A REVIEW ON RED SANDERS (PTEROCARPUS SANTALINUS LINN.) – PHYTO-CHEMISTRY AND PHARMACOLOGICAL IMPORTANCE

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ABSTRACT

Herbal medicines are often referred as phyto-medicines -- mainly obtained from plant sources like wood, bark leaves, seeds, berries, roots, leaves or flowers for medicinal purposes. Red sanders (Pterocarpus santalinus) wood a highly valued and medicinally important wood which is much in demand in domestic and international market, particularly China and Japan. Red sanders wood of best quality fetches an average price of Rs. 12,00,000/- per ton, but the non-grade wood obtains Rs. 8,00,000/- per ton as per the government rate. Red sanders have a localized distribution in dry and hilly areas of southern part of Andhra Pradesh and northern part of Tamil Nadu. The red dye obtained from the wood is used as colouring agent for textile, medicine and food. The heartwood can accumulate various elements and rare earth elements like strontium cadmium, zinc, copper and uranium. The wood has different uses in traditional and folklore medicines and is used for the treatment of diabetes, prickly heat, skin diseases, ulcers, eye diseases, inducing vomiting, mental aberrations, snake bites, scorpion stings and for various other ailments. The heartwood is known to have antihyperglycaemic activity, antipyretic, anti-inflammatory, anthelmintic, tonic, hemorrhage, dysentery, aphrodisiac, diaphoretic activities and cooling agent. This review discovers the phytochemical and pharmacological effects of the P. santalinus and compiled essential information will be helpful for further investigation. However, the species has remained unexplored for many pharmacological activities claimed. Thus, this paper reviewed about phytochemical and pharmacological/ biological activities.

KEYWORDS: Red sanders, Pterocarpus santalinus, Phytochemistry, Pharmacological, Traditional medicine, Folklore medicines.
INTRODUCTION

Pterocarpus santalinus Linn. commonly known as Red sanders (English), Erra chandanam (Telugu), Sivappu chandanam (Tamil) and Rakta chandan (Sanskrit) belongs to the family Fabaceae. It is an endangered plant species, endemic to Eastern Ghats. Red sanders natural distribution occurs almost exclusively in the south eastern parts of Andhra Pradesh in the tropical dry deciduous forests and northern parts of Tamil Nadu. It is a highly demanded rare medicinal plant \(^{70}\). Red sanders wood is much in demand in foreign countries, particularly China and Japan. Red sanders wood of best quality fetches an average price of Rs. 12, 00,000/- per ton, but the non-grade wood obtains Rs. 8, 00,000/- per ton as per the government rate \(^{71}\). Awareness of medicinal plants usage is a result of the many years of struggles against illnesses due to which man learned to pursue drugs in barks, seeds, fruit bodies and other parts of the plants \(^{72}\), The knowledge of the development of ideas related to the usage of medicinal plants as well as the evolution of awareness has increased the ability of pharmacists and physicians to respond to the challenges that have emerged with the spreading of professional services in facilitation of man's life. Therapeutic properties of medicinal plants are well recognized at global level \(^{57}\). World Health Organization has emphasized on the use of traditional medicines and reported about 80% of population from developing countries relies on medicinal plants for their primary health care \(^{58}\). In developing countries, all over the world, 80% of population continues to use traditional medicine in primary medical problems \(^{14}\). In the rural areas, people collect their requirements of medicinal plants from forests and communities practiced sustainable concepts with minimal damage to the habitats in which these precious plants are found. Medicinal plants are plants containing inherent active ingredients used to cure disease or relieve pain \(^{40}\). The use of traditional medicines and medicinal plants in most developing countries as therapeutic agents for the maintenance of good health has often been reported \(^{69}\). The wood has different uses in traditional and folklore medicines and is used for the treatment of diabetes, prickly heat, skin diseases, ulcers, eye diseases, inducing vomiting, mental aberrations, snake bites, scorpion stings and for various other ailments. The heartwood is known to have anti-hyperglycemic activity, anti-pyretic, anti-inflammatory, anthelmintic, tonic, hemorrhage, dysentery, aphrodisiac, diaphoretic activities and cooling agent. This review discovers the phyto-chemical and pharmacological importance of the species. However, the species has remained unexplored for many pharmacological activities claimed.
History
The chronology of Red sanders in its cultural perspective can be easily recorded on the strength of extant texts and its products used through successive centuries of Indian civilization. A mention of red sanders in literature dates as far back as the epic times of Ramayana and Mahabharata. In the Ramayana, the chandana paste used for besmearing the body is stated to be of the colour of the blood of a boar and highly scented.

