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Tree Species for Timber

Vol. 3, Issue 4, January - March 2023

ICFRE - INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY, BENGALURU

Indian Council of Forestry Research and Education

(An Autonomous Body Under Ministry of Environment, Forest & Climate Change)



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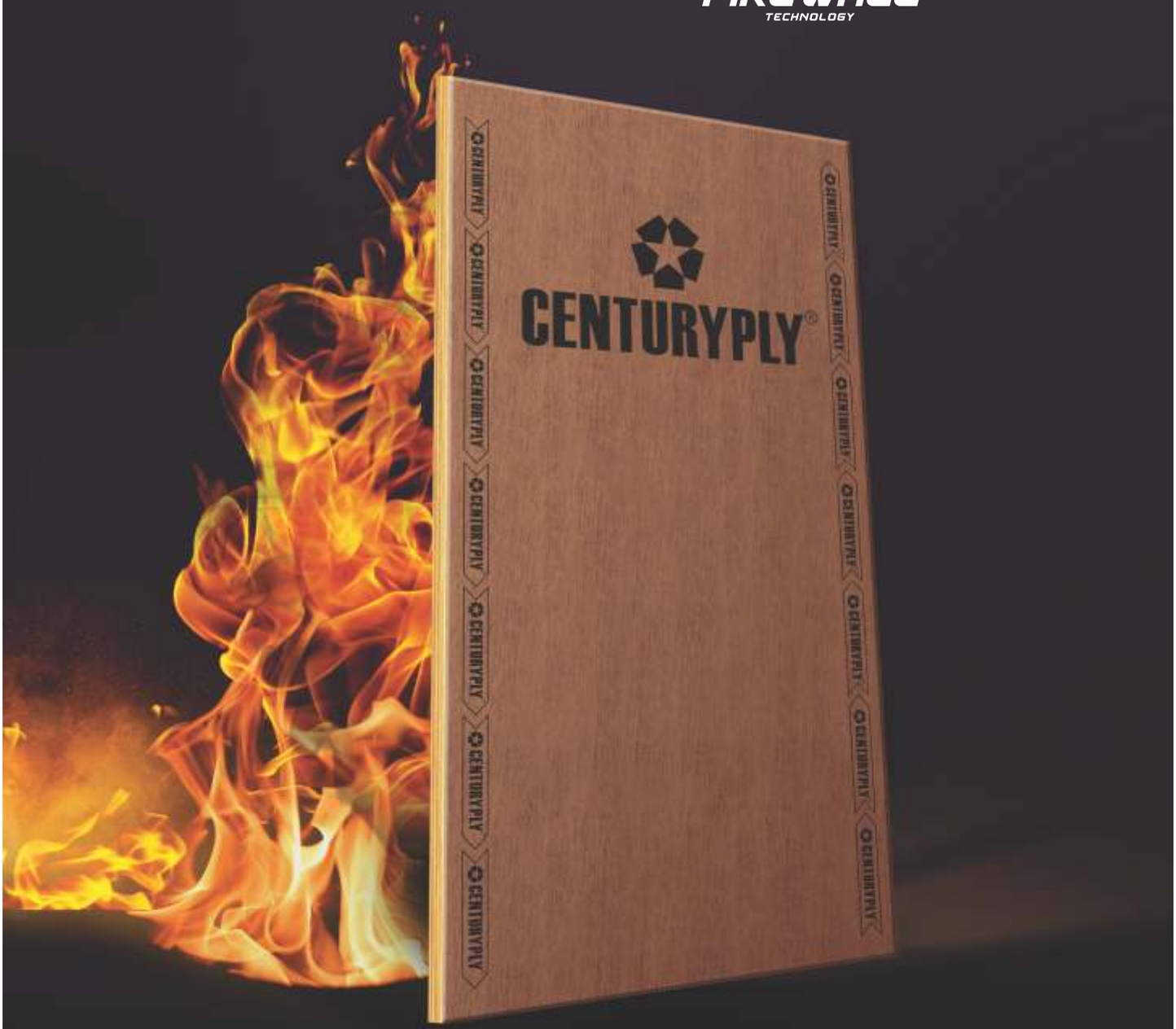

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INDIAN COUNCIL OF FORESTRY RESEARCH AND EDUCATION

(An Autonomous Council of Ministry of Environment Forest and Climate Change, Government of India)

VISION

To achieve long-term ecological stability, sustainable development and economic security through conservation and scientific management of forest ecosystems

MISSION

To generate, advance and disseminate scientific knowledge and technologies for ecological security, improved productivity, livelihoods enhancement and sustainable use of forest resources through forestry research and education

ZiBOC

- A new wood preservative which is comparable to CCA.
- Judicious use of preservative in a non-durable wood greatly enhances (6-8 folds) life of products.

Varieties/ Clones developed

- Developed improved germplasm of many forest tree species.
- Released 47 high performing and disease resistant clones of *Eucalyptus, Casuarina, Shisham, Melia* and *Sarpagandha* with a envisaged production gain of more than 20%. The developed germplasm are being made available to the State Forest Departments and farmers for use in plantations.

High performing and disease resistant clone of *Melia* sp.

CYCUS v. 1.0

- Casuarina Yield Calculator Utility Software (CYCUS v1.0) software has been developed to facilitate the farmer and other user agencies in yield estimation which requires only observations on girth of 100 sample trees per acre of plantation.

Wood Welding

Wood welding is new to our country. In this technique wood joints can be made without using nails and adhesives making them more natural and chemical free. A wood welding machine has been designed and fabricated at Forest Research Institute, Dehradun. Success has been achieved in spin welding of wood pieces of few species.

Wood Welding Machine

Indian Council of Forestry Research and Education

New Initiatives

- Transparent wood- a flexible and biodegradable transparent wood has been fabricated using poplar wood veneer and water soluble polymer- polyvinyl alcohol. The transparent wood exhibited high optical transmittance, high haze and light diffusing property.

Natural wood (Left most), Lignin modified wood (middle) and Transparent wood (right most) placed on a paper with letters "IWST"

Heat storage based modified Solar Kiln

- Solar heat storage system based solar kiln has been developed by Forest Research Institute, Dehradun for timber drying. The solar heat is trapped using suitable phase change material (PCM). The New solar kiln is able to trap 39 % more heat in winters as compared to traditional green-house based traditional FRI solar kiln developed during 1970.

Head based storage Solar Kiln

Xylarium

- Collection of authentic wood samples both from India and other countries, depicting wood biodiversity of the country like lightest, heaviest, sweet-smelling, foul smelling, smoothest, streaked, variegated wood and wood of different coloures, etc. The collection of wood cross sectional discs depicting variation in sapwood and heartwood colour is a unique feature of the xylarium.
- Wood identification services.

Xylarium- Collection of Authentic wood samples

Tree hollowness detection technique based on ultrasonic waves

- Forest Research Institute, Dehradun has developed ultrasonic techniques (Non-destructive testing) to detect the location and magnitude of the hollowness of the standing tree. This will help to remove the potential human hazards by way of falling down of such trees during a high wind regime in Urban Forestry.

Measurement of hollowness in a tree using ultrasonic detector

Agroforestry models

- Various agroforestry models (Poplar, Eucalyptus, Melia, Casuarina and Babool) have been developed to improve green cover, enhance farmers income and to mitigate climate change .

Poplar based agroforestry model with wheat

Innovative Bamboo Bottles

- Techniques for making bamboo bottles by using Bamboo Treatment Technologies of ICFRE. Most suitable bamboo species for making bottles are Shil Barak (*Bambusa salarkhanii*) & Barak (*Bambusa balcooa*). One full bamboo is sufficient for making 21 full size bottles and 12 small bottles.

Bamboo bottles

For further details please contact :
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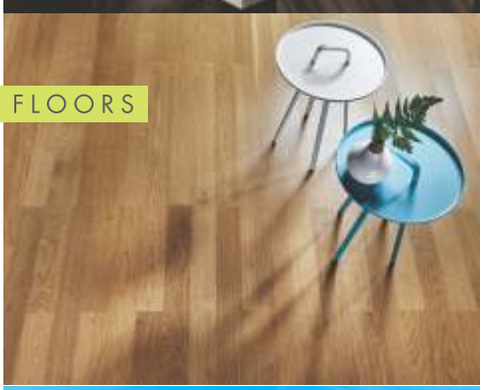

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DR. M.P. SINGH, IFS

DIRECTOR
INSTITUTE OF WOOD SCIENCE
AND TECHNOLOGY,
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BENGALURU – 560003

Preface

Wood based industries in the country is very diverse including paper and pulp, panel, furniture and handicraft. Availability of raw material is the major bottleneck against the predicted growth of these industries. While paper and pulp industries are quite organised and have already made concentrated effort to augment the raw material production to meet their demand, the scenario with panel, furniture and handicraft industries is not that promising. Though, most of these industries are now dependant on tree outside forest (ToF), still the raw material base is very narrow in spite of having a huge diversity of wood yielding species in the country. The industry has already moved from the traditional species to alternative species. For instance, the major furniture hubs such as Jodhpur and Saharanpur are largely depending on three species namely Sisoo (*Dalbergia sisoo*), Babul (*Acacia nilotica*) and Mango (*Mangifera indica*). While, these species are mainly sourced from ToF, long term supply of these species is unpredictable. The industry has already started feeling the crunch of raw material supply as evident from frequent price hike and gradual decline in the quality of raw material. There are about 1500 timber yielding species in India and ICFRE institutes have already assessed the properties of about 400 species. However, majority of these species are underutilized due to lack of awareness about their potential uses and lack of linkages among stakeholders.

Thus, there is a strong need to identify and prioritize tree species having potential to meet the demand of wood-based industries. Besides, it is also the need of the hour to take up tree improvement programmes to increase the productivity of the species already used by the industry. ICFRE has already initiated efforts to improve some of the species though all India co-ordinated projects and more synergistic efforts are needed with the collaboration of other stake holders such as Forest Departments, Agriculture Universities and Industries.

In this endeavor, IWST, Bangalore conducted an interactive session on 21st March 2023 (on the occasion of International Day of Forests along with World Wood Day) entitled "Prioritization for Promotion of Tree Species for Sustainable Utilization' in which it was recommended to shortlist potential species as raw material source for wood-based industries. As a follow-up of the same, IWST, Bangalore is bringing out this issue of "Wood is Good" magazine with a theme of "Tree Species for Timber" by covering 35 important wood yielding species. I am sure, this issue will certainly create renewed interest among various stakeholders in accepting and promoting these species.

Dated: 21st August 2023

(M.P. Singh)

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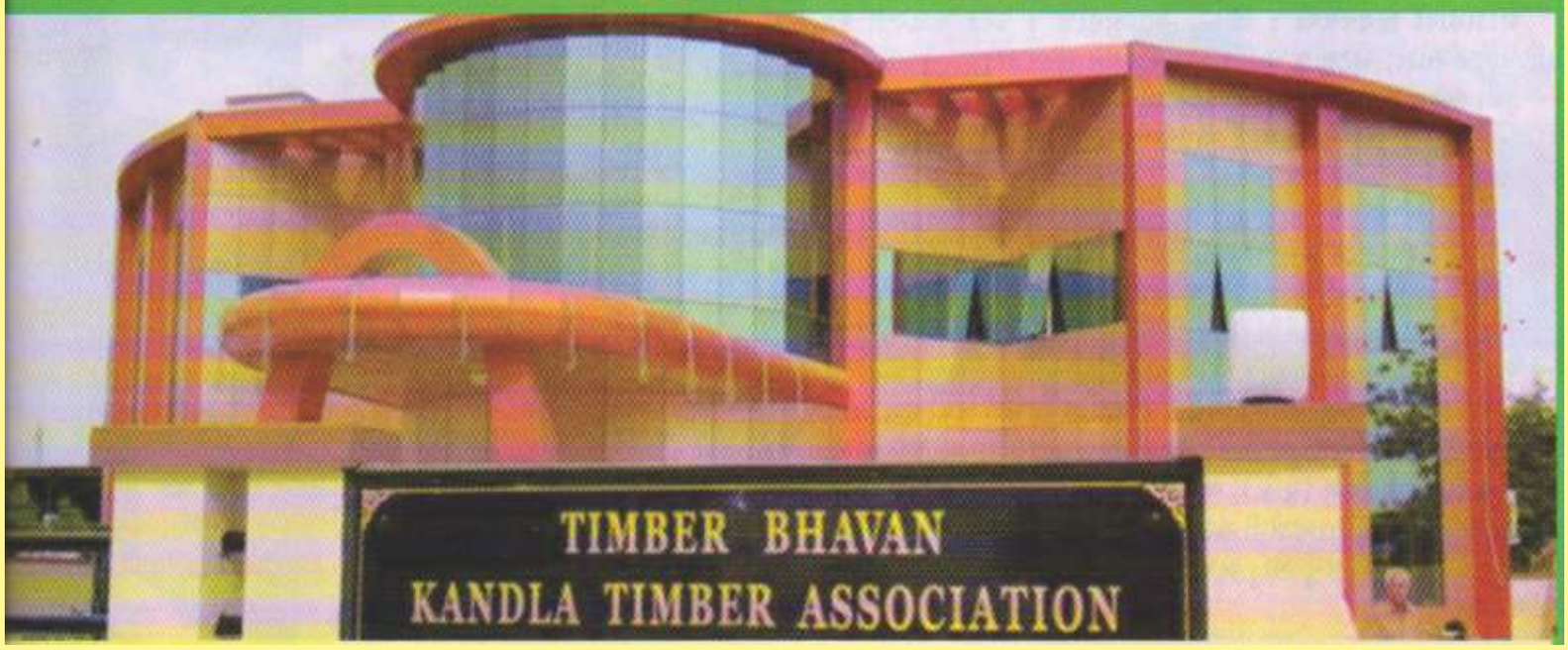

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ICFRE-IWST activities during January - March, 2023

Visit of IFS Probationary Officers

Two batches comprising 33 IFS Probationers of 2021-23 batch from Indira Gandhi National Forest Academy, Dehradun visited ICFRE-IWST Malleshwarm and IPIRTI campus on 13th and 21st January 2023. The officers were given an overview about the research activities of the institute. They interacted with Director and his team of scientists. This was followed by visit to laboratories, Xylarium, Nursery, Wood workshops, Advance Woodworking Training Centre, Plywood and Particle Board/MDF Plant, CBD Plant, Bamboo Houses and Fire Door Testing Lab in the two campuses of the institute.

Azadi Ka Amrit Mahotsav (India@75)

Awareness program on "**Introduction to Green Building Materials for Sustainable Development"**

As part of celebration of Azadi Ka Amrut Mahotsav, the Institute conducted Awareness program on **Introduction to Green Building Materials for Sustainable Development on** 25th January 2023 for better outreach of science and technical updates from the institute. The theme of the program was on Introduction to green building materials for sustainable development. Fifteen students from civil and mechanical engineering background from Dr. Ambedkar Institute of Technology, Bengaluru and Sri Ramakrishna Engineering College, Coimbatore attended the program. Technical presentation on Green building materials for sustainable development: Scenario in India and testing & standardization of green building materials for utilization focused on creating awareness about the concept of using wood and wood based composites for housing and its advantages over conventional housing systems.

Republic Day

ICFRE-IWST, Bangalore celebrated 74th Republic Day. Dr. M.P. Singh, Director IWST unfurled the National Flag and administered the Preamble of the Indian Constitution. Director and HoDs addressed the gathering of officers, scientists, staff and students. On this occasion, cultural events were held and two meritorious staff members were recognized and given **"The Outstanding Employee Award"** for their excellent contribution to the organization.

Deliberation on Draft Guidelines for Wood Based Industries

ICFRE-IWST organized deliberation on **Draft Guidelines for Wood Based Industries** through hybrid mode on 8th February 2023 to review, discuss and obtain views, concerns, suggestions and comments from stakeholders/end users for further consideration of MoEF & CC. Shri B. K. Singh, IFS, Additional Director General of forests (Forestry) was the chief Guest. Shri. Sajjan bhajanka, President, Federation of Indian Plywood & panel Industry (FIPPI), Shri. Jikesh Thakkar, Executive Director, Association of Indian Panel board Manufacturers (AIPM) and Shri. Navalkedia, President, Federation of All India Timber Merchants Saw Millers and Allied Industries were the Guest of honour. Dr. M. P. Singh, Director, IWST welcomed the Guests and gave the opening remarks. Dr. H. R. Prabuddha, IFS, IWST presented the draft guidelines for wood based industries. Representatives from Wood Based Industries, officers and scientists from the institute were part of the discussion.

Training on "Testing of Flush door, Plywood, Block board standards"

ICFRE-IWST Field Station Kolkata conducted five days short term training course on "Testing of Flush door, Plywood, Block board" from 6th February to 10th February 2023. Six personnel from 'Naval Ship Repair Yard, Naval Base, Kochi' joined this course to upgrade their skills and after successfully completion of the course certificate was given to them.

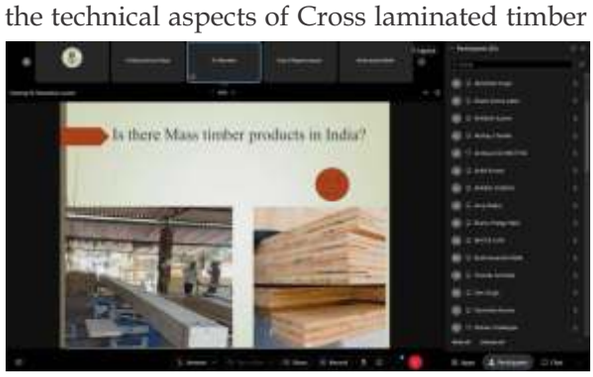
Training for IFS officers on Wood/Bamboo Resource Management and Value Addition for Sustained Livelihood

MoEF & CC sponsored one week compulsory training (through physical mode) for IFS officers on **Wood/Bamboo Resource Management and Value Addition for Sustained Livelihood** was organized by ICFRE-IWST. A total of 7 IFS officers nominated by MoEF & CC from different states attended the training from 20 – 24 February 2023. The training included Scenario of wood & panel industries in India; Wood properties, processing and utilization; wood composites and technologies; Importance of BIS for wood based industry; Bamboo products and their Industrial production; Perspective of plywood industry and Forest Certification in wood based industry. The course curriculum included field trip to M/s BIESSE India, Bangalore, M/s. Spectrus Sustainable Solutions Pvt. Ltd. (for WPC), Bangalore, M/s Hunsur Ply, Hunsur and Mysore Sandal Depot, Mysore The officers also visited IWST laboratories, Plant Nursery, Xylarium, WPC & Wood Workshop, Plywood and Particle Board/MDF Plant, Fire Door Testing Lab, Bamboo Houses, Advance Wood working training Centre and Wood Museum to get an understanding of the research activities being carried out at the institute.

Azadi Ka Amrit Mahotsav (India@75)

Webinar on "Engineered wood composite: Cross Laminated Timber for Green Buildings"

A Webinar on Engineered wood composite : Cross Laminated Timber for Green Buildings was organized on 20th February 2023 as part of Azadi ka Amrit Mahotsav celebration. Dr. Manoj Kumar Dubey, Head, Extension Division introduced the topic and envisaged on the uses of Cross laminated timber and its importance in sustainable development. Dr. Mamatha, Scientist E explained the technical aspects of Cross laminated timber elements such as wood and its importance in designing the process. Importance of adhesives and processing methodology of manufacturing cross laminated using Indian plantation species were also highlighted. The webinar referred few standards requirement for the evaluation of this mass timber product. About 56 participants comprising of personnel from educational institutions, research institutes, students and academicians interested in engineered wood composites participated in the program.



Azadi Ka Amrit Mahotsav (India@75)

Webinar on "Utilization of *Melia dubia* for panel products"

As part of Azadi Ka Amrit Mahotsav celebration, the Institute conducted a webinar on Utilization of *Melia dubia* for panel products on 4th March 2023. The webinar was attended by 40 members including professionals from academic institutions, representatives of wood based industries, stakeholders, scientists and staff of IWST. The webinar touched upon present timber raw material scenario, panel industry status, plywood industry market, shortage of raw material, possible solutions, agro forestry / farm foresty, importance and advantages of short rotation plantation timber species "Melia dubia" and panel products developed by ICFRE-IWST (Erstwhile IPIRTI).

Training on "Bamboo Cultivation, Preservation and Commercial Utilization"

One day training program on **Bamboo cultivation, preservation and commercial utilization** was organized for about 80 Prisoners (Farmers) and Jail Staff of Open Jail, Devanahalli, Bangalore Rural District on 10th March 2023. Mr. Chokkappa (Jailor), Mr. I.B.Uppina, Mr. Ravi Kumar (BRDO) and Ms. Triveni CTO, IWST inaugurated the program by watering a bamboo sapling. Sri. L. Manjunath, Senior Technician presented on Nursery technology and propagation of bamboo, Mrs. Vani C.N. explained about various preservation techniques and commercial utilization of bamboo was highlighted by Ms. Mohini J.B. (JPF). Bamboo seedling were planted in the jail campus by staff and the inmates.

Azadi Ka Amrit Mahotsav (India@75)

Webinar on "Impact of Formaldehyde emission from panel products on environment"

As part of the celebration of Azadi Ka Amrit Mahotsav, the Institute conducted a webinar/workshop on **"Impact of Formaldehyde emission from panel products on environment"** on 20th March 2023.About 90 participants attended the workshop, out of which 10 participants from the industries attended physically (offline) and 80 through online.

The webinar highlighted, adhesives and process parameters to minimize the formaldehyde emission; test methods and compliance of formaldehyde emission and Utilization of waste LDPE (Low-Density Polyethylene) materials (to convert into sheets/film) as a binding agent for making plywood. Various kinds of volatile organic compounds released from wood based panel products, impact of formaldehyde released from the panel products on health and environment was also highlighted. Participants who attended physically were shown the test facilities at formaldehyde emission laboratory.

BTSG-ICFRE -NBM program
Training on "Bamboo-Nursery Management, Value Addition and Technologies"

A one-week training for farmers and artisans on nursery, management, value addition and bamboo technologies was organized at ICFRE- IWST, Bangalore from 27th to 31st March 2023 under BTSG-ICFRE (NBM). The program was inaugurated by Dr. M.P. Singh, IFS, Director, ICFRE- IWST, Bangalore. A total of 50 farmers from 7 states of India attended the training. The technical session of training program included 10 theory classes and three hands on practical sessions on nursery, bamboo craft making, & bamboo seasoning, industrial visit, visit of bambusetum & bamboo plantation at Gottipura field station.

The theory part included 26 lectures covering introduction, distribution, taxonomy, nursery, propagation methods, bamboo seedling certification, tissue culture, macro-propagation, and management, harvesting methods, physical, mechanical properties, preservation and utilization of bamboos.

VVK – KVK – Demo Village Trainings

ICFRE-IWST, Bengaluru in collaboration with Krishi Vigyana Kendra (KVK) conducted training programs on Sandalwood based agroforestry models for farmers at Chitoor (through KVK Kalikiri) and Nellore Districts of Andhra Pradesh. Training on Sandalwood based Agroforestry Models & Spike Disease was also organized jointly with KFD, Chikamagalur & Akhila Karnataka Sandal Growers Association as part of Vana Vigyan Kendra training. Training on Bamboo Cultivation, Seasoning and Preservation was organized at Demo Village in Attivatta Hoskote Taluk, Bangalore Rural under CAMPA Extension funding. Farmers from surrounding areas also participated in the training programs and enhanced their knowledge.

Activities of Mission LiFE

Dr. M. P. Singh, Director, ICFRE-IWST, Bangalore flagged off Mission LiFE program at the institute on 3rd February 2023 in the presence of officers, staff, research scholars and also 37 graduate and Post Graduate students (Botany) of Maharani Lakshmi Ammani College for Women, Bangalore. Mission LiFE pledge was administered and an awareness session on highlighting need for individual and community action to adopt a lifestyle to protect and preserve the environment was followed by nature walk within the campus. The students also visted Xylarium and wood anatomy laboratory.

Memorandum of Understanding

- Dr. S.S. Chauhan, Scientist G and Head, WPP Division, IWST, Bangalore and Mr. M. V. Francis, Proprietor, Kavery Fertilizer Industries, Kerala on 5th January 2023 to provide R&D support in developing sustainable products using HDPE based Bamboo Plastic Composites.
- Dr. S.R. Shukla, Scientist G and Head, WPP Division, IWST, Bangalore (in presence of Director General, ICFRE, Dehradun) and Sri. G. H. Basavaraj, Managing Director Chetana Exponential Technologies Private Limited, Bangalore on 19th January 2023 for Development of Bamboo Lumber.
- Dr. S.R. Shukla, Scientist G and Head, WPP Division, IWST, Bangalore and Mr. Sandeep Mukherjee, Director, M/s. Quercus Space Bengaluru (India) on 3rd February 2023 to provide technical support for construction of wooden structure using mass timber.

Activities of iGoT Karmayogi

Karmayogi Bharatha is an e platform of the Government of India which facilitates civil servants and Government officials to learn anywhere, anytime and bridge competency gaps using impactful and engaging learning content. It facilitates discussion and learning with peers, colleagues, civil servants and experts across the country. Institute of Wood Science and Technology has uploaded five learning modules related to wood science, ply & panel and bamboo composites on iGoT Karmayogi portal of Government of India. The modules posted by IWST on iGoT portal are Seed Handling and Nursery Technique for Sandalwood, Bamboo Composite Technology, Plywood Manufacturing Technology, Field Identification of Important Timbers of India and Wood Seasoning & Preservation.

Dignitaries visit

- Sri. A.S. Rawat, IFS, Director General, ICFRE, Dehradun interacted with Dr. M.P. Singh, IFS, Director, scientists, staff and students during his visit to laboratories, Xylarium, AWTC, wood workshop, plywood plant etc. at IWST Malleshwaram and IPIRTI campus during 20 - 21 January 2023.
- Prof. Tony Collins Senior Fellow, UNCCD visited IWST Bengaluru and interacted with the officials and scientists of the institute on agroforestry, certification, landscape restoration, wood and climate change. He also visited Xylarium, labs and facilitates of the institute.

International Women's Day

ICFRE-IWST, Bengaluru celebrated International Women's Day on 8th March 2023. Smt. Tresa Hamalton, Scientist-D welcomed the chief guest and other dignitaries on the occasion. Smt. Shobha H.G., Founder & Chief functionary of Samaja Seva Samiti NGO delivered the key note speech on "Gender Equality and Women Empowerment". She emphasized on importance of women empowerment in workplace. An interactive session was conducted by chief guest with officers, scientists and employees of the Institute followed by speech by Dr.M.P. Singh, IFS, Director on this occasion.

World Wildlife Day

ICFRE-IWST celebrated World Wildlife day on 3rd March 2023. A movie "Wild Karnataka" showcasing rich wildlife diversity of Karnataka was screened at lecture hall, IWST, Bangalore and at conference hall, IPIRTI campus, Peenya to create awareness regarding the conservation of wildlife among students and staff of ICFRE-IWST.

International Day of Forests and World Wood Day

An interactive session on Prioritization for promotion of tree species for sustainable utilization was organized on 21st March 2023 to commemorate International Day of Forests and World Wood Day. About 90 participants comprising Directors from ICFRE Institutes, Scientists from IWST and stakeholders from industries were part of the program.

Proceedings of webinar on

"Prioritization for Promotion of Tree Species for Sustainable Utilization"
held at ICFRE_IWST on 21.03. 2023

On the occasion of *International Day of Forests* along with World Wood Day, IWST, Bengaluru organized a webinar on Prioritization for Promotion of Tree Species for Sustainable Utilization, on 21.03.2023 to review, discuss and obtain views, and comments from stakeholders. The session was chaired by Dr A.S. Rawat, IFS, Director General, ICFRE, Dehradun and Co-chaired by Dr B.K. Singh ADG (Forests), MOEFCC, Government of India. The meeting was attended by more than 90 participants representing ICFRE institutes (AFRI Jodhpur, IFGTB Coimbatore, IFB Hyderabad, IFP Ranchi), Wood based industries, Universities, students and other stakeholders.

Dr. M.P. Singh, Director, IWST, welcomed the Chair, Vice-Chair and other participants and briefed that Wood based industries in the country is diversified and so far most the raw materials grown outside forests mainly under agro-forestry systems of species mainly eucalyptus, poplar, silver oak etc are being grown and/or utilized by pulp, paper and panel industries. With the significant growth predicted for paper and panel industries supply of raw material in future is also uncertain. On other hand, furniture, handicraft and other sectors have not received much attention or priority with regard to supply of raw materials or development of tree improvement programme focusing their needs. For example, furniture and handicraft hubs based in Saharanpur and Jodhpur are mainly utilizing mango, shisham and acacias and long term supply of these species is unpredictable. There is also lack of link among research institutes, farmers, industry and other stakeholders. These situation results in over exploitation of few species and unsustainable wood utilization, which is resulting in loss of income and enthusiasm for farmers to plant trees causing shortage of raw material for industry and higher import bills. India is a diverse country with a wide variety of underutilized tree species due to lack of awareness about their potential uses. ICFRE has a vital role in promoting the tree species for different wood based industries specially, improving the raw material for industries through tree improvement programme. There is strong need to identify and prioritize underutilized tree species with potential to meet the demand of wood based industries.

Shri A. S Rawat, IFS, DG, ICFRE in his opening remarks appreciated IWST for bringing discussion on this issue. He has emphasized on current scenario of industries in furniture, handicraft and panel.He talked about the research work carried out by ICFRE on rosewood, Teak. He focused on horticultural species as a raw material to industries apart from Mango, Babul and Sisham. He suggested to identify the species which are used for timber as well as in agroforestry with short rotation period to meet the demand and supply of timber in plywood. He concluded that to increase the quality and quantity as no research support is provided to plywood and panel industry.

Shri B. K. Singh, ADGF (Forestry) congratulated IWST for organizing the interactive session on the International Day of Forest. He elaborated major issues related to wood utilization and emphasized that utilization of trees is equally important along with growing trees. There is lack of backward and forward linkages for which interactive protocols may be developed where research institutions, industry and Ministry can interact with each other for better coordination. At the end, he requested to industries that if they have any proposal/idea on these issues, it may be shared with ICFRE and/or Ministry for the further action on it.

Sh BS Chandrashekar, Scientist IWST, gave a

presentation covering brief introduction on wood and wood based industries. He elaborates the scenario of wood based industries in various sectors. Paper and pulp industry are quite organised in terms of raw material production whereas panel, furniture and handicraft industries are highly unorganized and sustainability of raw material is very uncertain. He emphasized that issue of raw material to be addressed as availability is major bottleneck. He then talked about shortlisted species from the available tree resources which can be prioritized for the promotion to meet the raw material needs of (a) solid wood industry; (b) plywood and other panel products and (c) furniture and handicraft industry. Comments and suggestions of participants were invited over these shortlisted for further modifications.

The main views and comments of the participants expressed are as under-

- **ICFRE-IFB, Hyderabad:** They are working on tree improvement program of red sanders, sandalwood and casuarina spp. and other species. Species like Mahagony and Red sanders may be included to the list.
- **ICFRE-IFGTB Coimbatore:** IFGTB is importing three Eucalypts species from Australia for introduction of Eucalypts for wood purpose, within few years the organization may be able to handover to the farmers. IFGTB is also working on tree improvement programme on indigenous species which may be promoted such as *Gmelina arboria. Thespesia populnea, Ailanthus spp., Neolamarcki acadamba, Calophyllum spp., Tamarindus spp., Artocarpus* sp.
- **ICFE-AFRI, Jodhpur:** Pointed out about use of Australian acacia in handicraft industry.
- *Mr. Sivakumar, IFGTB* explained about eucalyptus as short rotational crop and used for pulp. They have been importing this species. They are also working on *Gmelina, Calophyllum, Tamarind, Artocarpussps.* for mass multiplication and supply. He suggested to include mango.
- *Mr. RajaShekar* from Timber foundation suggested to make a representative and lot of impact to be made by government to elocate timber.
- *Mr. Naval Kedia* explained the status of saw millers in wood industries and suggested that the species prioritized are old and known and hence to be implemented. He also suggested to give more focus on seasoning of wood specially rubber wood.
- *Mr. Moiz S Vagh* talked about melia and suggested to include species which grows in wide regions as it will benefit the farmers. He also emphasized on promotion of species as farmers lack information on growth.
- *Mr. Arun Bansal* asked about the years taken for tree improvement programme. W.r.t to Mr. Arun s query Director replied that tree improvement programme is 2 phase and depends on the species. Mr. Arun suggested to include Neem, Jackfruit as they have huge crown and useful in agroforestry.
- *Dr. C.N Pandey* suggested to refine the prioritized species based on parameters such as durability, physical and mechanical properties. He also suggested to bring forest development cooperation into system. In each state, there is a forest corporation and their mandate is just to harvest and sell the timber but why not they should take the responsibility to grow this timber in the land which is available with it.
- *Mr. Rajesh Nair* suggested to consider construction timber as currently, industry is mostly dependent on imported timbers for construction purpose.
- *Mr. Velmurugan* suggested to identity some native species for paper makingto replace exotic species like Eucalyptus spp. and Casuarina spp.
- *Mr. Ashish Mathew* talked about wood testing facilities. He is also asked about wood supply information.
- *Mr. K.S. Rao* suggested for effective technology transfer and how to promote and maintain sustainability.
- *Mr. Dwara Ramakrishna* emphasis on selection of

wood, treatment of wood by solar system. Promote wood species available in country.

- One of the participant asked about use of seasoned eucalyptus in handicraft industry. To which Dr. Chauhan explained that seasoned eucalyptus tends to crack as it has high density hence not preferred in handicraft.

The webinar was concluded by brief summary of the interactive sessions by Dr. Shakti Singh Chauhan, Head WPP division, followed by Vote of thanks by DrManoj K. Dubey, Head Extension, ICFRE-IWST.

"Teak" is "Teak", but modern wood technology can make any other wood also like "Teak"

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This article just wants to add caution to current plantation spree of Teak, anywhere and everywhere. It gives some cogent reasons to avoid such "monoculture" and rather suggest to increase the diversity of species to meet the supply. Even if the alternate species may not be exactly copy of Teak on various counts, but the current advancement of Wood technology can improve these substitutes-thus wherein the other so-called secondary species can be brought at par with Teak, the most wanted timber. This shift on diversity on supply -side can help us in achieving the broad goals of "Sustainability". The suggested shift is no more an option, but mandatory and hence desirable in our broader context of sustainable forestry.

Teak is one such wonder species; called king of wood, globe over for its unique physical characteristics and has rightly been accorded "most favored status" in the timber world; scoring over its near estrivals like Mahogany etc. – due to strength and aesthetic reasons. The statistics below reveal its position of its importance it has in India, how much of it is domestically produced–either in forest or in farms. How much is imported and exported?.

Planted teak forests according to various estimates cover between 4.35 to 6.89 million ha globally. Between 2005 and 2014, the global annual trade of teak round wood was more than 1 million cubic meters on average; the imports were valued at US$ 487 million per year, which is about 3 per cent of the value of the global timber trade (US$ 15.5 billion). The three major importing countries were led by India (74% of the total trade volume from more than 100 countries). (source-ITTO).

The famous Connoly's plot of malabar teak , the first manmade teak plantation in the world- Kerala,India

Imports of teak roundwood have doubled from about half a million m^3 in 2009 to slightly more than a million m^3 in 2019 while sawn teak has remained subdued due to high tariffs. On the export front, the volumes traded were consistently low with only veneer and fibreboard showing a marginal presence.

Owing to its excellent properties, teak is traditionally the most preferred species in India. The total area of teak plantations is about 1.7 million hectares. An insignificant volume of teak, about 50 000 m^3, is harvested annually from domestic sources. Most of India's teak demand is met from roundwood imports which in recent years have exceeded one million m^3. The quantity of sawn teak imported is relatively insignificant. Exports of teak, both round and sawn, have been negligible (Kant, P and

Nautiyal 2021).

These figures indicate the fascination for teak in the mind of Indianand Global consumers as well. It is also very succinct portrayal of global assessment of Teak timber, the demand and supply of teak; in the context of Indian wood industry, and also offers very critical take aways to "Indian wood industry" to move ahead strategically- both for its domestic production and also for catering to export market. It also gives strategic clues for getting supplies from private plantations and as well from "Public forestry"(which has limited relevance here, given the need of high volume of supply - only big and organised industrial players / or conglomeration of smaller players/farmers – can make it happen) which various studies highlights .

But over a period, this extra love for teak has resulted into gross redistribution of this species in the non-natural range of natural forest of India and other countries as well. So is the case of its proliferation in plantations, both in India and abroad –resulting almost in monoculture of it. But sustainability (including the provision of environmental services) is emerging a key concern in the management of planted forests/plantations. India; where "Sal" has been dominant species–particularly in its North, East, Upper Zones of Southern states and whole of North East states –where it has evolved over millions of years to reach that dominating composition: guided by the local soil, rainfall, temperature etc. and culminating into a mosaic of ecosystems and its services – which are being used by dependent society/flora/fauna etc. harmoniously for generations. But with the"accidental" finding of teak, particularly for its proven value for ship building etc. and thus"greedily" promoted by the Britishers – it got introduced to more and more and newer area – often replacing Sal or other native species in the natural forest. The plantations of Teak in Malabar by britishers (in 1824) is celebrated as the pioneer attempt to shape the"public forestry of India". Later more and more teak was introduced in different and diverse locations, ignoring its harmful effects on local ecology and consequent loss of ecological services.

The lucrative economic return on teak prices often lured the government to go for this mindless spree – though it was known to everybody that teak takes 60-70 years to harvest and many a times non-conducive climate and dry/ difficult locations will take even more time to attain its maturity. Incidentally, the rewarding prices teak timber lured farmers too, who also gave it prime place in their farm land indiscriminately, despite high upfront raising cost and long gestation period. The suitability of site, soil, climate etc. were conveniently ignored by the farmers- in the hope of huge returns.

