A Review on Ethnopharmacology of *Tectona grandis*

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Abstract

Medicinal plants constitute an important natural wealth of a country. They play a significant role in providing primary health care services to rural people. Herbs are used to treat or prevent a range of health problems. Although the high technology approaches of conventional medicine are especially useful for acute disease treatment and emergency care. Herbal medicines are more suitable for chronic ailment. *Tectona grandis* is one of the important medicinal plant. The name tectone is said by benthall to be derived from greek 'tectone' meaning a carpenter, 'grandis' meaning large and refers to the size of the plant. *Tectona grandis* Linn is a tree of commercial important distributed in south east Asia. Commonly known as "sagwn", "jati", belongs to the family Verbeceae. These plants have an ayurvedic function such as anti-bronchitis, scabbiest, diarrhoea, leucoderm, laxative, and expectorant. *Tectona grandis* Linn. (Verbenaceae) is a large deciduous tree. Considering the medicinal importance of *Tectona grandis* Linn, this inculcated the need to review the ethnopharmacology of this pant.

Keywords: *Tectona grandis* Linn, ayurvedic, anti-bronchitis, expectorant, ethnopharmacology

Introduction

Herbs are major component of traditional, Ayurvedic, Unani, Homeopathic and natural remedies are superior to manmade drugs because they are always associated with natural and biological

entities like protein, lipids, carbohydrates. Plants have the ability to synthesize a wide variety of chemical compounds that are used to perform important biological functions, and to defend against attack from predators such as insects, fungi and herbivorous mammals. The use of plants as medicine predates written human history. Many of the herbs and spices used by humans to season food also yield useful medicinal compounds[1.] According to WHO, a medicinal plant is any plant which, in one or more of its organ, contains substance that can be used for therapeutic purpose or which is a precursor for synthesis of useful drugs. The different parts of the plant used include seeds, berries, roots, leaves, bark or flowers etc. Today the plant products find wide variety of their applications as foodstuffs, flavoring agents and spices, perfumes and cosmetics, pharmaceutical and biological agents, recreational substances etc. Plant products are also utilized by the human population to cure and prevent various ailments. Herbs may be used for anti-inflammatory, haemostatic, expectorant, antispasmodic or immunostimulatory properties etc[2].

Herbal remedies are taken internally or applied to the skin. Fresh herbs can also be incorporated into the diet. There are various methods of intensive herbal treatment: -Tinctures, Infusion, cold infusion, decoction poultics[3].

Over 120 compounds from 90 plant species are available as prescription drugs. Over 80% of world's population relies on plant-based medicines mainly as self prescribed products. This type of herbal drug use is typically based on a simple matching of a particular herb to particular disease or symptom. For example, Valerian (*Valeriana officinalis*) for sleep disturbance and St John's Wort for anxiety and stress. Health food shops for herbal remedies are now considered equivalent to conventional drugstores by some.[3] Many conventional drugs originate from plant sources: some of the most effective drugs are plant based, such as aspirin derived from bark of willow, digoxin derived from foxglove, quinine derived from the bark of cinchona and morphine derived from the opium poppy. The development of drugs from plants by drug companies encourages large scale pharmacological screening of herbs[3]. The importance of traditional/ herbal medicine as a source of primary health care was first officially recognized by World Health Organization (WHO). In India there are 880 medicinal plants species involved in all India trade. Of this, 48 species are exported and about 42 spices are imported. The Ministry of Environment and Forests, Government of India, reveals that there are over 8000 species of medicinal plants grown in the country. About 70 percent of these plants are found in the tropical forest; spread across the Western and Eastern Ghats. According to the Export-Import Bank of

India, in its report for the year 1997, medicinal plants related trade in India at $.5.5 billion and the same is growing rapidly. According to World Health Organisation (WHO) the international market of herbal products is around $6.2 billion, which is poised to grow to $5 trillion by the year 2050. Unfortunately, India's share in the global medicinal plants related export trade is just 0.5 percent[4].

Hence medicinal plants constitute an important natural wealth of a country. They play a significant role in providing primary health care services to rural people. Herbs are used to treat or prevent a range of health problems. Although the high technology approaches of conventional medicine are especially useful for acute disease treatment and emergency care. Herbal medicines are more suitable for chronic ailment. *Tectona grandis* is one of the important medicinal plant.