In Hinduism, Red sanders wood has been traditionally used as a sacred wood. The priests extensively use this wood on many of their rituals [19].

Red sanders wood with normal grains called as non-quality wood, it is used for cremation purposes in Calcutta and other north Indian cities and also in Burma where considerable sanctity is attached to it. For this purpose the timber is converted into one foot billets. The saw dust as well as the chips is also exported to foreign countries, probably for the preparation of red dye and medicine. At Tiruchanur (near Tirupati, Andhra Pradesh, India), this non grains wood is utilised for the manufacture of dolls, images of deities, utensils and other toys [53].

The Medicinal value of Red sanders has been recognized long ago by the local physicians, specializing in Ayurveda and Sidda systems of medicine. The wood is bitter with a characteristic flavour. It is used in eye and blood diseases, skin diseases, chronic dysentery, snake bite and as an antiseptic ointment. Small pieces are carved into dolls and images. Wood is also exported for manufacturing of musical instruments called Shamusen [49].

The wood has historically been valued in China, particularly during the Ming and Qing periods, referred to in Chinese as zitan and spelt tzu-t'an by earlier western authors such Gustav Ecke, who introduced classical Chinese furniture to the west. It has been one of the most prized woods for millennia. King Solomon was given tribute logs of Almug in Sanskrit valgu, valgum by the Queen of Sheba. Due to its slow growth and rarity, furniture made from zitan is difficult to find and can be expensive. Between the 17th and 19th centuries in China the rarity of this wood led to the reservation of zitan furniture for the Qing dynasty imperial household. Rakta chandan, the Indian word for Red sandalwood which is Tzu-t’an, are linked by etymology. The word tan in Chinese is a perfect homonym of “tan”, meaning cinnabar, vermilion and the cognition is suggested by the interchange of chan for oriflamme, the vermilion ensign of the ancients. Chinese traders would have been familiar with Chandan.
Tzu-t’an then is the ancient Chinese interpretation for the Indian word chandan for Red sandalwood [19].

When forest management was first introduced in Red sanders forests, about the middle of the 19th century, the Red sanders were removed in great quantities under the licence system. Recognizing the importance of the species during 1865, realizing the valuable forest disappearing fast; cutting of the Red sanders was totally prohibited by grouping it with teak. Thus, combined with stringent protective measures, had a salutary effect. Between 1870 and 1882, around 1, 50,472 tons of firewood was thus supplied, which means that cutting of more than 10,000 acres of forests within easy accessibility. The areas marked for felling contained a high percentage of Red sanders and with the grass invading and fires sweeping the open areas of felled forest; one can imagine the retrogression that is possible. Thanks to the fire hardiness of the species and its wonderful capacity to coppice, the original forest has survived.

Mr. Yarde, the then District Forest Officer (1875) wrote "the railway company would eventually have to fall back on English coal and patent fuel as the department would be unable to supply the demand for railway fuel". After the inspection of the forests by Sir Dietrich Brandis in 1883, these forests were put under a regular management plan. Well established silvicultural techniques were introduced to conserve Red sanders but these techniques underwent periodic charges, according to prevailing circumstances.

The selection system was first prescribed, but since this provided for the removal of the very best of the Red sanders trees, which had already been subjected to severe exploitation, the system was replaced by improved felling. To Mr. White Head goes the credit of extending this system throughout the district, and much commendable work was done under his guidance. The system consisted in retaining well-formed trees of the better timber species and also saplings below 6” in girth and coppicing the rest. Regeneration of burnt patches by direct sowing was prescribed but the results were not encouraging. Then followed the system of coppice with standards, with a rotation of 25 to 30 years for the coppice and 60 to 75 years for the standards; 20 to 30 standards were retained per acre.

In 1928, the simple-coppice replaced the coppice with standards for two reasons; firstly it was found difficult to protect the standards which stood out temptingly, inviting the smugglers, and secondly there was great demand for fuel in the Madras market. When all along the timber value of the Red sanders was recognized and suitable measures were being devised for its conservation, it is unfortunate that the silvicultural considerations have been
subordinated to considerations of revenue and practical difficulties and the simple coppice system with a rotation of 40 years come to stay [52].