Later, after independence, the modern "Indian Forestry" was expected to be more sensitive in meeting the need of people and country. The scheme of various 5 years plans, and each of it tried to give different focus to forestry-juggling between the demand of people/nation, production–economics and ecological focus. But in this blind race for higher returns continued and both the Govt. and farmers have failed to appreciate the value of native species; which teak has been replacing. The PES (Payment for Ecological Services); as a concept evolved in recent decades, needs to be appreciated – as it also helps in deciding the suitability of any forest management decisions. Sal or any other native species – encourage alot of biodiversity and efficient soil/water consumption regime – which teak or any implanted species cannot match. The Ecosystem Services evaluation makes this comparison – lucid in monetary terms-and helps in arriving at the right choice of species, which often is native species. For example -the Sal also provides – very useful leaves for plates; fruits which are edible and also yield oil and thus is always economical for the natives even if the Sal trees are in any stage of growth. They also have religious and cultural values to the native society. Sal is important part of "Sacred-groves" but the same is not valid for the "implanted teak". Those kind of religious / sentiment for Sal have been used to"destroy/ encroach" the "planted teak forest" in Bihar, few decades backed by the locals to mark protest against "insensitive government" and demand a separate state.

Hence; the economic argument for indiscriminate introduction of "teak" in its non-native landscape is no more valid when valued against the host of other ecosystem services offered by native species. The current paradigm shift to "Eco restoration" would also justify discouraging, singular introduction of

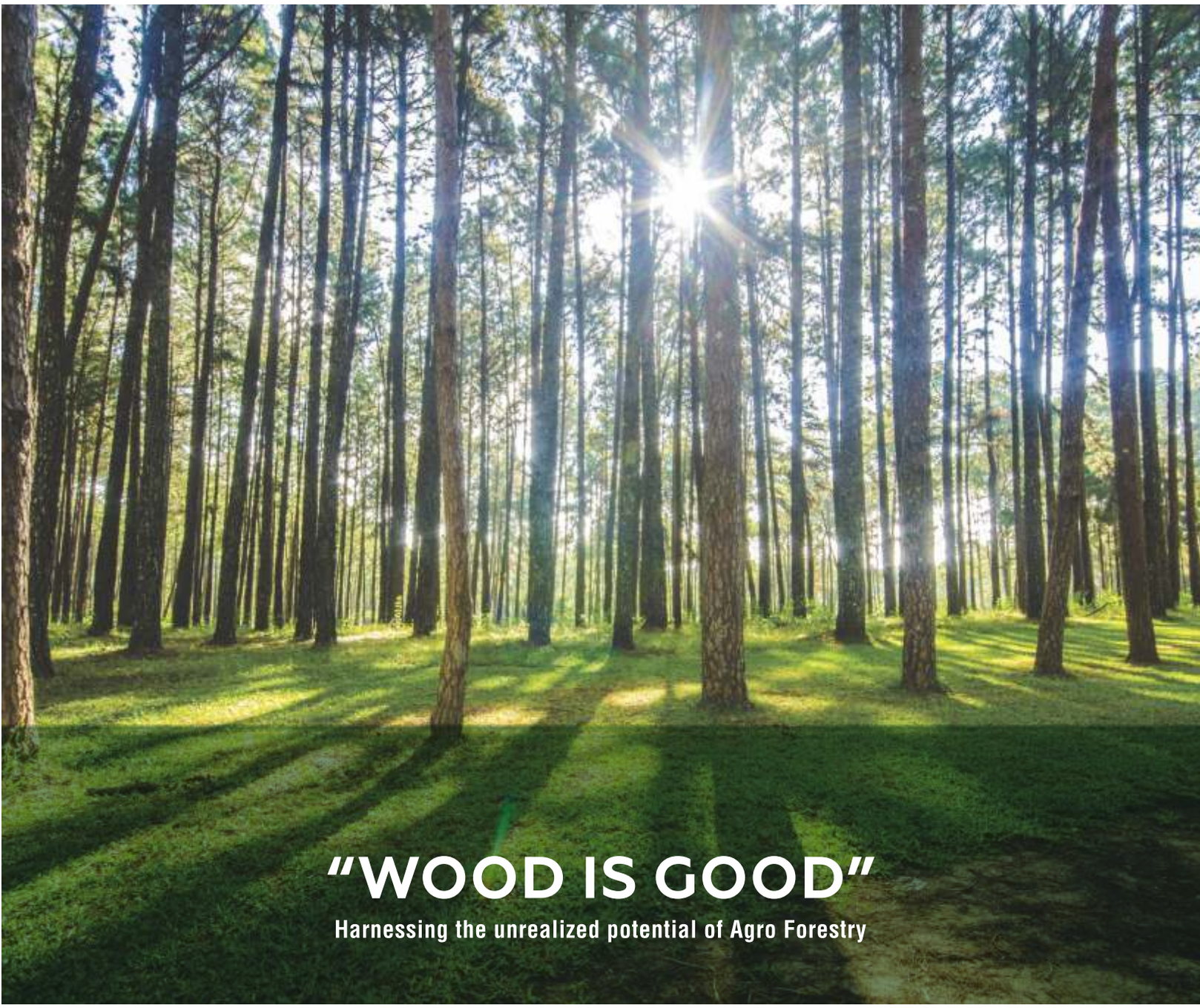
such implanted species.

But teak is a teak till it commands the market. However the modern forestry science and technology offers–choice of many a species, which are native/fast growing and its wood can even imitate the teak. Further, the wood technologists can help these inferior species by various kind of physical /chemical modifications–making these species even better than teak. This is a welcome development of Indian Forestry. Anecologically sensitive country like India – can no more afford to divert its natural forest for implanted species like teak alone, at the cost of losing diverse eco systems services. Further the advances in forestry sciences, are helping planters to improve the productivity and quality of forest using the various biological technology like – tissue/culture/clones/stump raising, etc. on one hand and then to wood improvement technology for refining the physical/chemical/appearances of any wood, which can bring high value to any inferior wood to make it look like teaks or even better. This is another way to cater to the demand side, using local/native/diverse resources.

We must not forget that the Teak (or for that matter any other commodity) is a part of an ecosystem, where small/ingenuous humans, their groups are often behind the scene –as different "stakeholders"_ and they in turn , in different combination guide or are being guided by the "Efficient market ".This market often triggers the growers to decide the species, it's rotation age and subsequent value addition, resulting in forest/farm production to offer a diverse range of products with best price discovery at different stages and locations- and thus this "diversity" also offers solution to limit the mindless proliferation of " Teak " too. Hence this market, need not follow the conventional silvicultural wisdom but the same must combine economics too- which is getting facilitated by the other branch of forestry like genetics, soil science, ecology, wood science etc.

Currently, the teak which is no more used a structural timber but is more valued/needed for aesthetic purposes, given its high cost. Hence short rotation of teak, replacement of teak with many look alike native or imported species like *Gmelina arborea, Acacia auriculiformis*, Nigerian/ African teaks, use of technologies like composite-wood, fine veneers, chemical/ physical improvement, polishing etc is resulting in most efficient use of available alternate species of timbers– to cater the market- which still fancies the name of teak. This alternate sourcing of other timbers, which look alike the "teak"- is also helping, the Indian and global forestry to become more "sustainable".

If we see this issue in larger perspective, saving the natural forest from the forced and indiscriminate plantation of teak, where it is native or not makes a lot ecological sense. This diagnosis appears to be appropriate and hints to every stakeholder for commensurate recipe for action from their end.



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Acacia nilotica (Babul)

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INTRODUCTION

Babul (*Acacia nilotica)* is a species belonging to the Acacia genus of the Mimosaceae family. It encompasses nine subspecies and is widely known by different names such asBabla (Beng.), bamura (Gon.), baval, bawal (Guj.), babul (Hind.), fali, gobli jail (Kan.), kikar (Punj.) karuvai, karuvelam (Tam.) and nellatuma (Tel.). This tree is of moderate height and possesses a spreading crown. Native to various regions including the Indian Subcontinent, Tropical Africa, Burma, Sri Lanka, Saudi Arabia, Egypt, and West and East Sudan, Acacia nilotica thrives in diverse habitats.

In India, natural babul forests can be found throughout the country, with states like Maharashtra, Gujarat, Andhra Pradesh, Rajasthan, Haryana, and Karnataka hosting significant populations. While dispersed groups of babul trees occur naturally in most states and union territories, they are also widely cultivated. This versatile species offers multiple benefits, with its wood being used for furniture and highly valued by rural communities. Additionally, its leaves and pods serve as animal feed, and its gum finds various applications. The adaptability of *A. nilotica is* noteworthy, as it can tolerate extreme variations in moisture and temperature, making it suitable for planting on marginal lands.

In this article, we will delve into the characteristics, ecological significance, and diverse uses of the multipurpose *A.nilotica,* exploring its value and potential for various applications.

Source: https://en.wikipedia.org/wiki/Vachellia_nilotica

Growth Characteristics:

A. nilotica which is commonly known as babul, thrives in a variety of habitats including plains, ravines, and flat or gently sloping terrains. It demonstrates remarkable adaptability, even in alkaline soils and areas with subsoil containing saltwater. This species is predominantly found in the tropical and subtropical regions of India, where annual rainfall ranges from 200 to 1270 mm. *A. nilotica* exhibits resilience to temperature ranging from 4°C to 47°C.

A. nilotica is an evergreen tree which is known for its vigorous growth. Under favourable conditions, this tree can grow up to 15 to 25 meters height and can obtain a girth of 2.4 to 3 meters. In less suitable environments, babul trees may appear as stunted, shrubby, or straggling trees. In this article, we have collected information on growth patterns, adaptability, and ecological significance of babul trees, shedding light on their role in sustainable land management and their numerous uses in diverse sectors.

General Growth Pattern of *Acacia nilotica*

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Leaf Fall												
Flowering												
Pod Formation												
Seed Drop												
Germination												

A. nilotica in agroforestry

Enhancing Sustainability in Arid and Semi-Arid Climates

A. nilotica is a widely cultivated agroforestry tree species in India, particularly suitable for arid and semi-arid climates. In regions like Rajasthan, it has gained popularity in the northern and central areas. *A. nilotica* sub-species cuppressi form is preferred for agricultural croplands due to its narrow crown. With its rapid growth rate, ability to coppice easily, and nitrogen fixation capacity, babul is a valuable source of fodder. Camels and goats often browse on its leaves in dry areas.

The role of babul extends beyond providing fodder. It contributes to soil conservation efforts by offering shade, shelter, and acting as an excellent soil binder. Its versatility is demonstrated through successful cultivation in various environments, including semi-arid regions and irrigated farmlands. Babul is highly regarded by farmers, who grow it near homes, wells, compounds, and farmlands due to its multiple uses. Every part of the tree serves a purpose, making it a valuable asset in homestead plantations.

Yield Table of *Acacia nilotica*

Crop Age (Years)	**5**	**10**	**15**	**20**	**25**
Average age diameter (cm)	7.36	13.71	18.79	22.60	25.14
Maximum diameter (cm)	12.19	20.83	26.92	31.49	34.29
Main average height (m)	8.22	11.58	14.02	16.15	17.67
Crop top height (m)	8.14	12.19	14.93	16.70	17.98
No. of trees/ha	538	246	155	120	99
Total volume (cu.m)/ha	10.19	22.08	35.53	45.49	50.26
Thinning volume (cu.m)/ha	11.27	3.22	4.95	6.39	7.27
Final yield (cu.m)/ha	11.46	25.31	40.49	51.98	57.54
Accumulated yield of thinning (cu.m)/ha	1.27	4.50	9.45	15.85	23.13
Total yield (cu.m)/ha	**11.46**	**26.58**	**44.99**	**61.44**	**73.39**

Source: Babul (*Acacia nilotica*) Forest Research Institute, ICFRE 33p.

A. nilotica is extensively cultivated in agroforestry plantations across diverse regions of India. From the foothills of the Himalaya to the southern state of Tamil Nadu, and from the arid landscapes of Rajasthan to the eastern state of West Bengal, babul has found its place in agroforestry systems. These plantations extend beyond protected areas like the Sunderban Delta National Park, where *A. nilotica* and other non-mangrove species are strategically planted. Interestingly, fish farming is being practiced in areas encircled by earthen embankments, showcasing the versatility of babul in such systems. The leaf litter of babul decomposes rapidly, enriching the soil with organic matter and making it a valuable component of agroforestry practices.

A. nilotica as avenue trees

Babul serves as a hardy and resilient avenue tree, especially in regions where species selection poses challenges. It is commonly used as a live-hedge fence around circular trenches, providing a protective barrier for other significant avenue trees. The adaptability of babul is evident through its minimal shade-casting due to its thin crown, which ensures minimal interference with crop growth beneath its canopy. Nitrogen fixation is another notable attribute of babul, making it a preferred choice for planting on field embankments in arid and hot regions. As such, babul is poised to play a crucial role in social forestry endeavors in the future.

A. nilotica as species for rehabilitation and reclamation of degraded forests

Babul has emerged as a key species for large-scale plantation efforts aimed at rehabilitating degraded forest lands. It is particularly suited for afforestation initiatives in diverse environments, including saline, alkaline, ravine, and waterlogged areas. Babul's ability to thrive in such challenging conditions makes it an ideal choice for restoring balance to ecosystems.

Furthermore, its suitability for black cotton soils further enhances its potential for land reclamation projects.

General properties of wood

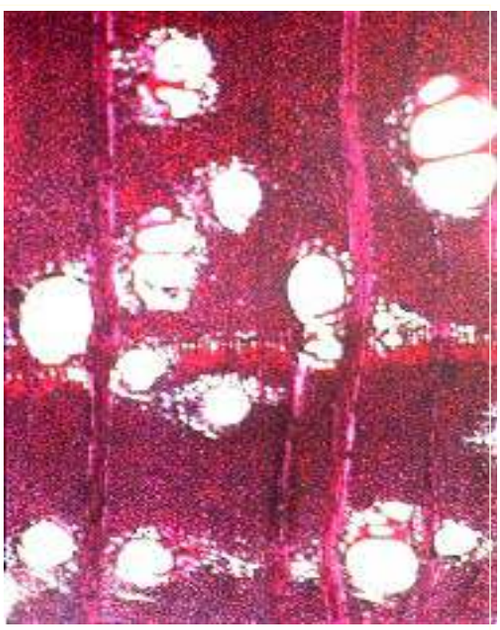
A. nilotica wood has a distinct sapwood and heartwood. Heartwood is pinkish brown to reddish brown in color. It is moderately heavy to heavy wood with a specific gravity ranging between 0.71-0.90 (air dry). Wood is moderately hard and medium coarse in texture. The wood features interlocking grains, contributing to its overall strength and resistance to warping or splitting. This unique grain structure enhances its structural integrity, making it suitable for a variety of applications.

Gross structure

The anatomical properties of babul wood contribute to its distinct structure and functional properties. *A. nilotica* is a diffuse porous wood. It has very variable growth rings that are indistinct or sometimes visible under lens. These growth rings are characterized by thin banded parenchyma, highlighting the growth zone within the wood. Vessels are moderately large and are visible to the eyes. The vessels have a tangential diameter averaging 271 ± 51 µm. The length of the vessels is approximately 507.3 ± 6.6 µm, and the frequency of vessels is around 4 ± 0.4 per mm^2. The vessels have simple perforation plates, and the pits between the vessels are alternate and elongated, with a diameter of 8.9 ± 0.9 µm. Babul wood exhibits sparse to moderately abundant parenchyma, which is primarily vasicentric in nature. The parenchyma forms prominent sheaths around the pores and is usually 2-4 cells wide. It tends to form aliform structures, particularly around the smaller pores in 2-4 celled stands. The wood has rays that are 4.3 ± 0.2 rows/mm and range from 1-4 seriate. The average length of the rays is approximately 1554 ± 86µm. The diameter of the fibers within the rays is around 36.6 ± 0.4 µm, with a lumen diameter of 2.2 ± 0.05 µm. The fiber pits in the rays have a diameter of about 3.8 ± 0.2 µm. Rays are of the similar color as the background, broad to fine and irregularly spaced.

These anatomical properties provide insights into the cellular structure of babul wood, highlighting its distinct features such as growth rings, vessel characteristics, parenchyma distribution, and ray structures. Understanding the anatomical properties of babul wood contributes to its utilization in various applications, taking into account its specific structure and functional attributes.

a. Transverse surface (scale 1 mm)



b. Transverse surface (scale 200 µm)

Mechanical Properties of Babul wood

With its high density, babul wood exhibits exceptional strength, ensuring it can support heavy weight without bending or breaking (Table 2). Its sturdiness contributes to its longevity. These mechanical properties of babul wood make it a reliable choice for a wide range of applications, including furniture making, construction, and other uses where strength and durability are paramount.

Table 2. Physical and mechanical properties of the Babul wood.

Properties	Babul Green	Air Dry
Moisture content (%)	70	12
Static Bending		
(a) Fibre stress at elastic limit (kg/cm^2)	421	487
(b) Modulus of rupture (kg/cm^2)	776	894
(c) Modulus of elasticity (1000 kg/cm^2)	977	1128
Impact bending		
(a) Fibre stress at elastic limit (kg/cm^2)	1085	1306
(b) Maximum height of drof in impact binding (cm)	130	104
(c) Modulus of elasticity (kg/cm^2)	108400	140100
Compression parallel to grain (kg/cm^2)		
(a) Compressive stress	207	260
(b) Maxi. Crushing stress	354	536
(c) Modulus of elasticity	101800	118000
Compression perpendicular to grain (kg/cm^2)		
(a) Compressive stress at elastic limit	91	124
Hardness-load in kg to embed 1.128 cm diameter ball to half diameter		
(a) Radial	720	824
(b) Tangential	755	855
(c) End	671	915
Shear parallel to grain (kg/cm^2)		
(a) Radial	119	168
(b) Tangential	143	192
Tension perpendicular to grain (kg/cm^2)		
(a) Radial	89	71
(b) Tangential	107	93

Natural durability:

A. nilotica seasoned heartwood is very durable, whereas, the sapwood is quite prone to insect and fungal attack. The borers such as *Lyctus africanus, Sinoxylonanale* and *Stromatiumbarbatumare* commonly seen infecting on this species.

Workability: It is quite easy to saw wood in green condition, however, somewhat difficult to convert the dried wood. Babul wood is known for its ease of workability (particularly with hand tools), allowing for precise cutting, shaping, and sanding to create intricate designs and details. It also responds well to staining and finishing techniques (sometimes require filler), providing versatility in achieving various looks and styles. Its working quality index, a measure of surface quality and ease of working, is rated at 84 out of 100 compared to teak.

In this article, we have explored the diverse applications and benefits of babul as an agroforestry species, highlighting its adaptability, contributions to sustainable land use, and its potential as a valuable timber resource.

Source: Alireza Dorostkar 2015.

Seasoning and preservative treatment

The wood is moderately refractory in nature. It liable to develop surface cracks and end splitting, however, it can be air dried without much difficulty. Under kiln drying the timber can be dried within 16 to 20 days, following a mild drying schedule. Heartwood of this species is treatable as the vessels are moderately large but complete penetration of preservative is difficult to achieve.

Wood uses

A. nilotica wood is highly valued for its timber. It is commonly used for furniture making, carving, turnery, and boat building. The wood is also widely employed in construction for posts, rafters, beams, and door frames. In agriculture, it is favoured for implements such as ploughs, harrows, crushers, and rice pounders. Babul wood is also recommended for the production of sports and athletic goods like clubs, wall bars, and parallel bars. Its distinct appearance and carving potential contribute to the creation of artistically valuable products. Babul wood is an excellent fuelwood and is commonly used as a source of charcoal. The calorific value of wood is relatively high, making it a reliable source of heat energy. The charcoal produced from wood is considered superior to that derived from other species. It exhibits characteristics such as high density, high heat of combustion, low ash content, and low initial moisture content, which make it ideal for fuelwood and charcoal production. The quality of charcoal is favorable for use in locomotives, river steamers, and boilers in small-scale industries. The fresh bark of *A. nilotica* is a valuable resource for tannin extraction. Tannins are water-soluble polyphenolic compounds with high molecular weight and rich phenolic group content. Industrially, tannins are used in the production of leather, adhesive materials, dyes, and inks. Additionally, tannins possess astringent properties and find use in medicinal applications for promoting rapid wound healing and tissue formation. Babul bark contains over 10% tannins, making it suitable for commercial exploitation in the tanning industry. Such versatile use of wood from this species in furniture, construction, fuelwood, charcoal production, and bark for tanning highlight its significance as a valuable resource.

Acrocarpus fraxinifolius Wight Ex Arn. (Balangi): A Prospective Timber Species for Panel Products

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INTRODUCTION

Wood is an integral part of our life as its use in solid form or in engineered product. Due to increasing urbanization and industrialization, the demand for wood and wood products has increased at faster rate; hence their import has increased manifolds in our country. To meet the growing needs of Industries it's necessary to focus more on locally grown timber species which is fast growing and is a good quality wood. *Acrocarpus fraxinifolius* species is one such fast growing plantation species having properties required to achieve desired wood panel product. This article discusses on the distribution of this species, its wood quality as well as utilization potential.

About the species:

Acrocarpus fraxinifolius species is a large deciduous fast-growing species from a family Fabaceae. It, is a fast-growing species resembles most physically to ash and walnut trees. The species is native to the tropical regions of Asia and distributed in countries like Bangladesh, Bhutan, China, India, Indonesia, Laos, Myanmar, Nepal, Thailand, tropical areas of Egypt and Brazil. It is called by different names in different countries such as Delimas or Madang pariek in Indonesia, Khan Khak in Laos, Yetama in Myanmar, Pink cedar in Africa, and Cedro Rosado and Lazcar in latin America. The other names in English for the tree includes Shingle tree, pink cedar, Indian ash, Kenya coffee shade, Australian ash. In India, this species is commonly called as Balanji, Mundani, Hantige, Hevulige, Kurangadi, Kurangan, Malankommao, Malaveppu, Mandane, Narivenga, Nelrai, Silchhal.

Geographical distribution in India, Growth, soil and PH

Acrocarpus fraxinifolius is distinguished as a part of tropical evergreen and subtropical forest. In India, it is spread in different parts of India such as Assam, Meghalaya, Arunachal Pradesh, Sikkim, Uttarakhand, West Bengal, Tamil Nadu, Karnataka, Kerala, Odisha, Punjab and Andhra Pradesh. *Acrocarpus fraxinifolius* grows best in sub-montane areas in the humid and sub humid tropics with a short and dry spell. It succeeds at elevations from sea level to about 2,000 metres, growing best in areas where the annual precipitation is between 500 - 3,000 mm and the temperature ranges between 15 – 260C. The plants are very sensitive to frost and prefer a fertile soil. It requires a position in full sun although; it can tolerate a small amount of shade. *Acrocarpus fraxinifolius* needs medium (loamy) soils and prefers well-drained soil. It requires a suitable pH, mildly acid, neutral and basic (mildly alkaline) soils and can grow in very acid and very alkaline soils. It cannot grow in the shade and prefers moist soil.

Fig.1 Acrocarpus trees

Acrocarpus fraxinifolius, (Nath et al. 2012), attaining heights of 30-60m. It has cylindrical stem and mostly free from branches for up to 75% of its total height. The branches remain relatively thin and are horizontally deployed. Bark is thin and light grey in colour. It is a deep rooting plant; in which the roots can penetrate up to 4.5 metres into the soil. The tree competes with crops if grown in fields. The leaves are bipinnate about 30cm with 3-4 compounded leaflets and consisting of 5-6 elliptical lance like leaflets 7-10 cm long and arranged in pairs. The leaves are bright red when young and the tree bark is green and smooth. The oval leaf colour is green with showy red colour flower. very small brown legume fruit is seen in summer and flowers grow in spring.

Acrocarpus fraxinifolius is quite fast growing which annually grows upto 3m and can reach to a height of 50-60m with a diameter of 2.4 m from seed. The straight trunk of the species has spurs and the round crown is composed of rising branches. Tree shape is rounded foliage type with partly deciduous. Maximum height of the tree is 70 feet with a growth rate: ~36 in/year. Young plants have been observed to behave as climbers and stranglers of other trees. According to the report of Tanzania, growth of older trees is still rapid, where the mean annual increment of 13-year-old trees was 120cm in height and 19mm in diameter. In Rwanda the mean height of trees was 150cm after 1 year, 4.4 metres after 2 years, 6.7 metres after 3 years, and 19 metres after 24 years with a bole diameter of 35cm.

Pests and diseases:

Young trees are susceptible to termite attack. It is reported that in India *Atractomorpha crenulata*, a grasshopper, and the caterpillar of *Eurema blanda* defoliate seedlings in nurseries and young plantations. The tree is also a host for the wood borer *Xylosandrus compactus,* a small Ambrosia beetle. *Ganoderma lucidum* causes trunk and root rot wherever *A. fraxinifolius* is cultivated.

Physical, mechanical, chemical and anatomical characterisation of wood

The wood exudes a gum-like resin when the trees are felled. The sapwood is whitish; the heartwood is bright red to brownish-red with darker veins, making it very decorative. The grain is straight to slightly interlocked, sometimes wavy, lustrous and the texture is coarse. The vessel is diffuse-porous, distinct, medium to small, very few to moderately few, mostly solitary or in short radial multiples or in clusters; often filled with whitish deposits. Paratracheal and apo-tracheal, vasicentric, aliform, fine lines, delimiting growth rings. Wood soft to moderately hard.

The wood is heavy, moderately hard, and compact. Density of the wood is about 863 kg/m^3 at 10% moisture content. It is reported to shrink 3% in radial direction and 5.2% in tangential direction from green to oven dry condition. Modulus of rupture (MOR) and modulus of elasticity (MOE) in air dry condition are 110.8 MPa and 13.35 GPa. The details of other mechanical properties of this wood sourced from south India and tested in air dry condition are presented in the following table.

Seasoning and Preservation:

The wood is moderately refractory (Class B) and can be seasoned following schedule III of IS 1141-

Species	Std. SG	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
		MOR	MOE	Max. drop (cm)	MOE	Max. C stress	MOE	CS at E.L..	R	T	E	R	T	R	T
Teak	0.598	95.9	12534	68.6	16381	54.5	14017	9.7	5004	4959	4670	8.4	9.8	3.7	4.4
A. fraxinifolius	0.828	110. 8	13355	124.5	-	54.6	13755	12.4	11498	10275	9541	13.0	13.7	3.6	7.5

(1993). The wood is not very durable and is prone to attack by fungi and insects, but it impregnates well. Heartwood of this is only partially treatable. A study conducted by Suirezs et al. (2013) explore the natural durability of heartwood and sapwood facing the action of the fungus *Laetiporus sulphureus* and also to determine the apparent specific weights of species grown in Misiones, Argentina. The heartwood of twelve years old A. fraxinifolius tree is concluded as non-resistant to the action of the fungus *Laetiporus sulphureus*, while the sapwood corresponds to the perishable group.

Uses of wood

Solid wood application:

Within its native range the wood is used for general construction, floors, stairways, doors, tea crates, beehive frames, and after being impregnated, for railway ties. The wood is sometimes used for firewood in many places. The tree is a good source of nectar and good bee forage. The natural durability and apparent specific weight characteristics of this species would allow it to be used in furniture and interior constructions. It is easy to work with tools and is well suited for turnery, carving and polishing. It is an excellent species for furniture industry satisfying the architects design as it can be easily bent. A study by Pandey et.al., 1995 demonstrated that *Acrocarpus fraxinifolius*, species would give satisfactory bends of radius 100-175 mm from 13 and 25-mm-thick strips when plasticized with ammonia at 5 kg/cm^2 pressure. The wood was subjected to heat treatment on an industrial scale, in an autoclave, with an application of heat and pressure. The wood showed uniform browning after the heat treatment allowing the use of the species for aesthetic and decorative purposes. After the heat treatment, the wood showed small cracks that contributed to the loss of mechanical strength (Carolin et.al., 2022)

Pulp

The holocellulose, constituting cellulose and hemicellulose, is the major portion of fibrous raw material which is about 70.7% in the species and the lignin content is 25.9. The unbleached pulp yield was found to be 42.4 %., The kappa number is an indicative of lignin content of pulp and gives an idea of bleaching demand in manufacturing process. The minimum kappa number for *Acrocarpus fraxinifolius* was found 21.4 at 16 percent chemical charge (Venilla et.al ,2021). Timber having long fibres, slenderness ratio, flexibility coefficient, and low Runkel ratio are considered for high quality pulp and paper production. A study emphasizing on wood trait indices of Acrocarpus fraxinifolius for understanding the suitability of the species for paper and pulp industries was conducted at the College of Forestry, Ponnampet, Karnataka in 2020. The mean Runkel ratio, Slenderness ratio, Flexibility coefficient, and Rigidity coefficient were 0.580, 60.132, 63.290, and 0.184 respectively. The anatomical screening of *A. fraxinifolius* for pulp suggested the species as raw material for paper production.

Panel products

The wood is suitable for face veneers, cores and cross bands in the manufacture of plywood and has been recommended for marine grade plywood. Parthiban et.al. (2019) studied its suitability for peeling and plywood manufacturing. The authors prepared boiling water proof plywood using phenol formaldehyde resin and obtained an average MOR 43 MPa and average MOE of 4.54 GPa. Henrique et.al., 2019 produced plywood using phenol-formaldehyde resin with *Acrocarpus fraxinifolius* in combination with Pine veneer and reported that the use of *Acrocarpus fraxinifolius* veneers improved the physical and mechanical properties of the plywood.

Study on glue shear strength properties of preservative treated veneers were carried out. Veneers of *Acrocarpus fraxinifolius* were treated with preservatives – ACC (Acid copper chrome), CAA (Chromic acid, Arsenic), CCB (Copper, chrome, boron,). Comparison of the glue shear strength of treated and untreated plywood indicated that ACC, borax and boric acid in *A. fraxinifolius*. interfered with the development glue bond strength.

Industrial trials by scientist of IPIRTI on peeling of balanje logs having girth above 1.5m showed that type -B surface veneers can be produced and good quality of core veneers can be obtained. Whereas few trials on face veneer type A veneer can be successfully

Fig. 2 Acrocarpus Logs

produced as it produces clear veneer having uniform texture and colour. Fig. 2 shows the peeling of balanje logs. Studies on drying of veneers shows that veneer could be dried fast without major drying degrade.

The peeled veneers were used for the manufacturing of plywood using urea formaldehyde

Fig. 3 Peeling studies of balanji species in Industry

resin at industrial scale. Fig. 3 shows the checking of moisture content of glued veneer before pressing. Successful trials of manufacturing plywood using alone balanje species and the combinations of balanje and silver oak species were carried out at Industry. Fig-3 displays the plywood manufacture using the combination of the species.

Fig. 4 Moisture checking of glue coated Balanji veneers during assembling

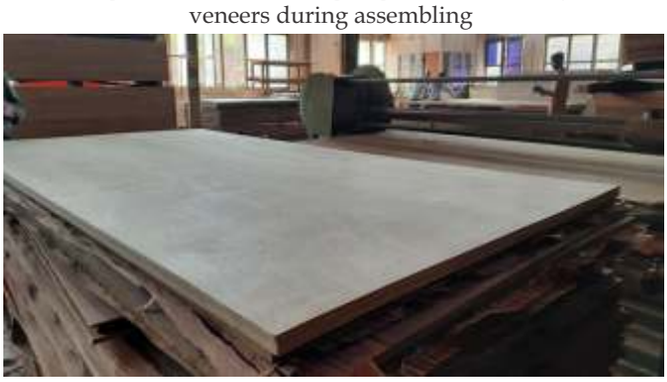

Fig. 5 Plywood made in combination of silver oak and balanji species at Industrial trial

Particle board:

Particle board is one of the engineered wood composites and has high demand as it does not require any high-quality material, even lops and tops or branches of the trees can be used. Many studies on balanjee species for the manufacture of particle board has used urea formaldehyde resin as adhesive pressing at 1600C for 15 mm thickness sample. Physical and mechanical properties of balanjee particle board has shown properties above the Pinus tanda species particle board.

Medium density Particle board of *Acrocarpus fraxinifolius* particles in combination with Pinus oocarpa by Henrique et.al. 2019 reported that the particle board panels has shown decreased water absorption but increased thickness Swelling after 24h of soaking. Panels with higher amounts of Acrocarpus obtained a significant improvement in mechanical properties, indicating the feasibility of this raw material in the production of particle board panels. The panels with 100% Acrocarpus particles showed potential to be suitable for wider uses, such as use in wet environments.

CONCLUSION:

Acrocarpus fraxinifolius is fast growing species, and competes with crops when grown in fields. The colour of the species is similar to ash and walnut which makes it still more attractive species. *Acrocarpus fraxinifolius* is used for interior panelling, furniture and cabinet work. The species is a potential alternative raw material for the production of plywood panels. The use of this species in the production of particle board is found technically feasible This species is recommended for manufacturing engineered wood composite and high-end application panel products.

Ailanthus excelsa Roxb.

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Ailanthus excelsa, commonly known as the Indian Tree of Heaven, is a large deciduous tree native to India. It is distributed in the southern central and western regions of the country, including states like Rajasthan, Bihar, Orissa, Madhya Pradesh, and Gujarat. The tree exhibits several favorable characteristics, making it suitable for agroforestry systems and wood-based industries.

Scientific names - *Ailianthus excelsa*Roxb. **Family-** Simaroubaceae
Vernicular names: Sanskrit (Madala, Katvariga, Dirghavrnta) ; Assam (Aralu); Hindi (Maharukha, Limbado, Maharuk, Mahanimb); Bengali (Mahanim); Gujarti (Motoardusa, Adusa, Arduri, Arlabo, Moto); Kanada (Doddamaru, Hemaraheera mara, Dodumani); Marathi(Mahanimb, Maharukh); Tamil (Peruppi, Perumaruttu, Peru, Pee); Oriya(Mahanim, Mahala, Gorni-Kawat, Palamow-Ghokaram)

Growth Behavior and Agroforestry Suitability

A. excelsa thrives in arid, semi-arid, and semi-moist regions of India with low rainfall (<500mm). It prefers porous sandy and loamy soils and grows well in full sunlight. The species can be propagated through natural reproduction via seeds and coppicing, and artificial regeneration can be achieved through direct seeding or pre-germinated seed planting. Its fast growth, ability to tolerate limited water availability and adaptability to strong light conditions make it a promising choice for agroforestry systems. A. excelsa has been successfully integrated into crop sequences like mung bean, wheat, and cowpea, leading to improved yields in agri-silvi systems.

Tree Improvement Efforts

Tree improvement initiatives for *A. excelsa* have included plus tree selection and progeny trials. Superior genotypes have been selected based on desirable traits like straight stems, self-pruning ability, and disease resistance. Progeny from plus trees have shown promising results in terms of seedling height, shoot length, and seedling dry weight. Additionally, tissue culture has been utilized for cloning superior genotypes, and research is ongoing to standardize rooting and grafting techniques for large-scale propagation of outstanding clones.

Wood Characteristics The wood of *A. excelsa* is lustrous with a faint yellowish color and exhibits a

straight grain and coarse texture. It is very light, with a density of 0.45 g/cm³. The wood is very light with a basic density of 361kg/m^3. The bending strength (MoR) ranges 30- 35 Mpa, tension parallel to grain ranges from 37 MPa to 39 MPa and tension perpendicular to grain of 10.7 – 12.3 MPa for 10 years old tree of different girth classes of wood (Divya et al. 2022). The compression strength parallel and perpendicular to grain ranges from 29-32 MPa and 10-11 Mpa respectively. Mechanical properties of the wood include bending strength, tension parallel and perpendicular to the grain, and compression strength, making it suitable for various applications.

Applications and Processing

A. excelsa has diverse applications in wood-based industries. It is widely used for match splints due to its specific properties like color, wax stability, consistent burning, and splinting ability. The wood finds use in packing cases, fishing floats, sword sheaths, plywood (Grade III and IV), and the paper industry. However, veneering may require special attention, as the wood can exhibit color variations and checks, making it suitable for B surface plywood.

Potential Scope in Wood-Based Industries

Given its various favorable attributes and applications, *A. excelsa* has a significant potential as raw material for different wood-based industries. Its use in plywood production, match splints, and other applications highlights its value as a valuable resource in the wood industry.

CONCLUSION

Ailanthus excelsa, with its versatile nature, fast growth, and adaptability, holds promise for sustainable wood-based industries and agroforestry systems in India. Through ongoing tree improvement efforts and research on processing techniques, this species can continue to contribute to various industries while conserving its genetic diversity and supporting ecological balance.

Alstonia scholaris (L.) R. Br.

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Scientific Name :
Alstonia scholaris (L.) R. Br
Family : Apocynaceae
Vernacular Names:
English : White cheesewood
Sanskrit : Saptaparni
Kannada : Maddale
Bengali : Satiani
Burmese : Lettok
Gujarati : Satuparni; Alstonia scholaris tree
Hindi : Chatian
Tamil : Elalaipalai
Nepali : Chhatiwan

Alstonia scholaris tree

INTRODUCTION:

Alstonia scholaris (L.) R. Br., commonly known as the "blackboard tree" or "scholar's tree," has interesting cultural associations and uses. Its wood is used for making blackboards, slates, and pencils, earning it the name "blackboard tree." It is also known as the "scholar's tree" due to its association with educational traditions. Additionally, the tree is called the "devil's tree" in folk stories, as it was believed to be inhabited by Yakshinis, and animals avoid eating its leaves due to the milky latex it contains.

Origin and Distribution:

Alstonia scholaris is native to the Indian subcontinent, Southern China, Indochina, the Philippines, Malaysia, Indonesia, Papua New Guinea, and tropical Australia. It is found in several tropical and subtropical countries, including Nepal, Pakistan, Bangladesh, Sri Lanka, Myanmar, Vietnam, and the Philippines. There are claims that the species is also native to Africa and Central America, with subsequent distribution to other regions.

Tree Characteristics:

Alstonia scholaris is an evergreen tree that can grow up to 40 meters (130 feet) in height. It features rough gray-white bark with yellowish inner layers. The leaves are thick, dark green, arranged in whorls of 4-8, and have a narrow spathulate shape. The fragrant flowers form compact, branched clusters at the shoot tips, blooming from October to March, with fruiting occurring from May to July.

