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Review

Tectona grandis L.f: A comprehensive review on its patents, chemical constituents, and biological activities

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ABSTRACT

Tectona grandis L.f is a timber plant that is commonly referred to as teak. Its wide use as a medicine in the various indigenous systems makes it a plant of importance. A wide gamut of phytoconstituents like alkaloids, phenolic glycosides, steroids, etc. has been reported. A renewed interest in this plant has resulted in scientific investigations by various researchers towards the isolation and identification of active constituents along with scientific proof of its biological activities. The different parts of the plant have been scientifically evaluated for their antioxidant, antipyretic, analgesic, hypoglycemic, wound healing, cytotoxic, and many more biological activities. Documentation of this scientific knowledge is of importance to have consolidated precise information encompassing the various aspects of this plant, which could provide a base for future studies. This review is a compilation of the salient reports on these investigations concerning phytochemistry, the methods used to identify and quantify the constituents, the evaluation methods of the biological activity, toxicological studies, allergies and the patent/patent applications. This will further help researchers to find an area of the gap for future studies.

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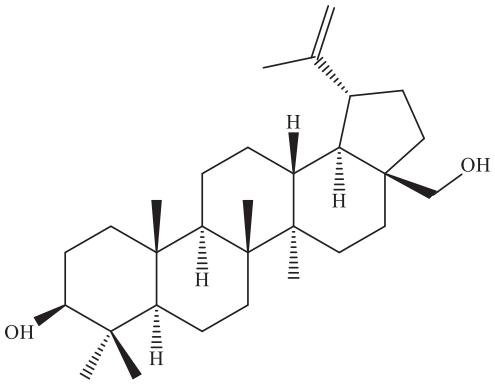
1. Introduction

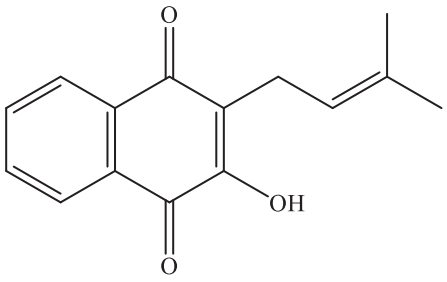
Plants are indispensable sources of medicine. Research on products obtained from nature is usually aimed to determine the medicinal values by exploring the available scientific knowledge and traditional uses. The phytochemicals isolated from these plants can be used as templates for further optimization of the lead molecules. It has been reported that in developing countries, 25% of the drugs are based on plants and their derivatives (Ramesh et al., 2013; Nahida et al., 2012). Several plants have been investigated for their phytochemical and pharmacological activities by various groups of researchers. One such plant of interest is *Tectona grandis L.f* (TG). It belongs to the family Verbenaceae. It is commonly referred to as teak. It is a large deciduous tree and may reach a height of 30–40 m with fluting and buttresses found at the base of older trees. The color of the bark is light grayish-brown. The leaves are large, shiny, opposite, and elliptic. The lower surface of the leaf is gray and covered with glandulous hairs. The flowers are small, white in color, and bisexual, appearing as large panicles. The fruit is a green, hairy, woody, irregularly rounded drupe (Nilesh et al., 2017). The tree can be found in several regions of south Asian countries and its parts such as root, bark, flowers, wood and oil are reported to be an important source of medical properties. The various parts of the plant have been used traditionally and ethnopharmacologically for the treatment of common cold, headache, in wound healing, bronchitis scabies, as a laxative, diuretic, antidiabetic, anti-inflammatory, antioxidant, lipid disorders, constipation, and diuretic (Kruger and Schulz, 2007). These pharmacological activities were found to be augmented when combined with other extracts. The unique combinations of such natural ingredients have been filed for patents. This review intended to compile the phytoconstituents identified along with the part and the solvent used for the extract and methods utilized for quantifying these compounds, listing the biological activities along with the methods applied, the extracts used, a brief account of toxicological evaluation, allergic manifestations and also the list of important information regarding patents/patent applications that have been filed concerning this plant.