**Distribution**

Red sanders are an endemic and threatened tree species confined to Cudappa area in Andhra Pradesh. It is naturally distributed in the Seshachalam hill ranges (Palakonda) of Chittoor, Kadapa, Kurnool, Nellore and Prakasam districts of Andhra Pradesh; North Arcot and Chengalpet districts of Tamil Nadu and Pondicherry [32] [48] [50] [51] [52] [54] [62]. Apart from natural population of Red sanders, plantations have been established by the State forest departments of Andhra Pradesh [44], Tamil Nadu [42], Kerala [5], Karnataka [41] [59], Orissa [7] [34] and West Bengal [34] [73]. It was introduced in Sri Lanka [23] [56], Philippines [46] and Taiwan [16]. Its status is uncertain condition at Yunnan, Guangdong and Guangxi states of China [9] [55].

**Phytochemistry**

Plants have been valuable resources of traditional remedies since ancient times and continue to be major sources and inspirations for the development of therapeutic agents [38]. It was estimated that current global market for plant-derived drugs is worth more than 20 billion and the market continues growing [60]. The medicinal plants are useful for healing as well as for curing of human diseases because of the presence of phytochemical constituents [45]. Phytochemicals are primary and secondary compounds. Chlorophyll, proteins and common sugars are included in primary constituents and secondary compounds have terpenoid, alkaloids and phenolic compounds [25]. Pharmacology is the study of drugs. It involves examining the interactions of chemical substances with living systems, with a view to understanding the properties of drugs and their actions, including the interactions between drug molecules and drug receptors and how these interactions elicit an effect. Pharmacology provides the scientific basis and principles for a variety of special applications, such as the study of drug actions in the health sciences, the use of drugs as therapeutic agents in medicine or as tools in scientific research and the development and regulation of pharmaceuticals. Pharmacology is a multi-disciplinary science with many subspecialties including clinical pharmacology, cardiovascular pharmacology, behavioural pharmacology, neuro-psycho-pharmacology, pharmacogenetics, and pharmaco-economics, to name a few [74]. Terpenoids exhibit various important pharmacological activities i.e., anti-inflammatory, anticancer, antimalarial, inhibition of cholesterol synthesis, anti-viral and anti-bacterial activities [35]. Alkaloids are used as anesthetic agents and are found in medicinal plants [15].
The phytochemical analysis of *Pterocarpus santalinus* Linn., showed that it contains various components, such as carbohydrates, steroids, anthocyanins, saponins, tannins, phenols, triterpenoids, flavonoids, glycosides and glycerides, and importantly the santalin A and B pigments. It is established that, although the Phenolic pigments of Red Sanders heartwood have been known for more than a century, only in 1975 the major components of the colouring matter were identified by spectroscopic methods as Santalin-A (C$_{30}$H$_{17}$O$_{7}$(OMe)$_{3}$) and Santalin-B (C$_{30}$H$_{16}$O$_{6}$(OMe)$_{4}$) both being polymethoxylated biflavonoids with a quinone methide system or having anhydro benzo pyranol character.

The other heartwood components include Homopterocarpin, Pterocarpin (Santal Isoflavonoid compounds), Isoliquiritigenin, liquiritigenin (flavonoidal compounds), eudesmols, cryptomeridiol, isopterocarpolone, Pterocarpol, Pterocarptriol, Pterocarpdiolone (sesquiterpenoids) and Pterostilbene. *Pterocarpus* species also contains isoflavonoids, terpenoids and phenolic compounds, β-sitosterol, lupeol & (-)-epicatechin. In addition auron glycosides viz., 6-OH-1-methyl-3’,4’,5’-trimethoxyaurone-4-O-rhamnoside and 6,4’-dihydroxyaurone-4-O-neohesperidoside, and isoflavone glycoside 4’,5-dihydroxy 7-methyl isoflavone 3’-O-beta-D-glucoside are present in *Pterocarpus santalinus*.[8]

The important phytochemical constituents extracted from various parts of Red sands plant (wood, bark leave and various other parts of plant) are depicted as below.

**Extract from Red sands wood**

Dr. Duke's Phytochemical and Ethno botanical Databases report the following chemical components that are extracted from wood: Acetyl-Oleanolic-Acid, Acetyloleanolaldehyde, Beta-Eudesmol, Cedrol, Cryptomeridiol, Desoxysantal, Essential Oil (EO), Gallic-Acid, Homopterocarpin, Isopterocarpin, Isopterocarpolone, Pterocarpdiolone, Pterocarpin, Pterocarpol, Pterocarptriol, Pterostilbene, Santal, Santalin, Santalin-A & Santalin-B. Small quantity of tannin and kino-tannic acid are also found in the wood. Triterpene has reported to be present in the callus of stem cuttings. It is reported that in addition Auron glycosides viz., 6-OH-1-Methyl-3’, 4’, 5’- trimethoxyaurone- 4-O-rhamnoside and 6, 4’-dihydroxyaurone-4-Oneohesperidoside, and isoflavone glycoside 4’, 5-dihydroxy 7-O-methyl isoflavone 3’-O-beta-D-glucoside are also present.
A new isoflavone together liquirigenin and isoliquirigenin has been isolated from the heartwood of *P. santalinus*. Based on spectral methods the structure of new compound were elucidated as 6-hydroxy, 7, 2',4',5'-terramethoxyisoflavone [26].