The name tectone is said by benthall to be derived from greek 'tectone' meaning a carpenter, 'grandis' meaning large and refers to the size of the plant. *Tectona grandis Linn* is a tree of commercial important distributed in south east Asia. Commonly known as "sagwn", "jati", belongs to the family Verbeceae. These plants have an ayurvedic function such as anti-bronchitis, scabbiest, diarrhoea, leucoderm, laxative, and expectorant. *Tectona grandis* Linn. (Verbenaceae) is a large deciduous tree. Branchlets are quadrangular, channeled and stellately tomentose. The tree is growing in higher situations, Teak is a hardwood species of worldwide reputation. Tree 30-35 metre tall with light brown bark, leaves simple, opposite, broadly elliptical or acute or acuminate, with minute glandular dots, flowers are white in colour, small and have a pleasant smell.

Pharmacognosy of *Tectona grandis. Linn*

Synonym or common name or Other names[3]

Language	**Common name**
English	Indian Teak, Teak
Hindi	Sagwan, Sagauna, Sagu, Sagun, Sakhu
Bengali	Segunngachh, Segun
Gujarati	Sagwan, Sag, Saga, Sagach
Kannada:	Tegu, Sagawani, Thega, Jadi, Tega, Tyagadamara, Tekka mara
Malyalam	Thekku, Tekka-maram, Tekku, Tekka
Marwadi	Sagwan, Sag
Punjabi	Sagwan, Sagun
Tamil	Tekku, Tekkumaram, Tek, Kalindi
Telgu	Teku, Pedda, Tek, Peddateku, teku-manu, Adaviteku, Teechekka
Arab	Saj
Assam	Chingjagu sagun
Oriya	Saguana, Sagan, Sagun, Singuru
Persian	Saj, Sal
Santhal	Saguna
Sind	Loheru
Sanskrit	Anila, Arjunopama, Arna, Atipatraka, Balasara, Balesara, Bhumiruha, Dvarada, Gandhasara, Grihadruma, Halimaka
Urdu	Sagwan

Taxonomical classification[5,7]

Kingdom	Plantae - Plants
Subkingdom	Tracheobionta - Vascular Plant
Superdivision Division Class Subclass	Spermatophyta - Seed Plants Magnoliophyta - Flowering Plants Magnoliopsida - Dicotyledons Astridae
Order	Lamiales
Family	Verbenaceae - Verbena family
Genus	Tectona L.f. - Tectona
Species	*Tectona grandis* L.f. –Teak

Distribution [3,6,7]

Konkaan
Western ghats of Bombay
Madras presidencies
Circars
Deccan
Central India
Malay peninsula
Sumatra
Java
Burma

Tectona grandis has a natural distribution from India to Vietnam and Thailand. It is also found in cultivation throughout the tropics. Planted in various parts of the Philippines, especially parts of Mindanao and the Sulu Archipelago. Now established in the southern part of the Archipelago.

Morphology[3,4]

Leaves

Colour - green, grayish green
Size - 30-60 by15-30 cm. In seedling often long
Shape - Elliptic or obovte, acuminate

Apex - Acute

Surface - Upper surface is rough but usually glabrous,
Lower surface –clothed with dense stellate

Margin - Entire tawny to mentum

Base - Cuneate

Veinnation - 8-10 pairs of coarse vein 2 or 3 large branges

Petiole - present

Flowers

Size - Small and numerous

Type - Bisexual and often zygomorphic

Arrangement - Erect terminal lanceolate bracts the forks

Bracts beneath calyx - 2.5mm long

Calyx -3mm long panulate

Corolla - white, imbricate, tube short glabrous 5-6 lobed

Androecium (stamen) - 5-6. Inserted near the base of corolla. Epipetalous stamen.

Gynoeciun -Superior ovary.

Fruit

Size - 1.3cm diameter

Surface - Subgloubose

Type - 4 lobed, the pericarb soft with dense felted stellate hairs

Endocarp - bony

Seeds: Erect, oblong

Chemical constituent

Several classes of phytochemicals like alkaloids, glycosides, saponins, steroids, flavonoids, proteins and carbohydrates have been reported in *Tectona grandis*[8].

