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Reveiw Article

TEAK (*TECTONA GRANDIS* LINN.): A RENOWNED TIMBER PLANT WITH POTENTIAL MEDICINAL VALUES

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ABSTRACT

Tectona grandis Linn. (*T. grandis* Linn.) (Family - Verbenaceae) is one of the most famous timber plant in the world and is renowned for its dimensional stability, extreme durability and hard which also resists decay even when unprotected by paints and preservatives. This plant is commonly called as teak and locally known as sagon, sagwan. Teak is moreover considered as a major constituent in many of the traditional medicines. A variety of interesting but limited compounds have been isolated and identified from *T. grandis* Linn. An overview and details of the phytochemical and pharmacological investigations on the *T. grandis* Linn. is presented in this review.

Keywords: Teak, *Tectona grandis* Linn., Ethnomedicinal plant, Bioactive constituents.

INTRODUCTION

Plants are indispensible sources of medicine since time immemorial. Studies on natural products are aimed to determine medicinal values of plants by exploration of existing scientific knowledge, traditional uses and discovery of potential therapeutic agents. Phytochemicals are used as templates for lead optimization programs, which are intended to make safe and effective drugs. In the developed countries, 25% of the medicinal drugs are based on plants and their derivatives [1-3].

T. grandis Linn. (Family - Verbenaceae) is one of the most famous timbers in the world and is renowned for its dimensional stability, extreme durability and hard which also resists decay even when unprotected by paints and preservatives. This plant is commonly called as teak and locally known as sagon, sagwan (Table 1). It is one of the most important heart wood of the world over. Timber value of teak has been well known from decades [4,5].

Table 1: Common names for *T. grandis* Linn.

Kannada: Sagavani
Sanskrit: saka
Hindi: sagun, sagwan, saigun
Bengali: Segun
Malayalam: jati
Tamil: tek, tekku, tekkumaram
Myanmar: kyun
Burmese: kyun
English: Indian oak, teak tree, teak wood
Filipino: dalanang, djati
French: teck
German: tiek
Indonesian : deleg, jati, kulidawa
Malaysia: jati
Javanese: deleg, kulidawa
Lao (Sino-Tibetan): sak
Nepali: saguan, teak
Spanish: teca
Thai: mai-sak, sak

Table 2: Taxonomy of *T. grandis* Linn.

Kingdom	Plantae
Super division	Angiosperms
Division	Eudicots
Class	Asterids
Order	Lamiales
Family	Verbenaceae
Genus	*Tectona*
Species	*Grandis*

Distribution and description

Natural distribution of teak ranges from the Indian sub-continent through Myanmar and Thailand. It is common in deciduous forests and well-drained alluvial soils. India has one-third of the natural distribution. It is discontinuously distributed throughout Peninsular India below the latitude of 24°N, in the states of Madhya Pradesh, Maharashtra, Tamilnadu, Karnataka and Kerala. In Myanmar, the species is distributed throughout the country up to latitude 25°N. In Thailand, it occurs naturally up to 17.5°N and from 97° to 101°E in the watershed areas of Mae Khong, Salween and Chao Phya rivers. Teak has been introduced as a plantation species in as many as 36 tropical countries across tropical Asia, Africa and South and Central America [6,7].

T. grandis Linn. is a large, deciduous tree reaching over 30m in height in favourable conditions. Crown open with many small branches; the branch is often buttressed and may be fluted, up to 15m long below the 1st branches. Stem usually cylindrical but becoming fluted and slightly buttressed at base when mature. Bark is light brown or grey, distinctly fibrous with shallow, longitudinal fissures. The root system is superficial, often no deeper than 50cm, but roots may extend laterally up to 15m from the stem. The very large, 4-sided leaves are shed for 3-4 months during the later half of the dry season, leaving the branchlets bare. The leaves are shiny above, hairy below, vein network clear, broadly ovate or oval with shortly pointed or blunt tip and taping base, about 30X20cm but young leaves are up to 1m long. Flowers small, about 8mm across, mauve to white and arranged in large, flowering heads, about 45cm long; found on the topmost branches in the unshaded part of the crown. Fruit is a drupe with 4 chambers and these are 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 1000-3500 fruits/kg [6].