Study on the absorption properties of Red sanders (*P. santalinus*) for beta and gamma radiations and obtained the suitability of this wood as shielding material to these radiations[10].

Santalins, the pigments of Red sanders wood, have been isolated using simple extraction and crystallization techniques with a yield of 5%. On spectroscopic examination, it was found to be a mixture of santalin A and B which are the major colouring constituents of Red sanders. As this method of isolation of santalin pigments is simple and easy, it will be of interest to dyeing and pharmaceutical industries and can be exploited [75].

**Santalins**

Chemical structure of santalin (R=OH, santalin A; R=OCH3, santalin B). *Pterocarpus* species also contains isoflavonoids, terpenoids and phenolic compounds, β-sitosterol, lupeol, (-) epicatechin [22].

**Chemical features of Santalins –A & B:**

Santalin - A

C_{30}H_{17}O_{7}(OMe)_3. Formed red needles from aqueous methanol, melting point (m.p) 302-303°C

\[ \lambda_{\text{max}} \text{(MeOH)} = 241, 280, 319, 471, 504 \text{ nm} \]

\[ \gamma_{\text{KBr}} \text{ max} = 3636, 1639, 1613, 1538, 846, 784 \text{ cm}^{-1} \]
Santalin A

Santalin - B

C$_{30}$H$_{16}$O$_6$ (OMe)$_4$ obtained as red needles from aqueous methanol, m.p 292-294$^\circ$C

$\lambda_{\max}$ (MeOH) 238, 280, 320, 472, 504 nm

$\gamma_{\text{KBr}}^{\max}$ 3636, 1639, 1613, 1540, 846, 784 cm$^{-1}$

Santalin B

Both Santalin-A and Santalin-B gave the same Per methyl ether (totally methylated) on methylation and therefore, they are partial methyl ethers of the same polyphenol for which the name Santalin has been reserved [8].

In addition auron glycosides viz., 6-OH-1-methyl-3',4',5'-trimethoxyaurone-4-O-rhamnoside and 6,4'-dihydroxyaurone-4-O-neohesperidoside, and isoflavone glycoside 4',5'-dihydroxy 7-methyl isoflavone 3'-O-beta-D-glucoside are present in *Pterocarpus santalinus* [26].

The heartwood also contains pterocarpol, santalins A and B, pterocarpatriol, ispterocarpolone, pterocarpo-diolones with β-eudeslol and cryptomeridol [76].

Extract from Red sanders leaves

Dr. Duke's Phytochemical and Ethno botanical Databases report that the following chemical components have been extracted from leaves: Beta-Amyrin, Beta-Amyrone, Beta-sitosterol, Erythrodiol, Eudes-4(15)-Ene-2, 11-Diol, Liquiritigenin and Stigmasterol,

Extract from Red sanders bark

Betulin, Epilupeol, Lup-20(29)-En-2alpha, 3 beta-Diol, Lupenone, Lupeol chemical components were extracted from the bark of red sanders, as reported by Dr. Duke's Phytochemical and Ethno botanical Databases.
Biological activities have not reported for the following chemical component of Red sanders: Acetyl-Oleanolic-Acid, Acetyloleanolaldehyde, Beta-Amyrone, Cryptomeridiol, Desoxyxantalin, Erythrodiol, Eudes-4(15)-Ene-2, 11-Diol, Homopterocarpin, Isopterocarpin, Isopterocarpolone, Lup-20(29)-En-2alpha, 3beta-Diol, Lupenone, Pterocarpdilone, Pterocarpin, Pterocarpol, Pterocarptriol, Santal, Santalin, and Santalin-A, Santalin-B \[13\].

According to Dr. Duke's Phytochemical and Ethnobotanical Databases the chemical component associated with the pharmacological/biological activities are given below.

