% MeOH and ethyl acetate extracts showed a significant cytotoxic effect at LC50 = 100.0 and 125.89 µg/ mL respectively . Several classes of plant secondary metabolite are responsible for the observed cytotoxic activity, but the most important and diverse bio-potencies have been observed in phenolic acids, flavonoids and tannins, so the observed activity may be due to the presence of secondary metabolites in *T.grandis* fractions (Pooja et al., 2010). This indicates that this plant contain potential bioactive compounds, which if properly and extensively studied, could provide many chemically interesting and biologically active drug candidates, including some with potential antitumor properties. Liver carcinoma cell line (HepG2) Cancer or malignant disease is one of the major causes of death in humans reported that malignant neoplasm is the third (12.4%) leading cause of death worldwide. Thus, it is urgent to find more and safer new active constituents that attack and kill cancer cells. The results showed the cytotoxic effects of the defated 90% methanolic extract, ethyl acetate and n-butanol fractions of the leaves part of *T. grandis* against HepG2 cell line using the sulforhodamine B (SRB) method (Skehan et al., 1990). The n-BuOH fraction showed high cytotoxic activity toward the HepG2 cell line with IC50 = 11.6 µg/ ml, followed by the 90% defatted methanol with IC50 = 19.7 µg/ ml and ethyl acetate fraction with IC50 =22.1 µg/ ml comparing with the reference standard doxorubicin with IC50 = 4 µg/ ml. According to the American Cancer Institute (ACI), the criteria and the conditions of cytotoxic activity for the crude extract is an IC50 values ≤ 20 µg/ ml, is considered to be potentially cytotoxic (Boik, 2001; AbdelHameed et al., 2012). Two tested fractions (defatted 90% MeOH and n-BuOH) showed IC50 values exist under the ACI criteria, accordingly these fractions are considered as promising cytotoxic agents.

The petrol extract of the root heart wood of *T. grandis* were showed a high level of activity in cytotoxicity test against Atremia salina (Brine shrimp) with an LC50 of 5ppm. The isolation and identification of a new compound 5-hydroxy lapachol along with reported compound lapachol found to be cytotoxic. Expression from *T. grandis* plant were found to reduce the genotoxicity of three mutacarcinogens viz. methylmethane sulfonate, mitomycin-C and dimethylnitrasamine.

Antimitotic activity was evaluated using the meristematic cells of *Allium cepa* root. The *A. cepa* bulbs were sprouted in tap water at room temperature. The sprouted root tips were then treated with ethanol and aqueous extracts (10 mg/ml) for 1 hour. The sprouted root tips treated with distilled water and methotrexate (0.1 mg/ml) were used as control and standard, respectively. The root were fixed

and stained with carmine stain and mitotic index was calculated. Results showed that 70% ethanol extract exhibited significant antimitotic activity.

Lukmandaru and Ogiyama (2005) have reported brine shrimp toxicity for *T. grandis*, and isolated seven antifeedant compounds from the chromatographic EtOAc fraction not tested for cytotoxicity. Neha and Sangeeta (2013) attributed cytotoxicity of the plant to lapachol and its derivatives. Synthesized ZnO nanoparticles from *T. grandis* leaf extract were found to exhibit in vitro cytotoxicity by MTT assay (Senthilkumar et al., 2017). Cytotoxicity of *T. grandis* stem bark presented in this report serves to compliment earlier studies. Ghareeb et al. (2014) have reported cytotoxic potential of *T. grandis* defatted leaf methanol extract and butanol fraction on liver cancer cell lines, which Khan and Mlungwana (1999) attributed to 5- hydroxylapachol. In a subsequent investigation, Krishna and Nair (2010) reported cytotoxic activity in MTT model for the leaf, bark and wood extracts of *T. grandis*.

Antidiabetic activity

Methanol extract of *Tectona grandis* has shown optimistic antidiabetic and antioxidant properties in alloxan induced diabetes in rat models. Further investigations are in process to know the active principles. The active principles may be single compound or synergetic activity.

Antinociceptive activity

The aqueous extract of *T. grandis* has both peripheral and central analgesic properties. Its peripheral analgesic activity was deduced from its inhibitory effects on chemical (acetic acid, inflammatory phase) induced nociceptive stimuli. At 100mg/kg (39.08%), 200 mg/kg (54.31%), 400 mg/kg (67.51%) of ATG, and 100 mg/kg (73.60%) of indomethacine, the peripheral analgesic action of the extract on acetic acid induced pain was found to be significant as comparable to vehicle treated animals. The centrally acting protective effects of the extract were corroborated by the first phase of tail immersion and hotplate test results. The tail immersion test indicated that the pharmacological actions were mediated by mu (μ) opioid receptors rather than kappa (k) and delta receptors[224,215]. At 200 and 400 mg/kg of ATG, the central analgesic action of the extracts on hot plate test were found to be significant ($p<0.01$ and 0.001) at 30, 60 and 90 mins.