Secondary metabolites [9, 10, 11, 12, 13, 14]

Quinones	Tectoquinone, lapachol, deoxylapachol and its isomer, tectoleafoquinone, anthraquinone – napthaquinone pigment.
Steroidal compounds	Squalene, poly isoprene-á-tolyl methyl ether, betulinic acid, tecto grandone, monoterpene, Apocarotenoids: Tectoionols-A, Tectoionols-B.
Glycosides	Anthraquinone glycosides, Apocarotenoids: tectoionols A and B Steroidal glycoside: beta-sitosterol-beta-D-[4'-linolenyl-6'-(tridecan-4'"-one-1'"-oxy)] glucuranopyranoside
Phenolic acids	Tannic acid, Gallic acid, Ferulic acid, Caffeic acid and ellagic acid

Flavonoids	Rutin and Quercitin
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
Fatty esters	7'-hydroxy-n-octacosanoyl n-decanoate, 20'-hydroxy eicosanyl linolenate and 18'-hydroxy n-hexacosanyl n-decanoate
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 and zhebeiresinol

- betulinic aldehyde
- Acetovanillone
- E-isofuraldehyde
- Evofolin,
- syringaresinol
- medioresinol
- balaphonin
- lariciresinol
- zhebeiresinol.
- Roots are rich in lapachol, tectol, tectoquinone, β-sitosterol and diterpenes, tectograndinol[22].

Traditional Uses [3,15,16,17,18,19]

Parts	Use
Bark	astringent, constipation, anthelmintic and depurative, bronchitis, hyperacidity, dysentery, verminosis, burning sensation, diabetes, difficult labor, leprosy and skin diseases.
Leaves	are cooling, haemostatic, depurative, anti-inflammatory and vulnerary. They are

	useful in inflammations, leprosy, skin diseases, pruritus, stomatitis, indolent ulcers, haemorrhages and haemoptysis. • In India - preparation jackfruit dumpling • In Java, Indonesia - preparation of *gudeg*, a dish of young jackfruit, providing the dish with a dark brown color • In the Philippines - decoction of fresh or dried leaves used for menstrual disorders and hemorrhages in general • Decoction of leaves, fresh or dried - hemoptysis gargle for sore throat • Decoction of fallen yellow leaves used for anemia
Wood	Acrid, cooling, laxative, sedative to gravid uterus, useful in treatment of piles, leucoderma and dysentery. Oil extracted from the wood is best for headache, biliousness, burning pains particularly over a region of liver. The ashes of wood are applied to swollen eyelids and are said to strengthen the sight.
Roots	are useful in anuria and retention of urine.
Flowers	acrid, bitter, dry, increase vata, in bronchitis ,urinary discharge, diuretic, oil from the flower promotes the growth of the hair, useful in scabies. Remedies used in snake bite

Cultivation[20]

Tectona grandis grows best in a warm, tropical climate with a temperature above 22ºC. Teak prefers well-drained, fertile soils and is a strong light demander. Trees are 96 to 100% self incompatible. The species is hermaphroditic and pollinated by insects, especially bees. Propagation by seed involves pre-treatment to break the dormancy, involving wetting and drying the seed every 12 hours, over a period of two weeks. When seeds are sown in a mix of sand and coir, at 22 to 25ºC, germination will take place within two to four weeks. The germination rate is low, and teak seedlings need shading. Vegetative propagation can be achieved by grafting and budding. Tissue cultures have also been developed for the propagation of teak.

Pharmacological Activity

Ramachandran S et al[21] evaluated the anti inflammatory and analgesic potential of methanol extract of *Tectona grandis* flowers in mice and rats. Female and male Wistar albino rats (180-200g) and male Swiss albino mice (25-30 g) were used. They reported that there is reduction in rat paw edema and analgesia which was induced by carrageenan and o.6% v/v acetic acid in two doses 100, 200 mg/kg. In this dose the mice did not show any toxicity. So this suggests the potential anti –inflammatory and analgesic effect in rats.

Gururaja MP et al[22] had found anthelmintic activity of *Tectona grandis* fruits by using Indian earthworm *Pheretima posthuma*. Piperazine citrate was used as reference standard. The result is crude ethanolic extracts of *Tectona grandis* clearly demonstrate the paralysis and causes death of worms especially at higher concentration (50mg/ml) compared to the standard reference. So the use of fruits of *Tectona grandis* as anthelmintic has been confirmed.