**BETA-AMYRIN**
Beta-Amyrin exhibits various important pharmacological/biological activities such as Analgesic, Antiedemic, Anti-inflammatory, Antinociceptive, Antiulcer, Gastro protective, Hepatoprotective, Larvicidal and Mosquitocidal.

**BETA-EUDESMOL:** Beta-Eudesmol exhibits various important pharmacological/biological activities such as Antianoxic, Antimutagenic, Antipeptic, Antisalmonella, Antitumor-Promoter, Antiulcer, Central nervous system (CNS)-Inhibitor, Calcium-Antagonist, Hepatoprotective, Neurogenic and Sedative.

**BETA-SITOSTEROL:** Beta-Sitosterol exhibits various important pharmacological/biological activities such as Androgenic, Angiogenic, Anorexic, Antiadenomic, Antiandrogenic, Antibacterial, Anticancer (Breast), Anticancer (Cervix), Anticancer (Lung), Antiedemic, Antiestrogenic, Antifeedant, Antifertility, Antigonadotrophic, Antihyperlipoproteinaemic, Anti-inflammatory, Antileukemic, Antilymphonic, Antimutagenic, Antiophidic, Antioxidant, Antiprogesterational, Antiprotaglandin, Antiprostatadnamic, Antiprostatic, Antipyretic, Antitumor (Breast), Antitumor (Cervix), Antitumor (Lung), Antiviral, Apoptotic, Artemicidal, Cancer-Preventive, Candidicidal, Caspase-8-Inducer, Estrogenic, Febrifuge, Gonadotrophic, Hepatoprotective, Hypcholesterolemic, Hypoglycemic, Hypolipidemic, Spermicide, Ubiquit, Ulcerogenic.

**BETULIN:** Betulin exhibits various important pharmacological/biological activities such as AntiHIV, Anticarcinomic, Antifeedant, Antiflu, Anti-inflammatory, Antitumor, Antiviral, Aphidicidal, Cytotoxic, Hypolipemic, Prostaglandin-Synthesis-Inhibitor and Topoisomerase-II-Inhibitor.
CEDROL: Cedrol exhibits various important pharmacological/biological activities such as Termiticide.

EPILUPEOL: Epilupeol exhibits various important pharmacological/biological activities such as Antiviral.


LIQUIRITIGENIN: Liquiritigenin exhibits various important pharmacological/biological activities such as Antidepressant, Antiinflammatory, Antileukemic, Antispasmodic, Antiulcer, Central nervous system (CNS)-Active, Cancer-Preventive, Fungicide, Hemoglobin-Inducer, Monoamine oxidase -Inhibitor, Phytoalexin.

LUPEOL: Lupeol exhibits various important pharmacological/biological activities such as AntiEBV(Epstein–Barr virus), Antiangiogenic, Antiedemic, Antiflu, Antihyperglycemic, Antiinflammatotory, Antilithic, Antimalarial, Antioxalate, Antioxidant, Antiperoxidant, Antiprostaglandin, Antirheumatic, Antitumor, Antirethrotic, Antiviral, Cytotoxic, Farnesyl Protein Transferase (FPTase)-Inhibitor, Hypotensive and Topoisomerase (TOPO)-2-Inhibitor.

PTEROSTILBENE: Pterostilbene exhibits various important pharmacological/biological activities such as Anti-bacterial, Anti-diabetic, Antimelanomic, Anti-oxidant, Anti-radicular, Cyclooxygenase (COX) -1-Inhibitor, COX-2-Inhibitor, Chemo preventive, Cyclooxygenase-Inhibitor, Cytotoxic, Fungicide, Hyperglycemic, Hypocholesterolemic, Hypoglycemic, Hypolipidemic, Hypotensive, Insecticide and Phytoalexin.
STIGMASTEROL: Stigmasterol exhibits various important pharmacological/biological activities such as Antihepatotoxic, Antiinflammatory, Antinociceptive, Antiophidic, Antioxidant, Antiviral, Artemicide, Cancer-Preventive, Estrogenic, Hypocholesterolemic, Ovulant and Sedative.

Microbiologists and natural product chemists are exploring the Earth for phytochemicals, which could be developed for the treatment of infectious diseases. Polyphenols particularly, flavonoids are found to be effective antimicrobial agents against a wide array of microorganism. This is probably due to their ability to complex with extracellular and soluble proteins and also with the bacterial cell wall. Phenolics present in plants are known to be toxic to microorganisms [39].

The phytochemical analysis of Pterocarpus santalinus Linn. Showed that it contains various components, such as carbohydrates, steroids, anthocyanins, saponins, tannins, phenols, triterpenoids, flavonoids, glycosides and glycerides [43].