1.1. Search strategy, inclusion and exclusion crieteria

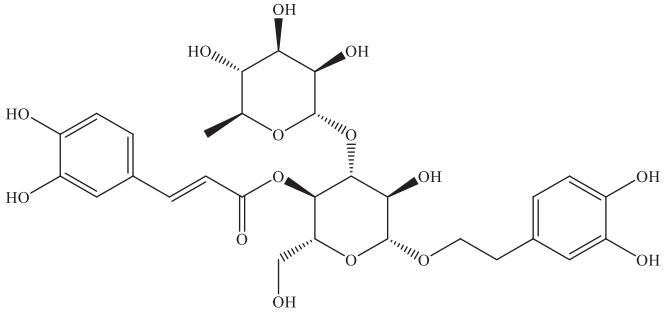
The search engines used for retrieving published data include databases that are universally recognized, specially Scopus, PubMed, Science Direct, Web of Science and Google Scholar. The



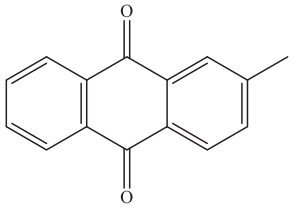
Betulin
(Triterpene)



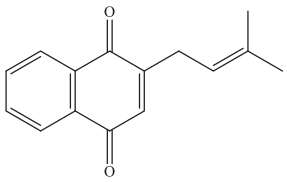
Lapachol
(Naphthaquinone)



Verbascoside
(Caffeoyl ethanoid)



Tectoquinone
(Anthraquinone)



Deoxylapachol
(Naphthaquinone)

various search terms used as key words were *Tectona grandis L.f,* phytochemical, biological activities, toxicology, allergy, phytoconstituents, HPLC,UV,IR GC–MS. The related articles were identified and screened for the title and abstract. Data extracted included the title, author(s), journal and year of publiction. Related articles were retrieved in full text and validated for including them in the review. This study focused on all the major aspects of the plant under consideration. Papers that reported the pharmacology, phytoconstituents, allergy, toxicological were included in this study. Dissertations were also included. The studies included in this review were in English language. Inappropriate articles were excluded for the following reasons i.e. unrelated topic, insufficient data, duplication and unavailablity of the abstract or full-text. The qualification of each paper was assessed by reading the full-text. There was no limitation in the search period. In the systematic review, articles were included from the available databases from 1986 to 2021.

2. Phytochemical profile of *Tectona grandis*

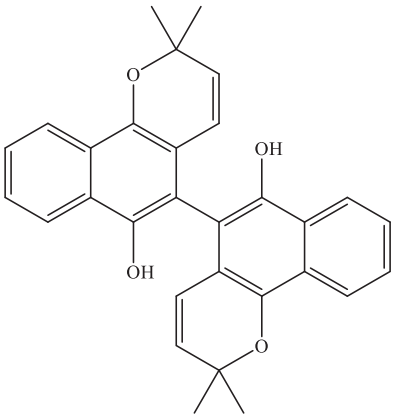
Several instrumental methods are available for identifying and quantifying the phytoconstituents in plants. The literature review describes the use of classical techniques such as high-performance liquid chromatography (HPLC), high-performance thin-layer chromatography (HPTLC), gas chromatography-mass spectrometry [GC–MS], and various other methods in the field of medicinal and aromatic plants (Kruger and Schulz, 2007). Researchers have reported a wide gamut of phytoconstituents. The preliminary investigation of the different parts of the plant, such as bark, wood, leaves, flowers, fruits, etc. has revealed the presence of flavonoids, phenolics, alkaloids, and certain glycosides (Nayeem and Karvekar, 2011a). Several methods have been reported for quantifying the secondary metabolites found in the various parts of TG following the ICH guidelines.

The chemical structures of the different constituents of TG are provided in earlier publications (Neha and Sangeetha, 2013; Vyas et al., 2019; Goswami et al., 2009). The chemical structures of some important constituents of TG are provided below.