Subramanian Ramachandran et al[23] evaluated the anti diabetic, antihyper lipidemic and antioxidant potential of methanol extract of *Tectona grandis* (METG) flowers activity in streptozotocin (STZ) induced diabetic rat. Acute toxicity study of METG and oral glucose tolerance test was performed to determine the dose and to evaluate METG effect on elevated glucose level. Diabetes was confirmed after 72 hr of administration of STZ. They found the affect of different doses of methanol extract of *Tectona grandis* flowers that is increase in body weight, serum insulin hemoglobin, total protein level in diabetic rat and also reduces the elevated glycosylted hemoglobin.

Priyanka Sharma et al[24] worked on antipyretic activity of methanolic extract of root of *Tectona grandis* on Wistar albino rats. The result was found that there is significant reduction in elevated body temperature in yeast induced pyrexia in albino rats at the dose 250 mg/kg and 500mg/kg. This was administered by oral route.

5. A. Neamatallah et al[25] found an extract from teak bark (*Tectona grandis*) inhibited *Listeria monocytogens* and methicillin resistant *Staphylococcus aureus*. Methanolic extracts of teak bark were inhibitory to those microorganism by disc diffusion, gas chromatography, NMR and ^{1}H and ^{13}C NMR analysis revealed that the inhibitory compound has the molecular weight of 174 and structure of 5-hydroxy-1,4-napthalenedione. They found 5-hydroxy-1,4-napthalenedione inhibits *Listeria monocytogens* and methicillin resistant *Staphylococcus aureus* .

M.M Ghaisas et al[26] studied in-vitro antioxidant of *Tectona grandis* and they suggested about effective activity against free radical mediated disease by using DPPH assay, ERAP scavenging assay and H_2O_2 radical scavenging assay and there is 50% reduction in ferricyanide complex at 190 μg/ml concentration. The effect is compared with ascorbic acid as a standard. Hence antioxidant property of TG may be due to presence of tannins and saponins. These results clearly indicate that TG is effective against free radical mediated diseases.

Rajkumar S. Bagali et al[27] researched on antidiabetic and antioxidant potential of ethanolic extraction of *Tectona grandis* bark and they suggested about the potential anti diabetic and antioxidant effect in alloxan induced Wistar albino rats. After administration of ethanolic extraction of *Tectona grandis* bark, reduction of fasting blood glucose level took place. And also they reported that the action is due to the presence of flavanoid and quinines.

Swit B. Gaikwad et al[28] researched on miotic activity and brine shrimp lethality test of *Tectona grandis bark* and they concluded about effective mitotic activity and brine shrimp by using allium cepa method and artemia saline egg respectively. The result showed that 70% alcohol extract was most effective in both model.

Goswami D.V. et al[29] antihistaminic activity of *Tectona grandis* bark and they reported that ethyl acetate extract of *Tectona grandis bark* showed significant anti-histaminic activity at the dose 100mg/kg in different in vivo animal model like clonidine and haloperidol induced catalepsy, milk induced leucocytosis and eiosinophilia.

Swit B. Gaikwad et al[30] worked on immuno modulatory screening of *Tectona grandis* bark. From their study they reported that aqueous extract with increasing dose has shown immunostimulatory properties in swiss albino mice. This study were carried out by delayed type hypersensitivity (DTH) for cellular immunity , cyclophosphamide induced myelosupression and neutrophiladhesion test. Cyclophosphamide was used as standard immunosuppressant drug.

D.V. Goswami et al[31] worked on effect of various extract of *Tectona grandis* bark on bronchitis especially asthma . The result is ethyl acetate extract of *Tectona grandis* bark shows significant anti-asthmatic activity by using animal models like mast cell degranulation and capillary permeability.

Mohammad Asif et al[32.] studied on in-vivo analgesic and anti inflammatory effect of *Tectona grandis* st*em bark* extracts in Wistar rat. For this experiment they used ethanol (TGEE) and water (TGAE) extracts. The phytochemical analysis revealed the presence of flavanoid, alkaloids, tannins, anthraquinones, saponins, carbohydrates and proteins . The both ethanol (TGEE) and water (TGAE) extracts shows significant analgesic and anti inflammatory effect in Wistar rats due to the presence of different chemical constituents like flavanoid, alkaloids, tannins, anthraquinones and saponins.

Neetu Singh et al[33] isolated verbascoside from *Tectona grandis* mediates gastric protection in rats via inhibiting proton pump activity . The aim of the study was to evaluate the gastroprotective mechanism of ethanolic extract of *Tectona grandis* , butanolic fraction and to identify its active constituents. They reported that antisecretory mechanism of verbascoside is through inhibition of H^+ K^+ -ATPase with corresponding decrease in plasma gastrin level. Gastro protection elicted by *Tectona grandis* might be through proton pump inhibition and consequent augmentation of defensive mechanism. Here anti ulcer activities were evaluated against cold resistant and pyloric ligation induced gastrin model.