Anti-hyperglycemic activity

The anti-hyperglycemic activity of *T. grandis* bark extract may be due to the regeneration of islets' β-cells following destruction by alloxan, as the extract shows significant reduction of blood glucose levels in 15 and 30 days, at a dosage of 2.5 and 5 g/ kg body wt., an effect similar to that of glibenclamide. But the *T. grandis* bark extract was more effective at a dose of 5 g/kg body wt. Glibenclamide is standard drug causes decrease in blood glucose 40 ± 2 mg/dl on 30th day while the *T. grandis* bark extract in the doses of 2.5gm/kg body wt. and 5gm/kg (Varma and Jaybhaye). Antihyperglycemic activity of *Tectona grandis* Linn body wt. also decrease the blood glucose 68 ± 3 and 50 ± 2.5 respectively on 30th day. This antihyperglycemic effect may be due to lapachol (a naphthoquinone), lapachonone,[264,271] deoxylapachol and tectoquinnone[267] which have been reported to be the constituents of *T. grandis*[269].

The results of methanol fractions of the *Tectona grandis* bark on blood sugar level of multi dose treated normoglycemic rats are observed. The test result indicates that, there is a significant reduction ($p<0.05$) in blood glucose level from15th day onwards, and registered 23.19, 28.5 and 33.61% reduction at the end of 30 days, in animals treated with 50, 100 and 200 mg/kg of the test fractions. However the standard drug Glibenclamide at the same day reduces the blood glucose 37.03% with $p<0.01$, when compared with normal control group. The study result suggests that, the fractions exhibit a dose proportionate hypoglycemic effect on long term use,(Bishwanath Mishra1 * Research J. Pharm. and Tech. 2021; 14(8):4247-4252. DOI: 10.52711/0974-360X.2021.00737).

Hepatoprotective activity

Rats subjected to CCl4 only, developed significant hepatocellular damage as evident from significant increase in serum activities of GPT, GOT, ALP and Total bilirubin concentration as compared to normal control group, which has been used as reliable marker of hepatotoxicity. Oral administration of ethanolic extract of *Tectona grandis* bark (200 mg/kg, p.o) exhibited significant reduction ($p<0.05$) in CCl4 -induced increase in levels of GPT, GOT, ALP and bilirubin (Total) concentration. Treatment with Liv 52 syrup also reversed the hepatotoxicity significantly ($p<0.05$).

Kapil Sachan et al. (Int. J. Pharm. Med. Res. 2014; 2(3):105-108) stated that by the administration of hydroalcoholic extract of *Tectona grandis* leaf showed significant hepatoprotective activity, which was comparable with the standard drug silymarin. Normally biochemical parameters like SGOT, SGPT and ALP are present in high concentration in liver. The reduced concentrations of SGOT, SGPT and ALP

as a result of plant extract administration observed during the study might probably be due to the presence of flavonoids. Liver protective herbal drugs contain a variety of chemical constituents like phenols, coumarins, lignans, essential oil, monoterpenes, carotinoids, glycosides, flavanoids, organic acids, lipids, alkaloids and xanthenes.

Fatty infiltration in liver

The influence of protein, isolated from teak seed upon albino rats with respect to some of their serum, liver and intestinal enzyme and liver lipid has been studied. The protein in question contains aspartic acid, thereonine, serine, glutamic acid, praline, glycine, alanine, valine, isoleucine, leucine, tyrosine, lysine, phenylalanine, histidine and arginine as determined by amino acid analyzer. After feeding experiment an increase in body weight including the liver weight was noted in the test animals due to excess protein in the diet. A marked increase was observed in G.O.T., G.P.T. and total lipid of liver, whereas G.O.T. and G.P.T. of serum were decreased. The observed increased concentration of lipid in liver may be due to excess addition of protein in diet. The overall observation is an indication of probable fatty infiltration in liver of test animals.

Immunomodulatory activity

Aqueous extract of bark has shown the presence of flavonoids, tannins and phenolic compounds and also showed significant immunomodulatory activity at 100 mg/ kg dose as studied in delayed type hypersensitivity, cyclophosphamide induced myelosuppression, and neutrophil adhesion test. So may be above mentioned constituents are responsible for immunomodulation. It can be concluded that, the aqueous extract of bark can be used as an immuno- adjuvant during the different therapies (Switi B.Gaikwad et al. / Journal of Pharmacy Research 2011,4(12),4625-4627).

Anti-arthritic activity

The result of anti-arthritic activity measured by inhibition of proteinase enzyme. The pooled fraction BVLC-2 gave concentration-dependent inhibition (24 - 71%) at 200 - 1000 µg/ml which is less (IC50 659.24 µg/ml) than the activity of the standard drug, acetyl salicylic acid (322.61 µg/ml) tested at similar concentrations. Percentage inhibition of proteinase by control was nil. The quantities of the four major semi-pure isolates derived from this fraction were too small for comparison. Fraction BVLC-2 which showed 50% antiarthritic potency of the standard drug would be a candidate for further investigation to unravel its bioactive constituents. Proteinases have been suggested to be connected to arthritis (Sandhya et al., 2018), and act by degrading the collagen and proteoglycan matrix of bone and cartilage thereby inhibiting tissue damage. The presence of flavonoid glycosides in *T. grandis* based on this present investigation, also suggests these phytochemicals as contributing to its anti-arthritic activity.