Growth Behaviour and Agroforestry Suitability:

This species adapts well to a range of climatic conditions and prefers moist habitats. It thrives in areas with an annual rainfall of about 100-150 cm. It can grow in various soil types, including red alluvial, black, alluvial, lateritic, and volcanic soils. *Alstonia scholaris* can be easily propagated and is suitable for agroforestry systems.

Physical, mechanical, chemical and anatomical characterization of wood and processing issues

A. scholaris is one of the sources of timber although it is non-durable and very perishable species. Wood is diffuse porous. The light-coloured parenchyma tissue appearing as bands of varying widths or in patches (*Apgaua et al*., 2015). Sapwood very wide and undefined from the heartwood. Heartwood of the species is

yellowish, cream-white or straw-coloured to pale yellow-brown. No clear-cut demarcation is present between heartwood and sap wood. Grain straight to interlocked. Texture moderately fine to moderately coarse, variable. Growth rings not evident but sometimes indistinct rings will be seen if the wood is bit denser; vessels present are of intermediate to small in size, distinct or indistinct to the naked eyes; rays are visible under lens. Open slit-like radial passages will be formed by characteristic latex traces. Polished wood surface is moderately lustrous. Tangential surface occasionally with zigzag markings.

Chemically wood of *A. scholaris* contains 54% cellulose, 25% lignin, 15% pentosan, and 0.9% ash and no silica content was found. The solubility is 1.4% in alcohol-benzene, 0.3% in cold water, 3.6% in hot water and 11.1% in a 1% NaOH solution. The energy value is 19 900 kJ/kg. Triterpenes, particularly α-amyrin, ß-amyrin and lupeol are present in the latex. Alkaloids are present in the leaves and bark of the *A. scholaris*.

At 15% moisture content, density of the wood is 270-490 kg/m^3 and at the root, wood may be much lighter, 48-80 kg/m^3. Modulus of rupture of *A. scholaris* wood is 33-52 N/mm^2 and modulus of elasticity is 6300-9000 N/mm^2,; compression parallel to grain 22-32 N/mm^2, compression perpendicular to grain 2-4 N/mm^2, shear 5-7 N/mm^2, cleavage 26-45 N/mm radial and 30-51 N/mm tangential, Janka side hardness 725-2000 N and Janka end hardness 1315-3225 N. Shrinkage rate of *A. scholaris* is moderately low. At moisture content reduction to 15% from green timber shrinkage was about 2.3% in radial direction and 2.8% in tangential direction, and from green to oven dry it was 3.1-3.4% and 4.9-6.1% in radial and tangential direction respectively. The mechanical properties of *A. scholaris* wood tested from Mangalore, Karnataka in comparison to teak wood in air dry condition has been presented in the following table.

Species	Location	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)		
		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at E.L..	R	T	E
Tectona grandis	Burma and Malabar	95.9	12534	27	1638	54.5	14017	9.7	5004	4959	4670
Alstonia scholaris	North Mangalore, Madras	42.3	-	19	-	24.13	6433	2.9	1668	1957	2402

Drying properties:

The wood can be dried easily without many defects. Air-drying is fast and easy. No defects were observed except for slight cupping, bowing, twisting and end checking of wood. The time requirement for air-drying of 15 mm thick boards is 1-1.5 months and 40 mm boards is approximately 2.5 months. Boards of 25 mm thick can be kiln dried from 50% to 10% moisture content in about 5 days.

Wood of *A.scholaris* is easy to saw, plane and bore both in green as well as dry condition; dry wood is also easy to turn. The surfaces produced by this wood species are generally smooth and has an excellent resistance to splitting and nailing. Many countries are already using this wood for different purposes including the production of plywood. Veneer with a smooth surface can be made at a 90-peeling angle. Plywood prepared using these veneers without pre-treatment glued with urea-formaldehyde were of adequate standards. However, reports from Malaysia states that the species is easy to peel but produces veneer with fuzzy grain due to the presence of traces of latex and is considered as unsuitable for plywood production.

The wood is very susceptible to fungal and insect attack, hence immediate drying and chemical treatment is recommended. Graveyard test or field

exposure of *A. scholaris* carried out in Indonesia and Malaysia showed an average service life in contact with the ground of only 6-16 months making it highly susceptible to termites and putting under the category of non-durable and very perishable species. The wood is also highly susceptible to blue stain fungi and wood destroying fungi along with powder post beetle attack. However, the wood is highly treatable with preservatives under dipping and vacuum-pressure treatment method.

Major Wood Applications:

The wood of *Alstonia scholaris* is used for various purposes, such as boxes, crates, coffins, drawing boards, picture frames, matches, interior trim, furniture components, and handicrafts. It has potential for plywood production, although peeling issues need to be addressed. The wood is also suitable for papermaking and charcoal production. With proper treatment against insects and weathering, it can be used for household furniture and cabinets. As a fast-growing tree, *Alstonia scholaris* holds promise for timber and pulp production.

FEDERATION OF INDIAN PLYWOOD & PANEL INDUSTRY (FIPPI)

REGISTERED UNDER THE SOCIETIES REGISTRATION ACT XXI OF 1860, REGN. NO. S/2985/1968-69 DT. 4.1.1969

Part of FIPPI Achievements

With great efforts of Federation of Indian Plywood & Panel Industry (FIPPI), an Apex representative body of Plywood / Panel / Other Allied products including Furniture and Wood / Bamboo Working Machinery Manufacturers in India alongwith close cooperation with various Ministries and Premier Institutes through Agro and Farm Forestry and other Captive Plantation programme, the dying woodbased industry is again reviving in the country to produce various standard products like Veneer, Plywood, Panelboard, Particleboard, MDF, Laminates etc. which are internationally accepted. Further with great pursuance of the President and Senior Executive members of FIPPI we are highlighting and representing the crucial issues confronting the Plywood & Panel Industry. FIPPI also publishes quarterly Journal Indian Wood & Allied Products highlighting the development taking place in India and abroad, market profile, world timber market report, statistics, international exhibition and conferences, articles, write-ups etc.

FIPPI is cordially inviting all plywood / panel / bamboo / Laminates and other allied products manufacturers to become active member for the strengthening the platform of FIPPI and working for the development of the industry which is Internationally recognized by ITTO, FAO, European Union, IWPA, BIS, MoEFCC, Ministry of Commerce & Industry, BIS, FICCI, CII and other renowned Organizations.

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Benth. *Albizia lebbeck (L.)*

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Species information:

Albizia lebbeck is a tree from the *leguminosea (Mimosoideae)* family originally from Africa and widely distributed in dense deciduous forests of tropical and subtropical countries in Asia such as Laos, Cambodia, Malaysia, Indonesia, Vietnam, China, Thailand, Malaysia, Sri Lanka, and the eastern islands of Indonesia. It is also found in northern Australia and the American continent. In India, this popular multi-purpose legume tree species can be found from the Andaman Islands to an altitude of 1200m in the Himalayas.

This tree can thrive in various climatic conditions, particularly in tropical and sub-tropical areas. It has the ability to tolerate extreme rainfall, different soil types, and varying altitudes. Once watered at the time of planting, the tree requires minimal care in terms of fertilizer or watering, although it shows more vigorous growth in moist soil. It can adapt to annual rainfall ranging from 600 to 2500 mm and can even grow successfully in areas with as little as 400 mm of annual rainfall. It can be found at sea level up to an altitude of 1800 m. The species demonstrates high adaptability to a wide range of soil types, from acidic to alkaline and saline soils, eroded soils, and laterites, except for heavy clay conditions. While young seedlings are susceptible to forest fires, frost, and grazing, mature trees are known to withstand heavy grazing, frost, and fire by utilizing reserves stored in the root system.

A. lebbek is a moderate to large deciduous tree with greyish bark and glabrous young shoots. It is extensively grown in roadside plantation & tea gardens. Its leaves are evenly 2-pinnate, with 5-9 pairs of leaflets that are 2.5-5.0 cm long, broadly oblong, pale green, unequal-sided, very obtuse, glabrous above, and reticulate veined beneath. The tree produces flat, straw-colored pods that are 10-30 cm long and 2.5-5.0 cm broad, containing 4-12 pale brown seeds.

Scientific Name : *Albizia lebbeck*(L.)Benth.
Family : Fabaceae

Vernacular names:

Bengali	: Siris
Hindi	: Siris
Punjabi	: Sarin
Gujarati	: Sarshio
Kannada	: Bage MaraA. lebbek tree
Sanskrit	: East Indian walnut

A. lebbek tree

The growth of *A. lebbek* is influenced by locality and environment. In open areas, it tends to have a large spreading crown and a low branching pattern with a short bole. In forests or closed canopy areas, it typically develops a medium-sized crown and a long, straight bole. The growth of *Albizia lebbek* is most favorable in the Andaman Islands, where it can reach a height of 18-30 m and a girth of 1.8-3.0 m. In other parts of India, it generally attains a height of 18 m and a girth of 1.5-1.8 m. During the 1920s and 1930s, *Albizia lebbek* logs were in high demand in Europe and North America, and the wood was traded under names such as East Indian Walnut, Koko, or Kokko wood.

A. lebbek is well-known in the Indian subcontinent for its nitrogen-fixing characteristics, as well as its use of leaves for fodder or green manure and wood for timber, making it a preferred species for agroforestry. Studies have shown that onion cultivation can be profitable in *A. lebbek* -based agroforestry systems, and the woodlots of *A. lebbek*, Melia azedarach, and Leucaena leucocephala have been found to be beneficial for growing cucumbers with mulching. Additionally, extracts from *A. lebbeck* stem bark have shown promising results in terms of anti-inflammatory, analgesic, antioxidant, cytotoxic, and antimicrobial activities.

Tree improvement work in *A. lebbeck*

Limited research has been conducted on tree improvement aspects of *A. lebbeck.* Rego et al. (2005) investigated the genetic variability and heritability of germination traits in parent trees of *A. lebbeck.* They reported moderate to high genetic control, with broad-sense heritability estimates of 0.43 at the individual level and 0.79 at the parent tree mean level. Another study examined the genetic variability of phenotypic and seed traits in *A. lebbeck* trees from fifteen different provenances. Significant differences were found for various traits, including tree height, diameter, crown spread, seed length, seed width, and 100 seed weight. The study also discussed phenotypic coefficient of variation, genotypic coefficient of variation, and genetic parameters such as heritability, genetic advance, and genetic gain. Perveen and Anis (2015) studied the physiological and biochemical parameters influencing the establishment of in vitro regenerants of *A. lebbeck.*

Gross structure of wood

The wood of *A. lebbeck* is diffused porous, meaning that the distribution of pores is relatively uniform throughout the wood. The growth rings are usually clearly visible and are defined by radially flattened thin-walled fibers that are accompanied by parenchyma cells. The vessels, which can be observed without the aid of a hand lens, are of sufficient size and are arranged singly or in radial multiples of 2-3 or more (Fig. a). It is common for the vessel pores to contain deposits of gummy substances that appear brown or black in color (Fig. b). The parenchyma cells are distinct and can be observed with the naked eye, appearing as small "eyelets" surrounding individual vessels or groups of vessels. The rays, which are fine to very fine, are visible only under a lens and appear as pinkish or light-colored lines of varying thicknesses (Fig. a and b).

Growth Rate and Water Harvesting

The growth rate of *A. lebbeck* was examined in the Indian arid zone using different methods of micro-catchment water harvesting. The treatments included control (only pitting), saucers of 2.5 m diameter, ringpits, trench-cum-mound, trench and mound, and deep ploughing. The water harvesting treatments resulted in significant increases in height and collar girth compared to the control. After twenty-one months of planting, the trees in ring-pits were 2.3 times taller, and those in saucers and trench and mound were two times taller than the control.

General Properties of Wood

The wood of *A. lebbeck* can be distinguished into sapwood and heartwood. The sapwood is light yellow or yellowish-white, which turns into a greyish-yellow color as it ages. The heartwood typically appears golden brown and darkens with time. The wood exhibits a distinct pattern of light and dark colors between the early wood and late wood. It remains moderately heavy, with a specific gravity ranging from 0.55 to 0.88 (air dry). The wood has a naturally glossy appearance and is characterized as having straight to somewhat interlocked grains with a coarse texture.

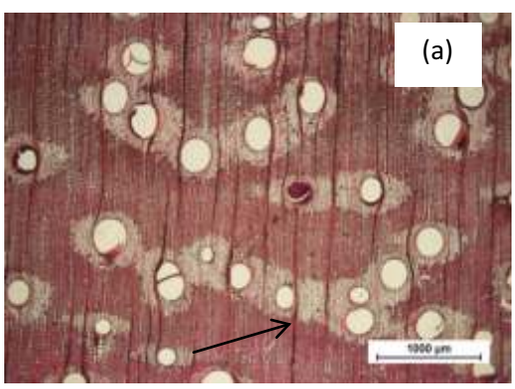

Fig. a Arrow mark in the cross section showing vasicentric or aliform parenchyma

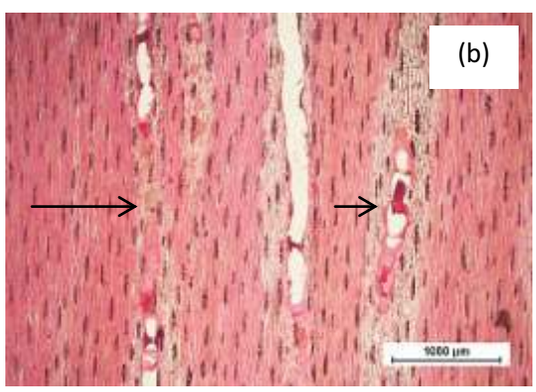

Fig b- arrow mark is showing vessels that are plugged with gummy deposits (original photographs)

Strength properties

A. lebbek is moderately heavy and strong timber. The mechanical properties of *A. lebbek wood* are mentioned in Table 1. The properties of *A. lebbek* are compared with *Dalbergia sissoo* which is a prominent timber species used for manufacturing furniture, door and window frames, handicraft items etc.

Table 1 Mechanical property of *A. lebbek* and *D. sissoo* (Source: appendix I-Indian wood vol. 3 page 208 and 211)

Species	Locality	Specific gravity (oven dry wt and green vol)	Modulus of rupture (kg/cm^2) Air-dry	Modulus of elasticity (kg/cm^2) Air-dry	Impact bending (max. height of drop of 22.68 kg of hammer in cm (Air-dry)	Compression parallel to grain (max. crushing stress kg/cm^2) (Air-dry)
A. lebbek	South Andaman	0.55	887	122,700	69	534
D. sissoo	Punjab (Hoshiarpur)	0.68	926	94,500	94	518

The Modulus of Rupture (MOR) is a measure of a wood specimen's overall strength against rupture, while the Modulus of Elasticity (MOE) measures its ability to resist deflection. Comparing the values presented in Table 1, it is evident that the MOR value (expressed in kg/cm^2) of *A. lebbek* (887) is similar to that of *D. sissoo*, which is 926.MOE perpendicular to the grain, which indicates a wood specimen's ability to maintain its shape and size under stress, also shows interesting results. In Table 1, the maximum MOE value (expressed in kg/cm^2) perpendicular to the grain was observed in *A. lebbek* wood (122,700) obtained from south Andaman, while D. *sissoo* wood (94,500) from Hoshiarpur, Punjab showed slightly lower values. Further more, the values of compression parallel to the grain (expressed in kg/cm^2) in wood samples of *A. lebbek* and *D. sissoo* are quite comparable, with respective values of 534 and 518 (Table 1). This suggests that the wood of these two species exhibits similar properties, with minimal differences.

However, it is worth noting that the major significant differences between the two species, as shown in Table 1, lie in their specific gravity and impact bending values, which are higher in D. sissoo specimens.

Natural durability and wood preservation

Wood is a natural material composed of cellulose, hemicellulose, lignin, and extractive compounds that provide structural support and some resistance against decay. *A. lebbek* is considered moderately durable according to worldwide checklists . It has an average life of 139 months under outdoor conditions or in contact with soil. The wood of *A. lebbek* can be attacked by borers and Irpex flavus fungus, mainly in the dead wood. The sapwood is easier to treat compared to the refractory heartwood, which contains dark gummy deposits. Preservative treatments like borax, boric acid, and zinc chloride can help protect the wood from insects and fungal attacks.

Seasoning

A. lebbek requires moderate effort for seasoning. Air drying planks of this species, about 2.5 cm thick, may take 6 to 9 months [12]. To ensure proper air drying, it is important to use raised platforms to prevent direct contact with soil and staking of the wood with a roof cover. Logs should be converted into planks as soon as possible to minimize defects like end splitting and cracking. Coating the end surface of logs is advisable. Kiln drying takes approximately 10 to 15 days and helps improve dimensional stability and luster of the timber after seasoning.

Woodworking Quality

A. lebbek is known for its suitability in carving, turning, and excellent polish. For wood with larger pores, it may be necessary to fill the pores before finishing. It has good gluing properties and produces excellent finished products. However, the presence of interlocked grains makes it unsuitable for rotary peeling or sawing. Slicing method can be used to obtain decorative face veneers. The wood dust may cause irritation to the eyes and nose, so precautions are needed during sawing.

Uses of Wood

A. lebbek, also known as East Indian Walnut, is highly valued for its beautiful grains and golden sheen. It has been used for parquet and strip flooring, panelling, railway carriage work, decorative veneers, tea-chests, commercial scantlings, planks, doors, windows, furniture, turned objects, carving, and other small specialty wood items. It was previously exported to Europe and the USA from Andaman.

Albizia procera (Roxb.) Benth.

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Scientific name: *Albizia procera* (Roxb.) Benth.
Family : Mimosaceae

Vernacular names:

English	: White siris
Hindi	: Safed siris
Urdu	: Sarapatri sirsi
Assamese	: Tantari-asing
Telugu	: Tella chinduga
Kannada	: Belari
Malayalam	: Jalavaka
Manipuri	: Khaal
Marathi	: Pandhra shirish, Kinhai

Albiziaprocera tree

INTRODUCTION:

Albizia procera, commonly known as Australia forest siris or rain siris tee-coma, is a tree species with diverse applications in tropical and subtropical regions. It is valued for its fast growth, nitrogen-fixing ability, and suitability for various agroforestry systems. This article aims to provide an overview of Albizia procera, including its origin, distribution, tree characteristics, growth behavior, and suitability for agroforestry. Additionally, information on tree improvement and the physical, mechanical, chemical, and anatomical characteristics of its wood will be discussed.

Origin and Distribution:

Albizia procera is native to moist deciduous and semi-evergreen hill forests, swamp forests, and lowland savanna woodlands. It thrives in well-drained loams or clays, particularly on moist, alluvial sites. The species naturally occurs in India, Southeast Asia, the Philippines, Indonesia, Melanesia, northern Australia, and extends northward to China, including Hainan and Taiwan.

Tree Characteristics and Growth Behaviour:

A. procera is a perennial, broadleaved tree that typically reaches a height of 7-15 meters, although it can grow up to 30 meters. It features a straight or slightly curved stem, smooth light brown to light greenish grey bark, and a spreading thin crown. This moderately fast-growing, semi-deciduous tree is well-adapted to humid and sub-humid tropical climates. It exhibits nitrogen-fixing properties and can thrive in areas with a long dry season and degraded soils.

Suitability under Agroforestry Systems:

A. procera is commonly encouraged for natural regeneration on farms to provide small timber, fuelwood, charcoal, fodder, and shade. It is also cultivated in family forests and home gardens for similar purposes. The species is suitable as shade for tea plantations, although *Albizia odoratissima* is preferred for this specific application. The protein-rich fodder produced by *A. procera* is consumed by various livestock species in South Asia and the Philippines. Mixed planting and pruning techniques can enhance stem form and crown density, while thinning is necessary after nine years of growth.

Other Relevant Information:

Efforts in tree improvement for *Albizia procera* include plus tree selection, provenance and progeny trials, development of clones, tissue culture, and the release of improved varieties or clones by organizations like ICFRE (Indian Council of Forestry Research and Education). The wood of *A. procera* exhibits distinct physical and mechanical characteristics. The sapwood is usually wide, white or yellowish-white, while the heartwood is typically brown to dark brown with various markings. The timber is moderately hard to hard and ranges from moderately heavy to heavy.

Table: Physical & mechanical properties (Source: Indian Forest Record)

Properties	Value
Specific Gravity	0.313
Density kg/3	368
Shrinkage % (radial)	2.4
Shrinkage % (tangential)	2.9
Shrinkage % (volumetric)	7.8
FS at EL (MPa)	33.9
MOR (MPa)	52.7
MOE (MPa)	6715
Impact (FS at EL) (MPa)	64.4
Maximum height of drop (cm)	43
Compression parallel to grain (CS at EL) (MPa)	21.4
Compression parallel to grain (MCS) (MPa)	30.0
Compression parallel to grain (MOE) (MPa)	7426
CS perpendicular to grain (at EL) (MPa)	3.8
Hardness (N)	1690 (R); 1846 (T) ; 1824 (E)

Unless specified properties measured at 12 % mc (if applicable)

Anatomical Characteristics of *Albizia procera* Wood:

The wood of *Albizia procera* exhibits specific anatomical features. It is generally diffuse-porous, although there may be a slight tendency towards semi-ring-porousness. The growth rings are typically not very distinct and may not be easily noticeable. However, they can be delineated by thin-walled fibres that are flattened radially and are associated with parenchyma cells. The number of growth rings per centimeter can vary from a few scattered cells to a fairly continuous line, typically ranging from 1 to 5 per cm.

The wood of *A. procera* contains vessels that are large to moderately large and can be easily seen with the naked eye. The number of vessels per millimeter can range from very few to moderately few, usually less than 1 to 8 per mm. These vessels are evenly distributed and can occur singly or in radial groups of 2-3 or more. In some cases, they may form small clusters. The shape of the vessels is generally round to oval, and they often contain dark brown or black gummy deposits.

The parenchyma cells in the wood are visible to the naked eye and appear as distinct 'eyelets' surrounding the vessels or groups of vessels. Sometimes, they extend laterally to connect two or more adjacent vessels. The parenchyma cells also form interrupted to fairly continuous lines that delimit the growth rings, which can only be observed under a lens. Additionally, there may be sparsely diffuse parenchyma cells that are occasionally visible as minute scattered white dots when observed under a hand lens.

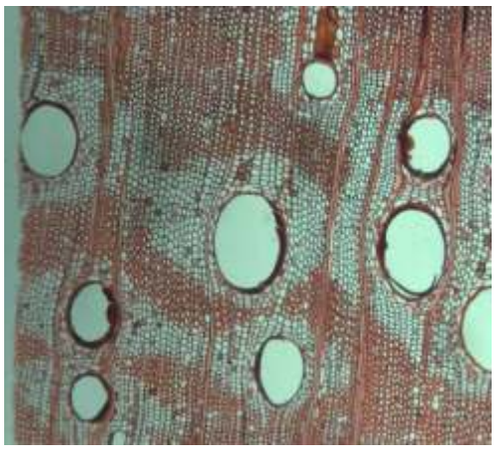
The rays in *A. procera* wood are generally fine to indistinct and may only be visible to the naked eye in certain cases. However, they become more apparent when observed under a lens, appearing as pinkish or light-colored lines of varying thickness. These rays often appear to run out after a short distance. They can be somewhat widely spaced to fairly closely spaced.

Overall, the anatomical characteristics of *Albizia procera* wood possess unique features that contribute to its distinct appearance and properties.

Wood Macro Photo Radial Plane

Source: ITTO 2023

Wood Micro Photo of Transversal Section



Cross section of A. procera showing semi-ring porosity (Meena and Gupta 2014)

Major Application and Usage of Albizia procera Wood:

Albizia procera has diverse applications with a special emphasis on its wood. It is commonly used in amenity planting, shelter belts, and firebreaks, especially in India. The leaves of *A. procera* are highly regarded as good fodder for various ruminant animals, including cattle, sheep, goats, elephants, and deer. In many states, the tree is lopped specifically for fodder purposes. Additionally, A. procera is valued for fuelwood production and high-quality charcoal.

The wood of *A. procera* finds multiple uses in construction, furniture making, farm implements, fencing, and pulp and paper production. It is known for its strength, elasticity, toughness, and hardness, making it suitable for cabinet and furniture timber. The wood is also used in general construction, agricultural tools, household products, poles, house posts, and packaging materials. Furthermore, A. procera serves as a suitable source material for paper pulp, providing satisfactory yields of bleached pulp.

The species exhibits a high rate of biomass production and vigorous coppicing after felling, making it a recommended choice for fuelwood production. It is well-regarded for its excellent charcoal and fuelwood properties. The International Tropical Timber Organization (ITTO) has reported various uses for A. procera, including bridges, stakes, posts, flooring, frames, plywood, veneer, cooperage, truck bodies, boat oars, and handicrafts.

Processing Considerations:

Albizia procera wood has distinctive characteristics for processing. It features non-durable yellowish-white sapwood and hard, heavy heartwood, often with light and dark bands resembling walnut. The wood is resistant to several termite species but susceptible to the pest Coptotermes curvignathus in India. The sapwood is permeable, while the heartwood resists preservative treatments. The wood has straight grain, is easily worked, seasons well, and is durable.

For specific end uses, blending the short fibers of *A. procera* with long-fibered pulp may be necessary to enhance strength properties. The wood is also suitable for peeling and plywood production.

Potential Scope for Different Wood-Based Industries:

Albizia procera holds great potential as raw material for various wood-based industries. It is favored for cabinet and furniture timber, construction materials, agricultural implements, household products, poles, house posts, truck and bus bodies, and packaging cases. The species's wood also serves as a suitable source material for paper pulp, producing satisfactory yields of bleached pulp. Overall, *Albizia procera* wood offers a wide range of applications and exhibits favorable characteristics for processing, making it valuable for multiple industries.

Artocarpus heterophyllus Lam.

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Scientific Name :*Artocarpus heterophyllus* Lam.
Family : Moraceae

Vernacular names :

Tamil	: Pilavu chakka
Kannada	: Halasu
English	: Jack
Telugu	: Panasa
Hindi	: Kathal

Artocarpus heterophyllus tree

INTRODUCTION:

The jackfruit, also known as the jack tree (*Artocarpus heterophyllus*), is a large fruit-bearing tree in the fig, mulberry, and breadfruit family. It originated in the Western Ghats of southern India and is commonly grown in tropical regions worldwide. The jackfruit is known for producing the largest fruit among all trees, weighing up to 55 kg (120 pounds) and measuring 90 cm (35 inches) in length and 50 cm (20 inches) in diameter. A mature jackfruit tree can yield around 200 to 500 fruits per year. The jackfruit was independently domesticated in South Asia and Southeast Asia.

Common Names

The jackfruit is referred to as "jak" or "jack" in English, derived from the Portuguese word "jaca." It has various common names in different countries, such as "kanthal" in Bangladesh, "jaca" in Brazil, "Nangka" in Indonesia and Malaysia, and "langka" in the Philippines.

Botanical Description

The jackfruit tree is an evergreen tree with a relatively short trunk and a dense treetop. It can grow up to 10 to 20 meters (33 to 66 feet) in height and have trunk diameters of 30 to 80 cm (12 to 31 inches). The tree has buttress roots and reddish-brown smooth bark that releases a milky sap when injured. The leaves are alternate, spirally arranged, gummy, and thick. They have a petiole (leaf stalk) measuring 2.5 to 7.5 cm (1 to 3 inches) and an oblong to ovate-shaped leaf blade, 20 to 40 cm (7 to 15 inches) long and 7.5 to 18 cm (3 to 7 inches) wide. The leaves have a prominent main nerve, lateral nerves, and egg-shaped stipules.

Origin and Distribution of Jackfruit

The exact region of origin of jackfruit is a topic of debate, with different theories suggesting India, Malaysia, or tropical Asia. However, most experts believe it originated in the rainforests of the Western Ghats in India. From there, it spread to neighbouring countries in South and Southeast Asia and later to tropical Africa, Australia, and the Americas. It is widely grown in Asian countries like Bangladesh, Myanmar, Nepal, Sri Lanka, Thailand, Malaysia, Indonesia, India, and the Philippines. It also grows in regions of Southern China, Zanzibar, Kenya, Uganda, Madagascar, Mauritius, Brazil, Surinam, the Caribbean, the USA (particularly Puerto Rico), and Australia.

Climate and Ecology

Jackfruit thrives in humid tropical and subtropical climates, with an altitude range up to 1600 meters. It can tolerate a wide range of climates, from intermediate to wet and moist types. The

tree prefers warm, humid climates with at least 1500 mm of evenly distributed rainfall per year. Jackfruit is not tolerant of continuously wet or flooded soil conditions but exhibits moderate tolerance to saline soils. It grows well in various soil types, including alluvial, sandy loam, clay loam, calcareous, lateritic, shallow limestone, and stony soil, with pH ranging from 5.0 to 7.5.

Use in Agroforestry

Jackfruit is commonly incorporated into agroforestry and household farming systems. It is often planted in coconut groves, used as an intercrop in durian orchards, and grown alongside other fruit trees such as mango and citrus. Jackfruit trees provide shade for coffee, areca nut, and support for black pepper vines. In Bangladesh, it is a dominant tree on household farms, grown alongside various perennial trees and annual crops. Jackfruit is also recommended for reforestation programs in degraded lands to protect watersheds.

Genetic Resources and Crop Improvement

Jackfruit is primarily cultivated and propagated by seed. It exhibits a wide range of variation in morpho-agronomic characteristics. Limited studies have been conducted to assess genetic diversity in jackfruit through morphological characterization. Some germplasm collections and evaluations have been carried out in various countries, but detailed information on the performance of different accessions is limited. Jackfruit shows potential for clonal propagation through the selection of superior clones.

Wood Anatomy

Macroscopic features:

The heartwood of jackfruit is typically yellow to yellowish-brown or golden brown, and it may darken when exposed to air. The grain of jackfruit wood is interlocked, resulting in a wavy pattern. The texture of the wood is coarse. Growth rings are not clearly defined and may have occasional short and fine light-colored bands. Sometimes, vessels contain a yellowish or whitish chalky substance, and ray cells and axial parenchyma may contain an orange-colored substance. These features can often be seen with a hand lens. Fine yellowish-brown streaks may also be visible in the rays on the radial surface.

Microscopic features:

Growth rings in jackfruit wood are usually not well-defined. However, when present, they are marked by long wings of parenchyma and smaller pores. Vessels in the wood are scattered throughout and typically range from 3 to 6 (or up to 9) vessels per square millimetre. They can occur singly or in groups of 2 to 3 (or up to 4) vessels arranged radially. The percentage of solitary vessels can vary from 45% to 80% even within a sample. The tangential diameter of the vessels is around 160 to 370 micrometers. Perforations in the vessel walls are simple, and the pits between vessels alternate and measure 8 to 13 micrometers in diameter. The pits between vessels and ray cells or vessel and parenchyma cells can be enlarged, round to oval, and sometimes elongated, with or without distinct borders. Occasionally, a yellowish or whitish chalky substance may be present. Tyloses (outgrowths of parenchyma cells) are often abundant, and occasional sclerotic (hardened) cells may be present.

Fibers in the wood are typically 1.2 to 2.6 millimeters long, non-septate (lacking crosswalls), and have thin to thick cell walls. They have fairly distinct but small and relatively few simple pits. The parenchyma cells in jackfruit wood are vasicentric to aliform (wing-shaped), often with longer wings at the boundaries of growth rings. They are also present in diffuse and interrupted fine lines, typically arranged in strands of 3 to 4 cells. Rays in the wood range from 3 to 7 per millimeter and can be 1 to 8 (or up to 10) cells high. They are hetero cellular, meaning they contain different types of cells. Upright marginal cells are present, mostly belonging to the Kribs type heterogeneous II or III. Sheath cells may be present but are not well developed. Some species of jackfruit wood may contain vitreous silica in the fibers. Latex tubes are often found in the rays, and there have been reports of axial latex tubes in jackfruit wood.

Transverse section of Artocarpus heterophyllus wood

Jackfruit Wood/Timber: Jackfruit trees provide valuable timber across the Indian subcontinent. The wood is easy to season and resembles mahogany. It has a beautiful polish and can be smoothed with the right tools. The color of the wood changes over time, starting from yellow or orange and turning into a rich brown-red. It is considered a medium-hardwood. Jackfruit timber has exceptional natural durability against fungi, bacteria, and termites. It is highly sought-after in the market, second only to teak in many Asian countries. India exports jackfruit timber to Europe. The wood is commonly used for furniture, house construction, and various wooden products like masts, doors, chairs, and musical instruments. In Indonesia, the timber is highly valued for chieftains' palaces, while in Indochina, it has been used in temple construction. In Sri Lanka, small holders recognize the versatile uses of jackfruit trees when deciding which trees to plant in their home gardens. Jackfruit timber commands a good price in the local market, similar to mahogany but lower than teak. Small-scale farmers in survival mode do not primarily rely on timber use. However, jackfruit trees can make up a significant percentage of trees in some home gardens. It can also be used as fuelwood, producing charcoal with good properties. The bark of the tree produces a dark resinous gum containing tannin. It has additional uses such as dyeing and making cordage or cloth. Buddhist priests use splinters of jackfruit heartwood to color silk and cotton robes. The timber price varies in Bangladesh, and jackfruit wood is exported from India and Sri Lanka to Europe, mainly for manufacturing guitars. Woodworkers make the instrument parts, which are then sold to wholesalers, retailers, or factories for finishing.

Uses of Wood:

The golden yellow timber with a good grain of jackfruit wood is used for building furniture and houses in India. It is termite-resistant and considered superior to teak for furniture construction. In Sri Lanka, jackfruit wood is important and exported to Europe. It is widely used in furniture, doors, windows, roof construction, and fish sauce barrels. The wood is also popular for making musical instruments. In Indonesia, the hardwood from the trunk is carved to create the barrels of drums used in the gamelan orchestra, while in the Philippines, the soft wood is used to make the body of the kutiyapi, a boat lute. Jackfruit wood is also used for the bodies of the Indian string instrument veena and the drums mridangam, thimila, and kanjira. It finds applications in light construction, house and bridge building, beams, poles, flooring, joinery, cabinet work, household utensils, musical instruments, telegraph poles, wharves, large canoes, boat building, tool handles, turnery, veneer, and plywood (especially for core layers). The wood is sometimes attractively figured and suitable for decorative purposes, such as furniture, joinery, and paneling.

The roots of mature *A. heterophyllus* trees are highly prized for carving and picture framing.

Artocarpus species, including breadfruit, jackfruit, chempedak, and marang, are important fruit-bearing trees, and their wood is sometimes used. In addition to the fruits, which can be prepared in various ways, the seeds are roasted and eaten. Some species yield a yellow dye, and the bark of jackfruit trees produces tannin. Bark from other species can be used to make fibers for cloth and rope. Latex, bark, leaves, and roots of certain species have medicinal properties, and latex can be used to produce birdlime, substitute milk in sauces, serve as cooking oil, mix with wax for batik production, or mix with turpentine and paint. The bark and roots of a few species can be chewed with betel. In Papua New Guinea, Artocarpus leaves are traditionally used for cleaning pots and plates. The leaves of *A. lakoocha* are used as fodder in Nepal and India. Some species are used for reforestation.

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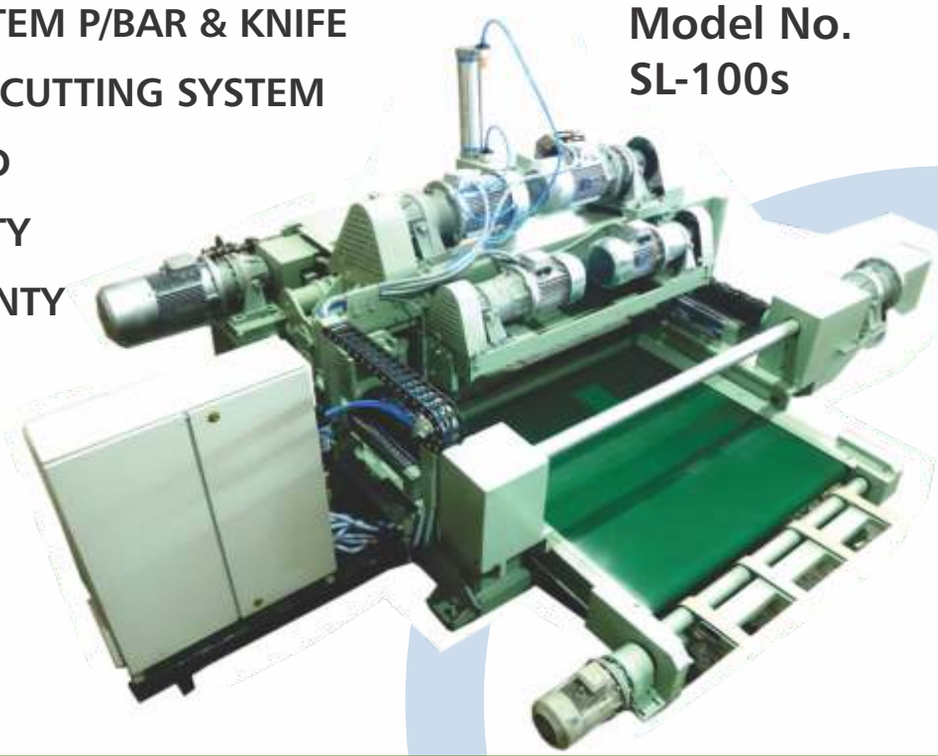

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A General Perspective on *Wild Jack- Artocarpus hirsutus*

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INTRODUCTION

The genus *Artocarpus,* also known as "Breadfruits," encompasses around 70 tropical plant species known for their nectary and fleshy fruits (Jarrett, 1977). These plants exhibit significant variability in terms of size, height, flower/fruit morphology, developmental processes, and functional properties (Zerega et al., 2010). Many species in this genus provide valuable resources such as food, timber, and other products, making them popular in their native regions (Jagtap and Bapat, 2010).

Artocarpus hirsutus, commonly known as Wild jack, belongs to the family Moraceae and is an elusive forest species endemic to the Indian Western Ghats. It serves as a prominent multipurpose tree in home gardens and mixed species systems in southern India. The tree's identification can be traced back to the literature of Hortus Indicus Malabaricus (Rheede, 1682). Wild jack has several vernacular names in different states. Geographically, it is limited to the southern Western Ghats, ranging from the Kalinadi river in Maharashtra State to Agasthyamala in Thiruvananthapuram district of Kerala State (Ramesh & Pascal, 1997). However, its highest frequency of occurrence is observed along the Malabar Coast.