Naira Nayeem et al[34,72] worked on antimicrobial and antioxidant property of isolated compound from the methanolic extract from leaves of *Tectona grandis.* They found the significant anti microbial property against both gram +ve and -ve bacteria by using cup plate method and they found potential anti oxidant property by using 1,1-diphenyl-2-picryl-hydrazyl.

K.N.V. Rao et al[35] described in vitro antioxidant and free radical scavenging activity of various extract of leaves of *Tectona grandis* and their report is water juice extract showed marked reducing power superoxide radical scavenging and inhibition of hydrogen peroxide induced erythrocyte haemolysis activity and also shows presence of high amount of phenolic content.

Naira Nayeem et al[36] studied on preliminary phytochemical analysis and wound healing activity of various extract of frontal leaves of *Tectona grandis* by using Sprague dwaly rats. The activity was confirmed by rate of wound contraction and the period of epethelization in excision and burn wound model.

Jaingame C.M et al[37] researched on hepatoprotective activity of methanolic and petroleum ether extract of *Tectona grandis* and they found that significant and dose dependent hepatoprotective activity against paracetamol induced hepatotoxicity.

S.G. Phalphate et al [38] evaluated on diuretic activity of *Tectona grandis* by male adult Wistar rats. This study indicates that the aqueous extract of *Tectona grandis* in different doses at different time interval and there is increase in urinary $Na^{+}Cl^{-}$ ion exretion analysis is done by autoanalyzer. It is calculated by dunnet, S test evaluation of diuretic activity is due to the presence of phenolic compound carbohydrates, saponins, tannins, flavanoids.

Pooja et al[39] described hyperglycemic activity of methanolic extract of *Tectona grandis* root and they suggested about the effective hyperglycemic activity of *Tectona grandis* in alloxan induced diabetic albino rats. Activity was compared with drug glibenclamide. Hyperglycemic activity exhibited at 500mg/kg dose level.

Pattarawadee. Sumthong et al[40] identified anti-wood rot compounds in teak sawdust extract . In this experiment centrifugal partition chromatography was used to separate and isolate the compounds. They analyzed it to found inhibition of rot fungi Deoxylapachol inhibited the brown rot fungi *Gloeophyllum sepiarium* CBS 353.74 and *Gloeophyllum trabeum* CBS 318.50 and the white rot fungi *Merulius tremellosus* CBS 280.73 and *Phlebia brevispora* CBS 509.92. Hemitectol together with tectol showed a high percentage of cellulase inhibition followed by 3′-OH-deoxyisolapachol and deoxylapachol.

MR. Gururaj MP[41] worked on evaluation of antiulcer activity of leaves and fruits of *Tectona grandis*. In this experiment alcoholic extracts of leaves and fruits of *Tectona grandis* was studied on gastric secretion and gastric ulcer in pylorus ligation. The result is reduction in ulcer induced rat and reduction in free and total acidity, volume of gastric acid and increase in pH of gastric fluid in pylorus ligated rats proves anti ulcer activity.

Sheela Maria D'Souza[42,73] evaluated the antioxidant and immunomodulatory activity of fruits of *Tectona grandis* by taking ethanolic extract. The result is found that *Tectona grandis* extract shown effective free radical scavenging and immuno suppressant activity and this may be due to the presence of phenolic and flavanoids. Anti oxidant study was determined by reducing power assay, DPPH assay, superoxide radical scavenging activity, lipid peroxidation assay. Immunomodulatory study was determine by using cyclophosphamide induced immunosuppression model.

Ghaisas M.M. etal[43] describes antidiabetic and nephroprotective effect of *Tectona grandis* by using ethanolic extract. They found significant antidiabetic and nephroprotective effect by using

alloxan induced and assosiated renal complication to the rats. They found decrease in serum creatinine, urine albumin decrease in level of cholesterol triglyceride. The result is it has potential to treat diabetes mellitus and prevent associated renal damage.