Antifungal activity

The antifungal activity of methanolic crude extract of *T. grandis* was studied at different concentrations (1000, 2000, 3000, 4000 and 5000 ug/ml). The extract of *T.grandis* showed 90.00% and 86.84% inhibition growth against Alternaria cajani and Helminthosporium. The higher concentration of methnolic extract impart maximal antifungal activity (292,307).

Antiviral activity

The extract of *T. grandis* showed high percentage about 85% of inhibition of Tomato Spotted Virus (308). Anti fertility agent *T. grandis* plant along with *Lawsonia inermis, Butea monosperma* and *Carica papaya* shows antifertility action for birth control.

Antianaemic effect

The extract of *T. grandis* leaves is evaluated on anaemic model of rat induced by intraperitoneal injection of phenylhydrazine at 40mg/kg for 2 days. Oral administration of *T. grandis* extract at 1g/kg/day, to the rats previously treated with phenylhydrazine, increased the concentration of haemoglobin, red blood cells number, haematocrit and reticulocytes rate. Moreover, the extract of *T. grandis* enhanced the osmotic resistance of the red blood cells that confirm the important presence of young red blood cells. These results support partially the traditional use of *T. grandis* in the treatment of anaemia[313].

Antiulcerogenic activity

Lapachol (a naphthaquinone) isolated from the roots of *T. grandis* given at a dose of 5 mg/kg twice daily for 3 days was found to have an anti-ulcerogenic effect on subsequently induced experimental gastric and duodenal ulcers in rats and quinea-pigs. Its action appears to be associated with an effect

in the protein content of gastric juice, and it reversed aspirininduced changes in peptic activity, protein and sialic acid[315,320].

Wound healing activity

The present study was carried out to evaluate the effect of hydrochloric extract of *T. grandis* on experimentally induced wounds in rats and compared the effect observed with a known healing agent, Aloe vera. The models selected were excision wound, incision wound, burn wound and dead space wound. A suitable gel formulation was selected for the application using cellophane membrane penetration. In the excision wound and burn wound models, animals treated with *T. grandis* leaf extract showed significant reduction in period of epithelization and wound contraction by 50%. In the incision wound model, a significant increase in the breaking strength was observed. *T. grandis* leaf extract treatment orally produced a significant increase in the breaking strength, dry weight and hydroxyproline content of the granulation tissue in dead space wound. It was concluded that *T. grandis* leaf extract applied topically (5% and 10% gel formulation) or administered orally (250 and 500 mg/kg body weight) possesses wound healing activity[334].

Hair growth promoting activity

Leaf extracts of *T. grandis* could be the potential ingredients in alternative medicines/cosmetics for hair loss treatment. This is demonstrated by their S5AR inhibitory activity, effect on HFDPCs, anti-testosterone activity as well as antiinflammatory activity through 1L-1β secretion inhibition. (*Fachrunniza, yunda, Naresuan University, Pharmaceutical chemistry &Pharmacognosy. University of Phayao, School of Pharmaceutical Sciences Wisuitiprot, Vanuchawan*)

Insecticidal activity

The tests of ethanolic and methanolic extracts from three varieties of teak leaves: Sak– Syamindra (SS), Sak–Mahesak (SM) and Sak–Thong (ST) to the 3rd instar larvae of DBM revealed that all teak leave extracts gave a rather high effect in killing the larva of DBM, at 10% concentration of extract caused 65.6–82.6 and >96.3% mortality at 24 and 48 hr, respectively. All three varieties of teak extracted by both solvents showed the larval mortality of DBM with no significant difference ($p > 0.05$) when the LC50 values at 24 and 48 hr were 7.2–8.8 and 4.9–6.4%, respectively.(J. Pumnuan1,* Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand 2 Program in Horticulture, Division of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang).

Miscellaneous Myanmar timber extract of *T. grandis* was showing potent leishmanicidal activity. The chemical constituent of the plant was found quinone derivatives[411].

CONCLUSION

Tectona grandis is a forest species, which is very famous for its timber value and decay resistance. It possesses a wide spectrum of pharmacological properties such as wound healing, antimicrobial, antioxidant, anti-inflammatory,antifungal, antiviral, anti termitic, insecticidal, allelopathic cytotoxic and hair growth, natural dye etc. In addition to these, cultivation of *T. grandis* has also become an efficient tool for pest control towards sustainable agriculture due to its phytotoxic activity. However, pharmacological and phytochemical studies have been carried out independentl. The number of studies on this plant is quite high although most of the studies have been done on the extract and isolation level. Hence, more research is required to correlate its pharmacological activity with chemical constituents, so that promising potential drug candidates could be developed. Based upon this critical review it can be concluded that there is sufficient scientifically valid evidence to state that, *T. grandis* is an interesting source of bioactive compounds used for commercial exploitation.

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