In the 1600s, this tree species was referred to as *Ansjeli by Malabaris,* Angeli by the Portuguese, and Anjeli by the Belgians (Rheede, 1682). It is also known by different names in different regions of India, including Hebbalasu in Karnataka, Anjalee or Aiyanee in Kerala, Pat pahnnas in Maharashtra, and Anjale in Tamil Nadu (Kanda et al., 2021).

Characteristics and Growth Behavior of the Tree:

Wild Jack (*A. hirsutus*) exhibits a unique phenotype compared to other popular Artocarpus species, making it one of the "keystone species" of the Western Ghats (Nayar, 1996). The tree can reach a height of 45-50 m with a girth of up to 4.5 m in well-adapted moist evergreen forests. It's simple, alternate leaves exude latex when broken, and the tree bears unisexual flowers in axillary inflorescences. The edible fruits, which are syncarps, are smaller than jackfruit (*Artocarpus heterophyllus Lamk.*) and turn orange when ripe, with a very sweet taste (Kumar et al., 1995). *A. hirsutus* typically reaches maturity for timber extraction within 25 to 40 years. It flowers and fruits from January to March, with fruit ripening occurring in May and June. The tree is characterized by dark grey bark in its young stage, which later becomes scaly or flaky, eventually turning cream in color. The extracted wood is strong yet light in weight. It naturally prefers moist, deciduous to partially evergreen woodlands in the Western Ghats' evergreen forests and can tolerate shade but thrives best under full sunlight (CSIR, 1985). It is found at altitudes from sea level to 1000 m, with an average annual rainfall of 1500mm, predominantly in sandy and rocky soils. The tree exhibits vigorous growth near backwaters and lagoons and achieves maximum girth within a relatively short range. The practice of coppicing results in the production of potential root suckers (Jarrett, 1977).

Agroforestry System with Wild Jack:

In India, the concept of agroforestry is gaining tremendous scope as a means to achieve self-sufficiency in meeting the raw material demands of various industries. Agroforestry focuses on incorporating a variety of trees with multidimensional practices based on their

Artocarpus hirsutus tree, Fruits along with bunch of leaves Bark of the tree

suitability. In the case of wild jack, it has been reported that it may not be a promising species under monoculture practices but shows impressive growth in polyculture systems (Jamaludheen, 1994). The tree is typically found scattered in farm fields and/or as trees on farm boundaries (Kumar et al., 1994). While being a key component of many agroforestry systems, farmers are concerned that wild jack trees may compete with associated field and tree crops in terms of growth parameters. Several research reports have shed light on the feeder roots of trees in the surface layers of soil (Jonsson et al., 1988).

Properties of Wild Jack wood:

Wild jack wood possesses distinct color, texture, density, and strength. It is widely used along the Malabar Coast for various purposes due to its excellent properties, such as a high strength-to-weight ratio and aesthetically pleasing appearance (Ates et al., 2009). The wood of wild jack is utilized in building construction, ship and boat making, agricultural implements, carts and carriages, musical instruments, packing cases, furniture, and more. It has made its presence felt in the wood market, especially in Kerala. Therefore, it is important to have multidimensional knowledge of the wood properties of wild jack, including physical, chemical, mechanical, and anatomical characteristics.

Various studies have been conducted to uncover the wood properties of wild jack. For instance, Nampelly et al. (2022) analyzed the physical properties of hardwood versus softwood species, including *Artocarpushirsutus, Pterocarpus santalinus, Givotiarottleriformis, Bombax ceiba, Abiespindrow*, and *Pinus roxburghii,* with a focus on toy-making properties. The study revealed that wild jack possesses physical properties such as wood density of 513 kg/m3, water absorption of 39.39% and volumetric shrinkage of 9.08%, making it suitable for timber among the selected wood species. The International Tropical Timber Organization (1998) also listed the wood quality of wild jack as having greyish or yellowish-white sapwood, golden yellow to yellowish-brown heartwood, lustrous when first exposed, medium texture, durable, air-dry density of 0.60 g/cm^3, tangential shrinkage (T) of 5.3%, radial shrinkage (R) of 3.4%, and T/R ratio of 1.6%.

The wood anatomy of *A. hirsutus* exhibits similarities to *Artocarpuschaplasha,* but it is darker in color and coarser-textured, with larger or sometimes medium-sized vessels and narrow aureoles of paratracheal-zonate thin-walled parenchyma and narrow lower rays. The wood is diffuse porous, with occasional vessels having a tangential diameter of 200 micron or more and vessels per mm^2 less than 6 (Matthew et al., 2006).

Regarding the chemical properties of wild jack, many of its constituents make it an excellent source of medicine. Phytochemical analyses of leaf and stem wood extracts have revealed the presence of sterols, terpenoids, flavonoids, tannins, and saponins (Nayak et al., 2017). Other studies have reported the presence of alkaloids, carbohydrates, proteins, amino acids, and more in various parts of the wild jack tree (Vinay et al., 2020).

In terms of mechanical properties, the wild jack exhibits a bending strength of 95 MPa, stiffness of 12.0 GPa, and compression parallel to fiber of 60.4 MPa (ITTO, 1998). The mechanical properties of *A. hirsuta* wood (in air dry condition) sourced from southern India in comparison to standard Teak is presented in the following table.

Species	Std. SG	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
		MOR	MOE	Max. drop (cm)	MOE	Max. C stress	MOE	CS at E.L..	R	T	E	R	T	R	T
Teak	0.598	95.9	12534	68.6	16381	54.5	14017	9.7	5004	4959	4670	8.4	9.8	3.7	4.4
A. hirsutus	0.61 4	72.1	9962	66	12707	41.3	10810	8.6	5449	5226	6249	-	9.3	2.4	4.3

Processing:

Newly cut down wild jack wood dries easily through air and kiln seasoning, and it offers no difficulty in terms of shrinkage from green to oven dry. The wood is easy to saw and machine when green and turns well to achieve a good shining surface. It takes a lasting polish.

Tree Improvement

Unlike other wood species such as Teak and Rosewood, no significant studies has been conducted on A. hirsutus as a crop, as the species has not gained popularity beyond the southern Western Ghats region. However, there have been notable studies exploring the medicinal and chemical properties of the fruit. Nevertheless, there is a pressing need for studies focused on improving the wood quality of wild jack.

Applications of Wild Jack:

Wild jack serves as a multipurpose plant with economic and ecological importance. It provides long-lasting, high-quality, pathogen-resistant timber, making it widely used in building houses, boats, and large structures. In Kerala, where wild jack is abundant, it has significantly influenced the cultural diversity expressed in construction, including roofing, foundations, walls, and floors of temples, palaces, and mansions. The wood is still commonly used for making frames of doors and windows. Notably, 140 tons of A. hirsutus wood from Kerala was used for Tim Severin's ship, Sohar, during his voyage from Muscat to Canton in 1980-81.

Wild jack is the most commonly used timber for traditional nailed plank-built boats. Solanki et al. (2020) provide a comprehensive description of the usage of wild jack trees in boat construction along the Malabar Coast, including various types of plank-built boats used for multiple purposes such as maccua and vallam (travel boats), uru (small cargo boats), kovallam (large cargo vessels), palliyodam (ritual boats used in Hindu temples during New Year festivals), and chundan, churulan, odi, and iruttukuthy (snake boats or country race boats).

Agricultural Uses:

The wild jack tree is exclusively used in agricultural practices, where it offers versatility in usage. It has been traditionally used in the construction of giant granaries, known as naalukettu and ettukettu, to store paddy grains. The water resistance and durability of the wood makes it suitable forcisterns and utensils such as ural (used for pounding grain) and maravi (a wooden vessel for keeping common salt pellets for cooking). Although ural and maravi have become uncommon and have disappeared from the households of Keralites, the wood is considered excellent for making yolks and chackrum (traditional water tread wheels) used to regulate water flow in paddy fields. It is also used to make poultry cages. In the past, wild jack wood was widely used by the Indian Railway for constructing railway sleepers and continues to be used in the construction of handmade truck cabs.

Artocarpushirsutus wood cross sectional view and sawn timber

Usage of Wild jackformaking of household items and boat making

The leaves of *A. hirsutus* were commonly used on the Malabar coast for making green manure and compost, especially in paddy cultivation. However, they are rarely used as fodder for cattle or goats in interior villages. In higher altitudes in Kerala, the trees are used as supports for pepper vines.

Miscellaneous Uses:

The latex of the wild jack tree has insect-repellent properties and is used as a wood coating in some areas of the Malabar Coast to prevent insect attacks. The wood, wood peelings, small branches, and stumps of the tree are used as firewood or fuel due to their high calorific value. It is also used as a substitute for making "oil massage cot" (wooden vessel for Ayurvedic oil massage) for the "panchakrma" treatment in the Ayurvedic system practiced in Kerala. The bark infusion is applied to cure small pimples and cracks in the skin, while powdered bark is used to heal sores. Dry leaves are used to treat burbose and hydrocele.

Scope as a Raw Material for Wood-Based Industries:

Wild jack possesses high timber value due to its comparable quality with teak, along with the advantage of being lightweight. It is strong enough to be used in boat and ship construction, as well as for agricultural implements. It is highly sought after in the furniture industry, for ceilings, and even for traditional homes in Kerala. However, the endemic and sparse distribution of the species in the Western Ghats hinders its ability to meet the increasing demand in the timber market (Matthew et al., 2006). Additionally, factors such as road widening and industrial construction under the concept of urbanization threaten the existence of the tree. Furthermore, the trend of modernization is erasing the cultural traditions of Keralites, where traditional yolks, water wheels, granaries, and cisterns have been replaced by mechanized cultivation and modern storage methods, ultimately impacting the survival of the tree (Jonsson et al., 1988).

In conclusion, Wild Jack (*Artocarpus hirsutus*) is an excellent multipurpose tree that has had a remarkable influence on the cultural diversity of the people along the Malabar Coast. However, as time passes, the concept of tree conservation is suffering due to factors such as urbanization, industrialization, and modernization. Additionally, the endemic nature of the tree diverts research focus away from tree improvement concepts. Given that this giant tree possesses characteristics similar to teak and has vast potential in the wood-based industry, there is a need for high-quality studies to fully exploit the timber and other advantages of the tree.

Azadirachta indica A. Juss.

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Scientific Name: *Azadirachta indica*

Vernacular names:

English	: Neem
Bengali	: Nim
Gujarati	: Limado
Hindi	: Neem
Kannada	: Bevu
Malayalam	: Veppu
Marathi	: Nim, Limba
Panjabi	: Nimoriya
Tamil	: Vembu
Telugu	: Vepa
Urdu	: Nim

INTRODUCTION:

Azadirachta indica is regarded as the most important and helpful medicinal tree, as well as the fastest growing evergreen popular tree found in India, Africa, and America (Shirish, 2010). The Neem tree is gaining popularity due to its extensive commercialization in agriculture, veterinary, cosmetics, medicine, toiletries, and other industries. Neem is becoming increasingly popular in cosmetics and beauty aids. Some businesses are currently employing Neem products (Neem oil and leaves) to make cosmetics like facial creams, nail polishes, nail oils, shampoos, and conditioners (Brahmachari, 2004; Aneesa and Gayathri, 2016).

The neem tree has the potential to significantly benefit small and marginal farmers in rural India, Africa, and Latin America. Farmers with limited resources can profit from neem in a variety of ways. There are easily exploitable job and revenue production opportunities in neem cultivation and processing, some of which are decentralised and may be done with little capital. The majority of developing countries have large regions of marginal lands with low production. Because neem has various applications, its cultivation on marginal areas can contribute significantly to rural economies.

Incentives for neem seed collection must be enhanced in line with contemporary economic realities, as well as organisational changes for neem seed selling. To realise this potential, organisational, financial, and policy inputs, as well as a policy for integrating neem into agriculture, rural, and small industries policies, are required. An adequate supply of high-quality neem seeds delivered on schedule is important to the commercial viability of the plant. Oil extraction from neem seeds is currently possible in India. It is possible to obtain better extracts using existing facilities. However, unlike oil extraction, high-quality Neem active extracts require rigorous extraction processes. Handling of seeds requires caution.

Classification of Neem

Class: Dicotyledonae

Order: Rutales

Family: Meliaceae

Genus: *Azadirachta indica*

Species *Azadirachta indica*

Origin

This species exact native range is unknown, however it is assumed to be native to the Indian Subcontinent (India and Bangladesh) and South-east Asia.

Geographical distribution of Neem

Native to the Indian subcontinent, neem has spread widely by introduction in the more arid (dry) tropical and subtropical climates, primarily in Asia, Africa, the Americas, Australia, and the South Pacific Islands. It is widely utilised in various Indian states. It is highly prevalent in Myanmar, particularly in the country's central region. In Ghana, yields of 108-137 m^3/h have been documented (National Research Council (US) Panel on Neem, 1992). Pacific neem grows in Fiji, Indonesia, and Australia to the south. He was first introduced in the Philippines in the 1970s and 1980s, roughly 60-70 years ago. *A. indica* was cultivated in China on the island of Hainan and the subtropical islands.

Neem trees grow along the coast of Iran all the way to Chat el-Arab in Iraq on the Arabian Peninsula. Neem is planted in boulevards and parks in Qatar and Abu Dhabi that are irrigated with desalinated saltwater. To offer shade for pilgrims, large plantings were constructed on the Arafat plain near Mecca.

Habitat: *Azadirachta indica* has the ability to overrun shrublands, open woods, grasslands, floodplains, riparian zones (watercourse banks), coastal locations, and other disturbed natural vegetation.

Tree characteristics: Neem trees are lovely broad-leave evergreens that can reach heights of 30 m and girths of 2.5 m. Their spreading branches generate circular crowns up to 20 m in diameter. Except in extreme dryness, when the leaves may fall off, they remain in leaf. The bark on the short, typically straight trunk is somewhat thick and furrowed. The roots enter the earth deeply, at least where the site allows, and develop suckers, especially when wounded. This Neem can withstand a lot of abuse. It can endure pollarding (repeated lopping at heights above about 1.5 m), for example, and its topmost trunk resprouts strongly. It also coppices freely (repeated lopping at near-ground level). Pollarding and coppicing can both result in very quick regrowth since they are served by root systems large enough to feed a full-grown tree. The axillary clusters of little white bisexual flowers are borne. They have a honey-like fragrance that attracts a lot of bees. Neem honey is popular and is said to contain no azadirachtin.

PHYSICAL, MECHANICAL AND ANATOMICAL CHARACTERIZATION OF WOOD

Wood physical properties

Basic density or specific gravity
(o.d. weight/vol. green) (g/cm^3) -0.61

Air-dry density
(weight and volume at 12%mc) (g/cm^3) - 0.67

Total shrinkage tangential
(saturated to 0%mc) (%) - 6.2

Total shrinkage radial
(saturated to 0%mc) (%) - 4.5

Dimensional stability ratio
(total tangential shrinkage
%/total radial shrinkage %) - 1.4

Wood mechanical properties

Bending strength (mor),
12%mc (kgf/cm^2) - 805
Stiffness (moe) 12%mc (kgf/cm^2) - 70922
Compression parallel to fiber 12%mc
(kgf/cm^2) - 469

Neem tree

Neem Fruits

Drying defects

Ease of Drying

Plantation material is easy to dry, otherwise it is difficult. Drying Defects: Forest grown stock is reported to be prone to honeycomb and collapse. Kiln Schedules: Kiln drying of heavier grades of eucalyptus timber is only practicable in boards up to 25 mm in thickness. It is strongly recommended to air dry the wood to 30% moisture content prior to kiln drying. Boards of this species wood of 25 m thick will require

Wood identification

Anatomic description of wood

Wood diffuse porous. Occasionally wood semi-ring porous and/or ring porous. Vessels of two distinct diameter classes, wood not ring-porous. Colored deposits in heartwood vessels. Vessels per mm^2 5 to 20. Simple perforation plates. Vessel-ray pits similar to int Prismatic crystals in non-chambered axial parenchyma cells. Over 9 cells per parenchyma strand. Axial parenchyma bands more than 3 cells wide. Body ray cells procumbent with mostly 2 to 4 rows of upright and/or square marginal cells (Kribs-II). Fibers with simple to minutely bordered pits.

Neem Wood:

Indian wood species have a stellar reputation in the wood business. In India, neem has a unique place and importance. It is well-known not just for its therapeutic benefits, but also for its spiritual significance in Hindu mythology.

However, in addition to the metaphysical capabilities of the Neem tree, the material worth of its very prized wood, heartwood ranges in colour from reddish to reddish brown. This pleasant colour lends a pleasing aspect to neem wood furniture.

Durability and strength

The interlocking grains of Neem wood make it sturdy and powerful. The wood does not shatter or split readily because to the interlocking grains. Because of its strength, Neem wood is the favoured wood for constructing cart axles, oars, and as a residential hardwood.

Neem wood is easy to work with due to its strength and durability. Both machine and hand tools produce good results. Neem wood is easily transformed into exquisite woodwork or toys.

Neem as a source of fuelwood and timber

The calorific value of neem is reported to be 4322.81cal/g (Shaheen and Harode, 1987). According to Parmar and Ketkar (1993), a full-grown tree in India may provide between 400 and 500 kg of fuel wood.

Ghanaians place a high value on neem as a fuel wood and earn a lot of money from the selling of neem charcoal (Childs, 1999). The neem tree has a relatively heavy reddish-brown heartwood and can be harvested for lumber 35-40 years after planting (Hedge, 1993; Gunasena and Marambe, 1998). The wood is long-lasting and resistant to insect. It is simple to deal with and compares favourably to teak wood. As a result, neem can be used for posts, beams, window and door frames, furniture, and so on.

Agricultural implements, boat making, and wood carvings are all examples of craftsmanship. Despite its multiple advantages, neem wood is marketed in India for Rs. 7000 per cubic meter, compared to Rs. 24 000 for teak (Hedge, 1993).

Borassus flabellifer L.

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Borassus flabellifer tree

Borassus flabellifer Linn. is a tall palm tree that thrives in sandy soil, reaching heights of 20-30 meters with a straight trunk. The roots are hairy, branching out into slender transverse branches. The bark and wood exhibit dark hues. The stem is black and comprises a hard-outer portion made of stiff longitudinal fibers, while the central part contains a soft and starchy pith. The leaves are fan-shaped and palmately divided, with petioles measuring 0.6-1.2 meters in length. The leaves have spinulose margins. The flowers are yellow and arranged in spadices. The female spadix bears a few scattered solitary flowers and is sparingly branched. Male flowers are small and mixed with scaly bracts, arranged in two series within a small spikelet. Female flowers are larger and globose. The fruits are large and fibrous, typically containing three nut-like portions, each enclosing a seed. *Borassus flabellifer* flowers and bears fruits from December to August.

Information about species:

Scientific Name	: *Borassus flabellifer* L.
Family	: Arecaceae;

Vernacular Names:

English	: Palmyra palm, brab tree, toddy palm;
Sanskrit	: Tal;
Hindi	: tār, tāḍ; tar-ka-jhar (Wealth of India);
Kannada	: taalimara, taatinungu mara;
Malayalam	: karimpana, nongu (kernel), pana, talam;
Marathi	: tad, talat-mad, tamar (Wealth of India)

Origin and Distribution: Borassus flabellifer Linn. is native to South-East Asia, including regions like Burma (Myanmar), New Guinea, and Cambodia. It is commonly found in dry or sandy areas along riverbanks throughout India. The plant is harvested in various states such as Tamil Nadu, Odisha, West Bengal, Andhra Pradesh, Bihar, Karnataka, and Maharashtra.

Cultivation: The palm grows naturally and requires no specific cultivation practices. It can thrive without artificial irrigation or manuring. The direct sowing method is used for propagation. In the initial stages of germination, only the underground stem portion thickens, while the aerial part of the trunk elongates and develops into its characteristic cylindrical black stem after 15-20 years. The Palmyra palm usually starts flowering around the age of 15 years, after the commencement of aerial growth. It flowers during March to May in some areas and during August to September in others.

Fruit: The palm starts producing fruits when it reaches 15-20 years old, yielding an annual crop of 50-200 fruits in 6-12 bunches per tree. The tender fruits appear from May to August, while the ripe ones are available from July to October, with the timing varying depending on the locality. The seeds contain a soft, sweet, jelly-like endosperm with sap. As the gelatinous pulp gradually hardens, it forms a bony kernel surrounded by a fibrous coat. Ripe fruits can range in colour from light gold to brown, attached to the spadix and nearly black at the end.

Chemical Constituents: *Borassus flabellifer* Linn. contains various important chemical constituents. It is rich in amino acids, with lysine, aspartate, glutamate, and phenylalanine being dominant. The plant also contains steroidal saponins known as flabelliferins. The main digestible carbohydrates present are simple sugars, with sucrose, glucose, and fructose being the primary ones. *Borassus flabellifer* Linn. is a good source of carotenoids, including β-carotene, a mixture of 4 main carotenoids such as α-carotene, β-zeacarotene, lycopene, and zeta-carotene. Additionally, the plant contains minor constituents such as vitamin C and various B complex vitamins.

Physical and Mechanical Properties: The evaluation of physical and mechanical properties of *Borassus flabellifer* Linn. wood followed the guidelines of IS: 1708 since specific methods for determining mechanical properties of palm wood are not yet established. Due to the distinct characteristics of the wood, with a hard outer portion and a soft inner portion, small clear specimens were employed for testing. However, the limited availability of suitable thickness for the hard portion posed challenges in making specimens. Despite these obstacles, physical and mechanical tests were carried out on specimens from the outer hard portion and the inner soft portion separately (refer to Table 1)

Table 1 physical and mechanical properties of air dried palmyrah wood.

Sl .No	Property	Soft central portion	Hard outer portion
1.	Density	90 kg/m^3	700-800 kg/m^3
2.	Shrinkage (volumetric)		2%
3.	Compressive strength		500-650 kg/cm^2
4.	Modulus of Rupture	15.5 kg/m^2	745 kg/m^2
5.	Modulus of Elasticity	8733 kg/m^2	67041 kg/m^2
6.	Nail holding strength		44 kg
7.	Hardness		637 kg

Uses / applications:

Borassus flabellifer Linn. yields a variety of valuable by-products from its different plant parts. These include:

Toddy: Formed by fermenting the sugary sap, toddy is a traditional drink with a refreshing quality, containing approximately 4-8% alcohol.

Jaggery: Derived from the plant's sap, jaggery is known for its nutritional and medicinal properties, offering an earthy, intense taste similar to chocolate.

Sugar: Prepared from the fruits of *Borassus flabellifer Linn.*

Oil: Obtained from the fruit through wet processing.

Candy: Made by heating the "Neera" (sugary sap) until it reaches a thick consistency.

Spread: The fruit pulp is extracted using water and heat, then mixed with other ingredients and cooked before being bottled and stored.

Toffee: Prepared by combining fruit pulp with sugar, skim milk powder, glucose, refined flour, and starch. The mixture is cooked, stretched, and left to set.

Wine: Made using fermented flower sap, resulting in a white, alcoholic, sweet beverage with a strong aroma and mild taste.

Burfi: Prepared with khoa, butter, lime water, fruit pulp, and sugar.

Pickle: Made from small fruits pickled in vinegar.

Borassus flabellifer is well-studied for its nutritive and nutraceutical properties, with researchers exploring its potential medicinal applications. It serves as a generous source of biopharmaceuticals, exhibiting various biological properties and being utilized as a remedy for multiple diseases.

Some of the traditional uses of palm trees

Fruits of palm
treegelatinous seeds

Seedlings sold in tamil regionseedlings sold in paris

Young leaf as food supportplates made with a petiole base

Manuscript (ola) in Oriya dating back more than 1000 years

Potential End-Use Applications: The species has following potential applications:

Construction: In traditional rural housing, palmyrah wood can be effectively used as rafters, beams, and battens for supporting light loads and short spans with tile or sheet roofing. To enhance its durability and resistance against decay and insects, simple dip diffusion methods can be employed for wood treatment. Both the hard and soft portions of the wood can be easily treated using this method, making it suitable for construction purposes.

Door/Window Frames: Palmyrah wood is an excellent choice for door frames, especially when employing the glue laminating technique to build up the required sections. The combination of small dimensioned harder palmyrah wood with the hard/soft wood can create sturdy door frames. The harder portion's high screw holding power can be advantageous in this application.

Flush Doors: The wood can also serve as core material for hollow, cellular, or solid core flush doors. By using harder portion wood for rails and stiles and softer portion for the cellular core consisting battens, the doors can exhibit adequate resistance to slamming and indentation while accepting hinges securely.

Block Boards: Palmyrah battens can be utilized as core material for block boards with appropriate cross band and face veneer. The core material should be treated against insects, and care should be taken to ensure uniform density of the wood.

Challenges in Utilization: Palmyrah wood does not face any serious insect or disease issues. However, it may be slightly prone to lethal yellowing, and proper measures should be taken to address this concern.

Overall, *Borassus flabellifer* Linn. wood offers great potential for various construction applications, especially in rural housing settings, where its unique properties can be effectively utilized. By treating the wood and carefully selecting its different portions for specific applications, it can become a valuable resource for building durable and functional structures. However, it is essential to monitor and address any potential susceptibility to lethal yellowing to ensure the wood's long-term viability in various end-use applications.

THE INDIAN ACADEMY OF WOOD SCIENCE

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The Indian Academy of Wood Science was founded in 1968 to advance the knowledge of wood science & technology and covers in its activities all the aspects related to wood, cellulose and their products such as logging, saw milling, wood working, plywood, fibre boards, particle boards, improved and composite woods, cellulose and cellulose based sciences and industries and allied fields. The Academy runs a Journal called "Journal of the Indian Academy of Wood Science". In addition to this, it also organises seminars and workshops. During some annual meetings, lectures from eminent scientists are also arranged. The Academy has joined hands with Springer, an internationally reputed publishing house, for bringing out the journal fully online for wider international readership. Authors may submit the manuscript of their research papers online following the Springer publication link http://www.editorialmanager.com/jiaw

APPLICATION FOR MEMBERSHIP

To,

The General Secretary
Indian Academy of Wood Science
Institute of Wood Science & Technology Campus
P.O. Malleswaram, Bangalore-560 003 (India)

Sir,

I wish to become a member of the Indian Academy of Wood Science and give below the necessary particulars for enrolling as "Corporate Member/Institutional Member/Individual Member" (as the case may be). Necessary remittance of Rs.* ..... is made by a Demand Draft/Cash, which may please be acknowledged. I agree to abide by the constitution of the academy and agree to the code of ethics contained therein.

Place: ..... (Signature of the Applicant)

Date: .....

1. Name of applicant in full (in block capitals)	
2. (a) Date of Birth, (b) Age (in case of individuals only)	
3. Academic and professional qualifications (in case of individuals only)	
4. Present employment/how engaged and brief history of previous career in case of individuals (separate sheet may be attached, if necessary)	
5. Brief description of general activities in case of Corporate, Institutional Members	
6. Address to which communications should be sent including phone, fax & e-mail	

* *Demand Draft should be drawn in favour of 'Indian Academy of Wood Science' and payable at Bangalore.*

Membership Type	Annual Fee	Life Time Fee
Indian :		
Corporate	N. A.	Rs. 100,000
Institutional	Rs. 2,000	N.A.
Individual	Rs. 500	Rs. 5,000
Foreign :		
Corporate	N. A.	US $ 2,500
Institutional	US $ 50	N.A.
Individual	US $ 20	US $ 200

(To be Photocopied for Use)

Bombax ceiba L.

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Scientific Name : *Bombax ceiba L.*
Family : Bombacaceae
Vernacular Names:
- English : Silk Cotton Tree, Malabar Semal
- Assamese : Simul
- Bengali : Katseori, Roktosimul
- Hindi : Simal, Kaantisenbal
- Malayalam : Ellavu, Illavu
- Kannada : Burga, Pula
- Tamil : Pulai, Purani

Bombax ceiba

INTRODUCTION

Bombax ceiba L., commonly known as Semal, Simbal, Simul, Indian kapok, Katsavar, Indian bombax or Red Silk cotton tree, is a lager deciduous tree with spine. It is distributed across countries like Pakistan, India, Myanmar, Indonesia, Vietnam and Thailand, China, Taiwan, Javaand Philippine. In India, it can be found at altitudes up to 1500 m. B. ceiba is commonly seen in areas adjoining rivers, in the dry as well as moist deciduous forests in peninsular India. This is a strong light demanding tree which is best grown in deep sandy loams or other well drained soils, particularly in valleys, in regions receiving 50 to 460 cm annual rainfall. Due to its fast growing characteristics, this tree species holds potential towards addressing the escalating demand for timber. B. ceiba has been explored for its chemical constituents, genetic diversity, wood properties, and diverse industrial applications. Hence, this article aims to provide a deep understanding of the wood anatomy and chemical composition of this species, with a focus on wood properties and value addition. Moreover, the commercial utilization of this species and its role in conservation and economic development is discussed.

Bombax species display substantial height and trunk diameter, making them among the largest trees in their respective regions. B. ceiba trees grow to a height of 30 to 40 m and up to 3 m in trunk diameter. As evident from Fig 1, the tree grows straight with horizontally spreading branches (Fig 1a) and tree bole is covered with hard prickle (Fig 1b). It has buttress roots (Fig. 1c) and flowers are red in colour. During the time of flowering, the trees remain leafless (Fig. 1d). The fruits of this species are brown capsule-like which is up to 15 mm long and are filled with numerous black seeds.

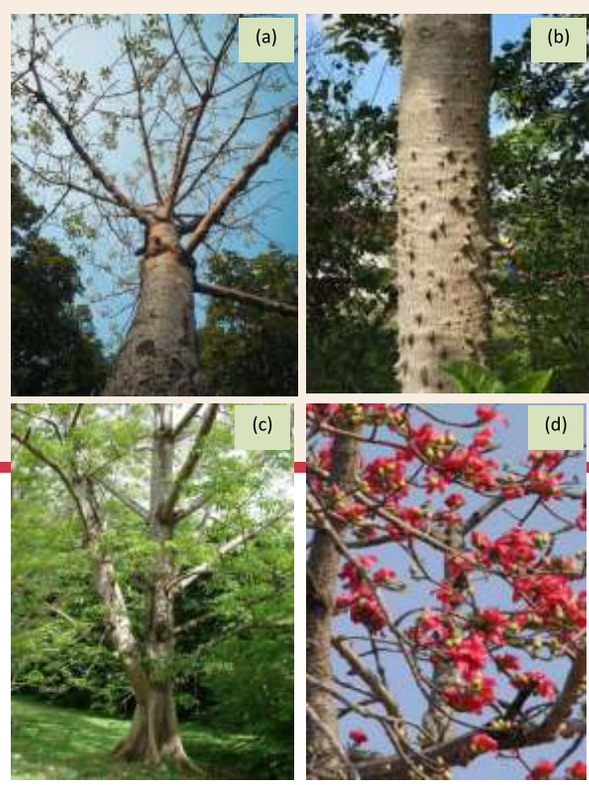

Fig.1. Images of B. Ceiba (a) Tree with horizontally spreading branches (b) young stem covered with hard prickles (c) buttress roots (d) red colour flowers and leaves less tree during flowering

Silvicultural Characteristics:

Semal thrives in well-lit environments, displaying resilience to mild frosts but vulnerability to severe frost events in hilly regions. Despite being subjected to burning during the seedling and sapling stages, the species showcases commendable recovery abilities owing to its protective thick bark, rendering it more fire-resistant compared to other species. Early coppicing is observed in young Semal trees, although this ability diminishes as they mature. The production of root suckers further contributes to its regeneration potential, albeit with limited survival for extended periods. Grazing poses a challenge, particularly during the early stages of Semal's growth, necessitating the protection of thorny bushes to shield saplings from grazing animals.

Regeneration:

Semal exhibits natural regeneration through abundant seed production, dispersed by wind. New alluvial flats, savannas, and open spaces provide favourable environments for natural establishment. The species plays a significant role in the process of natural succession of vegetation, appearing after the dominance of Dalbergia sissoo and Acacia catechu on alluvial grounds in Nepal and northern India. Early-stage protection from grazing by thorny shrubs, such as *Zizyphusmauritiana*, facilitates sapling establishment in heavily grazed areas. Artificial regeneration techniques involve local seed collection from March to May, followed by seed separation from floss. Seeds demonstrate varying weights and germinative capacities, remaining viable for up to two years. Experiments reveal that untreated seeds outperform cold water-treated seeds in germination rates.

Nursery Techniques and Afforestation:

Semal is well-suited for afforestation of new ground and grasslands in rivera in tracts, particularly on alluvial soils mixed with wilt or sand. Nursery practices involve sowing seeds in May or June, providing regular watering until the monsoon season. Seedlings benefit from shade during hot weather and can be suitable for stump planting when one year old. The use of 1-2 years old stock is also common for entire planting. Semal can be propagated through direct sowing, entire planting, and stump planting. The appropriate time for planting is after the monsoon outbreak, with larger stumps yielding better results. Planting pits, filled with well-worked soil, facilitate successful establishment, and proper soil compaction prevents water stagnation around the stumps.

Wood Properties

B. ceiba wood looks creamy-white when freshly cut and gradually turns to greyish-brown upon exposure. The wood shows no distinction between sapwood and heartwood, however, occasionally some wood shows pinkish brown color in the center part of the log. It is soft to very soft wood with an air-dry density of about 385 kg/cm^2. It is a diffused porous wood with growth rings indistinct to distinct. Pores very large, clearly visible to eyes, scanty, mostly solitary or in short radial multiples of 2-3. Parenchyma is apotracheal and visible under lens. Rays are fine to broad and are widely spaced. The mechanical properties ofB. ceiba wood are mentioned in Table 1.

Natural durability in *B. ceiba* wood is very less. The wood of this species is not at all durable under outdoor condition, and has an average life of around

Table 1 Mechanical property of *B. ceiba* (Source: appendix I-Indian wood vol. 1 page 184)

Species	Locality of test	Specific gravity (oven dry wt and green vol)	Modulus of rupture (kg/cm^2)- Air-dry	Modulus of elasticity (kg/cm^2)- Air-dry	Impact bending (max. height of drop of 22.68 kg of hammer in cm(Airdry)	Compression parallel to grain (max. crushing stress kg/cm^2) (Air-dry)
B. ceiba	Dehradun	0.33	382.0	51,000	53	181

one year. The converted timber or finished articles made out of B. ceiba wood is easily attacked by insect such as lyctus and powder post beetles (*Bostrychideae*). The converted timber or finished articles are also prone to sap stain and other kind of wood rot. The standing tree is also prone to insect attack such as by longhorn beetles, defoliators and Semal shoot borer. However, the wood of this species is said to be very durable under water condition.

Seasoning and preservation

The timber of this species is easy to saw and works with; however, given its susceptibility to decay from fungus, insects, and sap stains, timely conversion and kiln seasoning are essential to preserve its quality. Nevertheless, the wood's durability can be significantly enhanced through the application of preservatives, making it highly resilient, particularly when exposed to water. The wood of *B. ceiba* is very easy to season and easy to treat. It is important to convert the logs as soon as possible and carry out its drying. The wood can be easily air dried to 12% moisture content if the outdoor conditions are favourable, however, under high humidity and moisture condition it is recommended to kiln dry the timber before its use. Proper seasoning is helpful in preventing sap stain problem in *B. ceiba* wood. The wood is very easy to treat and attain complete penetration of preservatives. Preservative treated wood is moderately durable and can last for long time under indoor condition.

Wood Working properties

B. ceiba wood is a low density wood and is easy to saw. Wood working and peeling is also easy to carry out without any preliminary treatment given to wood. However, due to its coarse texture and predominant vessel lines it do not finishes well and also absorb much varnish and paint.

Uses

B. ceiba bark is said to be useful in haemorrhagic disorders, wound healing, removing pimples/acne and have a cooling effect in burning sensations. It is also used in hyper pigmentation, wounds, burns and stomatitis as a topical therapeutic agent. *B. ceiba* wood is in high demand for matchwood production, with much of the annual yield reserved for India's match industry. In Nepal, the pioneering match industry, "Juddha Match Industry," was largely based on *B. ceiba* trees. However, due to the decline in *B. ceiba* availability, some match factories have shifted to alternative materials. The wood is also commonly used in plywood manufacturing, as it is well-suited for light plywood containers that do not require high strength properties. Additionally, *B. ceiba* wood finds applications in diverse construction purposes, including packing cases, boarding, planking, boat making, and crafting items like shingles, toys, scab boards, coffins, brush handles, and opium chest partitions. The floss obtained from *B. ceiba* seeds, known as Indian Kapok, serves as valuable packing material and finds use in life-saving appliances, upholstery, and insulating materials. Semal's medicinal properties are recognized among traditional healers, who use various parts of the tree, such as roots, bark, and gum, for medicinal purposes. Its ornamental value is evident in its widespread planting in botanical gardens, public gardens, and avenues.

Calophyllum inophyllum

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INTRODUCTION

Calophyllum inophyllum, commonly known as "Surahonne" in the local language, is a significant timber species found in the Siddapur Taluk region of Uttara Kannada district in the Western Ghats region of Karnataka, India. The local geographical conditions of this coastal belt favour the distribution of *C. inophyllum,* making it an integral part of the region's ecosystem. This native wood species is highly valued by the local villagers for its versatile uses in various applications, such as reepers, windows, and cots, thereby highlighting its potential for agroforestry systems and plantations. *C. inophyllum* holds great importance as a timber species, serving multiple purposes in the local communities. The comprehensive outlook of *C. inophyllum* as a valuable resource contributes to its prominence in the region's timber industry and the livelihoods of the local people.

Keystone Species and Coastal Ecosystem

Beyond its utility as timber, *C. inophyllum* plays a crucial role as a keystone species in the coastal ecosystem. Its significance in maintaining the ecological balance and contributing to the well-being of the surrounding environment cannot be overlooked. This native species is recognized as an integral component of the coastal ecosystem in India, further emphasized by the various common names associated with it at the local level.By recognizing the comprehensive outlook of *C. inophyllum* and promoting its sustainable cultivation and utilization, the coastal communities of Karnataka can harness the benefits of this native wood species while ensuring the conservation of their natural resources.