Ether, alkalis and three other crystalline principles santal, pterocarpin, homopterocarpin, small quantity of tannin and kino-tannic acid are also found in the wood [11].

Triterpene has reported to be present in the callus of stem cuttings [28]. Methanol extract of Pterocarpus santalinus (leaves) preliminary phytochemical screening (HPTLC fingerprint) revealed the presence of terpenoids, steroids, flavonoids and carbohydrates [2] and Glibenclamide and anti-hyperglycemic activity of ethanolic extract of Pterocarpus santalinus bark was found to be more effective [21].

Eudesmol obtained from the heartwood of P. santalinus has been found to be a mixture of α-, β- and γ-isomers. Absolute configuration of pterocarpol (II), another sesquiterpenoid isolated from the same source has chemically been deduced and confirmed by its conversion to β-eudesmol [30].

The chloroform extract of the heartwood of P. santalinus yielded a mixture of red pigments which could be separated by polyamide column chromatography into two major compounds, santalin-A and santalin-B. Both gave the same permethyl ether, C_{38}H_{56}O_{10} which had 8 methoxyls and formed a number of derivatives typical of anhydrobenzopyranols [8].
The constituents of *P. santalinus* were re-examined by means of modern chromatography and obtained a novel yellow pigment named santalin Y, a light yellow 3-arylcoumarin derivative named satalin AC, and its methyl ether together with santalin A, B (-)-fisetinidol and marsupsin \(^{[20]}\).

Phytochemical investigation on the constituents of heartwood of *P. santalinus* and obtained the isolation of a new acylated isoflavone glucoside. The structure of the new compound was elucidated on the basis of spectral studies as 4',5-dihydroxy-7-O-methyl isoflavone 3'-'O-β-D-(3'-'E-cinnamoyl) glucoside \(^{[29]}\).

**Red sanders Sapwood**

The sapwood of *P. santalinus* constitutes with light petroleum extract. The concentrate was subjected to column chromatography over silica gel. It was eluted first with light petroleum and continued with light petroleum: C\(_6\)H\(_6\) (3: 1), light petroleum: C\(_6\)H\(_6\) (1:1) and pure C\(_6\)H\(_6\). Five compounds A, B, C, D and E were obtained and were characterized as follows.

**Compound A.** - It crystallised from MeOH as colourless tubes (200 mg), m.p. 226-8°, \([\alpha]_D^{-}\)61.5° (C, 0.9, CHCl\(_3\)). It gave +ve LB and TNM tests and was identified as acetyl oleanolic aldehyde by its infrared spectroscopy (IR) and Nuclear magnetic resonance spectroscopy (NMR) and confirmed by comparison with an authentic sample (m.p-melting point, T.L.C- Thin Layer Chromatography and I.R). It would appear that this compound does not occur outside the family, Leguminosae and is of chemotaxonomic value. This sapwood is a convenient source for its isolation.

**Compound B.** - It formed colourless needles from MeOH (300 mg), m.p. 266-8°, \([\alpha]_D^+\)72.0° (C, 0.8, CHCl\(_3\)). It gave + ve LB and TNM tests and was identified as acetyl oleanolic acid by direct comparison of its methyl ester with authentic sample of acetyl oleanolic acid methyl ester (m.p., T.L.C., I.R.).

**Compound C.** - It crystallised from MeOH as colourless needles (100 mg) m.p. 278-9°, \([\alpha]_D^+\)76.5° (C, 1.1, CHCl\(_3\)) It answered LB and TNM tests and was identified as erythrodiol by its IR and NMR and the identity confirmed by direct comparison with an authentic sample (m.p., T.L.C., I.R.).
Compound D.- It formed red needles (120 mg) from aq. MeOH, m.p. 294\(^0\) C. \(\lambda_{MeOH}\) max: 238, 280, 320, 472 and 504 nm. This was identical with a sample of santalin-B obtained from the heartwood (T.L.C. and mixed m.p.).

Compound E.- It came out of aq. MeOH as red needles (140 mg), m.p. 302-303\(^0\) C and showed Ultraviolet (UV) absorptions identical with those of santalin-A. The identity was confirmed by direct comparison with a sample obtained from the heartwood (T.L.C., m.m.p- mixed melting point).

The co-occurrence of the related compounds erythrodiol (- CH\(_2\)OH), acetyl oleanolic aldehyde (- CHO) and acetyl oleanolic acid (- COOH) is somewhat special in the sapwood and would be of biosynthetic interest. The presence of the corresponding compounds of the lupane and ursane series has been reported in other sources \[^{31}\].