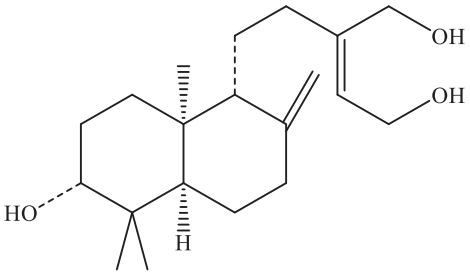
Some phytoconstituent, along with their techniques of identification/quantification, are listed in the following Table 1.

3. Biological activities of *Tectona grandis L.f* (non-patent literature)

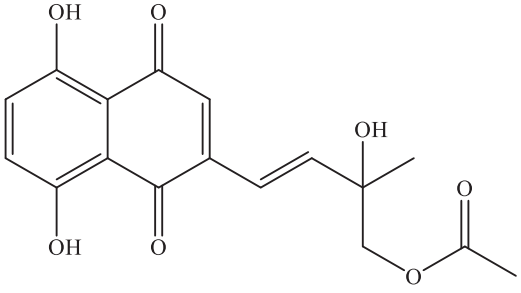
The plant has been used by traditional healers from time immemorial. Some of the mentioned traditional used in the literature are laxative, sedative, in treatment of piles, dysentery, leukoderma, anti-inflammatory, in bronchitis, urinary and liver related troubles, as hair promoter and useful in scabies. It also possesses anthelmintic and expectorant properties (Deepali et al., 2010a; Kruger and Schulz, 2007; Nayeem and Karvekar, 2011a, 2011b). Review reports several *in vitro* and *in vivo* biological activities of the plant of interest (Singh et al., 1996; Ramesh and Mahalakshmi, 2014). Extracts isolated from different parts of the plant is used either alone or in combination with other extracts for various diseased conditions. Some of the active constituents



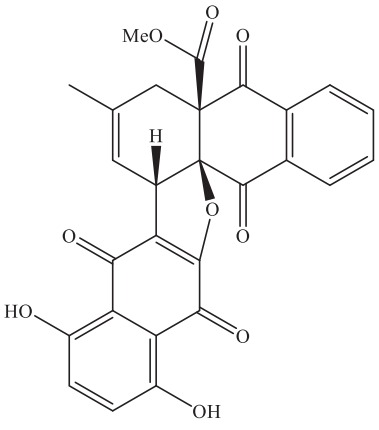
Tectol



Tectograndinol
(Diterpene)



Naphthotectone
(Naphthaquinone)



Anthratectone
(Anthraquinone)

Table 1
Phytochemical profile of TG.