Traditional uses

Teak is a pre-eminent tropical timber with sterling wood properties, having an average wood density of 650 kg/m^3. Because of its natural durability and dimensional stability, it is widely used for boat and shipbuilding in addition to construction, decorative veneers, furniture, cabinets, musical instruments and handicrafts/woodcarving [8].

Teak is moreover considered as a major constituent in many of the traditional medicines. The different extracts from various parts of teak shows expectorant, anti-inflammatory, anthelmintic properties. Traditionally, teak is used against bronchitis, biliousness, hyperacidity, diabetes, leprosy, astringent, and helmintiasis. In traditional medicine, a wood powder paste has been used against bilious headache and swellings. They are also used to treat swellings [9,10]. According to ayurveda, the teak wood is acrid, cooling, laxative, sedative to gravid uterus and useful in treatment of piles, leucoderma and dysentery. It allays thirst and possesses anthelmintic and expectorant properties [11]. *T. grandis* Linn. leaf extract are widely used in the folklore for the treatment of various kinds of wounds, especially burn wounds [12].

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: Details of secondary metabolite constituents of *T. grandis* Linn. [14-18]

Secondary Metabolites	Secondary Metabolite constituents	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 and zhebeiresinol	Stem, leaves seed & wood
Flavonoids	Rutin and quercitin	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'''-oxy)] glucuranopyranoside	Stem bark
Alkaloides	Quinones: 9,10-dimethoxy-2-methyl anthra-1,4- quinone. 1,4-anthraquinone, tectoquinone, lapachol, dehydro-a-lapachone, tecomaquinone I.	Heart wood
	Naphthoquinone and anthraquinone derlvatives	Leaves
	Naphthotectone and anthratectone	
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 bark

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/H_2O) active extract of leaves showed, four phenolic compounds named as acetovanillone (**1**), E-isofuraldehyde (**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**) (Figure 1)[13].

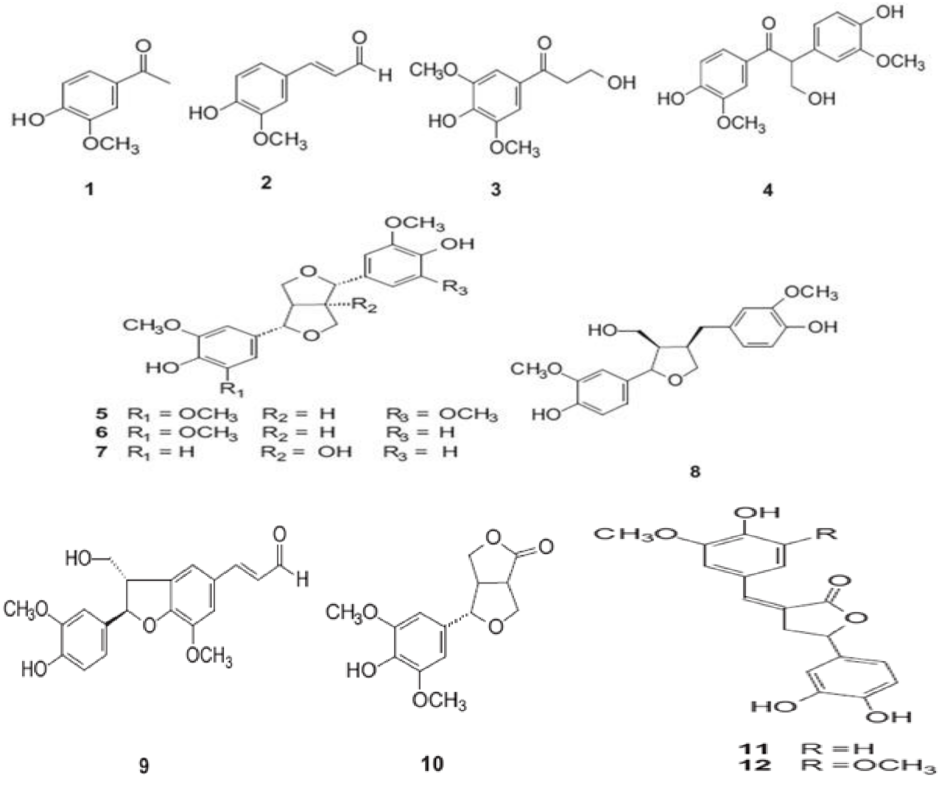


Fig. 1: Phenolic compounds (1-4) and lignans (8-12) of *T. grandis* Linn.