A new pentacyclic triterpene was isolated from the callus induced from the stem cuttings of \textit{P. santalinus}. Based on spectral methods, the structure of the new compound was elucidated as 3-ketooleanane \[^{28}\].

Bark of \textit{P. santalinus} has broad rhytidome formed by wavy anastomosing periderm bands. The tanniniferous idioblasts are abundant and are mostly in circular masses of 2-5 cells. The idioblasts in the collapsed phloem have dense amorphous tannin; those included within the rhytidome are empty idioblasts. Prismatic crystals are fairly common in the axial parenchyma; druses are also seen in the ray parenchyma. A special type of fan shaped crystals is seen specially associated with the idioblasts. The fan-shaped crystals are aggregation of numerous needles in the form of a semicircle; the fan crystals are attached on the outer walls of the tanniniferous cells \[^{4}\].

Pharmacological Importance

Antibacterial activity of leaf and stem bark of \textit{P. santalinus} was investigated for both gram-positive and gram-negative bacteria \[^{37}\]. The stem bark and leaf extracts showed inhibitory activity against a number of infectious microbial strains including \textit{Enterobacter aerogenes} and \textit{Staphylococcus aureus}. The broad-spectrum antibacterial activity exhibited by \textit{P. santalinus} may be attributed to its richness in isoflavone glucosides \[^{27}\]. Flavonoids are known to be synthesized by plants in response to microbial infections and therefore, very obviously they have been found \textit{In-vitro} to be effective antimicrobial substance against a
wide range of microorganisms. Catechins, an important group of flavonoids, have been extensively investigated due to their occurrence in Oolong green tea. It has been reported in the past, that tea possess antimicrobial activity and that they contain a mixture of catechin compounds [39].

Antimicrobial activity of leaf extract from *P. santalinus* exhibited significant antimicrobial activity at all the dosage tested (1.25 mg/disc, 2.5 mg/disc and 5 mg/disc). Leaf extract of *P. santalinus* can be a potential source of new antimicrobial agents for the tested drug resistant to bacterial strains and fungi [6].

Phytochemical analysis of active fraction showed the presence of flavonoids, glycosides and phenols. Active fraction of ethanolic extract of bark of *P. santalinus* decreases streptozotocin induced hyperglycemia by increasing glycolysis and decreasing gluconeogenesis [24].

The effect of administration of different doses of *P. santalinus* bark extracts in normal and diabetic rats, on blood glucose levels were compared with the diabetic rats treated with glibenclamide. The antihyperglycemic activity of ethanolic extract of *P. santalinus* bark at the dose of 0.25 g/kg body weight was found to be more effective than that of glibenclamide [21].

A histological stain prepared from the heartwood of *P. santalinus* has been found to be an excellent nuclear stain for various cells of animal and plant origin. As an elastic tissue stain, the results are comparable to standard elastic tissue stains. The stain can be used as counter stain with certain histochemical procedures with satisfactory results [63].

Freshly prepared Red sanders wood paste applied on face and gives the positive reaction on itchy erythema and mild oedema because the presence of active principles of santalin A and santalin B of *P. santalinus* [61].

Red sanders wood powders with following individual extracts have shown specific activity. Benzene Extract: Antifungal against *Aspergillus fumigatus*. Antiviral against *Encephalomyocarditis*. Ethylacetate Extract: Antibacterial against *Escherichia coli*. Alcohol Extract: Antibacterial against *Staphylococcus aureus* [64].
Synergistic effect of components of *P. santalinus* towards their anticancer and antioxidant activities. The additive roles of phytochemicals may contribute significantly to the potent antioxidant activity and the ability to inhibit cancer cells proliferation *in vitro* \(^{[47]}\).

Ethanol extract of stem bark of *P. santalinus* found to possess significant protective effect against hepato-toxicity induced by carbon tetrachloride which may be attributed to the individual or combined action of phyto-constituents present in it \(^{[36]}\).

A high performance liquid chromatography, ultraviolet–visible spectroscopy detection analytical approach to the identification of redwood species of historical important in textiles dying. The group of extracted dye stuffs considered as insoluble because of their non aqueous or alkaline extraction condition is present in the wood of *P. santalinus* \(^{[17]}\).