S. No.	Part (Solvent extract)	Phytoconstituents	Chemical class	Technique	Ref.
1	Stem bark (Methanol)	Betulin	Triterpenoid	HPLC	Singh et al., 2016
2	Roots (Methanol)	Tannic acid, Caffeic acid, Gallic acid, Ferulic acid	Phenolic acids	HPLC	Shalini and Srivastava, 2009
3	Leaves (Methanol)	Sinapic, gallic, p-hydroxybenzoic, ferulic, p-coumarate, chlorogenic, cinnamic, vanillic acids	Phenolic compounds	RP-HPLC	Murukan and Kumara, 2018
4	Seed (Petroleum ether)	Linoleic acid, Octadecenoic acid methyl ester, Palmitic acid, Oleic acid.	Fatty acids	GC & GCMS	Bachheti et al., 2012
5	Heartwood, sapwood (Dichloromethane, Ethanol, and Ethanol-Toluene)	Lapachol, 2-Methylanthraquinone, 1,4-Naphthoquinone	Quinones	GCMS and HPLC	Bhat et al., 2010
6	Leaves (Aqueous)	Verbascoside	Phenyl ethanoid	LCMS	Emmanuel et al., 2016
7	Heart wood (Acetone)	2,3-Dimethyl-1,4,4a,9a-tetrahydro-9,10-anthracenedione, Acetonyldimethylcarbinol, 4-Tert-butyl-2-phenyl-phenol, 2-Methyl-anthraquinone estriol, Lappaol, Deoxylactam, Squalene, Chloranol, Palmitic acid, 2,3-Dimethyl-1,4,4a,9a-tetrahydro-9,10-nonanedione	Phenols, Quinones, Fatty acids, Triterpene	GCMS	Qui et al., 2019
8	Heartwood (Aqueous)	2-(Hydroxymethyl)anthraquinone, 2-Anthraquinone carboxylic acid, Tectoquinone, 1,4-Naphthoquinone and 4′,5′-Dihydroxy-epiisocatalponol	Quinones	HPLC, NIR	Niamke et al., 2013
9	Leaf (Aqueous)	Protocatechuic acid, Quinic acid, and its derivatives, Apigenin 7-O-diglucuronide, Luteolin, Luteolin 7-O-diglucuronide, Luteolin glucuronide, Diglucuronide, Apigenin glucuronide,	Flavonoids, Phenolic acids, Glucuronides	LCMS	Koffi et al., 2015
10	Flower (Methanol)	Quercetin, Kaempferol Rutin, Ellagic acid, Gallic acid, Ferulic acid,	Flavonoids, Phenolic acids	HPLC	Ramachandran and Rajasekaran, 2014
11	Wood knots (Isopropanol)	Forsytoside B, Isoacteoside	Phenylethanoid, Glycosides	HPLC	Tsvetkov, et al., 2010
12	Leaf (Methanol)	Gallic acid, Cinnamic acid, Tannic, Ellagic acid, Rutin Quercetin, Umbelleferone	Phenolic acids, Flavonoids, Coumarin	HPLC	Nayeem and Karvekar, 2010a, Nayeem and Karvekar, 2010b
13	Seed (Methanol)	Luteolin, Acacetin, Quercetin, Narengin, Hesperdin, Rutin, Rosmarinic, Quercetin, Naringenin, Hespertin, Kaempferol, Apigenin, Rhamnetin	Flavonoids	HPLC	Hesham et al., 2017
14	Teak dust (Methanol)	Lapachol, deoxylapachol, Isodeoxylapachol, 4-Naphthoquinone, 2-Methylanthraquinone	Quinones	GC	Carrieri et al., 2014
15	Leaves (Not mentioned)	4-Hydroxy-4-methyl-2-pentanone, Glycerin monoacetate, Glycerin diacetate and 1-Eicosanol, Malvidin-3-o- (6-o-acetyl)-5-o-diglucoside	Aliphatic ketones, esters & alcohol, Anthocyanins	UV–Visible, GCMS, and LCMS	Suryanti et al., 2020
16	Wood (n-Hexane, Benzene, Chloroform, Water)	Bis(2-ethylhexyl) phthalate, n-Hexadecanoic acid, Phthalic acid, Di(2-propylpentyl) ester, Di(oct-3-yl) ester	Aromatic acids, Esters	GCMS	Alabi and Oyeku, 2017
17	Hardwood sawdust (Hexane, methanol)	Tectol, Hemitectol, Deoxylapachol, Tectoquinone, 2-Hydroxymethylanthraquinone, 3′–OH-deoxyisolapachol	Quinones	Centrifugal partition chromatography	Sumthong et al., 2008
18	Sawdust (n-Hexane-methanol–water)	Abeograndinoicacid, 2-Oxokovalenic acid, 9-Hydroxyferruginol	Diterpenes	CC, HPLC	Francisco et al., 2010
19	Heartwood (Methanol)	Rhein, Emodin, and Aloe-emodin Resveratrol, Coumestrol, Baicalein, 3-Hydroxyflavone, Rhamnetin Pinocembrin, 2′-Hydroxygenistein, Anhydroglycinol, Hydroxygenkwanin, Tectorigenin, Ginkgolide A, Rhein, Piperine	Phenylpropanoids, Flavonoids, and Anthraquinone	UPLC-ESI-MS/MS	Yang et al., 2020
20	Bioactive extracts (Not mentioned)	Naphthotectone and Anthratectone	Quinones	1D and 2D NMR	Lacret et al., 2011

identified for the therapeutic activities include; 5-hydroxy-1,4-naphthalenedione (antibacterial), 4-hydroxy lapachol (cytotoxic), naphthaquinone (anti-ulcerogenic), benzene-1-carboxylic acid-2-hexadeconate (antiviral), lapachol (anti-tumor), 4′,5′-dihydroxy epi-isocatalapachol (anti-fungal) and 5,8-dihydroxy-2-methyl anthraquinone (anti-plasmodic) (Vyas et al., 2019; Goswami et al., 2009). Some of the pharmacological activities reported are compiled in Table 2.