Mahesh S. Krishna et al[44] worked on Anthraquinones from leaves of *Tectona grandis*: A detailed study on its antibacterial activity and other biological properties. In the present study, attempts were made to isolate antibacterial compounds from *Tectona grandis* against *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Salmonella paratyphi* and *Proteus mirabilis* at different concentration. Antimycobacterial activity was checked against *Mycobacterium tuberculosis*. Cytotoxicity of isolated compounds was evaluated. As part of activity studies, antioxidant potential of both compounds was also checked. Antibacterial activity was checked by disc diffusion and microplate dilution method. Cytotoxicity of pure compounds was evaluated by MTT assay. Antioxidant activity was checked against DPPH and $ABTS^{+}$ free radicals.

Mosad Ahmed Ghareeb et al[45,74,75] studied antioxidant and cytotoxic activity of *Tectona grandis Linn.* leaves This study characterizes the antioxidant activity, total phenolic content (TPC) and cytotoxic activity of different methanolic extracts as well as the derived subfractions (Pet. ether; CHCl3, EtOAc and n-BuOH) from the 90% methanolic extract of *T.grandis*. The antioxidant activity was evaluated via three assays; 1,1'-diphenyl-2-picraylhydrazyl free radical (DPPH), phosphomolybdenum method (total antioxidant capacity; TAC and reducing power antioxidant assay (RPAA). Due to the high antioxidant activity of the tested fractions their cytotoxic activity was evaluated via using preliminary brine shrimp lethality test and toward liver cancer cell line; HepG2 using Sulphorhodamine-B assay. The HepG2 results showed that defatted 90% MeOH and n-BuOH fractions have cytotoxic activity with IC50 $\leq$ 20µg/ml which falls within the American Cancer Institute criteria. It was concluded that *T. grandis* extracts possess a powerful antioxidant and cytotoxic activities.

Ramesh B. Nidavani et al[46] worked on detailed study of medicinal values along with the chemistry of *Tectona grandis*. The chemical structures were determined through 1D and 2D nuclear magnetic resonance (NMR) experiments. The general bioactivities of isolated compounds have been studied using etiolated wheat coleoptiles the activities like antibacterial activity, adverse cutaneous reaction activity by teak wood, hair growth activity, anti-haemolytic

anemia activity, analgesic activity, hypoglycemic activity, antifungal activity, anti-inflammatory activity, diuretic activity, gastroprotective activity.

Deepali Jaybhaye et al[47] worked on effect of *Tectona grandis Linn*. Seeds on hair growth activity of albino rat by using petroleum ether extracts. The result of treatment with minoxidil 2% is 49% hair in anagenic phase. Hair growth initiation time was significantly reduced to half on treatment with the extracts compared to control animals. The treatment was successful in bringing a greater number of hair follicles (64% and 51%) in anagenic phase than standard minoxidil (49%). The results of treatment with 5% and 10% petroleum ether extracts were comparable to the positive control minoxidil.

Laskar S et al [48] worked on Influence of teak (*Tectona grandis*; family: Verbenaceae) seed protein on some enzymes and liver lipids of albino rats with respect to some of their serum, liver and intestinal enzymes and liver lipids has been studied. 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 overall observation is an indication of probable fatty infiltration in liver of test animals.

Ganis Lukmandaru [49] worked on antifungal activities of teak (*Tectona grandis*) extracts and their components against *Trametes versicolor, Fomitopsis palustris, Rhizopus oryzae, Cladosporium cladosporioides* and *Chaetomium globosum*. In this study, wood meal of 72 years old teak heartwood was successively refluxed with *n*-hexane, ethyl acetate and methanol. In the compound levels, the results were varied in which deoxylapachol could inhibit all fungi species except for the *C. globosum* while tecquinone merely deterred the growth of *R. oryzae* (58.9%). Squalene and C1 were growth inhibitors to *C. cladosporioides* (50-63%).

Phytochemical Studies

Fredy Mandey et al[50] spectroscopically studied an ether fraction isolated from stem bark of "Jati"(*Tectona grandis)*. Diethyl extract of jati undergo separation of chemical constituents by using column chromatography. After final column chromatography from the ether extraction , a white needles crystal was resulted which is commonly known as betulinic acid.

Rafiullah M. Khan et al[51] isolated 5-hydroxylapachol: a cytotoxic agent from *Tectona grandis* and they confirmed the presence of 5-hydroxylapachol along with other constituent like lapachol, dehydro-a-lapachon, methylquinizarin and squalene from the root heart wood of *Tectona grandis*

and both compound 5 hydroxylapachol and lapachol were found to be cytotoxic to Artemia salina (brine shrimp) with an LC_{50} of 5 ppm and its structure was found by using its spectral data ^{1}H and ^{13}C NMR.