Calophyllum inophyllum: The Indian Laurel Tree

C. inophyllum, also known as the Indian laurel or Alexandrian laurel, is a remarkable tree belonging to the Calophyllaceae/ Clusiaceae family. This broad-leaved evergreen tree boasts a wide-spread crown and horizontal branches, giving it an impressive appearance. With its scientific name derived from the Greek words for "beautiful leaf," it is often referred to as the "Beauty Leaf Tree" (BLT).

Habitat and Distribution

Native to the paleotropics, *C. inophyllum* has adapted to various habitats, primarily establishing it in littoral regions near the beach crests of Himalayas. While it can occasionally be found inland, its natural distribution spans from the west coast of India, southward from Mumbai to Southern Kerala, and along the east coast from Orissa to the south. The tree's ability to thrive in these coastal environments is a testament to its adaptability and resilience. *C. inophyllum* is naturally found in specific agro-climatic zones. It thrives in the Eastern coastal plains with alluvial soil and sub-humid climatic conditions. Additionally, it can be found in the red/laterite soils of the Western Ghats, where the climate ranges from pre-humid to sub-humid. These specific agro-climatic zones provide the ideal conditions for the growth and development of *C. inophyllum.*

Growth and Size

The Indian laurel tree is known for its slow growth rate, gradually reaching heights ranging from 10 to 22 meters. Despite its modest growth, *C. inophyllum* possesses an enchanting allure with its wide-spread crown and horizontal branches. This characteristic growth pattern contributes to its visual appeal and makes it a distinctive presence in the landscape.

As a species that combines aesthetic beauty, adaptability, and a distinctive growth habit, C. *inophyllum* holds immense value both in its natural habitat and in various human applications. Understanding its characteristics and potential uses can further enhance its appreciation and conservation efforts.

Figure 1: Thick and oblong leaf
Figure 2: Horizontal wide spread crown

Coexistence with Other Species

In its native habitat, *C. inophyllum* often coexists or forms associations with other littoral tree species such as *Manilkaralittoralis, Casuarina equisetifolia, Terminalia catappa, Heritieralittoralis, Pongamiapinnata, Barringtonia asiatica, and Erythrina variegata.* Thus collectively contribute to the rich biodiversity of the coastal regions. *C. inophyllum* thrives in areas with an average annual rainfall ranging from approximately 1000 to 5000mm, indicating its adaptability to a wide range of precipitation levels.

Flowering, Fruits, and Seed Dispersal

C. inophyllum exhibits a flowering period from March to September along both the east and west coasts, although flowers and fruits can be found at other times of the year as well. The ripe fruits of *C. inophyllum* are yellow or brownish in color and are mainly dispersed by water and fruit bats. Each fruit contains a large brown seed with a diameter of 2–4 cm. These seeds are of great value, as they are used to extract *C. inophyllum* oil, also known as Tamanu oil. This oil is highly valued for biodiesel production, traditional remedies, and cosmetic ingredients.

Conservation Status

Traditionally, the extraction of *C. inophyllum* oil and the collection of its fruits were important economic activities for the "Teli" community in the Konkan region. However, over time, these practices have declined due to various reasons. Alternatively, villagers began selling the wooden logs of old and mature C. inophyllum trees, as the wood's unique property of withstanding saline water makes it suitable for constructing fishing boats. Unfortunately, this shift in economic activities has resulted in a decline in the population of *C. inophyllum* trees beyond a considerable limit.

C. inophyllum, also known as the Indian laurel, is a versatile tree with a comprehensive outlook. Its ability to adapt to specific agro-climatic zones, coexist with other littoral species, and bear valuable fruits and seeds highlights its ecological significance. However, the decline in fruit collection and the growing demand for its wood have impacted its population. Conservation efforts are crucial to maintaining the population and ensuring the continued presence of *C. inophyllum* in its native habitat.

Figure 3: Partially ripe fruits Figure 4: Saplings in nursery condition

Exploration for Engine Oil and Therapeutic Applications

C. inophyllum holds significant value and is being extensively explored for its potential use in engine oil and therapeutic applications. The existing natural stands of *C, inophyllum*, particularly in the TOF (Trees Outside Forest) population, are primarily utilized for these purposes. Recognizing its importance, efforts are underway to propagate this species in nurseries (Figure 4), cultivate it, and establish plantations to develop superior clones.

Identification of High Yielding Clones and Biofuel Potential

The Institute of Forest Genetics and Tree Breeding (IFGTB) in Coimbatore has identified 220 high fruit-yielding CPTs (Clonal Propagation Techniques) of *C. inophyllum* from various regions, including Tamil Nadu, Kerala, Karnataka, Puducherry, and the Andaman Islands. Through experimentation, high-yielding Calophyllum oil superior clones have been found effective for establishment in harsh climatic conditions. These clones hold promise as tree crops for biofuel production, contributing to the renewable energy sector.

Agroforestry Potential

C. inophyllum exhibits a remarkable adaptability to various soil types, ranging from coastal sands to clay, including degraded and poorly drained sites. The tree thrives in areas with little shade and planting with moderate spacing promotes straight growth and also tends to regenerate rapidly with moderate coppice thus maximizes timber production (Friday & Okano, 2006). The tree also produces beautiful flowers (Fig. No. 5), which can be beneficial in attracting pollinators such as bees, butterflies, and other insects enhancing biodiversity and promoting the reproduction of other plants in the agroforestry system.*C. inophyllum* is commonly planted as shelterbelts or windbreaks in rows within farms or agroforests (Friday & Okano, 2006). These plantings serve to protect agricultural lands and human settlements, making it a suitable alternative to Casuarina for beach windbreaks and soil stabilization. The diverse adaptability and intrinsic characters qualify the tree as a potential agroforestry species.

Figure 5: *Calophyllum inophyllum* Flower

Calophyllum Wood: Exploring the Potential for Alternative Timber

As the demand for sustainable timber resources continues to rise, there is a need to explore alternative timber species. *C. inophyllum* possesses wood with unique characteristics that make it a promising candidate for timber applications. We delve into the general characters of *Calophyllum* wood and highlight its value and potential uses.

General Characteristics of Calophyllum Wood

The wood of *C. inophyllum* stands out with its distinctive features. It is heavier, stronger, and more durable compared to other *Calophyllum* species. The wood has a fine texture, giving it a lustrous appearance. The grain is interlocked, further enhancing its visual appeal. The heartwood displays a reddish-brown hue with darker streaks, while the sapwood exhibits a pale reddish-white coloration. With a specific gravity ranging from 0.47 to 0.84 and a density of 560-800 kg/m^3 cubic meter at 15% moisture content. Calophyllum wood possesses the desired qualities for various applications for light construction, flooring, joinery, wooden pallets, diving boards, cartwheels and axles, musical instruments, and blowpipes (Orwa et al., 2009). The rate of shrinkage is moderate, contributing to its stability during drying and use.

Properties of the Wood

The mechanical properties of the wood comprises modulus of rupture 48 N/mm^2, modulus of elasticity

7545 N/mm², compression parallel to grain 42 N/mm², shear 6 N/mm², cleavage 60 N/mm radial and 72 N/mm tangential, jankaside hardness 4820 N and jankaend hardness 6045 N. The rates of shrinkage are medium, from green to oven dry 4.2% radial, and 5.3% tangential. *C. inophyllum* timber is rated as moderately durable underexposed conditions and durable when used underwater.

Clear Bole and Trunk Characteristics

C. inophyllum tree exhibits distinct features in its trunk and bole, making it a notable species for timber purposes. In coastal belts, the trunk is typically short, with a clear bole reaching a height of 15 meters and a maximum girth of 7 meters, as reported from the Andaman region (Rao et al., 2001). Interestingly, these trees lack buttresses, contributing to their straight and uniform form.

Alternatively, in other regions, *C. inophyllum* trees can reach heights ranging from 8 to 20 meters, maintaining a clear bole (Fig.. 7). The bark of these trees displays unique characteristics, with diamond to boat-shaped fissures, adding to their visual appeal (Fig. 8) (Orwa et al., 2009).

These distinctive trunk and bole features of *C. inophyllum* underscore its potential as a valuable timber species, suitable for various applications in the construction, furniture, and woodworking industries.

Value of Calophyllum Wood

Despite the limited availability of Calophyllum timber, it holds great value in the market. The wood is highly sought after for handicrafts, owing to its inherent beauty and excellent carving quality. Artisans appreciate its aesthetic appeal and workability, making it a preferred choice for creating intricate designs. Additionally, Calophyllum wood has a long-standing tradition of being used in canoe, boat, and raft making (Fig. 6). Its durability and strength make it suitable for marine applications, showcasing its versatility.

C. inophyllum wood possesses exceptional properties that make it a promising alternative timber. Its strength, durability, and aesthetic appeal make it highly valued in the market, particularly for handicrafts and marine applications. As sustainable timber resources become increasingly crucial, exploring the potential of Calophyllum wood can contribute to meeting the demand while supporting the conservation and sustainable management of this remarkable species.

Also, the wood hasbeen used for paneling, furniture, general cabinetry and construction, boat building and with ostensible termite resistance.

Figure 6: A villager hews, with an axe, a dugout canoe from a single tree (*C. inophyllum*). The processes include felling the tree, drying out the trunk and carving. Papua, Indonesia. *Photo by Manuel Boissiere for CIRAD and CIFOR (cifor-mediainfo@cgiar.org and m.edliadi@cgiar.org)*

Figure 7: Straight / clear bole / trunk
Figure 8: Trunk with smooth bark

Timber Value and Future Research

Despite its immense potential, *C. inophyllum* remains largely unexplored for its timber value. The straight boles of the species hold promise for timber-yielding plantations. Further investigation and utilization of this valuable resource can contribute to the sustainable supply of raw material for various industries. Although there have been limited recent studies on the timber value of *C. inophyllum*, it is noteworthy that decades-old reports exist on the subject. Considering the increasing demand for sustainable timber resources, further research on the timber properties of Calophyllum wood is warranted. Exploring its potential as a valuable timber species could provide additional avenues for utilization and contribute to the conservation and sustainable management of *C. inophyllum*.The immense potential of *C. inophyllum* extends beyond its traditional uses in engine oil and therapeutic applications. Efforts to propagate superior clones and establish plantations highlight its significance as a versatile species. Furthermore, the exploration of its timber value and the development of biofuel tree crops open up new avenues for its utilization. By embracing a holistic approach to research and conservation, *C. inophyllum* can play a vital role in sustainable development and environmental conservation.

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Increasing Productivity and Wood Utilization of *Casuarina* to Benefit Farmers and Industries

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INTRODUCTION

India holds the distinction of being the largest *Casuarina*-growing country globally, boasting approximately half a million hectares of plantations. The eastern coastal regions, particularly the states of Andhra Pradesh, Odisha, Tamil Nadu, and the Union Territory of Puducherry, are home to a significant portion of these plantations. *Casuarina* exhibits remarkable adaptability, thriving in diverse edaphic and climatic conditions, including low-nutrient and moisture-limited sites. Moreover, it enriches the soil by fixing atmospheric nitrogen through its symbiotic relationship with Frankia and other endo and ecotomycorrhiza.

***Casuarina* Cultivation:** *Casuarina* is favored by small landholding farmers due to its ease of cultivation and ready marketability, making it an appealing alternative to traditional agricultural crops. In short-rotation cycles lasting 3 to 5 years, farmers typically plant up to 10,000 trees per hectare using seed-origin planting material, while this density is reduced to 6,000 to 7,000 trees per hectare when clones are employed. Planting activities can occur throughout the year with access to irrigation, but under rain-fed conditions, planting is timed during pre-monsoon showers. During the initial six months, when casuarina saplings are small, farmers often intercrop with groundnut, green gram, black gram, or watermelon. The income generated from the intercrop offsets the cost of establishing the casuarina plantations and aids in weed management. To promote lateral growth of stems and enhance pole quality, side branch pruning is undertaken annually during the first two years. Providing irrigation and fertilizers accelerates tree growth, leading to shorter rotation periods. One of the remarkable benefits of cultivating Casuarina is its role in returning nutrients to the soil through biological nitrogen fixation and leaf litter, effectively maintaining or even enhancing soil fertility, allowing farmers to switch to agricultural crops as needed.

Genetic Improvement: For over 25 years, the Coimbatore-based ICFRE-Institute of Forest Genetics and Tree Breeding has successfully implemented a systematic casuarina breeding program in collaboration with the Australian Tree Seed Centre, CSIRO. The breeding program focused on two Casuarina species, *C. equisetifolia* and *C. junghuhniana*, drawing upon a broad genetic base from their entire distribution range. Through interspecific hybridization, the most desirable traits of the two species, including fast growth, drought tolerance, stem straightness, and pulp yield, were combined to produce high-yielding hybrid clones. These genetically improved seeds and field-tested clones were registered with the Protection of Plant Varieties and Farmers Rights Authority, Government of India, securing their intellectual property rights. Non-exclusive licenses were then issued to paper industries and private nurseries for mass propagation of the clones and supply to farmers. With approximately 70 million plants produced annually by these licensees, farmers have established over 25,000 acres of plantations throughout the Peninsular region. Recent yield data from the 2022-23 plantations showed a doubling of wood production in CH clonal plantations compared to unimproved seed sources and a 30% increase compared to the benchmark clone CJ9 (Table 1). At the current pulpwood price of Rs. 5,000/- per tonne, the additional 20 tonnes of wood per acre produced with the hybrid clones translates to a one lakh rupee increase in farm income.

Utilization of *Casuarina* Wood

Casuarina has garnered a global reputation as an outstanding fuelwood tree, boasting one of the highest calorific values: 4600 kcal/kg as wood and over 7000 kcal/kg as charcoal (Pinyopusarerk and House, 1993).

Table 1. Adaptability and yield details of varieties / clone of Casuarina currently under planting

Name of variety / clone	Salient features	Rotation period	No. of trees per acre	Wood production (tonnes per acre)
Casuarina equisetifolia – unimproved seed	Coastal areas; irrigated. Highly variable growth and low productivity	5-6 years	4000	30-40
Casuarina equisetifolia – seed from orchard	Coastal areas; irrigated; low level of growth variation, better stem form	4-5 years	3000	40 - 45
Casuarina junghuhniana – seed from orchard	Coastal and inland areas; irrigated and rainfed. low level of growth variation, better stem form	4-5 years	3000	45-50
Casuarina junghuhniana – Clone CJ9	Coastal and inland areas; irrigated and rainfed. Uniform growth, straight stems	3-4 years	2700	60-70
Casuarina hybrid - Clones Ch1, CH2 and CH5	Coastal and inland areas except clayey soils and water logged areas; irrigated and rainfed. Uniform growth, straight stems	3-4 years	2400	70-80

Introduced to India during the 19th century primarily to meet the rising demand for fuelwood (Kaikini, 1937), this versatile tree has since embarked on a remarkable journey spanning nearly 150 years, evolving into a reliable source for wood production, environmental services, and livelihood improvement.

Pulpwood Production: *Casuarina* plays a crucial role as a significant source of pulpwood in India, serving as the primary raw material for six major pulp mills. With an annual consumption of approximately 1.5 million tonnes, it accounts for about 15% of the country's total pulpwood requirements. The preference for *Casuarina* wood stems from its high pulp yield (up to 51%) and desirable paper-making properties, such as tearing strength, brightness, and low chemical consumption (Sankaralingam and Sankar, 2013). The species' short rotation period (starting from 2.5 years) facilitates a faster wood flow from plantations compared to other species like Eucalyptus, making it an attractive choice for paper industries. Moreover, this enables paper industries to establish catchment areas for plantations and engage in farm forestry programs, fostering strong connections with farmers. The successful collaboration between research organizations, paper industries, and farmers has significantly expanded the reach of high-yielding planting stock and modern silvicultural techniques for *Casuarina.*

Solid Wood Uses: *Casuarina* finds widespread use as poles for scaffolding and rural construction. Its straight, cylindrical stems and high wood density (650-750 kg/m^3 at 3-5 years of age) contribute to the sturdiness of these poles. They are extensively employed in building construction, rural housing, fence-making, and as support for crops like banana. Although the pole market remains largely unorganized, it is estimated to be approximately twice the volume of pulpwood procured by paper industries. Farmers tend to sell only the portion of the tree that cannot be utilized as poles as pulpwood, resulting in an annual consumption of around three million tonnes of *Casuarina* poles. Consequently, this poses a significant competition with the paper industries. In recent years, the steep increase in steel prices has further amplified the use of Casuarina poles for various construction-related activities. However, exploring suitable treatment or seasoning methods to increase the poles' lifespan could potentially reduce their consumption, making them available for other valuable applications.

Although many traditional uses of solid wood of casuarina have been reported, in India such practices are limited. In its native region like Australia, casuarina wood is widely used for making shingles, agricultural implements, furniture and cabinet making (Churchill, 1983; Boland et al. 2006). Splitting in sawn wood of young aged trees and the high density and presence of knots in mature trees make casuarina wood unsuitable or difficult to use as sawn timber. In China, casuarina wood from 6 to 8 year old trees is used for making core veneer and log sizes not suitable for veneer or converted into chips (Zhong et al., 2011). Residual parts like root stumps and branches are converted into charcoal. But despite the large scale wood production in India, the possibility of using casuarina wood for

more valuable products like veneer and fibre boards has not been attempted seriously. Casuarina species possess a large amount of genetic variation for many growth and wood properties and they can further be influenced through appropriate silvicultural methods to obtain trees with a desirable package of characters to enhance their value. To begin with the industries need to set benchmark for high value utility like veneer and fibre board making with casuarina which can be pursued through targeted R & D efforts. Yet another utilization potential of Casuarina wood is biomass based power generation. Its wood has desirable the properties of high calorific value, density, volatile matter, low ash and fixed carbon content making it suitable for bio energy production. Development of high density plantation models with short rotation for maximizing biomass production for generation of energy will help in further diversification of Casuarina wood utilization.

Fig. 1. Utilization of Casuarina wood in China for chip and veneer production

R & D Outlook for Diversifying Casuarina Utilization

The ongoing *Casuarina* breeding program has achieved remarkable progress by prioritizing fast growth and stem straightness, resulting in increased wood production and improved pole quality over the first two breeding cycles. Looking ahead, the breeding objectives need to be expanded to encompass wood properties that will further diversify its utilization and enhance the economic viability of cultivation.

Expanding Utilization Potential: The high-yielding clones currently cultivated have primarily been selected for short rotations to meet the demands for pulpwood and poles. However, by considering longer rotations of 5-7 years and wider spacing, large-sized logs can be obtained and tested for their suitability in new end uses. These large-sized logs can be examined for compatibility with various industries' requirements. If found suitable, the plantations can be incrementally harvested to cater to different needs, consequently boosting cash flow to the farmers. Moreover, exploring new interspecific hybrid combinations holds the potential to amalgamate all desirable characteristics into a single clone or variety, purposefully deployed in plantations meant for specific products.

Silvicultural Practices: The existing silvicultural practices need to be reevaluated and effectively modified to accommodate the varietal diversity and the emerging array of end use requirements. A flexible approach to silviculture will enable farmers and industries to optimally manage their Casuarina plantations, ensuring maximum productivity and adaptability to various market demands.

Enhancing Wood Quality and Lifespan: To facilitate *Casuarina*'s application as solid wood and increase its lifespan, research and development efforts must focus on wood seasoning and treatment techniques. Implementing suitable seasoning methods will enhance the wood's dimensional stability, making it suitable for a broader range of applications. Additionally, exploring effective treatment options will enhance the durability and resistance of Casuarina wood against decay and pests, expanding its usability in diverse settings.

CONCLUSION:

The future of *Casuarina* utilization holds immense promise, and advancing research and development in specific areas will be pivotal in achieving this potential. By broadening breeding objectives, revisiting silvicultural practices, and developing wood seasoning and treatment techniques, *Casuarina* can be established as a versatile resource, diversifying its applications and augmenting the economic benefits for farmers and industries alike. Embracing this outlook for *Casuarina* will undoubtedly contribute to sustainable and lucrative cultivation practices in the years to come.

Chukrasia tabularis - A Natural and Commercial History of the Deciduous Species

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Chukrasia tabularis, commonly known as chickrassy, Burmese almond wood, or Chittagong wood, belongs to the family Meliaceae and is a valuable tree species native to Asia. This review aims to consolidate information on the suitability of *Chukrasia tabularis* for the manufacturing of wood-based composite products and its potential in agroforestry. With its deciduous nature, *Chukrasia tabularis* produces large-sized timber suitable for furniture, veneer for plywood, and construction purposes. It is extensively used in Southeast Asia and India for furniture making, windows, and light flooring. In Myanmar, *Chukrasia tabularis* is well-regarded and utilized in various construction applications. Studies have indicated that the plant is rich in various limonoids, making it suitable for use as a natural pesticide and insecticide, along with other members of the Meliaceae family.

INTRODUCTION

Plants play a vital role in the development of new therapeutic agents as they possess compounds with potential antioxidant, antimutagenic, and anticarcinogenic properties. Secondary metabolites found in higher plants, although not directly involved in physiological functions, hold prime importance for human well-being. They scavenge free radicals, prevent chain-reaction mediated damage, and bind with catalysts of oxidative reactions. *Chukrasia tabularis A. Juss* is a plant rich in secondary metabolites and has been used in Ayurveda. It is a valuable multipurpose tree species and dominates the canopy in South and Southeast Asia, including India, parts of China, Malaysia, and Thailand. It is also cultivated in West and South Africa, as well as in Caribbean countries and Costa Rica. *Chukrasia tabularis* is distributed within the latitudinal range of approximately 27°N to the equator, with an altitudinal range of 20-1450 m. It is predominantly found in lowland areas up to 800 m altitude, where rainfall ranges from 1400 to 4000 mm per year. These climatic conditions correspond to evergreen, moist evergreen, and mixed deciduous forests. *Chukrasia tabularis* tends to colonize disturbed areas and is considered a pioneer species in bare ground and road cuttings in the Malay Peninsula.

Scientific Name and Vernacular Names:

*Chukrasia tabularis A. Juss i*s a tree species belonging to the division Tracheophyta, class Magnoliopsida, order Sapindales, family Meliaceae, subfamily Swietenioideae, and tribe Swietenieae.

Vernacular/Common Names:

Chukrasia tabularis is known by several vernacular names, including Chittagong wood, Burmese almond wood, white cedar, bastard wood, and Red Indian wood in English. In different regions, it is referred to as Surianbatu, cheranaputeh, repoh, sutnagputeh in Malay; yinma in Burmese; siat-ka, yom-hin in Thai; Hulanhik, hirikita, kaloti in Sri Lanka (Brandis, 1971). In India, it is commonly known as laldevdari, agilmaleivembu, vedivembu in Tamil; chikrassi in Bengali; boga poma, bogipoma in Assamese; chukrasi in Gujarati; lal-devadari in Hindi; dalamara, kelgarike in Kannada; malaveepp in Malayalam; taimareng in Manipuri; laldevdaru in Marathi; *chananamalei* in Sanskrit; and amaradrumamu in Telugu. Trade names include Chittagong wood, chickrassy, yonhim, and yinma.

Natural Distribution:

Chukrasia tabularis is distributed across various regions, including India, Nepal, southern China, Indo-China, Cambodia, Thailand, Laos, Myanmar, Bangladesh, Sri Lanka, and the Andaman Islands, extending to western Malaysia (Anderson, 1980; Ho and Noshiro, 1995; Mabberley, 1995; Chen et al.,

1997). It is cultivated as an agroforestry tree in China, Sri Lanka, and Vietnam (Bandara, 1999; Kalinganire and Pinyopusarek, 2000). In India, it can be found in South India (Maharashtra and Tamil Nadu), the hills of Sikkim, grooves of Manipur, grooves of Madras, the western Peninsula, Assam, Arunachal Pradesh, the Malabar coast, Malacca, the Sandoor hills of Deccan, the western peninsula along the Western Ghats, West Bengal, and the Andaman Islands.

Figure 1. Natural distribution of *Chukrasiatabularis*

Tree characteristics:

Chukrasia tabularis is a medium-sized to fairly large tree, either evergreen or deciduous, with a monoecious nature. It can reach heights of up to 30 meters (maximum 40 meters) and has a branchless bole that can extend up to 18 meters (maximum 32 meters) in length. The diameter of the bole can reach up to 110 centimeters (maximum 175 centimeters) and is typically without buttresses. The bark surface is rusty brown or deep brown in color, deeply fissured or cracked, and adorned with lenticels. The inner bark has a reddish hue.

The leaves are paripinnate, measuring 30-50 centimeters in length. They consist of 4-6 pairs of opposite or alternate leaflets. The leaflets are entire, asymmetrical, and acuminate, while juvenile leaves may be imparipinnate and lobed or incised. The margins of the leaflets are dentate, and the leaf surface can be glabrous or adorned with simple hairs.

Figure 2. Tree of *C. tabularis A. Juss.*

Growth Behavior and Suitability for Agroforestry:

Chukrasia tabularis exhibits moderate growth during the initial years, with seedlings reaching heights of 1.2 to 2.1 meters within the first two years. By the third year, the plants can grow to 2.8 to 3.4 meters with a bole diameter of 4 to 5 centimeters. After six years, the height can reach 5.5 meters with a bole diameter of 15 centimeters, resulting in an average annual diameter increment of 2.5 centimeters. In some instances, *Chukrasia tabularis* trees planted on deep alluvial soil in South Africa achieved heights of 37 meters and a bole diameter of 63 centimeters after 49 years. However, on shallower soils, the trees only reached heights of 25 meters and a bole diameter of 47 centimeters after 51 years.

Under favorable conditions, *Chukrasia tabularis* can experience rapid growth during the first few years, with an annual height increment of up to 3 meters. Seedlings typically reach heights of 0.7 to 1.0 meter in the first few years and 2.1 to 2.7 meters in the second year. In India, impressive height growth of 2.7 to 5.5 meters after 2 years and 8.5 to 9.1 meters after 5 years has been observed, with an annual diameter increment of more than 2.5 centimeters up to six years. However, growth may be slow in areas with low soil fertility. In certain locations, *Chukrasia tabularis* can achieve a height of 31 meters and a diameter at breast height of 37 centimeters after 35 years.

Chukrasia tabularis has shown suitability for agroforestry systems. It is commonly planted as a shade tree in coffee plantations in India and is being domesticated for agroforestry and green manure in China. Additionally, it is used as an ornamental tree in parks and avenues in Vietnam, and in Europe, it has been cultivated as a greenhouse ornamental.

Wood Properties and processing:

The heartwood of *Chukrasia tabularis* exhibits a range of colors from pale reddish-brown to dark yellowish-brown, with variations depending on exposure. The wood is moderately heavy, with a density ranging from 625 to 880 kg/m^3 at 15% moisture content. It has relatively low rates of shrinkage and seasons fairly easily, with slight tendencies for checking, warping, and collapsing during drying. The wood is considered moderately hard and exhibits good nailing and screw-holding properties. The mechanical properties of *Chukrasia tabularis* wood (in air dry condition) sourced from West Bengal in comparison to standard Teak is presented in the following table.

Species	Std. SG	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardnessload in (N)			Shear (MPa)		Tension (MPa)	
		MOR	MOE	Max. drop (cm)	MOE	Max. C stress	MOE	CS at E.L..	R	T	E	R	T	R	T
Teak	0.598	95.9	12534	68.6	16381	54.5	14017	9.7	5004	4959	4670	8.4	9.8	3.7	4.4
Chukrasia tabularis	0.568	82.3	10817	91.4	17105	47.4	11210	10.8	5560	6071	6627	10.8	11.7	3.3	5.1

The processing of *Chukrasia tabularis* wood can vary in difficulty depending on the location. It can be difficult to saw, cross cut, turn, and bore in some instances, while in other areas, it is easily sawn and machined. The wood has good nailing and screw-holding properties and can be stained and polished effectively. It is suitable for veneer production, and the veneers can be glued satisfactorily. The wood seasons relatively easily, taking approximately six months under moderate weather conditions for material 5 centimeters thick to air-dry to a moisture content of 15%. Kiln seasoning in India typically takes 12 to 15 days. The wood has low rates of shrinkage and is considered non-durable to moderately durable under exposed conditions. It displays resistance to preservative treatment. The wood can be stained effectively, polished excellently, and has good steam bending properties.

Wood utilization:

The wood is suitable for peeling and slicing into veneers, which can be used to produce decorative plywood, fire-retardant treated plywood, and plywood for concrete shuttering and marine construction. *Chukrasia tabularis* wood is highly valued for its quality and finds extensive use in various industries. It is commonly used for high-grade cabinetry, decorative paneling, interior joinery (doors and windows), and light flooring. The wood is also suitable for carving, toys, turnery, railway sleepers, ship and boat building, and packing boxes. It is in high demand in India for cabinet making, piano cases, and decorative boards. *Chukrasia tabularis* wood has additional applications, including carving, cooperage, paper pulp, propellers, and general construction. The plant's bark and leaves contain commercially valuable gums and tannins, and its flowers are known to contain dyes.

CONCLUSION:

Chukrasia tabularis exhibits promising characteristics for both commercial and agroforestry purposes. Its growth, high-quality wood, and suitability for various applications make it a valuable species. Additionally, its rich content of limonoids offers potential as a natural pesticide and insecticide, aligning with the growing demand for eco-friendly solutions. *Chukrasia tabularis* holds significant potential for plantation establishment and utilization in different wood-based industries. Further research and exploration of the plant's biological activities and potential medicinal uses are recommended.

Corymbia Hybrids: A Fast-Growing Timber Species for India's Growing Demand

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With India's position as the fifth-largest economy and the country's youthful and burgeoning population, there is a growing demand for housing, lifestyle improvements, and related commodities like wood and fiber. Currently, India relies heavily on wood imports, amounting to an annual value of approximately Rs 500 billion, and this figure is projected to double in the near future.

In the past, the wood industry relied on forest resources for raw materials. However, with changes in policies, the country's industrial wood demand is now largely fulfilled by trees cultivated in 12 million hectares of non-forest land, primarily through agroforestry and social forestry practices. These sectors have experienced significant growth due to advancements in clonal improvement techniques for species such as Eucalypts, Poplars, Casuarinas, and Melia spp. This has resulted in the development of short-rotation, high-yielding clones that cater to the needs of the veneer, plywood, composite wood, and paper and pulp industries.

Despite these advancements, there remains a significant gap between supply and demand in the solid timber sector. Local timber varieties that were once abundant are now scarce, with mango trees being the most readily available option. As a result, the industry heavily relies on imports to meet the demand. The conventional practice of long rotation periods for timber cultivation is not appealing to farmers and non-forest growers. They are seeking shorter rotation cycles of 8-12 years to maximize timber production.

To address this need for faster-growing timber species, C. hybrids have emerged as a promising solution. These hybrids offer the potential for accelerated growth, allowing for shorter rotation periods and increased timber availability. By adopting C. hybrids in the timber industry, India can bridge the gap between supply and demand, reduce reliance on imports, and meet the growing requirements of the construction and woodworking sectors.In this article, we will explore the potential of *C. hybrids* as a fast-growing timber species in India and discussed their suitability for addressing the country's timber needs. We will examine the characteristics and benefits of these hybrids, their adaptability to Indian climatic conditions, and their role in supporting sustainable timber production. By embracing *C. hybrids*, India can pave the way for a more self-sufficient and thriving timber industry that meets the demands of its growing economy and population.

Corymbia: A fast growing timber species

Corymbia citriodora (formerly known as *Eucalyptus citriodora*) and *C. torelliana* (formerly known as *E. torelliana*) are valuable tree species within the *Corymbia* genus that are utilized for timber, paper, and pulp production. These species offer fast growth rates, making them well-suited to meet the increasing demand for industrial wood in India. Despite their significance, many stakeholders in India remain unaware of these species due to their previous classification under the Eucalyptus genus. However, it is important to note that *Corymbia* has long been recognized as a distinct timber group, known as bloodwood gums and spotted gum wood. The recent clarification in taxonomy confirms that *Corymbia* is a distinct genus, separate from Eucalyptus, comprising 113 species.

C. citriodora is a tall tree that can reach heights of up to 51 meters and is native to temperate and tropical northeastern Australia. Its timber, commercially known as blue spotted gum or lemon-scented gum, is highly valued for structural purposes. On the other hand, *C. torelliana,* also known as blood-leaf gum, is naturally found in Australian rainforests and exhibits adaptability to various regions. It is a relatively short but stout tree, reaching heights of up to 30 meters. The

timber from this species, commercially known as Cadagi wood, is now grouped under the broader category of spotted gums.

In its native range, *C. citriodora* readily hybridizes with *C. torelliana,* resulting in hybrids that exhibit excellent growth rates. This led researchers to focus on tree improvement programs for *Corymbia* and conduct augmented plantations in eastern Australia. During the 1970s, the inter-specific hybridization program of this genus was initiated at the ICFRE-FRI, resulting in hybrids between *C. citriodora* and *C. torelliana*. These hybrids demonstrated outstanding growth, desirable stem form, and high-quality wood. However, the main challenge faced in realizing the benefits of hybrid vigor was the low rooting percentage, even in young seedlings.

The potential of *Corymbia* as a fast-growing timber species for meeting the demand for industrial wood in India is noteworthy. The ability to hybridize within the genus opens up opportunities for further improvement and expansion of *Corymbia* plantations. By raising awareness about these species and investing in research and development, India can harness the benefits of *Corymbia's* rapid growth and high-quality timber. This will contribute to meeting the country's industrial wood needs, reducing dependence on imports, and supporting sustainable timber production.

In 2010, a research project was initiated at ICFRE-FRI, focusing on clonal production of *Corymbia* hybrids through tissue culture (Figure 1). These hybrids were subjected to multi-locational field testing in block plantations, revealing their fast growth potential. In irrigated conditions, the hybrids achieved a girth of over 75 cm at breast height within 6-7 years (Figure 2), demonstrating their suitability for short rotation cycles. Notably, trees growing on bunds at farmers' fields exhibited even more encouraging growth, with some attaining a girth of 100 cm at breast height within 5 years (Figure 3).

A multilocation trial of clonal hybrids between *C. citriodora* and *C. torreliana,* along with local eucalypt clones (P23 and 413) as control, was established on forest department lands in Haryana and Uttarakhand. The results highlighted the excellent performance of a select few clonal hybrids in the trial. One particular hybrid showcased remarkable productivity, yielding 24 m3 of wood per year per hectare after four years (Figure 4). This not only surpassed the productivity of the local eucalypt clones (P23 and 413) but also exhibited superior stem quality.

These findings signify the tremendous potential of clonal hybrids in *Corymbia* species for achieving high productivity and superior wood quality. The success of these hybrids, as demonstrated in field trials, offers promising prospects for meeting the growing demand for industrial wood in India. Furthermore, it underlines the importance of further research and widespread adoption of these hybrids in commercial plantations to enhance the country's timber production and reduce reliance on imports.

Timber Quality

The Corymbia hybrids cultivated in India have demonstrated promising timber characteristics, including a shorter age of maturity. In a trial conducted at Bithmera (Haryana), where the hybrids were eleven years old, they exhibited a girth at breast height of 102 cm and a straight stem with a clear bole exceeding 13 m. To assess the wood quality, one of the trees was harvested, and the timber was allowed to air season. The resulting timber was found to be heavier than Eucalyptus, possessed good polishability, and was utilized to create beautiful furniture for the Bithmera guest house. Impressed by these outcomes, a comprehensive study was conducted to examine the mechanical properties of the hybrid wood. The wood properties of a 25-year-old Corymbia hybrid were assessed, revealing a wood density comparable to Dalbergia sissoo, Eucalyptus tereticornis, Terminalia tomentosa, and Acacia nilotica, with an average density of 0.71 g/cm^3 (Table 1). These findings highlight the favorable timber properties of Corymbia hybrids, further emphasizing their potential for commercial use in various applications. The wood's density and other desirable characteristics make it suitable for a wide range of purposes, including furniture making, construction, and other value-added wood products. By harnessing the timber potential of Corymbia hybrids, India can enhance its domestic wood supply, reduce reliance on imports, and promote sustainable and environmentally friendly forestry practices.

Table 1: Density of some common Indian timbers.

Spp	Density (g/cm^3)
Populusciliata	0.37
Melia dubia	0.39
Populus deltoides	0.40
Gmelina arborea	0.45
Tectona grandis	0.59
Mangifera indica	0.59
Eucalyptus camaldulensis	0.60
Eucalyptus hybrid	0.63
Dalbergia sissoo	0.70
Eucalyptus tereticornis	0.70
Corymbiahybrid	0.71
Terminalia tomentosa	0.73
Acacia nilotica	0.74
Shorearobusta	0.88

Wood Properties and Quality

The *Corymbia* hybrid exhibits notable radial and tangential shrinkage values of 7.74% and 9.64%, respectively, which are significantly higher compared to teak and mango woods. The T/R ratio for *Corymbia* is 1.25, lower than teak's T/R ratio of 1.49. A T/R value exceeding 2 indicates lower dimensional stability and requires careful seasoning. The relatively lower T/R ratio of *Corymbia* suggests that the timber poses fewer challenges during the seasoning process. Seasoning studies have shown the occurrence of smaller initial end cracks (1-5 mm) that may increase in size (up to 15-25 mm) during intermediate drying stages, accompanied by minor surface checks. However, these cracks do not pose significant issues regarding wood quality until the final drying stage. The drying process does not result in cross-sectional deformation or internal checks. Despite being a heavy timber, *Corymbia* wood exhibits favorable seasoning properties. A tentative kiln drying schedule has been developed, involving wet and dry bulb temperatures ranging from 45 °C and 43 °C for initial moisture content above 60% to 60 °C and 51 °C for moisture content below 20%. The heartwood of *Corymbia* has a slow preservative intake rate and is difficult to impregnate. In terms of mechanical properties, *Corymbia* demonstrates promising characteristics. The modulus of rupture (MoR) in the static bending test for *Corymbia* (895 kg/cm^2) is relatively higher than that of teak (841 kg/cm^2), shisham (795 kg/cm^2), and mango (435 kg/cm^2). Similarly, the modulus of elasticity (MoE) in the static bending test for *Corymbia* (80 x 103 kg/cm^2) is comparable to shisham wood (78 x 103 kg/cm^2) and higher than teak and mango woods. The maximum crushing stress at the elastic limit (compression parallel to the grain test) for *Corymbia* is 565 kg/cm^2, significantly higher than teak and other wood species. Notably, *Corymbia* exhibits outstanding hardness (747.5 kg in the radial direction and 758.5 kg in the tangential direction), making it a suitable alternative for flooring and decking applications. The working quality index for *Corymbia* is measured at 84.33. To assess the aesthetic and practical aspects of the wood, pieces were polished and furniture was created from the same lot. These samples were exhibited at the National Forest Library and Information Centre (NFLIC) in Dehradun (see Figures 5 and 6). The wood exhibited excellent polishing ability and maintained its attractive grain appearance even after wood turning. The end product showcases a lighter color and has received positive feedback from users.