4. Toxicological studies

Acute toxicity studies are designed so as to determine the dose that will produce death or serious toxicological manifestations when the dose is given once or over a few administrations. These studies are significant in determining the margin of safety of a drug. Several reports are available for the toxicological screening of the different parts of TG. Review reveals that various parts were evaluated for their toxicity in a dose ranging from 1000 mg/kg to 5000 mg/kg body weight. The solvents used for the preparation of the extracts were water, methanol and ethanol. The extract was found to show no signs of toxicity even at a dose of 5000 mg/kg. However the maximum dose used in most of the studies were limited to 2000 mg/kg. The following table depicts some of the toxicological studies conducted on the plant along with the part, solvent and animal used.

5. Teak allergy

Plants are one of the major causes of contact dermatitis (Verma et al., 2001). Dust from tropical hardwoods such as teak can cause

Table 2
Biological activity profile of TG (Non-Patent Literature).

S. No.	Part (Solvent)	Activity	Animal/Microorganism/ Other	Method of evaluation	Ref.
1	Leaf (Hydroalcoholic extract)	Wound healing	Sprague Dawley rat	Burn wound, Excision wound, incision wound, dead space wound	Nayeem and Karvekar, 2011a, 2011b
2	Bark, fruit (Methanol, Ethanol)	Anti-bacterial	*Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumonia, Escherichia aerogenes*	Disc diffusion, Broth micro-dilution method	Neamatallah et al., 2005; Lanka and Parimala, 2017; Kamath and Shabarya, 2020
3	Bark (Ethyl acetate, Petroleum, Ethanol, Water)	Anti-asthmatic	Swiss albino mice	Clonidine induced catalepsy, haloperidol-induced catalepsy, milk induced leucocytosis, *in vivo* animal models like mast cell degranulation and capillary permeability	Goswami et al., 2010a; Goswami et al., 2010b
4	Heartwood, Stem bark, leaves (Petroleum ether, Methanol)	Anti-tumor	*Artemia salina*	Brine shrimp assay	Pathak et al., 1988; Ghareeb et al., 2014
5	Heartwood, Sawdust (Dichloromethane)	Antifungal	*Aspergillus niger, Phanerochaete chrysosporium*	Disc diffusion	Florence et al., 2012; Sumthong et al., 2006; Bhat et al., 2010
6	Leaves, Fruits (Ethanol)	Anthelmintic	*Pheritima posthumaas*	Time of paralysis and time of death	Gururaj et al., 2011; Akshay et al., 2019
7	Bark (Petroleum ether, Chloroform, Ethanol, Water)	Anticonvulsant	Male Wistar rats	Maximal electroshock induced seizures and pentylenetetrazole induced seizures	Azizah et al., 2017
8	Seeds (Methanol)	Hepatoprotective	Rats	CCl_4 and Ranitidine induced hepatotoxicity model	Rawal and Patil, 2017; Jangame et al., 2017; Jangme et al., 2017
9	Fruit (Chloroform, Acetone, Methanol, Water)	Anti-urolithiatic	Calcium oxalate crystals	*In vitro* dissolution calcium oxalate crystals	Gudulkar et al., 2016
10	Leaves, Flowers (Petroleum ether, Chloroform, Methanol, n-Butanol, Ethanol, Water)	Antidiabetic	Rats	Alloxan-induced diabetes	Pradeep et al., 2012; Ramachandran and Rajasekaran, 2014; Shukla et al., 2010
11	Stem, Flowers (Methanol)	Analgesic and anti-inflammatory	Albino rats, mice	Radiant heat method, Writhing test Carrageenan of rat paw, Acetic acid, Hot-plate	Giri and Varma, 2015; Ramachandran et al., 2011; Nayeem and Karvekar, 2010a, Nayeem and Karvekar, 2010bNayeem and Karvekar, 2012
12	Roots (Methanol, Water)	Antitussive	Rats	Cough model induced by sulfur dioxide gas	Kaushik et al., 2011
13	Plant (Ethanol)	Gastroprotective	Rats	Cold restraint and pyloric ligation induced gastric ulcer models	Singh et al., 2010
14	Roots (Not mentioned)	Anti-ulcerogenic	Rats and guinea pigs	Experimentally induced ulcers	Goel et al., 1987
15	Stem bark (Ethanol)	Antioxidant	*In vitro* studies	DPPH, FRAP, H_2O_2 scavenging assay	Ghaisas et al., 2008; Sahay and Sharma, 2015
16	Plant (Aqueous)	Diuretic	Wistar rats	Hydrochlorothiazide induced	Kore et al., 2011
17	Roots (Methanol)	Hypoglycemic	Albino rats	Alloxan induced, Dexamethasone Induced	Mahesh et al., 2009; Pooja et al., 2011
18	Leaves (Ethanol)	Anti-hemolytic anemia.	Rats	Induced by intraperitoneal injection of phenylhydrazine	Diallo et al., 2008
19	Root, heartwood (Petroleum ether)	Cytotoxic activity	*Artemis*	Brine shrimps' assay	Rafullah and Suleiman, 1999
20	Seeds (Petroleum ether)	Hair growth activity	Albino mice	Shaved denuded skin of albino mice	Deepali et al., 2010b
21	Leaves (Methanol)	Antiplasmodial	*P. falciparum*	*In vitro*	Osman and Hadiani, 2018
22	Leaves (Ethanol)	Anti-hypertensive	Wistar rats	Renal artery occluded hypertensive rats	Ajayi et al., 2011
23	Leaves (Methanol)	Antifungal	*Arthrinium phaeospermum, Aspergillus fumigatus, Aspergillus flavus*	Well diffusion method, Agar slant double dilution tubes method	Astiti and Suprapta, 2012; Kouassi et al., 2016
24	Stem extract (Not mentioned)	Uterine relaxant activity	Female albino Wistar rats	Estradiol benzoate injected uterus	Deepali et al., 2010a
25	Leaves	Hepato protective	Mice	CCl4 induced liver injury	Somayya et al., 2021
26	Seeds	Antipyretic activity	Adult Wistar rats	Yeast induced antipyretic model	Jhansi and Lakshmi, 2021