Florence Boble Niamke et al[52] isolated the 4',5'-Dihydroxy–epiisocatalponol, a new napthoquinone from *Tectona grandis* and fungicidal activity. They confirmed the presence of new napthaquinone by 1D and 2-D NMR, HRMS and optical rotation and its fungicidal activity was found against *Trameetes versicolor*.

Fransisco A. Macias et al[53] isolated bioactive apocarotenoids from *Tectona grandis* and they yield seven apocarotinoid and determined their chemical structure by 1D and 2D NMR and bioactivity of apocarotenoid have been studied by using etiolated wheat coleoplities. Their activity were assayed on standard target species (*Lactuca sativa, Lycopersicum esculentum*, *Lepidium sativum* and *Allium cepa*).

Rodney Lacret et al[54] isolated Tectonoelins from bioactive extract of *Tectona grandis* and they confirmed the presence of Tectonoelins A and B and they evaluated the structure and bioactivity of new norligans. The structure and general bioactivities of the isolated compounds were determined by a combination of 1D and 2D NMR techniques by using etiolated wheat coleoptiles. The activity showed that the isolated ligans and norligans should be part of the defense mechanisms of this plant.

Rodney Lacret et al[55].described anthratectone and naphthotectone, two quinones from bioactive extract of *Tectona grandis* and they confirmed the presence of quinones and they determined the structure by using 1-D and 2-D NMR and etiolated wheat coleoptiles and also they confirmed the bioactivity. Nepthotectone showed high level of activities in bioassay. It may be involved in the allelopathic activity and defense mechanisms.

Naira Nayeem et al[56] worked on comparitative phytochemical and pharmacological screening of methanolic extract of frontal and matured leaves of *Tectona grandis* and they found the variation in the amount of phytoconstituent with development and also amount of phytoconstituent in frontal and mature leaf by using chemical analysis.

D.V. Goswami et al[57] done pharmacognostic and phytochemical investigation of stem bark of *Tectona grandis* and they found macroscopy and microscopy and chemical constituents of

Tectona grandis. All parameter was studied according to the WHO and pharmacopeial guidelines .

38. Rajuri Aradhana et al[58] worked on chemistry and medical uses of *Tectona grandis.* In the present study an attempt has been made to provide maximum information about the plant *Tectona grandis. Linn* which helps in its identity.

Naira Nayeem et al [59,76] worked on isolation of phenolic compounds from the methanolic extract of *Tectona grandis.* Phenolic compounds gallic acid, ellagic acid (phenolic acids), rutin and quercitin (flavonoids) were isolated and identified by their melting points, chemical tests, IR, NMR and mass spectra. The isolated compounds were qualified by comparison with the R_f values of that of the standards. Presence of these four phenolic compounds in the methanolic extract of the leaves of *Tectona grandis* may be an important contributing factor for wound healing activity, analgesic and anti-inflammatory activities.

F. Bobelé Niamke et al [60] worked on radial distribution of non-structural carbohydrates in Malaysian teak. The radial distribution of main non-structural carbohydrates (NSC) from the sapwood to the inner heartwood. NSC were analyzed by thin layer chromatography coupled to an enzymatic method. The main NSC were starch, glucose, fructose and sucrose. Stachyose and raffinose were also detected. Starch was the major NSC while sucrose was the less abundant. NSC were highly accumulated in sapwood and decreased drastically in heartwood.

Office of the Atomic Energy for Peace[61]. found neutron activation analysis of gold in teak (*Tectona grandis*). The amount of gold in teak had been determined by using neutron activation technique. The neutron flux utilized was of the order of 10^{10} n/cm^2/sec. As usual identified using a gamma multi channeled pulse height analyzer. The gold content of teak was 0.58 ±0.0037 ppm.

Khan Z et al [62] worked on a new steroidal glycoside and fatty acid esters from the stem bark of Tectona grandis Linn. 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.

Ajmal M et al [63] worked on adsorption studies on teak leaves (*Tectona grandis*): removal of lead ions from wastewater. Teak plant showed high sorption capacity for lead ions and were found efficient for the removal of lead ions from aqueous solutions. The extent of removal was found to be dependent on pH, temperature, concentration of metal ions and the dose of adsorbent. Thermodynamic parameters were calculated at different temperatures. The sorbent once used can be regenerated and recycled two-three times almost with the same capacity. However, regeneration by column operation gave better results than batch process.