Figure 1: Clonal multiplication of Corymbia hybrids using tissue culture

Figure 2: Growth of Corymbia hybrid after 6 years at Khadka, Hoshiarpur

Figure 3: Growth of Corymbia hybrid FRI CH -01 at Farmer's field (Buggawala, Uttarakhand)

Figure 4: Growth of Corymbia hybrid tissue cultures clone (FRI CH 01) after 5 years at ICFRE-FRI Dehradun.

Figure 5: Polishing of *Corymbia* wood with black stain, walnut stain, lac stain showing good grain (in order of top to bottom).

Figure 6: Furniture made from sawn wood of Corymbia hybrid being displayed at National Library and Information Centre at ICFRE- FRI, Dehradun.

Duabanga grandiflora – A Fast-Growing Tree Species for Sustainable Use

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Duabanga grandiflora is an evergreen tree from the family *Lythraceae*. Tropical deciduous forests in India possess a rich natural heritage, harboring a diverse range of timber species that can be harnessed sustainably and effectively. Among these species, *D.grandiflora*, commonly known as Lampati, stands out as a fast-growing tree with significant potential for timber utilization. This article aims to shed light on the attributes and benefits of *D. grandiflora*, promoting its wider adoption in various applications. With synonyms such as *Duabanga sonneratioides* Buch.-Ham., *Lagerstroemia grandiflor*a Roxb. ex DC., and *Leptospartian grandiflorum* (Roxb. ex DC.) Griff., this tree species holds promise for sustainable timber usage.

Distribution and Vernacular Names:

D. grandiflora is native to India (Assam), Thailand, Nepal, Malaysia, and Bogor. Its distribution encompasses Andaman Island, Assam, Bangladesh, Cambodia, China South-Central, East Himalaya, Laos, Malaya, Myanmar, Nepal, Thailand, Vietnam, and West Himalaya. The trees are distributed in moist and hilly areas at an elevation up to 1200 m. In India, it is commonly referred to as Lampati, which also serves as the standard trade name (IS 1150: 2000). The species carries numerous vernacular names across different regions, reflecting its significance and prevalence in local cultures.

Tree Characteristics:

D. grandiflora typically grows into medium to tall trees, reaching heights of 40 to 80 ft. The trunk is cylindrical, with a bole diameter that can extend up to 200 cm. Young trees feature horizontal branches arranged in whorls, while older trees often exhibit drooping or horizontal branches. The bark is light brown or grey, rough with vertical fissures that peel off in thin flakes, becoming thicker in mature trees. The leaves are rigid and distichous, with an ovate to oblong shape, pale green on the lower surface and dark green on the upper surface. The flowers, arranged in drooping corymbs at the ends of branches, emit an unpleasant odor. The species bears subglobose capsules and has numerous stamens that surpass the petals.

Agroforestry Potential and Future Considerations:

Despite its promising attributes, *D. grandiflora* has yet to be extensively studied and implemented in agroforestry practices. Ongoing work includes tree community studies involving *Duabanga grandiflora* to assess its role in tree assemblages and diversity patterns in tropical Juri forest, Bangladesh. Additionally, considering the tree's potential, it is crucial to undertake provenance trials, progeny trials, and explore tissue culture techniques to further understand and utilize its unique characteristics. By harnessing the potential of *D. grandiflora* and promoting its sustainable use, we can contribute to the conservation of tropical deciduous forests while meeting the growing demand for timber resources. The adoption of this fast-growing species has the potential to make a significant impact on the timber industry and promote a more sustainable future.

Fig. 1. Native distribution of *Duabanga grandiflora*.
Fig. 2. Tree of *D. grandiflora* showing bole and crown

Properties of *D. grandiflora* Wood Anatomical Characteristics:

The wood of *D. grandiflora* possesses distinct anatomical features. Notably, there is no differentiation into sapwood and heartwood in the studied samples. The wood is typically gray, often streaked or tinted with shades ranging from yellow to light brown. It can be categorized as soft to moderately hard and exhibits a wide range of density from very light to moderately heavy (specific gravity: 0.31-0.58 in air-dry conditions). The grain is usually straight or shallowly interlocked, and the texture is characterized as even and coarse.

Fig. 3. *Duabanga grandiflora* wood
Fig. 4. Cross section of *Duabanga grandiflora*

Gross Structure:

D. grandiflora wood is classified as diffuse-porous, with growth rings that are inconspicuous and most easily observed with the naked eye. These rings are delineated by slightly denser latewood fibers. The vessels in the wood are typically large to very large and can be seen without magnification. They are present in few to moderately few numbers (2-7 per mm2), evenly distributed throughout the wood. The majority of vessels appear solitary or in radial multiples of two, rarely more, and exhibit round to oval shapes. Some vessels may contain tyloses or be partially plugged. Vessel lines are clearly visible on the longitudinal surface. Parenchyma is observed as thin vasicentric sheaths around the pores. In some instances, it may enclose several vessels tangentially or obliquely. The rays in *D. grandiflora* wood are fine to very fine, only becoming distinct under magnification. They are closely spaced and evenly distributed.

Physical and Mechanical Properties

D. grandiflora wood is light yellow to light brown in color. The sapwood is not clearly demarcated. The grain can be straight or interlocked, while the texture is coarse. *D. grandiflora* wood is a low density wood. At a moisture content of 12%, the wood displays a density of 0.44 g/cm^3. The wood undergoes total tangential shrinkage (TS) of 6.7% and total radial shrinkage (RS) of 3.5%. The ratio of TS to RS is 1.9, and the fiber saturation point is 27%. Regarding mechanical properties, the average crushing strength is 39 MPa, static bending strength is 64 MPa, and the modulus of elasticity is 9.1 GPa (Tropix 7 database). The details of other mechanical properties of this wood sourced from West Bengal and tested in air dry condition are presented in the following table (Source: Indian Forest Record, Vol. XVIII).

Species	Std. SG	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
		MOR	MOE	Max. drop (cm)	MOE	Max. C stress	MOE	CS at E.L..	R	T	E	R	T	R	T
Teak	0.598	95.9	12534	68.6	16381	54.5	14017	9.7	5004	4959	4670	8.4	9.6	3.7	4.4
D. sonneratioides s	0.429	62.8	8735	55.6	10714	32.1	9873	3.5	2491	2980	3491	915	8.3	2.6	2.3

Processing and Durability Considerations:

D. grandiflora wood is non-refractory towards seasoning. It is easy to treat and easy to season wood. Kiln seasoning can be performed without any difficulty and without any defects and can be seasoned using schedule I as suggested by IS 1141 (1993). The wood with high moisture content is prone to staining, decay, and borer attacks. To mitigate these risks, it is recommended to perform green conversion and vertical stacking of the timber for a short period. While it is non-durable wood under exposed conditions, it performs well when used in covered environments. Graveyard tests conducted at FRI, Dehradun, yielded an average lifespan of 33 months, with a maximum of 50 months and a minimum of 20 months. In terms of insect and fungus attacks, observations included longhorn beetle (*Cerambycidae*) borers in dead wood, powder-post beetle (*Xylothrips flavipus*) borers in dead wood, and carpenter bee (*Xylocarpa sp.*) borers in constructional timber. To enhance its durability, treating the wood with preservatives is recommended, although it can be challenging to achieve effective treatment. However, some references suggest that *D. grandiflora* is not inherently susceptible to decay and does not require antiseptic treatment.

Working Qualities and Conclusion:

D. grandiflora exhibits excellent workability and can be easily sawn and worked to achieve a smooth finish with proper care. When cut off the quarter, it possesses a distinct ornamental appeal. The wood peels exceptionally well on a rotary lathe, making it suitable for producing clean and high-quality plywood sheets. While the wood may result in a fuzzy surface at times, the use of sharp tools and filling techniques can help achieve a good finish. However, the nailing property of *D. grandiflora* is poor.

Applications and Usage of D. grandiflora Wood

The physical, mechanical, chemical, and anatomical properties of *D. grandiflora* wood provide valuable insights into its potential applications and help in understanding its behavior in different uses and processing techniques. These characteristics contribute to the overall value and utilization of this fast-growing tree species. *D. grandiflora,* with its unique properties, finds diverse applications in various industries. Its utilization extends to furniture, fiber and particle boards, veneers for plywood, blockboards, floats, interior joinery, paneling, boxes and crates, molding, sliced veneer, pulp, and matches (Tropix 7 database). The timber is particularly suitable for planking and light packing cases, crates, and battens used in wooden packaging. Its lightweight nature makes it favorable for toy and delicate wooden jewel making, while its straight to slightly interlocked grain enhances workability for handicraft items. The species also offers excellent properties for shock absorbance applications. In the realm of composite wood and panel industries, D. grandiflora showcases desirable gluing and peeling characteristics, making it suitable for plywood, blockboard, and particleboard manufacturing. Its physical and mechanical properties demonstrate fair values for general-purpose panel products. It is approved for general-purpose plywood (Class II), face veneers for commercial blockboards, and flush door shutters. In conclusion, *D. grandiflora* holds significant potential for the wood-based industry. However, addressing the wood's durability through preservative treatments can further enhance its potential. Lastly, *D. grandiflora* exhibits potential for use in the pulpwood industry.

Givotia rottleriformis Griff. Ex Wight

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Scientific name: *Givotia rottleriformis* Griff. Ex Wight
Family : Euphorbiaceae

Vernacular names:
English : White catamaran tree
Marathi : Polki
Kannada : Polike, bellitalai
Telugu : Tellapoliki
Tamil : Kottaithanuku, Thaalamaram, VellaiPoothalai, Vendalai

***Fig 1. Givotia rottleriformis* tree**

Origin: The name "Givotia" is derived from an anagram of the surname of J.O. Voigt, who succeeded William Carey as the superintendent of the Serampore Botanical Garden in 1834. The genus was first described by Griffith in 1844 and is native to the Deccan Peninsula of India, represented by the species *Givotia rottleriformis Griff. Ex Wight* (Smith, 1968).

Distribution: *Givotia rottleriformis* is primarily native to India and Sri Lanka. Its distribution is limited and confined to specific regions in the following Indian states: Andhra Pradesh (Anantapur, Kurnool, and Kadapa districts), Tamil Nadu (deciduous forests), Telangana (Adilabad district), Kerala (Alampetty, Pothundy, Marayur, Chandiroor, Eramallur, Palakkad, Idukki, and Alappuzha districts), Karnataka (Bellary, Bagalkot, Belgaum, Bangalore, Bidar, Chamarajanagar, Vijayapura or Bijapur, Chikmagalur, Chitradurga, Chikkaballapura, Dakshina Kannada, Dharwad, Gadag, Davanagere, Kalaburagi or Gulbarga, Haveri, Hassan, Koppal, Kolar, Kodagu, Mysore, Mandya, Raichur, Shimoga, Ramanagara, Udupi, Tumkur, Uttar Kannada, and Yadgir), and West Bengal.

In addition to India, *Givotia rottleriformis* can also be found in small coastal regions of Sri Lanka.

Tree Characteristics:

Givotia rottleriformis is a deciduous tree with a semi-canopy covering. The leaves are simple, alternate, and broadly ovate with a long, glabrous petiole. They have a round shape with a narrow tip and coarsely toothed margins. The stems are weak, soft, and wooded, while the bark is smooth, brown, and peels off in circular thick scales, giving a blood-red sap when bruised. The tree produces dioecious flowers in sub-terminal pendulous panicles. Male flowers have five orbicular glands with 13-25 stamens crowded on a woolly receptacle, while female flowers have a stellate hairy ovary with 2-3 cells. The fruits are drupe-like, sub-globose/ ellipsoid, and fulvous-tomentose, with a diameter of 2-2.5 cm, and they ripen from May to June. The seeds are globose or ellipsoid in shape, with a bony testa, and yield oils suitable for lubricating fine machinery.

Growth Behavior and Seed Germination Potential:

Givotia rottleriformis belongs to the family Euphorbiaceae and is a moderately sized tree, reaching heights of about 15-20 meters

and a girth size of approximately 2 meters. The species exhibits medium competitiveness, fast growth, and high drought tolerance. Reproduction occurs through propagation techniques and direct sowing of seeds. Seed collection can be done from December to February, with around 387 seeds per kilogram. The seeds have a viability of about 6 months and a seed germination potential of approximately 43% under natural conditions. However, seed dormancy can pose challenges for propagation, and various methods like chilling, hot water treatment, scarification, and growth regulators have been attempted to enhance seed germination, with mechanical scarification showing the highest success rate.

Suitability under Agroforestry System:

Though separate documentation on the suitability of *Givotia rottleriformis* for agroforestry systems is yet to be reported. Its fast grown, medium competitiveness, and high drought tolerances have led to its planting in field borders and avenues. Considering its economic and medicinal importance and its semi-canopy covering characteristic, it is recommended for farmers to consider planting this species in their agroforestry systems.

Status of Tree Improvement:

Givotia rottleriformisis limited in distribution and is considered an endangered forest species. There is significant potential for improving its timber quality, but there is currently no documented report are available regarding a genetic improvement program for this species.

Physical, Mechanical, Chemical, and Anatomical Characteristics of Wood:

The physical properties of *Givotia rottleriformis* wood, including water absorption, density, volumetric swelling, and volumetric shrinkage, have been studied as per IS:1708 (1986). The recorded values are 391.6 kg/m^3 for density, 98.0% for water absorption, 5.2% for volumetric swelling, and 6.8% for volumetric shrinkage. These properties significantly influence the structural, mechanical, and wood-working qualities, thereby affecting its application in various industrial sectors. However, comprehensive documentation of the chemical and mechanical properties of this species is currently unavailable.

The wood of *Givotia rottleriformisis* characterized as diffuse porous with distinct to indistinct growth rings. Vessels are moderately large to small, mostly solitary, and occasionally found in short radial multiples. Parenchyma is diffuse to diffuse in aggregate, more distinct on moist surfaces, and visible under a hand lens. The medullary rays are fine, numerous, uniformly distributed, uniseriate square/upright ray cells, and closely spaced. The wood appears white when fresh and changes to grayish to yellowish-brown after exposure. It is very light with a specific gravity of 0.29-0.31, has a soft and lustrous texture, and displays a straight grain with a medium-coarse texture. Gross structural features of the wood, including cross-section, tangential longitudinal section, and radial longitudinal section, show oval-shaped vessels filled with tyloses and uniseriate rays.

Anatomical structure like cross-section (CS), tangential longitudinal section (TLS) and radial longitudinal section (RLS) of *G.rottleriformis* wood highlighted oval shaped vessel filled with tyloses and having uniseriate rays is shown in the Fig.2 A, B, & C.

Processing Considerations for *Givotia rottleriformis Griff. Ex Wight* Wood

1. **Seasoning:** The wood of *Givotia rottleriformis* is highly amenable to seasoning and the process is relatively straightforward. In the Kinnal cluster, where kiln drying machines are not readily available, the preferred method of seasoning is air drying. This simple technique allows the wood to reach an optimal moisture content for its intended application.
2. **Durability:** It is important to note that the wood of *Givotia rottleriformis* is naturally white in color, which may be considered an attractive feature for certain applications. However, this light hue is indicative of the wood's low content of natural wood extractives, leading to its reduced durability. As a result, the wood may be more susceptible to decay and damage over time when exposed to adverse environmental conditions. To enhance its longevity and protect it from decay, appropriate preservation treatments or

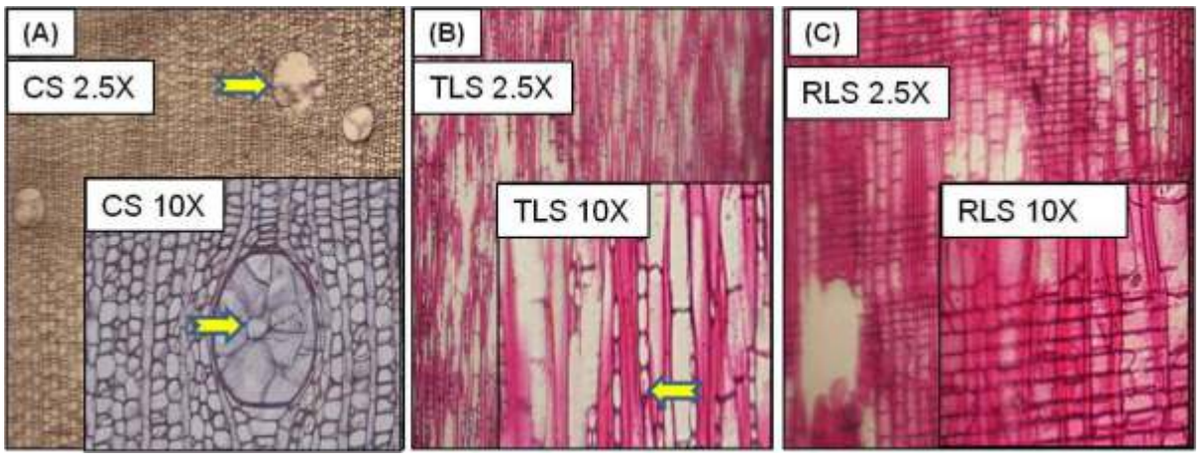

Fig. 2 Wood anatomy of *Givotiarottleriform* is visualized at 2.5X and 10X (A) cross section shows oval shaped vessel filled with tyloses (B) tangential longitudinal section shows uniseriate rays while (C) for radial longitudinal section (RLS)

coatings may be necessary, especially if used in exterior applications.

3. **Peeling and Veneering:** Unfortunately, there is currently limited information available regarding the peeling and veneering properties of this wood. Further research and testing would be beneficial to understand its behavior in these processes and explore its potential for use in veneer production.

Major Applications of *Givotia rottleriformis Griff. Ex Wight* Wood

The wood of *Givotia rottleriformis* finds its primary applications in the handicraft sector due to its unique properties. Being light and soft, it is highly favoured for various artistic and creative purposes. Some of the major applications of this wood are as follows:

1. **Handicrafts:** The wood is extensively used in the handicraft sector for creating a variety of items. In Mysore, it is used for crafting theatrical masks, while in Kondapalli (Andhra Pradesh), Nirmal (Telangana), and Kinnal (Karnataka) handicraft clusters, it is in high demand for making toys, carved figures, fancy articles, boxes, and lacquered items. In the Kinnal cluster, *Givotia rottleriformis* plays a significant role in the production of talking toys, (Fig 3) animal toys, idol's heads, religious idols, and vegetable baskets (Gowda et al., 2019).
2. **Catamarans:** In coastal areas of Madras, this species is commonly used for constructing catamarans, reflecting its suitability for watercraft due to its lightweight and buoyant properties.
3. **Carving:** The wood of *Givotia rottleriformisis* considered first-class for carving purposes. Its even grain and resistance to splitting or warping make it an ideal choice for intricate carving work. Additionally, the wood's surface easily takes paint, enhancing its artistic value.

Apart from the handicraft sector and catamaran construction, there are currently no documented reports regarding its applications in other sectors. However, its unique characteristics and suitability for creative work make it a sought-after material for artistic endeavours and traditional crafts.

In summary, the wood of *Givotia rottleriformisis* easy to season, but its natural whiteness may indicate lower durability. Additional research is needed to assess its peeling and veneering properties, which could potentially open up new avenues for its utilization in various industries. As with any wood species, proper treatment and maintenance are crucial to ensure its longevity and performance in specific applications.

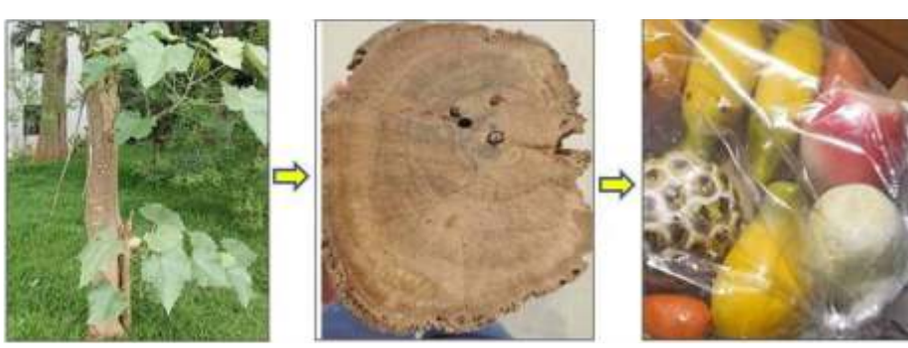

Fig.3 Talking toys made up of Givotia rottleriformis wood.

Gmelina arborea

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INTRODUCTION

Gmelina arborea, commonly known as Gamhar, is a significant tree species belonging to the family Lamiaceae (Syn. Verbenaceae). It holds various local names such as Gamhar, Khamer, Gambhari (in Hindi), Shevan (Gujurati), Shivanimara (Kannada), Gummadi, Gumartek (Telugu), Kumil (Tamil), Kumbil (Malayalam), Gomari (Assamese), Wang (Manipuri), Thlanvawng (Mizo), Imbehching (Naga), and White teak (English). It is naturally found in the tropical and subtropical regions of Southeast Asia, including countries like Bangladesh, Cambodia, China, India, Laos, Myanmar, Philippines, Nepal, (west) Pakistan, Sri Lanka, Thailand, and Vietnam (Dvorak 2004). Additionally, it has been introduced as a plantation species outside its native forest habitats (Naik et al., 2009). In India, it is widely distributed across the Eastern sub-Himalayan tracts, Indo-Gangetic plains, Aravali Hills, Central India, Western Peninsula, and Western Himalayas, often found in dry deciduous and moist deciduous forests, and occasionally in evergreen forests.

Tree characteristics:

Gmelina arborea is a light-demanding species, capable of tolerating drought conditions, but sensitive to waterlogging. It exhibits vigorous coppicing and enriches soil nutrients. The tree thrives in moist fertile soil, while it remains stunted on ill-drained, dry, sandy, or poor soils. It grows to a medium to large size, reaching heights of up to 35 meters with a girth ranging from 1.4 meters to 3.0 meters, often presenting multiple large stems (Wee et al., 2011). In its juvenile phase, the tree exhibits smooth, whitish-grey to yellow-grey bark, while the bark darkens and develops white mottling as it matures (Dvorak 2004). The blaze is thick, with a chlorophyll layer just beneath the outer bark. The species is known for its rapid growth rate, reaching up to 40-50 m^3/ha/year in regions with favorable soil and rainfall conditions (Zeaser, D., 1998). It typically thrives in areas with mean annual temperatures of 20-28°C and mean annual rainfall ranging from 750-4500 mm.

Leaf and Fruit Characteristics: The leaves of *Gmelina arborea* are arranged opposite-decussate and possess ovate leaf blades. The fruit is a drupe that appears glossy and yellow when ripened. The flowers are scented and can be reddish, brown, or yellow in color.

***Gmelina arborea* tree**

Stability under agroforestry system:

Gmelina arborea (G. arborea) has gained popularity for cultivation in small woodlots, home gardens, and agroforestry systems across tropical and subtropical regions (Verma et al., 2018). Its adaptability and versatile growth characteristics make it suitable for cultivation alongside various agricultural crops in

different parts of the country. In Tamil Nadu, *G. arborea* is commonly integrated into agroforestry models, such as *Gmelina* with groundnut, watermelon, pulses, maize, coconut, banana, and pepper (Mayavel et al., 2014). Swamy and Puri (2005) successfully cultivated G. arborea in combination with soybean and cowpea during the rainy season, and wheat and mustard during the winter season.

Agroforestry practices involving *G. arborea* have been found to contribute positively to carbon storage in the soil. After five years of planting, carbon storage increased by 13% and 34% in agrisilviculture systems and pure plantations, respectively (Mayavel et al., 2014). Additionally, intercropping *G. arborea* with other crops has shown promising results. For instance, in a study by Vanlalngurzauva et al. (2010), intercropping *G. arborea* with rice, cowpea, groundnut, and black gram yielded impressive results. When intercropped with black gram, *G. arborea* showed a tree height of 8.35 meters, diameter at breast height of 16.78 cm, and volume yield of 5.27 m^3/ha per year. Similarly, when intercropped with rice, it exhibited a tree height of 7.34 meters, diameter at breast height of 15.70 cm, and volume yield of 4.22 m^3/ha per year.

These agroforestry practices not only provide economic benefits but also contribute to sustainable land use and improved environmental conditions. By integrating *G. arborea* with various agricultural crops, farmers can optimize land utilization, diversify income streams, and promote ecological balance in the agroecosystem. The stability of *G. arborea* in agroforestry systems highlights its potential as a valuable component in sustainable farming practices.

Status of Tree Improvement and Pest Management in *Gmelina arborea*:

Tree Improvement: The tree improvement program for *Gmelina arborea* was initiated in India in the early 1990s. Kumar et al. (2003) selected a total of 119 plus trees from West Bengal and different Northeastern states using the point grading method of selection. The selected plus trees were chosen based on criteria such as growth superiority, clear bole height, girth at breast height, tree spread, and apical dominance. Among the states, Assam, Arunachal Pradesh, Mizoram, and West Bengal had

G. arborea based agroforestry system with coconut

38, 38, 18, and 25 plus trees selected, respectively. Trees selected from Mizoram showed the highest improvement in clear bole height (67.28%) and girth at breast height (31.52%), while trees from Arunachal Pradesh exhibited the highest improvement in height (22.74%). Progeny trials of 60 accessions were established at Kuruvampatty, Salem RF, and Thuvarankurichi, Trichy. Improved accessions and seeds from the clonal seed orchard are available at the Rain Forest Research Institute, Jorhat, and superior CPT seeds are available at IFGTB, Coimbatore. Clonal trials of *G. arborea* established at RFRI experimental station and Imphal, Manipur, were also evaluated for their performance, resulting in the selection of 24 promising clones based on their performance. However, seven clones were identified as moderately less resistant to the pest defoliator *Calopeplaleayana.*

Pest and Diseases in *G. arborea* Plantations: *Gmelina arborea* is susceptible to insect attacks and diseases. A survey conducted by the Tropical Forest Research Institute (TFRI), Jabalpur, in *G. arborea* plantations in Madhya Pradesh and Chhattisgarh found that approximately 81.1% of trees showed low to heavy infestation (36.8% with low infestation, 29.9% with medium, and 14.5% with heavy infestation), while only 18.9% of trees were recorded

as healthy without any infection. The major insect pests identified were *Tingis beesonii* and *Indarbella quadrinotata*, while the major fungi species associated with tree mortality were *Hendersonula, Hexagonia, Hypoxylon,* and *Torula*. To manage major defoliators of *G. arborea*, the Rain Forest Research Institute (RFRI), Jorhat, conducted research on entomo pathogenic fungi. The fungi *Beauveria bassiana* and *Metarhizium anisopliae* were found to be very effective in controlling the pests, with efficacy rates of 100% and 80%, respectively, after a 7-day period. These efforts in pest management aim to ensure the health and vitality of *G. arborea* plantations.

Anatomical, physical and mechanical properties wood:

The fresh wood of *Gmelina arborea* exhibits a pale yellowish to creamy color, which darkens to yellowish-brown upon exposure to air. It is characterized as light to moderately heavy, with a specific gravity in air dry conditions ranging from 0.39 to 0.66. The wood typically displays straight to irregular grain patterns and possesses a medium coarse texture, giving it a lustrous appearance in its fresh condition.

Anatomically, the wood of *Gmelina arborea* is diffuse porous, but it may sometimes show a tendency towards semi-ring porosity. The vessels are mostly solitary, but they can also occur in radial clusters. They are large to moderately large and often feature heavy deposition of tyloses. Parenchyma is found in thin or thick sheaths around the vessels, while the rays are widely spaced, uniformly distributed, and moderately broad (Purkayastha, S. K., 1985). Photomicrographs in Figure 1 illustrate the anatomical structure of *Gmelina arborea* wood in cross-section, tangential longitudinal section (TLS), and radial longitudinal section (RLS).

Logs and Planks of *G. arborea*

Tables 1 and 2 provide information on selected physical and mechanical properties of *G. arborea* wood from different locations, specifically Haldwani, India, and Insein, Myanmar, respectively in comparison to Teak (*Tectona grandis*). Based on these properties, the wood can be classified as light to moderately heavy, soft to moderately hard, and moderately strong timber.

Overall, *Gmelina arborea* wood possesses favorable properties, making it suitable for various applications in the timber industry. Its attractive color and moderate strength make it a popular choice for diverse uses, ranging from furniture making to construction and handicrafts.

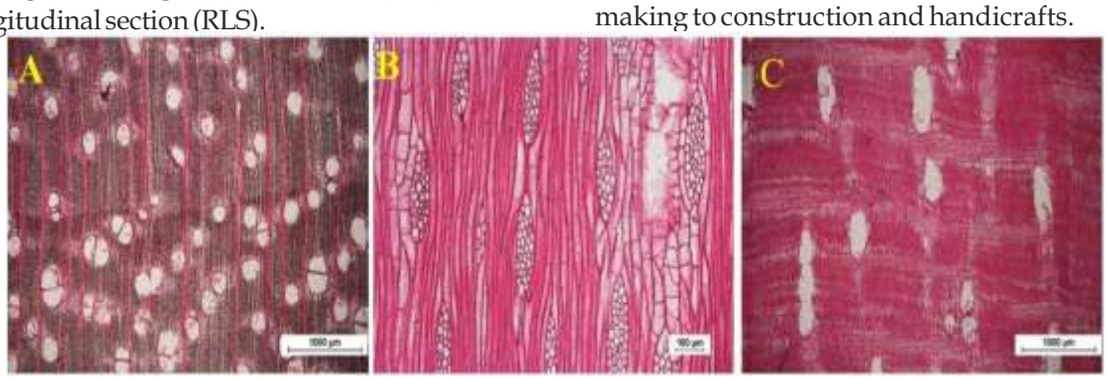

Figure 1. Anatomical structure of *Gmelina arborea*: - A: Cross-section, B:- Tangential longitudinal section (TLS), C:- Radial longitudinal section (RLS)

Table 1. Physical properties of *G. arborea* wood (Source: Indian Forest Record XVIII)

Location	Condition	SG based on OD weight and		MC at test	Shrinkage % green to oven dry		
		Vol. at test	Vol at O.D.		R	T	V
Haldwani (India)	G	0.445	0.481	144.5	2.7	4.8	8.8
	AR	0.447		14.2	-	-	-
Insein (Burma)	G	0.419	0.445	151.2	2.4	4.9	8.8
	AR	0.432		12.1	-	-	-

Table 2. Mechanical properties of *G. arborea* wood(Source: Indian Forest Record XVIII)

Species	Location	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
		MOR	MOE	Max. drop (inch)	MOE	Max.C stress	MOE	CS at E.L..	R	T	E	R	T	R	T
Teak	Burma and Malabar	95.9	12534	27	1638	54.5	14017	9.7	5004	4959	4670	8.4	9.6	3.7	4.4
`Gamhar	Haldwani (U.K.)	52.2	7377	19	11335	24.0	7157	4.6	2402	2669	3069	7.4	6.9	4.2	4.8
Gamhar	Insein (Burma)	64.6	8874	21	12755	33.4	8949	4.7	2180	2491	2335	7.2	7.2	3.3	2.9

Drying behaviour and treatability: *Gmelina arborea* timber is moderately refractory (Class-B) during seasoning and can be satisfactorily dried following schedule III (IS-1141-1993). While the wood can be seasoned without significant degradation of the surface, such as cracking, splitting, or warping, it does require a considerable amount of time to dry. Kiln seasoning takes around 8-10 days without causing cracking or splitting in plain swan (tangential) planks, but quarter sawn (radial) planks dry at a much slower rate. The heartwood is highly refractory to preservative treatment, with low penetration of preservative chemicals (Class-e, IS-401-2001). However, the heartwood has been reported to have Class-I durability, indicating its natural resistance to decay.

Major uses with special emphasis on wood: *Gmelina arborea* holds immense potential for its timber and medicinal value. The wood finds applications in various industries, including pulp and paper manufacturing, medium-density fiberboard (MDF), laminated veneer lumber (LVL), particle board production, furniture making, plywood interiors, finger-jointed lumber, door paneling, moldings, pallets, pencils, and matchsticks. Its fast growth and large leaves also make it a popular choice for ornamental tree planting. Moreover, *Gmelina arborea* is highly favored for carving and is used in crafting musical instruments. Additionally, the leaves serve as fodder and are used in silkworm rearing. The root of the tree holds medicinal significance and is a key ingredient in the Ayurvedic medicinal preparation called "Dasamool." Furthermore, the species is utilized for providing shade and as animal fodder.

Grevillea robusta

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INTRODUCTION

Grevillea robusta, commonly known as Silver Oak, is a versatile and highly valued tree in southern parts of India. Originally grown as a shade tree for tea and coffee plantations, it has now gained popularity in agroforestry. Silver Oak provides timber, poles, and firewood, while its unique leaves effectively filter light and offer shade during dry months. With its resilience against pests and diseases, deep roots, and suitability as a windbreak, it has become a preferred species in tea plantations. The timber exhibits desirable properties for paneling, joinery, and cabinet making. Silver Oak shows great potential for use in various wood-based industries, such as plywood manufacturing and medium-density fiberboard production.

Scientific and Vernacular name: Scientific name: *Grevillea robusta* **Common names:** Khadaw, khadaw (Burmese); Grevillea, river oak, silk oak, silk-oak grevillea, silky oak, silver oak, southern silky oak (English);Chêne, d'Australie, Grevilléerobusra (French); Australisch (German); Salamander (Indonesian); Agravilla, grevilea, helecho, roble australiano, roble de seda, roble plateado (Spanish); Savukkumaram (Tamil); Bahekar, Bekkar (Urdu)

Silver Oak, or *Grevillea robusta,* is highly regarded in southern India as a shade tree for tea and coffee plantations. However, its popularity has extended beyond these regions, finding widespread recognition in warm temperate, subtropical, and tropical highlands worldwide. In the context of tea plantations, Silver Oak has emerged as the preferred shade tree species. Its unique leaves effectively filter light, providing ample shade during dry months. Furthermore, the tree's deep roots ensure it doesn't compete with tea plants for nutrients and moisture. With its rapid growth, immunity to common pests and diseases, and potential as windbreaks, Silver Oak offers multiple advantages. It is a deciduous tree of medium to large size, reaching heights of 12-25 meters (and occasionally up to 40 meters). Its conical crown boasts dense foliage, featuring fernlike, pinnately compound leaves measuring 15-30 cm in length. Showy yellowish flowers, arranged in numerous pairs on long slender stalks, adorn the tree. These flowers consist of four narrow yellow or orange sepals, each 12 mm long, and form unbranched clusters 7.5-15 cm in length, predominantly emerging from the trunk. The

tree produces podlike fruits that are slightly flattened, broad, and approximately 2 cm long.

Grevillea robusta's agroforestry potential extends beyond shade provision. It offers valuable timber, poles, firewood, and leaf mulch, making it a highly versatile resource. Furthermore, the tree's easy propagation and management further contribute to its desirability for agricultural purposes.

Physical, Mechanical, Chemical, and Anatomical Characterization:

Grevillea robusta exhibits specific physical,

mechanical, and anatomical properties that contribute to its suitability for different applications. The wood has a basic density of 0.56 g/cm^3 and an air-dry density of 0.61 g/cm3. It shows a tangential shrinkage of 9.6% and radial shrinkage of 3.1% from green to oven dry condition. The dimensional stability ratio, calculated as the total tangential shrinkage percentage divided by the total radial shrinkage percentage, is 3.09. Additionally, the wood exhibits a bending strength (MOR) of 77.5MPa, a stiffness (MOE) of 10.5 GPa, a compression parallel to grain of 45 MPa, a radial shear strength of 11.5 MPa and a Janka hardness (side) of 3707 N at 12% moisture content.

Durability:

Timber durability of Silver Oak has been extensively studied in different age groups and regions of Karnataka. Tests conducted under laboratory conditions assessed the resistance of timber against brown and white rot fungi, as well as termite exposure in soil burial. Results indicated that timber from all age groups in both wet and dry regions fell within the resistant to moderately resistant class against decay fungi. However, timber from 5-year-old trees showed complete destruction by termites within 4 years of exposure in test yards. In contrast, 10, 15, and 20-year-old timber samples demonstrated good resistance (80-100%) against termites for up to 3 years of exposure. Notably, the susceptibility to termite attack reduced with increasing age, and timber from high rainfall areas exhibited higher vulnerability compared to that from low rainfall areas.

Major Applications and Wood Characteristics:

The wood of Silver Oak is renowned for its strength, silky texture, lightness, and ease of splitting. It possesses durability but exhibits porosity. These qualities make it suitable for various applications, including paneling, joinery, and cabinet making. Silver Oak timber finds specific usage in packaging and concrete shuttering. To address the tendency of the wood to develop warp and other defects during sawing and drying, the SDR (Saw-Dry-Rip) method of sawing can be effectively employed.