both irritant contact dermatitis and allergic contact dermatitis. Teak is a fairly potent sensitizer it contains primary irritants and is also a common cause of allergic contact dermatitis which have been confirmed by various studies (Rao and Balachandran, 2010; Estlander et al.,2001). The main allergens that have been identified are polyphenols, naphthoquinones, their dimers, lapachol and

Table 3
Toxicity studies of TG.

Sl no	Part	Solvent	Animal used	Lethal dose (DL50)	Reference
1	Leaves	Aqueous	Wistar albino rats	No signs of toxicity, even at a dose of 5000 mg/kg in a single administration.	Kamsu et al., 2021
2.	Leaves	Ethanol	Wistar rat	No physiological changes or toxicity, even at a dose of 5000 mg/kg	Hamdin et al., 2019
3	Seed	Methanol	Albino mice	No mortality upto 1000 mg/kg	Dokuparthi et al., 2017
4	Stem bark	Ethanol and water	Wistar rats	No toxicity upto2000 mg/kg	Asif, 2011
5	Seeds	Methanol, petroleum ether	Male albino rats	No toxicity upto2000 mg/kg	Jangme et al., 2017
6.	Root	Methanol	Albino rats	No toxicity upto3000 mg/kg	Pooja et al., 2011
7.	Seed	Methanol	Mice	No mortality upto 1000 mg/kg	Jhansi and Lakshmi, 2019
8.	Leaves	Methanol	Male Wistar rats	No mortality upto2000 mg/kg	Nayeem and Karvekar, 2012
9.	Leaves	Methanol	Sprague Dawley strain	No mortality upto2000 mg/kg	Kushwah et al., 2018

Table 4
Patent Literature of TG.