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 (Figure 2). The general bioactivities of isolated compounds have been studied using etiolated wheat coleoptiles [14].

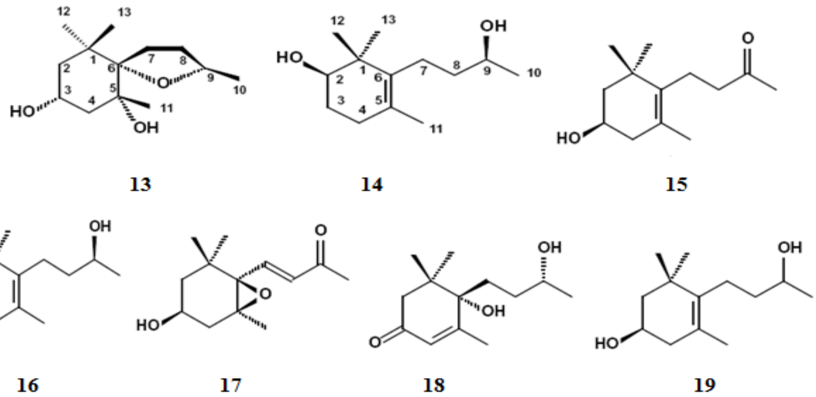


Fig. 2: Seven apocarotenoids among four (13-16) of which have been isolated for the first time as natural products and three (17-19) are yet to be named.

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. (Figure 3). 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].

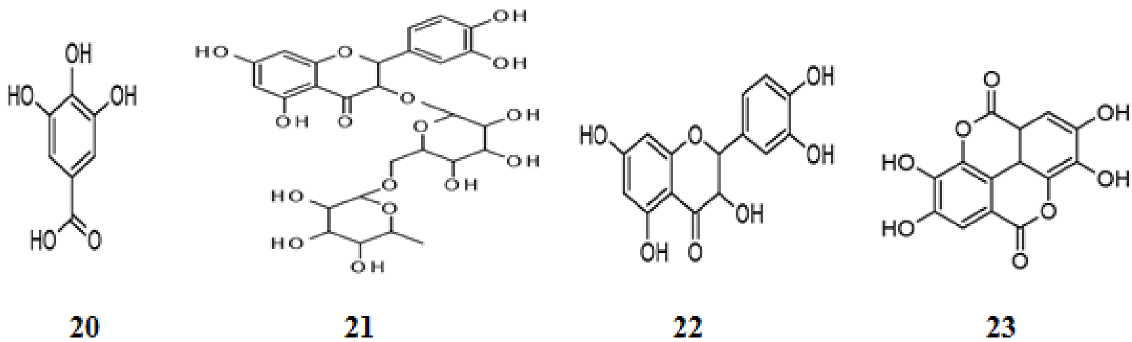


Fig. 3: The isolation of four phenolic compounds named TG1, TG2, TG3 and TG4 (**20-23**).

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 derlvatives 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].

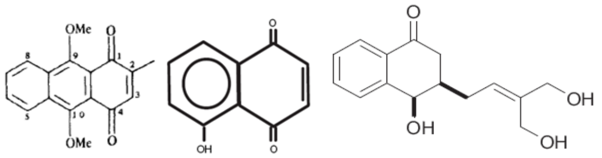
Two new quinones, (an isoprenoid quinone, and a dimeric anthraquinone) named naphthotectone and anthratectone, respectively, were isolated from bioactive leaf extracts from *T. grandis* Linn.. Their structures were determined by a combination of 1D and 2D NMR techniques and the bioactivity profile of 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].

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 presented here.

Antibacterial activity

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 ^{1}H and [13]C NMR analyses [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], and may explain the value of twigs/sticks used for oral hygiene in Africa and the Middle East [21,22].



24 **25** **26**

Fig. 4: The compounds from petrol extract of the heartwood (24), bark extract as antimicrobial (25), and stem heartwood of a naphthoquinone derivative (26) of *T. grandis* Linn.

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].