S. Tangmitcharoen et al [64] worked on behavior of major insect pollinators of teak (*Tectona grandis* L. f.): A comparison of clonal seed orchard versus wild trees. It made the most frequent visits and contributed to 67% of teak flowers being pollinated. Its foraging time was high in the morning (10:00–12:00 h), which coincided with the receptive period of teak flowers.

Gilles Chai X et al[65,77] worked on natural durability of teak (*Tectona grandis*) wood from plantations determined by Near-Infrared Spectroscopy tool. Near-infrared spectroscopy (NIRS) is useful for estimating chemical and physico-mechanical wood properties. Natural durability classes (identify by relative mass loss after fungi attack) estimated by standard methods of varied teak wood were determined and correlated (using partial least squares -PLS- regression) with NIRS spectra data taken from every cross-section for rapid prediction. Calibrations were tested by cross validation and predicted values were compared to measured ones.

Inza Jesus Fofana et al[66] worked on diversity and genetic structure of teak (*Tectona grandis* L.f) in its natural range was found using DNA microsatellite markers . Fifteen microsatellite markers were used to study the genetic variability and structure of 166 teak trees distributed over the whole natural area of teak. Analysis showed that in the teak natural area there were four main centers of genetic variability. Two clusters were in India and could be considered as main centers of genetic diversity in teak. The third cluster mainly consisting of populations in Thailand and Laos was genetically very distinct from the Indian populations but presented only half as much allelic variability. A fourth cluster from Central Laos showed even less genetic variability.

Eluyode O.S et al [67] worked on preliminary phytochemical screening of crude extract of *Tectona grandis, Gliricidial sepium* and *Hevea bracilliensis*. The roots, barks, seeds and leaves of *Tectona grandis, Gliricidial sepium* and *Hevea bracilliensis* were analyzed for their photochemical components (carbohydrate (sugar),tannins, phlobatannins, alkaloids, glycosides,

saponins, sterol and flavonoids). The results indicated that water extracts of these trees could be used as natural products for local therapeutic applications.

R. K. Bachheti et al[68] worked on fatty acid composition and elemental analysis of *Tectona grandis* collected from Dehradun, Uttarakhand, India. To study oil contents and fatty acid composition of *Tectona grandis* seeds gas chromatography (GC) and gas chromatography mass spectrum (GCMS) were employed. The seed oil contents (dry basis) was 39.27%.

The evaluation of fatty acid composition using gas chromatography (GC) and gas chromatography mass spectrum (GCMS) revealed that oleic (28.4578%), linoleic acid (56.2071 %), Palmitic acid (10.1302%) and Octadecenoic acid methyl ester (5.2049%).

Ashvin G. Godghate et al[69] worked on phytochemical analysis of leaves of *Tectona grandis Linn*. Present study deals with the phytochemical properties which have been carried out on the leaves of *Tectona grandis Linn* using Acetone, Chloroform, Methanol and Water solvents. Out of four solvents, Chloroform extract contains more number of secondary metabolites whereas methanolic extract contain least number of secondary metabolites.

King P et al[70] worked on sorption of copper(II) ion from aqueous solution by *Tectona grandis* L.f. (teak leaves powder). Adsorbent was investigated to remove copper(II) from aqueous solutions. The adsorption experiments were performed under various conditions such as different initial concentrations, pH, adsorbent dosage and adsorbent particle size. The data showed that 0.1 g of *Tectona grandis* L.f. was found to remove 71.66% of 20 mg/L copper(II) from 30 mL aqueous solution in 180 min . The best-adjusted model to the experimental equilibrium data for *Tectona grandis* L.f. was the Langmuir model.

Pattarawadee Sumthong et al[71] determined the activity of Quinones from teak (*Tectona grandis*) on fungal cell wall stress. Two *A. niger* transgenic strains which show induction of 1,3-α-*D*-glucan synthase were used as a cell wall damage model. The result showed that deoxylapachol from *T. grandis* extract induced fungal cell wall stress.

Conclusion

Tectona grandis Linn is one of the most important medicinal plant. The ethnopharmacology of this plant shows that it is associated with vast number of biological activities. It can be used as herbal medicine for the treatment of different diseases.

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Conflicts of Interest

The authors of this manuscript declare there were no conflicts of interest.

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