S. No.	Patent / Patent Application Number (Publication Date)	Assignee/Name of the First inventor	Short Description	Ref.
1	**CN108938948A** (December 7, 2018)	Wang Dengsheng	It discloses an incense coil containing a specified amount of teak wood, cypress seed, hehuanpi, lavender, lemongrass, Lingzhi, lounge, starch, and CM-cellulose for tranquilizing the nerves and aiding in sleep	Dengsheng, 2018
2	**CN106822380A** (June 13, 2017)	Jinan Haoyu Qingtian Medical Technology Co., Ltd. (China) (JHQMTCL)	It discloses a pharmaceutical composition comprising TG, *Trigonella ruthenica, Pedicularis longiflora, maritimetin*, and *Lindera obtusiloba* for the prevention and treatment of optic atrophy	Jinan Medical Technology Company, 2017a
3	**CN106728432A** (May 31, 2017)	JHQMTCL	It discloses a pharmaceutical composition comprising TG, *Plagiogyria distinctissima, jujuboside B, Lysimachia heterogeneous, and Centaurium pulchellum* for treating/preventing pneumonia	Jinan Medical Technology Company, 2017b
4	**CN106728431A** (May 31, 2017)	JHQMTCL	A pharmaceutical composition for the treatment of synovitis of the knee comprising TG, *Petrocosmea minor*, acrifoline, and nerolidol as crude drugs	Jinan Medical Technology Company, 2017c
5	**CN106728433A** (May 31, 2017)	JHQMTCL	A pharmaceutical composition for the prevention and treatment of insomnia comprising TG, *Doryopteris concolor, Lonicera caerulea*, saikosaponin C and Sium suave as crude drugs	Jinan Medical Technology Company, 2017d
6	**CN106668346A** (May 17, 2017)	JHQMTCL	A pharmaceutical composition for the prevention and treatment of thyroid diseases comprising TG, *Parthenocissus himalayana, Dalbergia hancei*, capaurine, and xylopinine as a crude drug	Jinan Medical Technology Company, 2017e
7	**CN106668337A** (May 17, 2017)	JHQMTCL	A pharmaceutical composition for the treatment of optic atrophy comprising TG, trifolirhizin, and *Lindera obtusiloba* as a crude drug	Jinan Medical Technology Company, 2017f
8	**CN106668336A** (May 17, 2017)	JHQMTCL	A pharmaceutical composition for the treatment of otitis media comprising TG, *Myriophyllum spicatum, asiatic acid, Euonymus myrianthus*, and *Ulva conglobata* as a crude drug	Jinan Medical Technology Company, 2017g
9	**CN106540004A** (March 29, 2017)	JHQMTCL	A pharmaceutical composition for the treatment of diabetic retinopathy comprising TG, rose apple, esculentoside B, *Parthenocissus himalayana*, and *globe amaranth* as bulk drugs	Jinan Medical Technology Company, 2017h
10	**CN106138463A** (November 23, 2016)	JHQMTCL	A pharmaceutical composition for treating advanced bladder cancer comprising TG, Limnaea, β-amyrin acetate, mesembrine, and dryocrassin	Jinan Medical Technology Company, 2016b
11	**CN106138462A** (November 23, 2016)	JHQMTCL	A pharmaceutical composition for treating advanced colon cancer comprising TG, *Diplazium donianum*, and *Nothosmyrnium japonicum*	Jinan Medical Technology Company, 2016a
12	**CN106074957A** (November 9, 2016)	Yantai Ruizhi Biomedical Technology Co., Ltd. (China)	The invention relates to a traditional Chinese medicine composition for treating liver and stomach disharmony type esophageal hiatus hernia comprising TG, *Tetrapanax papyrierus, Manglietia yuyuanensis, Citrius medica, Citrius wilsonii, Amomum tsaoko, Lithocarpus polystachyus, Pyropolyporus adamantinus, Kadsura coccinea, Microsorium dilatatum, Scirpus triqueter, Cremanthodium liheare, Quercus fabri, Rosa bracteaea*, coriander fruits, *Actinidia arguta*, and Glycyrrhiza sp. Roots	Yantai Biomedical technology company, 2016
13	**IN3267/CHE/2014A** (February 12, 2016)	Rajarajan Swaminathan	A method for preparing a lyophilized extract from TG for treating the Asian and East Central South African genotype of Chikungunya virus.	Rajarajan et al., 2016
14	**CN103356878B** (November 25, 2015)	Cheng Yueyin	A traditional Chinese medicine powder for treating pediatric eczema comprising TG, *Arcangelisia loureirin, pansy*, celastrus leaves, *Asparagus brachyphylus*, pine bark, *Carex lanceolata, Vaccinium fragile, Cudrania tricuspidata*, and talc	Yueyin, 2015
15	**WO2006075336A1** (July 20, 2006)	Katkar Rama Dhondiba	Herbal composition for treatment of blood and heart/skin related diseases comprising TG, *Murraya Paniculata, Latana camara, Terminalia, Todalia asiatica,* and Chawat	Dhondiba, 2006