Cytotoxic activity

The methanol extract of wood, hexane extract of leaf were checked by MTT [3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide] assay and chloroform extract of bark exhibited very high activity against chick embryo fibroblast (CEF) and human embryonic kidney (HEK 293) cells with 87 % and 95.3 % inhibition respectively [24]. The column chromatography of the concentrated petrol extract of the root heart wood, showed the presence of hydroxynaphthoquinone. As the petrol extract of the root heartwood of *T. grandis* Linn. showed a high level of activity for cytotoxicity test against brine shrimps, it was investigated in order to determine the nature of the active compounds. This results to the isolation and identification of a new compound, 5-hydroxylapachol along with the previously reported compounds lapachol, dehydro- a-lapachone, methylquinizarin and squalene. The 5-hydroxylapachol and lapachol were both found to be cytotoxic activity. The activity of 5-hydroxylapachol is signifcant, as it is as good as lapachol, its structure is very similar to lapachol with an additional hydroxy group which could increase its solubility. The study also suggests that, 5-hydroxylapachol general toxicity is better than lapachol. Hence it is good candidate for further investigation as a potent cytotoxic agent [25].

Anti-haemolytic anaemia activity

Traditional oral report indicates that *T. grandis* Linn. is used in the treatment of anemia in Togo. The ethanol extract of leaves of *T. grandis* Linn. was evaluated on anemia model of rat induced by intraperitoneal injection of phenylhydrazine at 40 mg/kg for 2 days. Criswell et al., has been demonstrated previously that intraperitoneal administration of Phenylhydrazine decreases haemoglobin (Hb) concentration, red blood cells (RBCs) number and haematocrit in rat [26]. This anemia which resulted from the early lysis of the RBCS was naturally reversed 7 days later by the regeneration of these blood cells due to the increase of the reticulocytes. Oral administration of leaves ethanol extract of 1 g/kg/day and 2 g/kg/day, to the rats previously treated with phenylhydrazine, significant increased the concentration of Hb, RBCs number, haematocrit and reticulocytes rate mainly 7 days after phenylhydrazine administration. So the study suggested that, the extract could stimulate erythropoisis process and which may increase the number of young RBCs (reticulocytes) [27].

Adverse cutaneous reaction activity by teak wood

Various adverse cutaneous reactions may occur as a result of exposure to wood dust or solid woods. These may include allergic contact dermatitis, irritant contact dermatitis and, more rarely, contact urticaria, photoallergic, phototoxic reactions and erythema multiforme-like reactions. Chomiczewska-Skóra D (2011) investigated that, contact dermatitis, both allergic and irritant, is most frequently provoked by exotic woods, e.g. wood of the *Dalbergia* spp., *Machaerium scleroxylon* or *T. grandis* Linn.. Cutaneous reactions are usually associated with manual or machine woodworking, in occupational setting or as a hobby. As a result of exposure to wood dust, airborne contact dermatitis is needed to be diagnosed, so the study suggested to identify respective compound from wood dust of teak for their adverse cutaneous reactions [28].

Hair growth activity

The seeds of *T. grandis* Linn. are traditionally acclaimed as hair tonic in the Indian system of medicine. Study evaluated the petroleum ether extract of seeds of *T. grandis* Linn. for its effect on hair growth in albino mice. The 5.00% and 10.00% extracts incorporated into simple ointment base were applied topically on shaved denuded skin of albino mice. The time required for initiation of hair growth as well as completion of hair growth cycle was recorded against minoxidil 2.00% solution as positive control. 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 in anagenic phase than standard minoxidil [29].

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 H_2O_2 scavenging activity, DPPH and FRAP assay proved its potential [24]. 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 H_2O_2 induced erythrocyte haemolysis method, in order to understand the usefulness of this plant as a foodstuff as well as in medicine [30]. 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 [31].

Seed protein of teak as nutrient

The influence of protein, isolated from seed of *T. grandis* Linn. upon albino rats with respect to some of their serum, liver and intestinal enzymes and also nature of liver lipids are studied. The seed protein contains aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, valine, isoleucine, leucine, tyrosine, lysine, phenylalanine, histidine and arginine as determined by amino acid analyser. 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. The enzyme estimations observed that marked increase in protein level and also increase in total lipid of liver. The observed increased concentration of lipid in liver may be due to excess addition of protein in diet. The observation suggests that an indication of probable fatty infiltration in liver of test animals [32].