Potential Scope for Wood-Based Industries:

Given the growing demand-supply gap and rising costs of timber, the scarcity of traditional species has led wood-based industries to utilize locally available plantation timbers. In this context, Silver Oak has emerged as a widely used resource. Studies have shown that peeling Silver Oak logs with a girth above 1.3 meters can yield type-B surface veneers and good-quality core veneers. Face veneer type-A can also be produced to some extent, albeit with lower recovery, resulting in clear veneers with a uniform texture and color. Panel industries in the southern part of India extensively employ Silver Oak in plywood manufacturing, primarily as a core and commercial face veneer. However, a few industries utilize it as a decorative face veneer by slicing Silver Oak flitches. Furthermore, Silver Oak fibers have demonstrated potential as raw materials for the production of Medium Density Fiberboard (MDF). These findings highlight the durability, versatility, and potential applications of Grevillea robusta, positioning it as a valuable resource for various wood-based industries.

Decorative Sliced FaceVeneer

Plywood with Silver Oak commercial face veneer.

Grewia optiva J.R.Drumm. ex Burret

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Scientific Name : *Grewiaoptiva* J.R.Drumm. ex Burret

Family : Malvaceae

Common Name : Bhimal, *biul, Beul, bhiunal, dhaman, Bihul biung, bhengal, bewal,* behel,

Nepali (shyalphusro, phusre, ghotli, Bhimal);

Grewia optiva **tree**

INTRODUCTION:

Grewia optiva J.R.Drumm. ex Burret, commonly known as Bihul, is a deciduous tree native to the Indian Subcontinent, specifically the foothills of the Himalayas. This article presents a comprehensive account of its distribution, growth behavior, and significance in agroforestry systems. Its wood properties, diverse applications, and medicinal value are discussed, emphasizing its importance in providing edible fruits, fiber, and nutritious fodder.

Distribution and Growth Behaviour:

Grewia optiva thrives in subtropical climates, ranging from -2°C to 38°C in day temperatures, with dry summers and autumns. The tree is commonly found in and around villages, along roadsides, and on the foothills of the Western Himalayas at elevations up to 1,800 meters. It prefers well-drained moist sandy loam soils but can adapt to various soil types. *Grewia optiva* exhibits flowering and fruiting from April to December, with mature fruits ripening between October and December. Ripe fruits are highly favored by birds, acting as the major dispersal agent for seeds.

Suitability under Agroforestry Systems:

Grewia optiva is an important species for agroforestry, providing various benefits such as leaf fodder, fiber, and fuelwood. It is typically planted in block or single-row arrangements along fields and requires complete overhead light for optimal growth. The tree demonstrates excellent pollarding and coppicing capabilities, with annual lopping of whippy branches for fodder and fiber. Seeds have good viability and can be stored for up to a year. Its role in agroforestry includes use in hedges, boundary trees, and intercropping, making it a valuable component of sustainable farming practices. Planting is done in July in pits dug in summer or at the beginning of the rainy season. Spacing is at 3 x 3 m for block planting and 4-5 m for single row planting along the fields. Plantation area should be protected against browsing, grazing and fire. The tree requires complete overhead light for optimum growth. Severe frost causes die back in seedlings. The tree pollards and coppices well, whippy branches are lopped yearly for fodder and fibre. There are 10 000 - 15 000 seeds/kg which can be stored for at least 1 year in the open without loss of viability. Fruits are rubbed and washed in water to remove the flesh. Each fruit contains 2-4 seeds. *Grewia optiva* is considered a good forage, particularly valuable during winter when no other green fodder is available.

Showing the (a) *Grewia optiva* tree(b) fibres extracted from *Grewia optiva* Ref. [Thakur, et al. 2014].

Green leaves represent about 70 % of the total green weight of branches. They have highest protein content when they are young and during winter and then lose their nutritive value during the rainy season [Orwa et al., 2009]. The plant yields an edible fruit, a fibre and a useful timber, and is usually gathered from the wild though it is sometimes cultivated in the Himalayas. It is often grown as a hedge plant along roadsides in the Himalayas. Fodder yield is variable, ranging from 2.95 to 11 t/ha of fresh fodder ha from 2-year-old plants [Mehta et al., 2011; Orwa et al., 2009]. The tree is often grown in agroforestry in the Himalayas, where it is used in hedges, as a boundary tree and in intercropping.

Physical, Mechanical, chemical and anatomical characterization of wood

The specific species data is untraceable, however, suitability indices of some other species of this genus such as *Grewia tiliaefolia, Grewia vestita, Grewia elasticadatas* are listed below in comparison to Teak taken as 100.

	Specific Gravity	Strength	Stiffness	Shear	Hardness	Screw Withdrawal	Nail Withdrawal
(Teak)	0.598	100	100	100	100	100	100
Grewiatiliaefolia (dhaman)	-	110	120	140	155	140	110
Grewiavestita	0.651	116	125	120	144	-	-
Grewiaelastica	0.679	108	100	107	149	-	-

Source: Suitability indices in terms of Teak [ITU, 2017]

Among the fiber-yielding species in Garhwal Himalaya, *Grewia optiva* is an important tree that yields fiber and used by villagers for several traditional purposes.

Wood Utilization:

The wood is whitish with reddish-brown heartwood, fine-textured, tough, strong, and elastic. While it is generally not preferred for fuel due to its unpleasant odour, it is used for various purposes such as oar shafts, poles, frames, and tool handles that require strength and elasticity. The bark yields a fiber used in paper and rope making, although it is not highly durable. Additionally, the sap of the bark is utilized as a natural shampoo, further demonstrating its versatility and significance in traditional practices.

Figure : *Grewia optiva* fiber sample from different altitudes.

Grewia optiva plays a significant role as a boundary tree and hedge plant along field peripheries, serving as an effective barrier and support system. Moreover, its widespread cultivation helps in checking soil erosion, making it an invaluable resource for sustainable land management in the region. The tree is also employed in intercropping, particularly in combination with climax grass, promoting agroforestry practices and enhancing overall farm productivity.

Processing Issues: The wood of *Grewia optiva* is

whitish with reddish-brown heartwood, weighing 801 kg/cu. m. Although the timber is heavy, fine-textured, and relatively easy to saw when green, it becomes hard and challenging to work with after seasoning. Additionally, the wood possesses an unpleasant odor, making it less suitable for firewood purposes. These characteristics necessitate careful processing and handling to optimize its usability.

Potential Scope as Raw Material for Industries: The bark of *Grewia optiva* yields a valuable fiber used in cordage and clothing. Recent studies have demonstrated the immense potential of *Grewia optiva* fiber for industrial applications, particularly in the development of fiber-reinforced composites. This potential opens up new avenues for manufacturing different industrial components, promoting the use of green and sustainable materials in various industries.

CONCLUSION:

Grewia optiva J.R.Drumm. ex Burret, offers a range of services in agroforestry, serving as an effective boundary tree, soil erosion control measure, and a valuable component in intercropping systems. Its wood properties and processing challenges underline the need for careful handling and utilization. However, the tree's bark fiber exhibits immense potential for industrial applications, particularly in the development of sustainable and eco-friendly fiber-reinforced composites. Understanding and harnessing the potential of *Grewiaoptiva* can contribute to sustainable land management and the development of green materials for various industries.

Ridsdale *Haldina cordifolia* (Roxb.)

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INTRODUCTION

Haldina cordifolia, commonly known as the Haldu, is a deciduous tree native to the Indian subcontinent and parts of Southeast Asia. It is revered for its cultural significance and has various uses: It is a member of the Rubiaceae family, is commonly known as Haldu, Yellow teak, Saffron teak, Turmeric wood, Manjakadambai (in Tamil), and Bahuphala (in Sanskrit). This versatile flowering plant holds cultural significance and has various regional names. Despite its various uses, the Haldu tree is facing challenges due to habitat loss and overexploitation. Sustainable management and conservation efforts are essential to protect this valuable species and ensure its continued contributions to society and the environment.

Scientific Name : *Haldina cordifolia* (Roxb.) Ridsdale
Family : Rubiaceae
Common name : Haldu

Synonyms
- *Adina cordifolia* (Roxb.) Brandis,
- *Nauclea cordifolia* Roxb.
- *Nauclea sterculiifolia* A.Rich. ex DC

Vernacular name:

Assamese : Lampatia, Tarak chapa
Bengali : Keli-kadam, Dakom, Petpuria
Burmese : Hnaw
Garo : Sandang
(Meghalaya, Assam, and Tripura)
Gujarati : Haladwan
Guji (Ethiopia) : Haladwan, Holdarvo
Hindi : Hardu, Haldu,
Karam Tree of *Haldina cordifolia*
Kannada : Kadambe, Anavu, Arsintega, Yettega
Kuki
(Sino-Tibetan) : Ting-khop-thing
Malayalam : Manjakadamba
Marathi : Heddi, Heddu Honangi Kalamb
Nepali : Karam
Punjabi : Haldu
Tamil : Manjakadambai, Pumpadari,
Telugu : Bandaru, Dodaga, Dadduga,

Tree of *Haldina cordifolia*

Distribution and Habitat: *Haldina cordifolia* is native to southern Asia, ranging from India to China, Vietnam, and Peninsular Malaysia. It can be found across different states in India, including Andhra Pradesh, Karnataka, Kerala, Odisha, Tamil Nadu, and West Bengal. The species is also distributed in Myanmar, Sri Lanka, China, Vietnam, Thailand, and Bangladesh.

Tree Characteristics: *Haldina cordifolia* is a large deciduous tree that typically reaches a height of 14 to 20 meters, although under favorable conditions, it can grow over 30 meters tall. The leaves are broadly oval or circular, with a heart-shaped base and an acute apex. The young leaves may have a slight hairiness and appear green or tinged with red or pink. The tree produces small, yellowish flowers that form balls around 2-3 cm in diameter. After shedding its leaves around February, the tree remains leafless until May-June when the stipules covering the buds become conspicuous. The flower balls are at their best from June to August.

Environmental Requirements: Haldu thrives in elevations up to 1,000 meters, and its ideal daytime temperatures range from 25°C to 35°C. The tree is

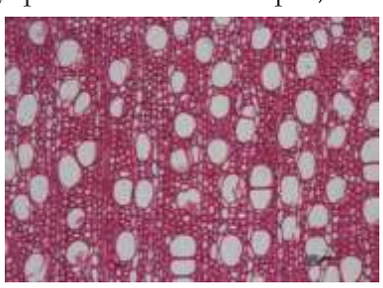
tolerant of temperatures between 5°C to 47°C but cannot survive temperatures of -1°C or lower. It prefers an annual rainfall between 1,000 to 2,000mm but can tolerate a range of 800 to 4,500mm.

Economic Significance Haldu holds immense economic value as an important timber tree. It prefers well-drained soil with a pH range of 5.5 to 6.5 but can tolerate soils with pH values up to 8.3. The tree is known for its massive root system, making it highly resistant to drought conditions.

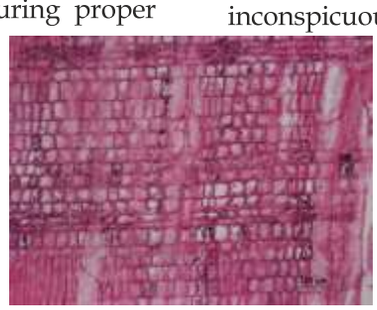
Seed Collection and Germination: The tree sheds its seeds between April and June, and wind carries them over considerable distances. Successful germination requires the seeds to fall on bare ground, such as alluvial soil near rivers or abandoned cultivation areas. The young seedlings benefit from shade initially, but as they mature, they become more light demanding.

Propagation and Field Planting: To propagate Haldu, poly-potted seedlings are nurtured in nurseries for 5-6 months before field planting. The seedlings are then carefully planted in suitable pits, ensuring proper terracing to avoid water stagnation. Around 70% of the field-planted seedlings survive the initial three months, but protection from drought is crucial for their survival. Within eight months, the seedlings can grow to a height of 16.7 cm in the field. Haldu stands out as a prominent timber tree in southern Asia, playing a significant role in the region's biodiversity and economy. Understanding its environmental requirements and propagation techniques is essential for effective conservation and sustainable management. The tree's cultural significance adds to its value and underscores the importance of preserving this species for future generations.

Structure of the Wood: Haldu exhibits a diffuse-porous wood structure with generally inconspicuous growth rings. Vessels are small to very small and appear angular at higher magnifications. They are evenly distributed and form fine vessel lines along the grain. Parenchyma is sparse and mostly restricted to cells contiguous to the tangential walls of vessels. Fibers are non-libriform, coarse, and aligned in radial rows, interrupted by parenchyma cells. Rays are very fine, numerous, and closely spaced, forming inconspicuous flecks on the radial surface.



Cross Section



Radial Section

Tangential section

Wood Properties: The wood of Haldu is moderately heavy, with an average weight of 503.0 to 663.5 kg/m³ at 12% moisture content. It has a fine texture and straight grain. The sapwood is pale yellowish or yellowish-white, while the heartwood is deep yellow, turning reddish or brownish on exposure. The specific gravity is 0.70 at 12% moisture content. It is moderately strong, about 10% harder than teak, and has good working qualities. The mechanical properties of Haldu wood (in air dry condition) sourced from southern India in comparison to standard Teak is presented in the following table.

Species	Std. SG	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at E.L..	R	T	E	R	T	R	T
Teak	0.598	95.9	12534	27	16382	54.5	14017	9.7	5004	4959	4670	8.4	9.8	3.7	4.4
Haldu	0.516	91.9	11762	23	13265	56.9	11480	8.5	3825	5182	6049	7.9	8.6	3.2	4.2

Seasoning and Preservative Treatment: The wood can be seasoned through both air drying and kiln drying. Kiln-seasoned stock retains its brightness better than air-seasoned timber. Halduis not durable in contact with the ground or exposed conditions, but it is durable under cover. Freshly converted and seasoned timber does not stain or discolor, but it may be susceptible to insect and fungus attacks.

Utilization: Haldu is a highly versatile timber with numerous applications. It is prized for turnery and carving work and is used in class I plywood, folding chairs, camp furniture, and household fitments. The wood's moderate strength and good polish make it suitable for interior use and various items such as canoes, packing cases, cigar boxes, furniture, toys, brush handles, agricultural implements, carving, and picture frames. It is especially in demand for making high-quality combs and bobbins. Additionally, Haldufinds use in flooring, paneling, railway carriages, and for pulp and paper production. It is also suitable for pencil manufacturing and veneering. Haldina cordifolia, with its distinct wood structure and a wide range of applications, is a valuable and sought-after timber species. Its utilization in various industries, from woodworking to furniture and crafts, highlights its economic and cultural significance. Understanding the wood properties and working qualities of this species is essential for maximizing its potential in sustainable forestry and promoting its conservation and responsible use.

Medicinal Uses: The therapeutic potential of Haldu extends to its leaves, bark, and roots. Extracts from different parts of the tree have shown significant antioxidant, antibacterial, anti-cancer, anti-diabetic, and hepatoprotective properties. These attributes make it a valuable resource for traditional Indian medicine, with applications ranging from treating fever, cold, and cough to addressing stomach ailments and inflammation.

Door and Windows

Research Initiatives and Future Prospects: Efforts to harness the higher wood productivity potential of Haldu is underway through collaboration between the Institute of Forest Genetics and Tree Breeding and the Tropical Forest Research Institute. The establishment of introduction trials and research projects signifies the growing interest in promoting the commercial plantation of this valuable tree across India.

CONCLUSION:

Haldu stands as a tree of immense significance due to its dual attributes of versatile timber and therapeutic value. Its wood has been widely utilized in various industries, while its traditional medicinal uses continue to find relevance in modern healthcare practices. Promoting commercial plantations of Haldu is essential to ensure its sustainable utilization and reap the economic and public health benefits it offers. Researchers and policymakers must collaborate to explore the full potential of this remarkable plant for the greater good.

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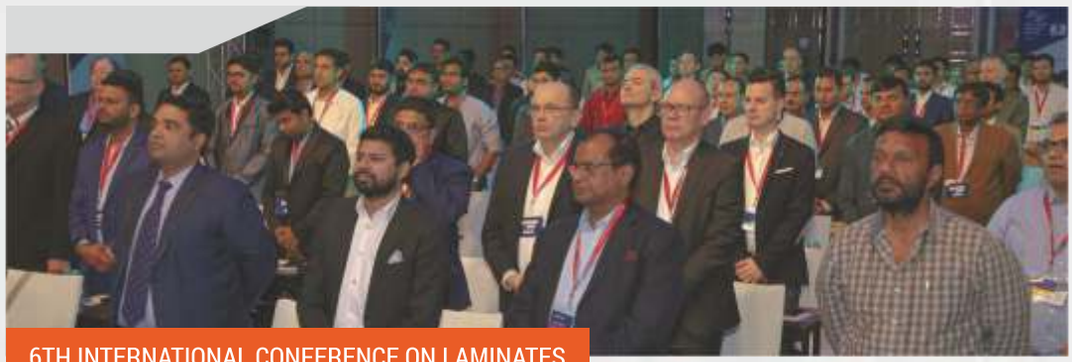
INDIAN LAMINATE MANUFACTURERS ASSOCIATION

ILMA



6TH INTERNATIONAL CONFERENCE ON LAMINATES

Strength of Unity

Indian Laminate Manufacturers Association (ILMA) is nonprofit making organization of manufacturers of Decorative and Compact laminates or high pressure laminates, Particle Boards, Plywood and Pre-lam (Short Cycle Laminates). It is the only registered association of the laminate industry at national level and we are proud to complete 20years since 1998. More than140 manufacturers of Laminates of India are the registered members of ILMA.

ILMA is a place where companies collaborate to get more opportunities to grow their business. ILMA is a symbol of Indian Laminate Manufacturer's unified commitment to provide seamless & world-class decorative surfaces. ILMA assembles its manufacturers on a unified platform & voices out its fair opinions. It unanimously provides a healthy competition, creating great opportunities by using different strategies and combining the views of the manufacturers.

Key Achievements

1. Organized six International Conference on Laminates between 2010 to 2018
2. ILMA Institute of Technology to enhance production capabilities of members employees
3. Restrict import of low quality laminate
4. Study on Cleaner Production
5. Launch of Technical book on laminate
6. Catalogue shows at National and International Level
7. Launch of awareness video on Laminate application
8. Networking with members for raw materials, production, market and government policy related issues
9. Export incentive benefits to laminate exporters
10. Support to PM Cares fund during pandemic

Upcoming Events

1. 7th International Conference on Laminates during Delhi wood March 2021
2. Catalogue show at Interzum, Germany 2021
3. Online technical workshop on production and environment aspects during October 2020.
4. Environment clinic with Pollution control board (December 2020)

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The success of *Hevea brasiliensis*, an agri wood for furniture and panel products

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Wood always finds its place for utilization in any form and has been one of the most widely used products for rural and urban household alike. With the Indian economic reforms and the subsequent rise in income there has been a swift in the consumption of wood and wood-based products. This rise in demand with a reducing supply from forests had led to a gap between the demand and supply of wood and wood-based products.

India is one of the fastest-growing wood based industries in the world. The ever-rising research base is paired with vital contribution from the growth-driven of the government. Wood-based industry includes pulp and paper, lac industry, handicraft, match industry, furniture and composites. At present there are about 238,907 wood-based industries in India that are facing major problem for the availability of raw material. It is estimated that the total consumption of wood in different wood-based industry are 402 million cum and production of wood in India 456.15 million cum (Arthnari Samy, 2022). The supply of wood for the wood-based industry is very low due to low productivity (0.7 m3 ha-1 year-1) in the country. It has been evaluated that there are very less chances to meet out the complete demand of raw material from the natural forest as they are now managed for ecosystem services. So, the only option lies in raising plantations outside the forest i.e., Wasteland, common land and agriculture lands. Keeping in view the scarcity of raw material in domestic market, industrial agroforestry is one of the most important alternatives to fulfill the demand of industries.

With the implementation of legal restrictions in accessibility of forest resources, it is difficult to obtain wood from natural forests. Under such condition, establishment of industrial forestry has increased its importance to meet out the requirement of industries. Along with this, The National Forest Policy, 1988, also directed to all the wood-based industries to generate their own resources through contract farming and industrial agroforestry. Therefore, the focus of industries has shifted to have farmlands.

One such species identified by the wood based industries as a sustainable raw material source is Hevea brasiliensis (rubber wood). The rubber industry is a major industry in India. It can be natural, synthetic (artificial), or reclaimed (recycled). Kerala is the largest producer of rubber, and the northeast region of India is progressing in the race. Tripura considered as the 'second rubber capital of India'-after Kerala-has emerged as the frontrunner among the non-traditional rubber growing regions. Meghalaya, Mizoram, Assam, Nagaland and Manipur, the other rubber producing states in the region, have also witnessed notable growth in production.

The production of rubber is persistent at the rate of 6% per annum. India is the 3rd largest consumer and the largest producer of natural rubber in the world. Emergence of Rubberwood Utilization concept in India commenced in 1980s. During the earlier days, the timber found its application as Domestic and industrial firewood, low cost packing cases where high durability was not required. However with the technological interventions the treatments schedules and the processing of wood to enhance the durability was successfully developed and this timber found wide applications for furniture, plywood, particle board and re constituted board products.

Wood is used for nearly 65% of all furniture made in India. The woodwork industry is one of the fastest growing in India. Various beautiful handicrafts have been crafted out of it. Wood products manufacturing companies design furniture both in traditional as well as ultramodern styles. Indian tradition and cultural heritage popularity around the globe have strengthened the demand for wood products in

India. Other than the well-known products such as lumber, furniture, and plywood, this is the raw material for wood-based panels, pulp and paper, and many chemical products.

About the species

Hevea brasiliensis, the Pará rubber tree, is a flowering plant belonging to the spurge family Euphorbiaceae. The rubber tree is native to the tropical rainforest of the Amazon basin and the Guianas. It is widespread in the northern part of South America (Bolivia, Colombia, Peru) and was introduced into South-East and to Africa. Rubberwood is a major plantation crop in Kerala and North-Eastern states. It grows best between 15°N and 10°S and from sea level up to 600 m, with the optimal altitude being below 200 m (Ecocrop, 2007). It is not very tolerant to soil erosion neither on hill slopes nor to the strong winds. It performs well with a day temperature between 26 and 28°C, and with annual rainfall ranging from 2000 to 3000 mm. It can withstand drought and waterlogging for a while, but prefers well drained soils (Ghani et al., 2000) with good moisture storage capacity. It can grow on acidic soils, volcanic soils and even peaty soils (Orwa et al., 2009).

Hevia brasiliensis is a sturdy, quick-growing, erect tree with a straight trunk and an open leafy crown (Fig.1). The bark is usually grey and fairly smooth. The bark of the trunk is the part from where rubber is harvested. In the wild, the trees may grow to over 40 m with a life span of more than 100 years. However, cultivated plants rarely grow beyond 25- 30 m in height because of the growth reduction due to harvesting of latex by tapping (Webster and Paardekooper, 1989). Moreover, the trees are usually replanted after about 30 years when yield falls to an uneconomic level. The young plants show characteristic growth pattern of alternating periods of rapid elongation and consolidation. The trees develop a strong tap root and extensive lateral roots forming the whole root system comprising about 15 percent of the total dry weight of the mature rubber tree. The leaves, fruit and extraction of latex is given in Fig. 2, Fig. 3 and Fig. 4 respectively.

Figure.1 Rubberwood tree

Figure 2 Rubber tree leaves

Figure 3 Flower and fruit of rubber tree

Figure 4 Latex collection from rubber tree

Simmonds, 1989 has studied the genetic behaviour of rubber wood and has reported that the genetic base of Hevea in the east is very narrow, limited to a few seedlings originally collected from a minuscule of the genetic range in Brazil referred to as the "Wickham base". Using the gene pool, substantial improvement in productivity has already been achieved over the past few decades. The parentage of popular clones bred in various rubber growing countries can be traced back to a handful of parent clones (Tan, 1987; Varghese, 1992; Mydin and Saraswathyamma, 2005). Recently, scientists from the Rubber Research Institute of India, Kottayam have taken initial steps towards breeding dual purpose rubber clones. They have studied wood properties variation and heritability of 11 progenies obtained from crossing superior latex yielding rubber clones which are cultivated on large scale. Based on the results of this study, scientists have concluded that there is a positive genetic relationship between rubber tree growth traits and fibre diameter as well as fibre wall thickness.

Rubber Board has taken measures to promote high

yielding Indian clones – RRII 429 – in the North-East to boost productivity of rubber in the region. North-East is the second-largest rubber cultivation belt in the country and accounts for 18 per cent of the total production of 7.15 lakh tonnes in the country. Considering the advantages of early opening of trees for tapping, as well as higher yield, the Rubber Board is promoting RRII 429 high yielding Indian clones in the North-East. Planting materials of the clone are being generated in various nurseries of the Rubber Board in the North-East.

Traditional rubber growing regions including Kerala, parts of Tamil Nadu and Karnataka account for 70 per cent of area and 82 per cent of production of NR in the country. The popular clone cultivated in this region is RRII 105Indian Hybrid rubber clone. The difference in the average annual life cycle yield between Indian Hybrid rubber clone decoded as RRII 105 and RRIM 600 (most popular exotic clone at the time of releasing RRII 105) is reported to be 370 kg ha–1 (Chandy and Sreelakshmi, 2008). Despite this significant difference in the yield performance, the estate sector exhibited a lethargic approach towards the adoption of indigenous clones and continued to depend on imported clones till the late 1980s (Joseph and Haridasan, 1990; Chandy et al, 2004).

Durability:

Rubberwood is perishable and has very little natural resistance to decay. It is also susceptible to fungal staining and insect attacks. Rubberwood lumber is typically taken from rubber plantations where the trees are tapped for latex, and harvested at the end of their useful life cycle—typically after about thirty years. The research inputs to enhance the durability using preservative chemicals has resulted with highly durable rubber wood making it as highly preferred material for all kinds of furniture. Optimized seasoning scheduled and preservative chemical treatments have yielded a more stable timber that doesn't bend or warp. The cracks also do not appear. The timber is also resistant to all kinds of pests and decay which makes it very easy to handle by any persons. The average life of treated timber is reported to be twenty five years (Yi Peng, 2011).

Wood properties

The heartwood of Rubberwood is naturally a light blonde to medium tan colour, sometimes with medium brown streaks. The Sapwood is not distinct from heartwood. The colour of the wood tends to darken slightly with ageing. Grain in this wood is straight with roughness on open texture with lownatural luster .

In juvenile wood, the chemical analysis of H. brasiliensis has shown 5.96%, 19.25%, and 73.55% extractives, lignin and holocellulose content respectively. While, in mature wood these contents were reported as 5.83%, 18.18%, and 73.89%, respectively. The specific gravity of the timber ranges from 435 to 626 kg m−3 at 12% moisture content (Rubber Board, 2005).The modulus of rupture and the elastic modulus of air dry wood were found to be about 71.9M.Pa and 9.07G.Pa respectively (Source : Wood data base)

End use applications:

Rubber wood industry is an allied industry to natural rubber industry which is developing in India. The density of rubber wood is suitable for building construction purposes and manufacturing of furniture. It has been reported by Chukwuemeka (2016) that treated rubber wood is used in many value added commercial applications such as sawn timber, kitchen items, wood panels (particle board, medium-density fibre board), joinery and carpentry, flooring, wooden frames, indoor building components etc., due to its physical-mechanical performance. Rubberwood is reported to be one of the finest furniture making timber due to its flexible properties. The timber is quite strong that makes it an ideal choice for making commercial cabinetry, trays, carvings etc.. This wood has good screw and nails holding properties and provides excellent support to the furniture. Rubber wood is popular for carving as it can hold neat designs and can bring out all the fine details. This wood can be painted but will need a lot of priming and filling to settle the rough surface. This wood is easy to carve and make furniture both with hands and machines. It is not suitable to keep near water sources as it can absorb moisture and cause shrinkage.

Figure 5. Furniture's made from rubber wood

Uses of Rubberwood in Panel products

Plywood:

The Perumbavoor region near Kochi has a large cluster of plywood manufacturing units catering to the demand in Southern India as well as in the Gulf markets. This region alone consumes about 7,500 tonnes of rubberwood daily. Due to its good rotary peeling property, the log can be easily transformed into thin sheets of veneers of thickness ranging from 1m to 2.4mm. These veneers are highly in demand by the plywood industries. The plywood industries situated in North Western regions source the rubber wood veneers from Kerala, while the southern regions procure in log form and convert them into veneers and finally into plywood. The plywood made using rubberwood veneers conform to all the physical and mechanical properties of IS 303 (Specification for general purpose plywood), IS 710(specification for Marine plywood) and also for IS 4990 (plywood for concrete shuttering applications). In addition to plywood the veneers are also used for producing high density panel product such as compreg for special applications.

Particle Board:

Rubberwood is one of the most commonly used raw materials for the manufacture of composites such as fibreboard and particle board in Malaysia. Currently waste materials from furniture and lumber manufacture and low-quality small logs are the main raw materials for composite panel producers in Malaysia. On similar lines of Malaysian particle board unit, a Kerala based Greenland Particle Boards Pvt Ltd has started manufacturing unit of Rubber based Particle Board since 2016 with 150 cubic meter installed capacity per day. The rubber veneer waste and the core left-over of the plywood units and the sawmilling units from the Perambavoor region form the raw material for the particle board making.

Medium Density Fibre Board (MDF)

For general purpose, medium density fibre (MDF) boards and fire retardant MDF manufacturing has been successful in Malaysia using rubber wood. However, in India at present rubber wood is not being used as a raw material for MDF units. This may be mainly due to the factor that the major raw materials are being utilized by the furniture sector.

CONCLUSIONS

Hevea brasiliensis is widely planted in India. Processing of rubber wood involves preservative treatment and seasoning. Once seasoned, strength and durability of the wood improves and matches any other hardwood like oak and teak. The wood is strong, durable and elegant as any other hard wood. The working characteristics of rubber wood are comparable to soft woods. Its smooth texture and uniform grain structure make it easy to work on. Operations like sawing, cross cutting, machining etc. are smoother and easier for rubber wood. The ease of workmanship is further enhanced with better nail and screw holding properties that makes it easier for furniture making. Its efficient gluing characteristics make it suitable for all kinds of panel products production. However, the major percentage of rubber wood finds its place in furniture sector.

Holoptelea integrifolia

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INTRODUCTION AND NATIVE RANGE

Holoptelea integrifolia, commonly known as the Indian Elm or Jungle cork tree, belongs to the Elm family (Ulmaceae). It is a large deciduous tree that can reach a height of 25 m, with a broad crown. The species is native to the Indian Subcontinent and extends to Indo-China and East Borneo. Its conservation status has not been evaluated by IUCN. The tree is recognized by its whitish grey bark that exfoliates in long irregular flakes, as well as the unequally rounded base of its leaves and samara fruit. *H. integrifolia* is distributed globally in East Asia, Indo-Malesia, and is particularly common in countries such as India, Sri Lanka, Himalayas, Myanmar, Nepal, Thailand, Cambodia, Laos, Vietnam, and Indo-China. In India, it is found throughout most states, except for Jammu & Kashmir, Himachal Pradesh, Sikkim, and Arunachal Pradesh. It is often encountered in semi-evergreen forests, while its presence is less common in the plains and deciduous forests. The tree is referred to by various local names, including Thapasi in Kannada & Telugu, Aaval or Njettaval in Malayalam, Aavimaram in Tamil, Chirabuilva in Sanskrit, Daurang in Oria, and Kaanjhu in Hindi.

Growth Characteristics and Utilization

H. integrifolia is a fast-growing tree that can be coppiced. It exhibits high competitiveness and demonstrates significant drought tolerance, making it suitable for planting in field borders, as an avenue tree, and in ecological forestry. However, despite its rapid growth, *H. integrifolia* is not extensively cultivated, possibly due to local beliefs associating the tree with ghosts and spirits. Interestingly, the Indian Elm is even used in exorcism by locals. Nevertheless, it is recommended for plantations in sandy soils, loams, and gravelly subsoils with good drainage, as the roots are not tolerant of stagnant water. The tree is primarily propagated through direct sowing of seeds. Fresh seeds are sown on the primary bed soon after collection and covered with a thin layer of soil. Overhead shade is necessary, and regular weeding and loosening of the soil are required. Seedlings are transplanted into polybags and planted out when they reach one year of age. There is limited information on tree improvement in this species due to its predominantly wild presence rather than domestication. However, callus formation has been induced from the leaves to generate somatic embryos for regeneration purposes.

Physical Characteristics and Reproduction

H. integrifolia can develop a diameter exceeding 100 cm, with cylindrical boles reaching up to 18 m. The bole often displays twisting and low branching. The tree's bark is grey and covered with blisters, peeling in corky scales on mature specimens, while the branchlets are pubescent. The leaves are simple, alternate, possess lateral scarious stipules, and are

Tree of *Holoptelea integrifolia*

Flowers, Fruits and Seeds of *Holoptelea integrifolia*

elliptic-ovate with rounded bases. They are supported by stout, pubescent petioles measuring 5-10 mm in length. The greenish-purple flowers are polygamous and appear before the leaves. The fruit of *H. integrifolia* is a samara—a thin, round, papery disc with a brown color that contains a single seed as shown in the figure.

The characteristics of *H. integrifolia* make it a distinct and noteworthy tree species, contributing to the ecological diversity and cultural beliefs associated with its presence.

Wood Utilization and Characteristics

The wood of *H. integrifolia* finds various applications due to its favorable characteristics. While it is commonly used for making matches, boxes, and brush frames, it is also employed locally in construction, cart-making, and statue carving. The wood's natural durability index is 5, indicating it is naturally non-durable. Although the heartwood can be treated, complete penetration is not always achieved. *H. integrifolia* wood is light, ranging in color from white yellow to yellow brown or yellowish grey, and exhibits a moderate luster. There is no distinct differentiation between the sapwood and heartwood. It is strong and moderately hard, with a density of 0.64 g/cm^3. The grain pattern can be straight or interlocked, and the texture is medium to coarse. The wood features a diffuse-porous gross structure with scarcely visible growth rings. The vessels are medium to small in size, moderately numerous, and often filled with chalky deposits. Paratracheal, aliform to aliform-confluent parenchyma is present, and the rays are moderately broad to fine and somewhat closely spaced. The basic density or specific gravity is 0.62 g/cm^3, while the air-dry density at 12% moisture content is 0.69 g/cm^3. The wood is easy to work with and capable of achieving a beautiful polished finish.

Utilization and Medicinal Uses

The Indian Elm tree (*H.integrifolia*) holds significant value in local communities as it serves various purposes. It is harvested from the wild for its medicinal properties, as a food source, and for oil and wood production. The fruits of *H. integrifolia* are consumed by monkeys, making it an excellent fodder source for livestock. The bark of the Indian Elm is used as a fish poison and holds multiple ethno medicinal uses. It is a key ingredient in many medicinal preparations in Ayurveda, Folk medicine, and Siddha, commonly employed for treating conditions such as scabies, ulcers, and scorpion stings. Decoctions made from the bark are applied to alleviate rheumatism, while the bark and leaves are used to treat oedema, diabetes, leprosy, skin diseases, intestinal disorders, piles, and sprue. Phytochemical screening has revealed the presence of tannins, saponins, phlobatannin, terpenoids, flavonoids, and cardiac glycosides in the leaf callus. Additionally, *H. integrifolia* exhibits antioxidant, antihelmintic, anti-inflammatory, antimicrobial, antidiabetic, antitumor, and antidiarrheal activities. The seed and stem bark are used to treat ringworm, and the seeds contain approximately 37.4% oil.

Anatomical properties

Anatomically, the wood of *H. integrifolia* exhibits small tangential diameter of vessel lumina (100 micras or less) and an abundance of vessels per mm² (more than 20). It features simple perforation plates and vessel-ray pits that are similar in size and shape to intervessel pits. The inter-vessel pits are small (7 micras or less). Axial parenchyma is either absent or extremely rare and not visible without magnification. Prismatic crystals are present in radial alignment within procumbent ray cells. The body ray cells are procumbent and consist of over four rows of upright and/or square marginal cells (Kribs-I). Additionally, the fibers in *H. integrifolia* wood possess distinctly bordered pits.

The multi-faceted utilization and anatomical characteristics of *H. integrifolia* make it a valuable resource, both medicinally and in various woodworking applications.

Strength Property of the Wood

The strength properties of *H. integrifolia* wood, as reported by Nazma et al. (1981), are as follows:

Property/Condition	Green	Air Dry
Modulus of Rupture (kg/cm^2)	598	719
Modulus of Elasticity(kg/cm^2)	74600	91500
Impact Bending		
(height of drop in cm)	94	66
Max. Crushing Stress(kg/cm^2)	270	411

Woodworking and Utilization

H. integrifolia wood is well-suited for various woodworking operations. It can be laminated through rotary veneer cutting or sliced veneer. Machining tasks such as sawing, molding, and sanding are relatively easy to perform with this timber. The wood turns to a fine and smooth surface, allowing for a good polish. Cutting resistance may vary within logs, but mean values show a parabolic relationship with density and a linear relationship with tensile strength across the grain. The quality of veneer, measured as the ratio of veneer tensile strength to timber strength, improves as cutting resistance decreases. This versatile timber finds applications in general construction, textile mills for bobbins and cotton reels, Class-I plywood for general purposes, tea chests, decorative plywood, furniture and cabinets, blockboards, tool handles, agricultural implements, bentwood articles, and toys. The wood undergoes successful seasoning and presents no difficulties during kiln drying. The strength properties and ease of woodworking make *H. integrifolia* wood a valuable resource suitable for a wide range of applications across various industries.

Khaya anthotheca

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INTRODUCTION

Khaya anthotheca, commonly known as Lombu or East African mahogany, is a member of the Meliaceae family, characterized by its paripinnate leaves and woody capsules. It is widely distributed across Africa, from Guinea Bissau to Uganda and Tanzania, extending south to Angola, Zambia, Zimbabwe, and Mozambique. The species has found its place in plantation forestry within its native range and has been introduced to other regions, such as South Africa, tropical Asia, and tropical America. With its multiple common names and vernacular associations, Khaya anthotheca holds cultural and economic importance in different regions. However, its identification and recognition have sometimes posed challenges due to the lack of flowering and fruiting materials.