The methanol extract of *P. santalinus* strongly inhibits cell proliferation and induces apoptosis in HeLa cells. Medical expenditure panel survey (MEPS) induced apoptosis through the mitochondrial pathway, involving cytochrome release from the mitochondria, the activation of caspases-9 and -3 and degradation of Poly ADP-ribose polymerase (PARP). Because apoptosis was regarded as a new target in discovery of anti cancer drugs, these results confirm the potential of *P. santalinus* as an agent of chemotherapeutic and cytostatic activity in human cervical adenocarcinoma cells \(^{[33]}\).

The hepato-protective activity of *P. santalinus* may be correlated to its containing alkaloid, triterpenoid and flavonoidal constituents. *P. santalinus* protects the liver from severe damage caused by D-galN and may serve as a useful adjuvant in several clinical conditions associated with liver damage \(^{[12]}\).

*P. santalinus* contributes towards its marked gastro-protection by its free radical scavenging property and also by maintaining the functional integrity of cell membrane through inhibition of acid secretion \(^{[65]}\).

The Anti-*Helicobacter pylori* activity of *P. santalinus* has been compared with that of bismuth subcitrate, through *in vitro* studies employing rat gastric epithelial cell cultures and *H. pylori* isolates from gastric mucosal biopsy patients. The use of ethanol extracts of *P. santalinus* as Anti-*Helicobacter pylori* has been confirmed through its ability to reduce urease activity \(^{[66]}\).
P. santalinus has beneficial effects on blood glucose levels as well as improving hyperlipidemia due to diabetes [1].

An in vivo study to the action of the ethanolic extract of heartwood P. santalinus has been found to prevent mitochondrial dysfunction, maintain the phospholipids content and mitochondrial cell integrity [67].

Two lignans were isolated from the heartwood of P. santalinus and compounds were identified as savinin and calocedrin, dibenzyl butyrolactone-type; lignan compounds having an α-arylidene, γ- lactone structure. These lignans significantly inhibited tumor necrosis factor (TNF)-α production in lipopolysaccharide (LPS)-stimulated RAW264.7 cells, and T cell proliferation elicited by concanavalin (Con A), without displaying cytotoxicity. Thus, savinin may act as an active principle in biological activities of P. santalinus, such as anti-inflammatory effect, by mediation of the butyrolactone ring as a valuable pharmacophore [18].

CONCLUSION

P. santalinus is a resilient species and its survival amidst over exploitation from the past few centuries indicates that it is necessary to seriously think about its revival strategies. One of the best ways of conserving Red sanders is not only to raise large scale seedling based plantations in its natural habitats but also in far away regions having similar growing conditions which would ensure that genetic material is safe for posterity. These plantations can also act as a source of plant material for initiating further tree improvement strategies. While growing Red sanders outside the forest area, it is paramount to educate the tree growers to consider the gestation of the crop. Usually, it is a tendency among growers to compare tree growing with agricultural crops, but on a long term basis the yield and the monetary benefits accrued by growing such valuable trees are definitely high [3]. The Government agencies must take a lead role to encourage the farmers and entrepreneurs to grow Red sanders [68] suggested that, it is imminent to have a sustainable wood trade policy formulated by strongly incorporating stakeholder’s perceptions. In view of the species having more demand in the international market, exit point control represents the most important enforcement strategy. It should be made mandatory to examine for correctness of its species identification of consignments of wooden articles irrespective of species declared by consignor and examination of handicrafts / musical instrument parts to check whether they really represent such musical instrument parts/ handicrafts or just morphs of sawn timber.
Plant biodiversity have been used extensively both in prevention and cure of various diseases of mankind. With the advent of human civilization, many systems of therapy have been developed primarily based on plants. Ayurveda, Homeopathy, Sidda, Unani, etc. are our traditional systems of medicines. The plant-based traditional medical systems continue to provide the remedial measures for many diseases for more than three-quarters of the world’s populace. Documentation of traditional knowledge pertaining to the medicinal plant utilization for the greater benefit of mankind is the need of the hour. *P. santalinus* wood has been used as ethenomedical remedy for various ailments afflicting people in various parts of India for a long time. However, research interest to evaluate its therapeutic potential has developed recently perhaps on realization that this plant may contain novel chemicals that exhibit a wide range of pharmacological effects [40]. Hence, more studies are required on phytochemical and pharmacological/biological importance of this important species.

**ACKNOWLEDGEMENT**

The authors are thankful to all Red sanders growing State Forest Departments for providing information. The authors are thankful to Director, Group Coordinator (Research) and other researchers of Institute of Wood Science & Technology for their kind guidance and help in this regard.

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