Hypoglycemic activity

The study indicates that *T. grandis* Linn. may prove to be useful in insulin resistance owing to its antioxidant activity and ability to increase the glucose uptake. Dexamethasone administration resulted in significant increase in blood glucose and triglyceride (TG) level. *T. grandis* Linn. showed dose dependent decrease in elevated plasma glucose and TG levels caused by dexamethasone, beta-lapachone, one of the chemical constituents of *T. grandis* Linn. was reported to possess glucocorticoid antagonistic action. They suggested that, the effect on the plasma glucose level and TG level may be due to the glucocorticoid antagonism and the presence of other chemical constituents like terpenoids and tannins which are reported to have antihyperglycemic action. It showed significant increase in insulin assisted glucose uptake, which indicates that there was increase in the insulin sensitivity [33,34]. Similarly another study investigated the hypoglycemic activity of methanol extract of root of *T. grandis* Linn. in alloxan induced diabetic albino rats with standard antidiabetic glibenclamide and study exhibited significant hypoglycemic activity [35]. Another research study was carried out to evaluate the anti-hyperglycemic effect of *T. grandis* Linn. bark extract in control and alloxan-diabetic rats. Oral administration of the bark suspension resulted in a significant reduction in blood glucose [36].

Anthelmintic activity

Ethanolic extract of fruits of *T. grandis* Linn. was investigated for their anthelmintic activity by using Indian earthworm *Pheritima posthuma* as a test worm. The experiment was performed by determination of time of paralysis and time of death of worms, against the standard reference drug piperazine citrate. The crude ethanolic extract of fruits of *T. grandis* Linn. shows significant activity at 50mg/ml against piperazine citrate [37].

Anti-inflammatory activity

Acute inflammation activity of methanol extract of *T. grandis* Linn. flowers (METGF)was investigated against carrageenan. The extract shows good effect at second phase of inflammation, and study advocates that, action may be due to inhibition of the inflammatory mediators release by methanol extract of flowers of *T. grandis* Linn [38].

Analgesic activity

Acetic acid induced writhing response and Eddy's hot-plate mediated pain reaction release by METGF. Study investigated for analgesic effect of METGF in two different animal models with the aimed to identify its possible peripheral and central action. Administration of METGF may mediate its action via opioid receptor. In both models, administration of METGF inhibited analgesia in a dose dependent manner and it reflects the peripheral and central analgesic action. The analgesic action may be due to presence of phenolic compounds and tannins in METGF [38].

Antifungal Activity

The antifungal activity of methanol crude extract of *T. grandis* Linn., *Shilajit*, *Valeriana wallachi* was investigated against *Alternaria cajani*, *Curvularia lunata*, *Fusarium sp.*, *Bipolaris sp.* and *Helminthosporium sp.* at different concentrations. Better antifungal activity was observed with the *T. grandis* Linn. extracts at concentration of 5000 µg/ml with other plant extracts. Study also investigated that the HPLC fingerprints of the crude extracts of *T. grandis* Linn., showed four types of the Phenolic acids i.e. Tannic acid, gallic acid, Ferulic acid and caffeic acid that are present in varying amount [39]. A new naphthoquinone derivative was isolated from the heartwood of the teak stem and the chemical structure of this compound, 4',5'-dihydroxy-epiisocatalponol (**26**) (Figure 4). This naphthoquinone derivative plays a key role in the variability of decay resistance in teak wood. A high negative correlation was found between its concentration and the mass losses of the wood samples after exposure to the brown rot *Antrodia* sp., the fungus that is the most virulent against teak. *In-vitro* bioassays demonstrated that 4',5'-dihydroxyepiisocatalponol acted as a fungicide against *Trametes versicolor* (white rot) at 58 mg/ml (0.22 mM) [40].

Diuretic activity

The study investigated that an aqueous extract of leaves of *T. grandis* Linn. showed the acute diuretic activity in Wistar rats by evaluating urine volume and urine electrolyte level. The study showed that a significant increase in urine volume and urine electrolyte excretion in a dose dependent manner as compared with furosemide and hydrochlorthiazide as standard diuretics [41].