(*continued on next page*)

Table 4 (*continued*)

S. No.	Patent / Patent Application Number (Publication Date)	Assignee/Name of the First inventor	Short Description	Ref.
16	**JP2013224318A** (October 31, 2013)	Kawabata Aya	It claims an active oxygen scavenger comprising the extracts of TG, *Anaquiculus pyrethrum, Anacyclus pyrethrum, Oculocarps longifolius*, and *Aganosma marginata*.	Aya and Misao, 2013
17	**JP2010018545A** (January 28, 2010)	Kawabata Aya	A reactive oxygen scavenger comprising extracts of TG, *Parkia speciose, Anachromus pyrethrum, Ochrocarpus longifolius, Wrightia tomentosa, Diospyros rhodocalyx*, and *Burmanica Griff*.	Aya and Misao, 2010
18	**JP2006176445A** (July 6, 2006)	Ikeda Naosuke	It relates to a composition comprising about 10 herbal drugs including TG that is effective for health promotion and nutrition.	Naosuke, 2006
19	**JP2006166803A** (June 29, 2006)	Nobashi Kenzou	A shelf life-improving composition comprising an organic acid and an acetone extract of TG.	Kenzou, 2006

deoxylapachol. The presence of these constituents explains the allergenic properties of this plant species. Lapachol is less potent than deoxylapachol as sensitizer (Christensen, 2018; Carrieri et al., 2014). The most common reactions are eye, skin, and respiratory irritation and nausea.

6. Patent literature of *Tectona grandis L.f*

The patents for plants were filed in diversified areas taking into consideration the cultivation, harvesting, drying, extraction, standardization, formulation methods, the devices used, etc (Pennyroyal et al., 2011). The patent literature of TG was collected by performing the Keyword search (*Tectona grandis* and teak wood) in the Espacenet Patent Search database (https://worldwide.espacenet.com/patent/search). The claims of the obtained patents/-patent applications were reviewed. The patents/patent applications mentioning the name of TG or teak wood along with pharmaceutical use were segregated. Authors independently analyzed the language, content and description mentioned in the patents. The important data from the selected patent applications are mentioned in Table 3.

It is evident from the data of Table 4 that TG is present as an ingredient in many pharmaceutical compositions, which are claimed to have different therapeutic uses. These uses include treatment/prevention of optic atrophy, pneumonia, synovitis, insomnia, thyroid diseases, otitis media, diabetic retinopathy, bladder cancer, colon cancer, esophageal hiatus hernia, Chikungunya, eczema, blood and heart/skin related diseases, active oxygen scavenger, and tranquilizing the nerves, aiding in sleep. However, this patent literature is silent about the mechanism of action/function of TG in the claimed compositions.

7. Conclusion

Herbs are widely used for the treatment of various diseases. This review highlights the importance of phytochemistry, biological activity, and the patents of *Tectona grandis*. The result of the phytochemical study shows that it contains compounds with diverse structures. The different parts of the plant possess various activities like antioxidants, wound healing, analgesic, anti-inflammatory, antipyretic, etc. However, it has come to the notice that very few patents have been fielded concerning this plant, thereby paving the way for more studies and applications of patents in the future.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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