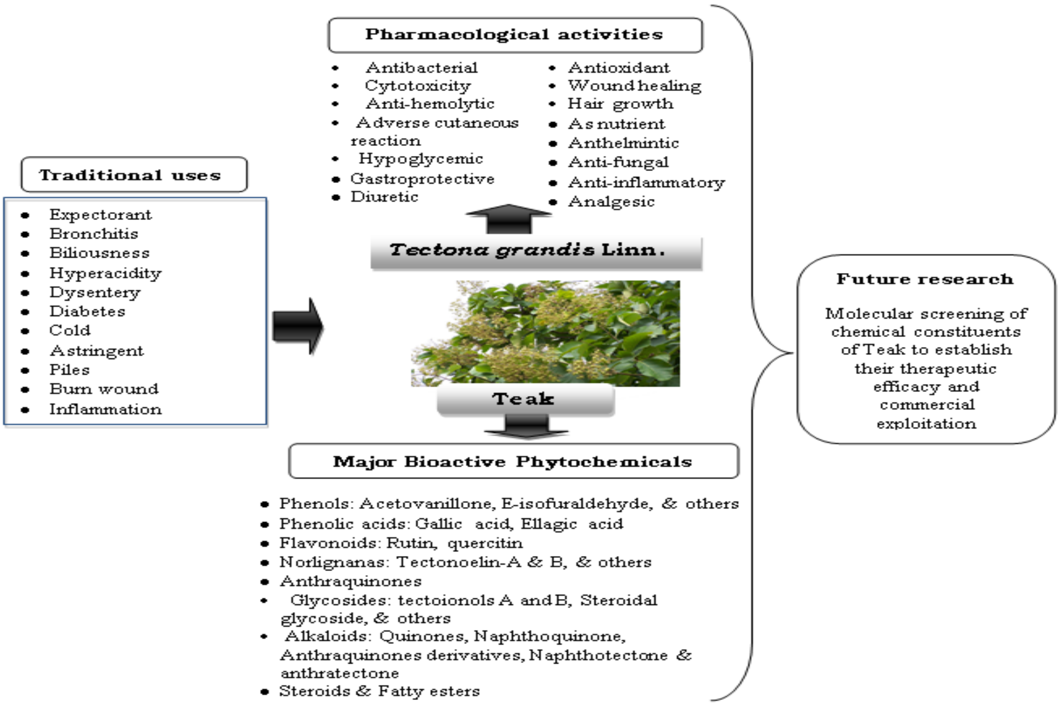


Fig. 5: Research of *T. grandis* Linn. past, present and future

Gastroprotective activity

The ethanol extract of *T. grandis* Linn. leaves shows anti-ulcer activities against in-vivo ulcer protective model as evident by significant protection in different gastric ulcer models, reduced gastric secretions through proton pump inhibition, increased PGE2 level and enhanced gastric mucin content. Study also investigated that, the proton pump inhibitory activity of ethanol extract of *T. grandis* Linn. leaves and its active butanolic fraction may be attributed to the presence of verbascoside which seems to regulate acid secretion via inhibiting gastrin hormone release. Thus, verbascoside of TG could act as a potent therapeutic agent against gastric ulcer disease [42].

A dye bearing plant

The colour components responsible for dyeing were isolated and their chemical constituents were established based on chemical and spectroscopic investigations. The principal colour components from the species *Morinda angustifolia* Roxb., *Rubia cordifolia* Linn. and *T. grandis* Linn. were found to contain mainly anthraquinone moieties in their molecules. The dyes obtained from the native plants may be alternative sources to synthetic dyes for the dyeing of natural silk and cotton. Leaves of *T. grandis* Linn. contained mainly anthraquinone moieties in their molecules [43].

The adsorption Experiment activity

The adsorption experiments were performed under various conditions such as different initial concentrations, pH, adsorbent dosage and adsorbent particle size. The presence of various heavy metals in the environment is of great concern because of their increased discharge, toxic nature and other adverse effects on receiving waters. The majority of toxic metal pollutants are waste products of industrial and some domestic processes. The adsorbent used in this study is *T. grandis* Linn. leaves powder, in which the adsorption takes place on surface of insoluble cellwalls of the teak leaves. Comparing the representative models of the adsorption between the adsorbents, a better adjustment of the equilibrium and *T. grandis* Linn. was found good adsorbent property [44].

CONCLUSION

This review highlights the importance of different pharmacological activities of *T. grandis* Linn.. The number of studies on this plant is quite high although most of the studies have been done on the extract and isolation level. Enormous numbers of studies are to be done to bring its products to commercial exploitation. This review may thus be an initiative for such studies (Figure 5).

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