Distribution:

Khaya anthotheca thrives in moist and dry semideciduous forest zones, predominantly within the West, Central, and East African regions. It is notably absent in the Upper Guinean and Lower Guinean rainforests, where it is replaced by Khaya ivorensis. The species' natural distribution encompasses a vast area, from Guinea Bissau in the west to Uganda and Tanzania in the east, and southwards to Angola, Zambia, Zimbabwe, and Mozambique. The species has gained popularity for plantation cultivation within its natural range and in other regions, including South Africa, tropical Asia, and tropical America. Plantations of *Khaya anthotheca* are rapidly expanding in several states of India, including the East and North East regions. The increasing demand has led to significant nursery activities in various states such as Andhra Pradesh, Assam, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Telangana, Rajasthan, Gujarat, Punjab, and Haryana.

Ecological Requirements and Growth Characteristics of *Khaya anthotheca*

Khaya anthotheca, a large to very large tree species, exhibits certain ecological requirements and growth characteristics that contribute to its overall development. These factors are essential to consider when cultivating and managing *Khaya anthotheca* plantations.

Khaya anthotheca trees are characterized as evergreen or deciduous, monoecious species. They can reach impressive heights of up to 60 meters, with straight and cylindrical boles that are branchless for up to 30 meters. The diameter of the bole can reach up to 120 centimeters, accompanied by prominent buttresses that may extend into surface roots. The bark of *Khaya anthotheca* is initially smooth and grey but later exfoliates into small circular scales, creating a pock-marked, mottled grey and yellowish-brown surface. The inner bark exhibits a pink to reddish coloration. The dense crown of the tree is complemented by large buttresses and a substantial bole.

The leaves of *Khaya anthotheca* are spirally arranged, often clustered near the ends of branches. New flushes towards the crown may exhibit a light reddish coloration. The leaflets are arranged in 4 to 16 pairs, with the apical 4 pairs being opposite in arrangement. The leaflets themselves are elliptical to ovate-elliptical or oblong-elliptic in shape. The fruit of *Khaya anthotheca* is a woody capsule, oval-ovoid in shape, and measures 3 to 5 centimeters in diameter. The capsule dehisces into four valves, exposing the seeds. The seeds are light brown in color and are arranged in rows around a central column, surrounded by a narrow wing.

During the early stages of growth, *Khaya anthotheca* trees have slender stems and small crowns. Once the upper canopy of the forest is reached, extensive lateral growth occurs. For instance, in Ghana, seedlings exhibit an average height of 2.5 meters and an average stem diameter of 4-4.5 centimeters after 2.5 years.In terms of plantation growth, *Khaya anthotheca* trees planted in the open within the semi-deciduous forest zone attain an average height of 12 meters and an average bole diameter of 18 centimeters after 10 years. However, in the evergreen forest zone, the same trees reach a height of only 6 meters and a diameter of 9 centimeters after 8 years. In Malawi, planted *Khaya anthotheca* trees achieve a height of 8 meters and a diameter of 9 centimeters after 7 years. It is worth noting that trees may start bearing fruits when their bole diameter reaches 18 centimeters, but abundant fruiting typically occurs at diameters above 70 centimeters. Therefore, removing trees below the 70-centimeter diameter class from the forest may hinder natural regeneration processes.

Understanding the ecological requirements and growth characteristics of *Khaya anthotheca* is crucial for successful cultivation and sustainable management of this valuable tree species. By considering these factors, practitioners can optimize plantation establishment, growth, and regeneration strategies, ensuring the long-term viability of *Khaya anthotheca* populations.

Cultivation and Growing Demand:

Khaya anthotheca has gained popularity as a fast-growing tree species suitable for plantation forestry.

Its tall stature, cylindrical bole, and rapid growth make it an attractive choice for timber production. The increasing demand for *Khaya anthotheca* saplings is evident from the rising number of nurseries and the substantial daily shipment of trees from West Bengal to different states in India. The species has shown potential for commercial plantation forestry due to its valuable timber properties. The growing demand for Lombu reflects its versatility. The species offers promising opportunities for sustainable timber production, providing an alternative to conventional timber sources. However, the increasing demand for Lombu highlights the need for responsible management practices to ensure its long-term sustainability. Further research and conservation efforts are necessary to understand its genetic diversity, optimize cultivation techniques, and promote sustainable use of this valuable resource.

Khaya anthotheca in Agroforestry Systems

Khaya anthotheca, a species with versatile uses and desirable growth characteristics, has the potential to be incorporated into agroforestry systems. Its natural growth patterns and adaptability to varied soil and climate conditions make it a suitable alternative species for Indian mahogany and other tree species in agroforestry. India, with its significant areas under cultivation and forest cover, as well as degraded lands, can benefit from rehabilitating these areas through the planting of multipurpose tree species like *Khaya anthotheca*. Despite being observed in various regions of India, there is limited information available on this species, warranting further research and exploration.

Plantation Establishment and Maintenance

The selection of superior phenotypes, referred to as plus trees, is crucial for conserving diversity at the species level. The variation in growth, form, and wood characteristics among *Khaya anthotheca* trees suggests a combination of genetic and environmental factors. Efforts to conserve genetic diversity through individual selection and breeding within locally adapted provenances can contribute to improving desired characteristics. *Khaya anthotheca* faces challenges in natural regeneration after logging due to the low density of adult trees, limited fruit production in smaller trees, and poor seed dispersal. Enhancing regeneration through additional sowing at favourable sites and incorporating shifting cultivation methods like taungya systems may promote sustainable management of *Khaya anthotheca*. Silvicultural techniques such as overhead shading, mixed planting, and lateral shoot removal can mitigate damage caused by Hypsipylarobusta shoot borers, which can negatively impact *Khaya anthotheca* plantations. Seed-boring beetles and small rodents pose threats to seeds and require appropriate management strategies.

Provenance Trials

Conducting urgent screening of genetic resources and identifying less susceptible genotypes is essential for plantation establishment and conservation of *Khaya anthotheca* germplasm. Provenance evaluations have shown that *H. robusta* attack occurs within six months of planting. After 2.5 years, no significant differences were observed in height and diameter growth among provenances. However, significant variations were observed among progenies in terms of height, diameter, and survival rate. The diverse habitats and populations of *Khaya anthotheca* suggest substantial provenance variation, reflecting genetic and physiological adaptation to different climates. Quantifying the relationship between species distribution, physiology, and climate is crucial for understanding the adaptability of Khaya species.

Development of Clones

In the Central African Republic, artificial regeneration studies for *Khaya anthotheca* and other local forest species are limited. Exploring different reproduction strategies, including sexual and asexual methods, such as seeds, cuttings, and roots, can contribute to the conservation and propagation of this valuable species. *Khaya anthotheca* is predominantly propagated by seed, with careful selection of undamaged seeds before sowing or storage. Storage can be done for up to one year in a cool and dry place, with the addition of ash to reduce insect damage. Germination takes between 8 to 35 days, and seedlings can be planted in the field when they reach 30 cm in height or as striplings after reaching 1-2 m in the nursery. Successful vegetative propagation through cuttings has been achieved, particularly with the application of growth hormone, resulting in a 75% rooting success rate in experiments conducted in Indonesia.

Incorporating *Khaya anthotheca* into agroforestry systems and implementing appropriate management practices, provenance selection, and propagation techniques can contribute to the sustainable cultivation and utilization of this valuable species, benefiting both ecological conservation and socioeconomic development. Further research and collaborative efforts are necessary to fully understand the potential of *Khaya anthotheca* and optimize its integration into agroforestry systems

Tissue culture

The challenges posed by *Hypsipyla robusta* and *H. grandella* attacks, along with the recalcitrant nature of khaya species seeds, have prompted the exploration of tissue culture as a viable propagation method. Large-scale plantations to meet the increasing global demand for mahogany face difficulties due to these pests. To address this, the storage of seeds under ambient temperatures is necessary, as their viability rapidly declines.

African mahoganies, including *Khaya anthotheca*, are light-demanding species that struggle to survive under a closed forest canopy during their early stages. However, the use of cleft grafting and air layering techniques holds promise for expanding the production of *K. anthotheca* in nurseries. Cleft grafting offers opportunities to preserve superior genotypes selected for breeding programs. These

grafts can be used to establish seed orchards, enabling the production of seeds from desired genetic materials. Additionally, the grafts serve as a source of propagules for vegetative propagation of *K. anthotheca* through methods such as cuttings, mini-cuttings, and potentially even micropropagation.

By exploring tissue culture techniques, such as micropropagation, the potential for mass production of *Khaya anthotheca* plants can be enhanced. This approach offers opportunities to overcome the challenges posed by pests and the limitations of seed viability, while also ensuring the preservation and propagation of desirable genetic traits. Further research and development in tissue culture methods specific to *Khaya anthotheca* can contribute to the sustainable production and conservation of this valuable species.

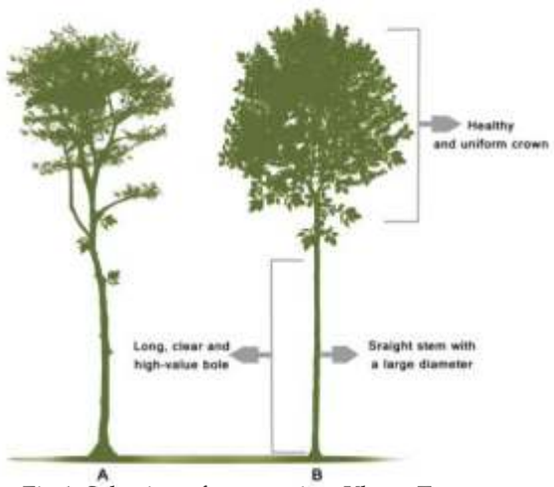
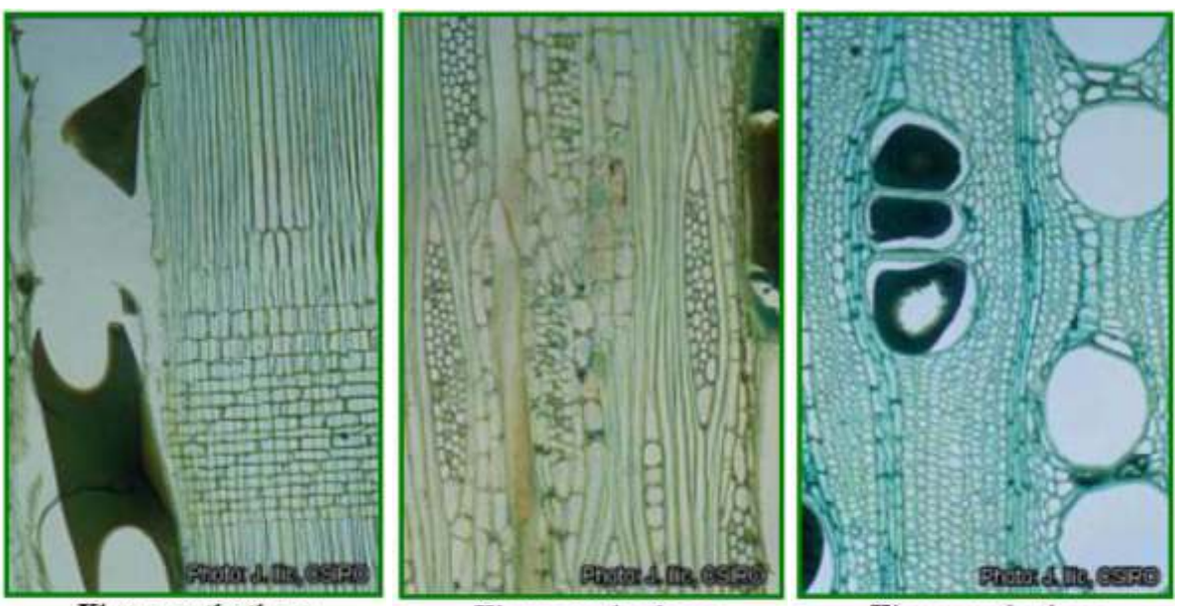


Fig 1. Selection of appropriate Khaya Tree
A = Unsuitable Khaya spp. tree
B = Suitable seed tree

Anatomical, physical and mechanical properties of *Khaya anthotheca* wood:



Khaya anthotheca
wood in radial section

Khaya anthotheca
wood in tangential section

Khaya anthotheca
wood in transverse section

The wood of *Khaya anthotheca* exhibits distinct physical and anatomical characteristics. The heartwood ranges in color from pinkish brown to deep red and is clearly demarcated from the pale brown sapwood, which can be up to 6 cm wide. The grain of the wood is typically straight, although it can also be interlocked, and the texture is rather coarse. One of the notable features of the wood is its attractive figure, which displays irregular ripple marks.It is a diffuse porous wood and the growth ring boundaries are indistinct or absent. Vessel frequency ranges from 5-20/mm^2 with mean tangential vessel lumina dimeter ranging from 100-200µm. Fibres with simple to minutely bordered pits and thin to thick walled. Primary crystals present in the upright

The average density of the wood ranges between 490–660 kg/m^3. Other physical and mechanical

properties of the wood are as follows:

- Radial Shrinkage: 2.7–4.1%
- Tangential Shrinkage: 5.8–6.4%
- Bending Strength (Modulus of Rupture): 50-110 N/mm^2
- Bending Stiffness (Modulus of Elasticity): 7800–10300 N/mm^2
- Crushing Strength: 24-53 N/mm^2
- Shear Strength (Parallel to Grain): 8-14 N/mm^2
- Hardness: 3.4-5.7 N/mm^2

Wood working qualities:

The wood of *Khaya anthotheca* is generally easy to saw and work, although the presence of interlocked grain may pose some challenges. Keeping saws sharp is recommended to prevent a woolly finish, and using a cutting angle of 20° can improve the cutting process. The wood can be finished to a smooth surface, but the use of a filler is necessary before staining and varnishing. It holds nails and screws well, although it may split upon nailing. The wood also glues satisfactorily. However, its bending properties are usually poor. The wood is suitable for peeling and slicing, resulting in high-quality veneer. It can be turned fairly well. While the wood is moderately durable, it may be susceptible to attacks by termites and pinhole borers. The heartwood is highly resistant to impregnation, while the sapwood shows moderate resistance. It is important to note that the wood dust may cause skin irritation.

Wood quality and utilization

The plantation of *Khaya anthotheca* is rapidly expanding in the East and North East states of India. It is considered a medium hardwood, and its growth rotation of 6 to 8 years ensures good quality timber suitable for plywood and panel industry. The wood's strength and resistance to termites and borers make it highly valuable for plywood factories in eastern India. Its straight length facilitates easy peeling, and its natural red color eliminates the need for additional coloring, making it suitable for face veneer. Plywood manufacturers in West Bengal have expressed satisfaction with the grain and strength of Khaya anthotheca, considering it a suitable and sustainable raw material for plywood production. A longer rotation period makes the wood ideal for furniture and other solid wood applications such as cabinet work, decorative boxes and cases,window frames, paneling, doors, staircases, light flooring, shipbuilding, vehicle bodies, sporting goods, musical instruments, toys, novelties, carving etc. The wood's attractive figure, straight or interlocked grain, and high luster make it desirable for decorative purposes.Overall, Khaya anthotheca wood offers a range of desirable qualities, making it suitable for a variety of applications and industries. Its quality, workability, and medicinal properties contribute to its value and potential in different sectors.

Maesopsis eminii MUSIZI

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INTRODUCTION

Maesopsis eminii, commonly known as the "umbrella tree," is an angiosperm belonging to the Rhamnaceae family. This species is known for its remarkable drought tolerance and finds applications as both a plantation tree and a shade tree in coffee plantations and other crops. Native to the Guineo-Congolian region, *M. eminii* derives its species name, eminii, in honor of Emin Pasha, an African explorer, administrator, and botanist. While the genus name, *Maesopsis,* bears some resemblance to Meese (Family Myrsinaceae), the similarities between the two trees are mainly observed in the shape and venation of their leaves. Other local names for this species include Kudamaram in Malayalam, and it is also referred to as Mutere or Musizi in trade.

Source: https://www.unaeastbourne.org/growth-rates.html

Source: https://www.unaeastbourne.org/agroforestry.html

Origin, Distribution and Human Introduction:

Maesopsis eminii is native to several African countries, including Angola, Benin, Burundi, Cameroon, Central African Republic, Congo, Democratic Republic of Congo, Equatorial Guinea, Ethiopia, Gabon, Ghana, Kenya, Liberia, Niger, Rwanda, Sao Tome et Principe, Somalia, Sudan, Tanzania, Togo, Uganda, and Zambia. *M. eminii* has been introduced by humans outside its native range, including East Africa in the early 20th century for reforestation purposes. It has been reported as a human-introduced species in countries such as Australia, the Philippines, Bangladesh, Brazil, Costa Rica, Fiji, India, Malaysia, Samoa, the Solomon Islands, Hawaii, Puerto Rico, and Indonesia (Hall 2010 & CABI 2016). In India, *M. eminii* is found in various locations, including Kerala (Pathanamthitta, Idukki, Wayanad, Kannur, Palakkad, Kollam, Kozhikkode) and Tamil Nadu (Yercaud Hills, Shevaroy Hills in Salem district, Sirumalai Hills in Dindigul district). The species was introduced to Valparai as a shade tree for coffee plants and served as a food source for hornbills in the plantations. It can grow well across various altitudes and topographical ranges. Although not naturally occurring on steep slopes, when planted in such terrain, it displays robust growth. The growth performance of *M. eminii* in terms of tree volume varies significantly across different growth categories,

Figure. 1.*Maesopsis eminii* Tree and Leaves (Zahidah et al. 2018)

Figure. 2. *Maesopsis eminii* line planting and Mature Tree (Orwa et. al., 2009)

Figure.3.(a) Figure.3.(b)
Fruit of *Maesopsis eminii* is shown in the figure 3(a) (Source: wikipedia.org) and 3(b) Hornbill adapted to fruit of *Maesopsis eminii* (Source: WCS-India, location: Valparai)

Figure.4. A profile of coffee plantation with a canopy cover of umbrella tree (*Maesopsis eminii*)(Source: http://www.sahyadrica.com/2017/05/on-book-of-revival.html)

Growth Characteristics:

The tree typically reaches a height of 50 to 90 feet, although in Kenya and Uganda it can grow up to 150 feet. In Nigeria, it is seldom over 50 feet high. The diameter of the tree ranges from 16 inches to 4 feet. The bole (main trunk) is generally straight and clear for 30 to 70 feet. When buttresses are present, they are usually short and blunt. The bark is thick, silvery grey t`o almost white, coarse, and deeply fissured. A cut or blaze on the bark may vary in color from pale red to yellow-white.The leaves are alternate to sub-opposite, glossy, measuring 3 to 6 inches in length and 1 to 2 inches in width, with widely spaced serrations. The small, green flowers grow in axillary clusters. The fruits are 3/4 to 1 inch long, solitary, or found in pairs or small clusters. They resemble small plums, initially yellow and turning black after falling.

M. eminii thrives under direct sunlight and exhibits a leaning growth habit when competing for light in the presence of other trees. It possesses an impressive tolerance for drought, capable of withstanding up to 2-6 months without water. In terms of soil preferences, this species can adapt to a wide range of conditions, although it performs best in deep, moist, and fertile sandy loam soils with a neutral to acid pH. Waterlogged soils are not suitable for *M. eminii* growth. Notably, this tree shows relatively higher yields on poor soils, making it beneficial for land reclamation. Apart from providing excellent timber, *M. eminii* offers valuable shade for crops, which accounts for its intentional cultivation (Joker 2000, Ani and Aminah 2006, Binggeli and Hamilton 1993, Orwa et al. 2009).

Suitability under agroforestry systems:

While *M. eminii* is suitable for agroforestry systems, successful plantation establishment depends on effective silvicultural management, including the selection of good planting materials, appropriate initial spacings, and post-planting maintenance. Various spacing configurations have been used, such as 1.8 x 2.7 m and 5 x 5 m for the taungya system in Ghana. Regular maintenance activities like weeding, thinning, and the application of fertilizers, fungicides, and insecticides are necessary for ensuring optimal growth performance of the trees. The storage behavior of *M. eminii* seeds is orthodox, and their viability can be maintained for up to one year at cool temperatures with dry seeds. Viability can be preserved for several years in hermetic storage at 3°C with a moisture content of 4-9%. Each kilogram of seeds contains approximately

700-1000 seeds when the pericarp is removed. To improve germination, seeds may be soaked in water for 1-2 days or in concentrated sulfuric acid for 20 minutes. Even with treatment, seed germination may take 4 months or more, with 65-80% germination rate. Due to the quick formation of a taproot, it is recommended to sow the seed in polybags, and if sown in seedbeds, the seedlings need to be potted up as soon as they are large enough to handle. Young plants can be transplanted into their permanent positions when they are around 2-4 months old.

Wood Structure:

The wood structure of *Maesopsis eminii* is characterized by indistinguishable growth rings. Figure 5 illustrates this feature, while Figures 6 and 7 provide transverse, tangential, and radial sections of the wood. The vessels in the wood are characterized by simple perforation and range from small to large, with a moderate number. They are mostly solitary but can also occur in radial multiples of 2. Tyloses, which are outgrowths in the vessel walls, are scarce or absent. Wood parenchyma is moderately abundant, with paratracheal elements that tend to be aliform (wing-shaped) and incomplete vasicentric (arranged around the pore). The wood also contains two distinct sizes of rays: moderately fine and medium-sized. The medium-sized rays are visibly distinct on cross-section and prominent on the radial surface. Fibres in the wood are non-septate and measure 275 µm in length. Prismatic crystals are fairly abundant in chambered axial parenchyma strands. Notably, the wood does not contain silica, ripple marks, or intercellular canals (Ani and Aminah 2006). The pores in the wood are visible without magnification, variable in abundance but not densely packed. The wood shares similarities with softer leguminous woods and possesses vestured pits on the vessel walls.

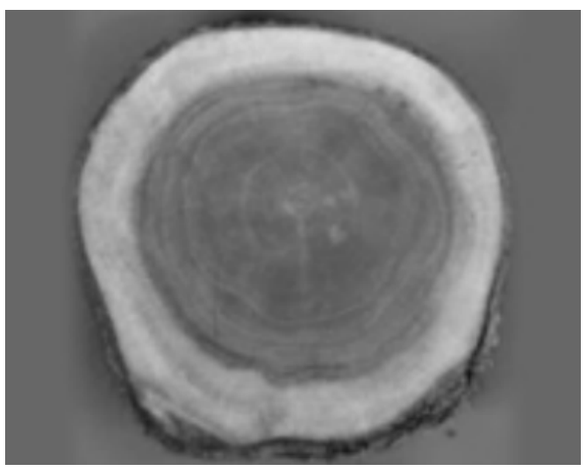

Figure.5. Disc of 6-Year-old *Maesopsis eminii* (Ani and Aminah 2006)

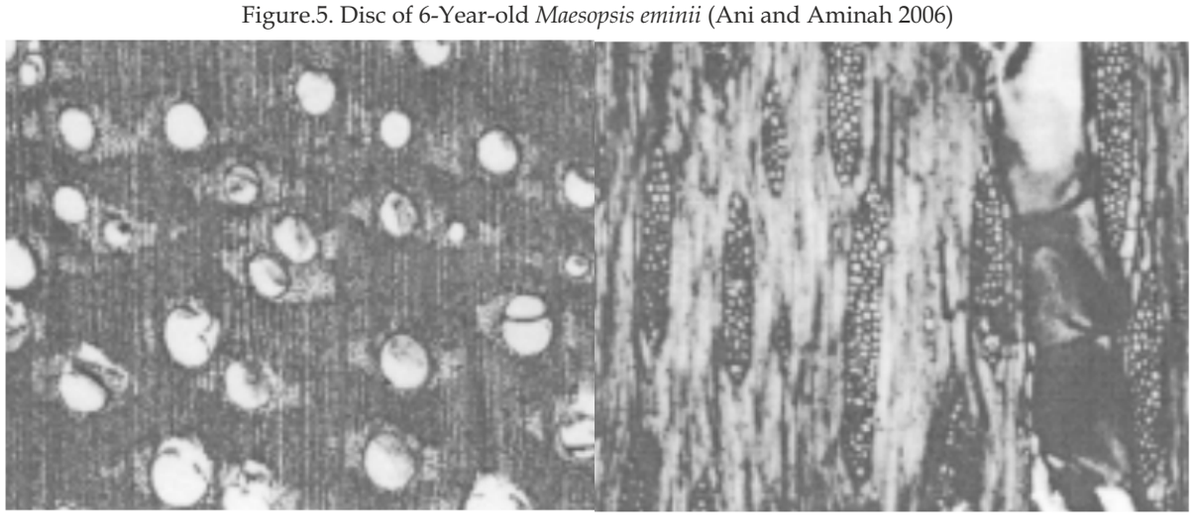

Figure.6.Transverse and Tangential section of *Maesopsis eminii* (Ani and Aminah 2006)

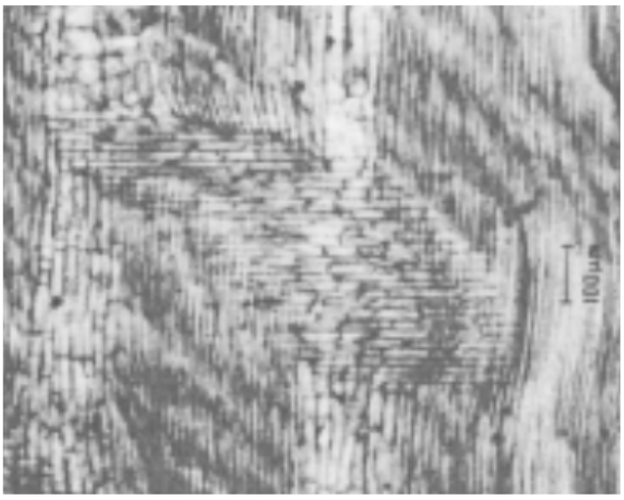

Figure.7. Radial Section of *Maesopsis eminii* (Ani and Aminah 2006)

Wood Properties of Musizi (*Maesopsis eminii*)

Characteristics of Wood:

The heartwood is bright yellow when freshly cut, gradually transforming into golden brown, russet, or dark brown upon exposure. The sapwood is nearly white, sharply distinct from the heartwood, and can be up to 3 inches thick. The wood is soft, lightweight, and exhibits a coarse grain. Wood density ranges from 0.38 to 0.52 g/cubic cm, and logs tend to split during felling and storage despite rapid drying (Orwa et al. 2009). The wood exhibits a satiny lustre without odour. The wood undergoes rapid air seasoning but is prone to splitting, warping, and collapsing during the drying process. The tangential and radial shrinkage reported are 4.9% and 3.0% respectively. The wood is rated as soft and light but firm. It is generally stronger than most woods of the same weight. The wood is known for its ease of sawing and machining, and its high absorbency makes it easy to treat with preservatives. The timber exhibits good nailing and gluing properties. Values obtained for the mechanical properties of *M. eminii* in the green and air-dry condition as well as the working qualities are presented in table 1 and table 2 respectively.

Table 1: Mechanical properties of *M. eminii*

Property	**Species and Origin** *Maesopsis eminii (M. eminii)*
Uganda, Africa	
Moisture Content	
Green (%)	165
Air-dry	12
Weight per cubic foot	
At 50 percent moisture content – (Kg).	17.23
At 12 percent moisture content – (Kg).	13.60
Static bending	
Modulus of rupture	
Green – N/mm^2	52.4
Air-dry – N/mm^2	71.7
Modulus of elasticity	
Green – N/mm^2	8618.44
Air-dry – N/mm^2	9859.5
Work to maximum load	
Green – g/cm^3	204.83
Air-dry – g/cm^3	218.67
Compression parallel to grain	
Maximum crushing strength	
Green – N/mm^2	27.5
Air-dry – N/mm^2	44.2
Shear	
Maximum shearing strength parallel to grain	
Green - N/mm^2	6.5
Air-dry - N/mm^2	9.44

This table shows strength values obtained in tests on *M. eminii* at the British Forest Products Research Laboratory (Kryn, 1954)

Table 2: Workability of *Maesopsis eminii*

Sl. No	Particular	Description
1	Sawing	It is easy to saw.
2	Peeling veneer cutting	Suitable for peeling after heat treatment.
3	Veneer slicing	Suitable for peeling after heat treatment.
4	Dulling effect	Slight blunting effect; ordinary tools can be used for sawing and machining.
5	Machining	Machining of this species is reportedly easy.
6	Planing	Easy; no particular problems.
7	Molding	Moderately easy; tools must be cautiously sharpened.
8	Drilling	Moderately easy; tools must be cautiously sharpened.
9	Slotting	Moderately easy; tools must be cautiously sharpened.
10	Nailing	No particular problem.
11	Bonding	Glues well if basic gluing technical rules are followed.
12	Sanding	Easy to perform; it gives good results.
13	Polishing	Needs pre-coating.
14	Compatibility with hand tools	No particular problems.

Source: http://www.tropicaltimber.info/fr/specie/Musizi -Maesopsis-eminii/?print=true

Processing Issues:

Maesopsis eminii wood is known to be easy to work with using most tools, and it can achieve a smooth and lustrous surface when finished. However, care should be taken in areas with pin knots and wound occlusions, as they may cause tearing. When planning quarter-sawn stock, a cutting angle of 20° can help overcome picking up. Adequate support should be provided during chipping, drilling, and mortising to prevent chipping. The wood accepts nails and stains well but requires a filler. Pin knots are often present, and flat-sawn material may exhibit pronounced grain waviness.

Major Application/Usage with Special Emphasis on Wood:

Maesopsis eminii is considered one of the most valuable light hardwoods in Central Africa and finds applications similar to imported softwoods such as Scotch pine (Pinus sylvestris). It has been traditionally used for constructing native buildings in Uganda and is widely employed in the Belgian Congo. The wood is suitable for furniture, joinery, and indoor construction, except when a high-quality paint finish is required. It is also considered suitable for purposes similar to Cedrela wood.

The wood can be peeled into high-quality veneer, making it suitable for plywood manufacturing due to its straight, branchless bole, medium and even texture, uniform density, cylindrical shape, and absence of buttresses (Buchholz et al., 2010). The timber of *M. eminii* is suitable for various applications such as stairs, boxes, crates, furniture components, decorative veneer, general molding, parquet flooring, pulp and paper products, and utility furniture. Despite its light hardwood nature and non-durable properties, the attractive wavy grain feature of *M. eminii* can be an aesthetic asset in furniture making, as shown in Figures 8 and 9. Additionally, *M. eminii* is suitable for producing oriented strand board (OSB).

Figure 8 Table made from *M. eminii* slabs (1200 mm × 2440 mm × 500 mm) (Zahidah et al. 2018)

Figure 9 Wooden bench (1800 mm length) with wavy feature (Zahidah et al. 2018)

Mangifera indica: A multipurpose tree

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Mango trees are highly valued and extensively utilized in India due to their cultural significance, economic importance, and wide range of applications. It also holds cultural and religious significance in India. The wood of the mango tree is strong and durable. It is used to make furniture, handicrafts, and various other wooden items. The wood is also used as fuel for cooking and as construction material for houses in some rural areas.

Mango tree (*Mangifera indica*) is a tropical fruit tree belonging to the Anacardiaceae family. It is widely recognized by its popular name, mango, and has various vernacular names in different languages such as Aam in Hindi and Bengali, Mangue in French, Manga in Portuguese, Maamidi in Tamil, Mamidi in Telugu, Mambazham in Malayalam, and Mavu in Kannada.

Origin: The mango tree is believed to have originated in the region of North-Eastern India, Bangladesh, and Myanmar (Burma). The wild ancestor of the mango, *Mangifera sylvatica,* can still be found in the forests of North East India and South East Asia.

Historical records suggest that mango tree cultivation in India dates back at least 4,000 years, and mangoes have played a significant role in Indian cuisine and culture ever since. Over time, mango trees were introduced to other regions of the world, including Africa, the Middle East, and eventually the Americas, through trade and migration.

Distribution: *Mangiferaindica*, commonly known as the mango tree, is widely distributed and cultivated in many parts of the world with tropical or subtropical climates. Originating from India, Bangladesh, and Myanmar, mango trees have been introduced to numerous countries in South East Asia, Africa, the Middle East, the Americas, Australia, and the Pacific Islands. Notably, India, China, Thailand, Indonesia, and Mexico are the largest mango producing countries, showcasing the global significance of this tree.

Tree Characteristics: Mango trees exhibit distinct characteristics that contribute to their allure and adaptability. They are large evergreen trees that can reach heights of 35-40 meters, with a bole diameter of up to 1.5 meters. The bole is typically straight, and the bark transitions from a light gray or brownish-graycolor when young to a rough and fissured texture as the tree matures. Mango trees possess a dense, spreading crown, providing shade with their profusion of dark green leaves arranged in an alternate pattern. Their deep taproot system and well-developed lateral roots enable them to withstand drought and wind.

Growth Behaviour: Mango trees exhibit moderate to rapid growth rates, with young trees growing up

Mangifera indica tree

Furniture using *Mangifera indica* Wood (Source: Pinterest)

to 1 meter per year under favourable conditions. Their height ranges from 10-20 meters on average, and their branching and canopy development result in abroad, spreading crown. Mango trees begin to bear fruit within 3-5 years, with full production typically achieved at 10-12 years. The amount of fruit produced varies based on cultivar, growing conditions, and management practices.

Suitability in Agroforestry Systems: Mango trees are highly suited to agroforestry systems due to their multifunctional benefits. They provide fruit, firewood, poles, organic matter for soil amendment, living fence posts, shade, soil conservation, and cattle feed. In India, mango trees have been successfully intercropped with crops like groundnut, black gram, cowpea, and pigeon pea, as they offer shade without competing for resources. The economic performance of fruit tree-based agroforestry systems, including mango trees, has shown higher net returns compared to other systems. Mango trees contribute to nutrient cycling and enhance soil fertility through leaf litter inputs, thereby improving crop yields.

Status of Tree Improvement: While mango tree improvement techniques, including tissue culture, progeny trials, and genetic transformation, have been explored, there is limited research specifically analysing the improvement of *Mangifera indica* trees. However, some Indian institutes have developed and released notable mango varieties, such as Arka Anmol, Arka Neelkiran, Pusa Arunima, and Mallika, known for their distinct flavours, flesh texture, and colour.

Physical and Mechanical Characteristics: Mango wood possesses unique physical and mechanical characteristics. The heartwood exhibits a reddish-brown colour, while the sapwood is yellowish-white. The wood has a fine texture and a straight or interlocked grain, occasionally displaying a wavy pattern. With a moderate density, mango wood showcases favourable mechanical properties. The mechanical properties of Mango wood from Puri, Orissa tested at air dry condition is shown in the following table.

Mangifera indica wood exhibits captivating physical attributes that contribute to its popularity in various applications. The wood showcases an appealing grain pattern with distinctive color variations, ranging from light yellow to dark brown. This natural beauty makes it highly sought after for furniture and decorative items. With a medium to coarse texture and a high density, the wood possesses exceptional strength and durability. These qualities enable it to withstand heavy usage and impacts, rendering it ideal for the production of sturdy furniture and flooring materials.

Chemical Characteristics: Mango wood contains various extractives, including tannins, flavonoids, and steroids, which contribute to its colour, durability, and resistance to decay. The chemical composition of mango leaves exhibits antimicrobial activity against several microorganisms and possesses antioxidant properties due to the presence of terpenoids, catechin, fatty acids, and microelements.

Species	Location	Stnd.SG	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
		Vol. at test	MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at E.L.	R	T	E	R	T	R	T
Teak	Burma and Malabar	0.598	95.9	12534	27	16381	54.5	14017	9.68	5004	4959	4670	8.4	9.8	3.7	4.4
Mango	Puri (Orissa)	0.588	87.4	10879	26	13313	42.9	10528	9.13	4870	4848	6116	8.9	9.5	3.6	2.2

Major Uses: *Mangifera indica* wood finds diverse applications across industries. It is widely utilized in construction and furniture-making, offering strength, durability, and workability. The wood's elegant grain patterns make it ideal for carving decorative objects, while its bark is employed in paper-making. Additionally, mango wood serves as a reliable fuel source for cooking and heating purposes. It encompasses a wealth of resources

beyond its renowned delicious fruit. Its adaptability, agroforestry suitability, and versatile wood make it a valuable asset across multiple sectors. With its robust growth, unique physical and mechanical properties, and favourable chemical characteristics, mango wood continues to captivate manufacturers and consumers alike, adding beauty and functionality to a wide range of applications.

Mango Wood Flooring (Source: Pinterest) Decorative Vase (Source: Pinterest)

Furniture : The increasing utilization of *Mangifera indica* wood in furniture making is attributed to its merits as a hardwood furniture material and its sustainability credentials. Additionally, the wood finds utility in the creation of light and heavy packing cases, emphasizing its versatility. Its high-grade timber and figured stock, featuring curly-grained patterns, make it particularly suitable for furniture and cabinet work.

Mango wood drawer (LHS) (woodenstreet.com) and Coffee table (RHS) (mangowoodfurniture.co.uk)

Medicinal Potential: *Mangifera indica* is not only a natural product but also an important medicinal plant. Its leaves have been found to contain various beneficial compounds such as saponins, glycosides, sterols, polyphenols, mangiferine, and tannins. The composition of polyphenols (tannins) and the properties of an associated enzyme, polyphenol oxidase (PPO), in the *Mangifera indica* kernel have been extensively studied. Additionally, several secondary metabolites have been identified from the leaves, including phenols, xanthones, flavanols, benzophenones, terpenoids, and derivatives of gallotannins. Notably, mangiferin, a pharmacologically active flavonoid found in *Mangifera indica,* exhibits a wide range of beneficial

Other applications of mango wood:

Handicrafts: Artisans often use mango wood to create intricate and decorative handicraft items. These include carved sculptures, figurines, wall hangings, bowls, trays, and other decorative pieces. Mango wood's workability makes it suitable for detailed carving and shaping.

Home Decor: Mango wood is used to produce various home decor items such as photo frames, mirrors, coasters, candle holders, and lamp bases. Its natural appeal adds a touch of elegance to interior spaces.

Doors and Windows: In some regions, mango wood is employed to make doors and windows for homes and buildings. Its strength and resistance to decay make it a practical choice for these structural elements.

Musical Instruments: Mango wood is occasionally used in the construction of musical instruments, particularly for acoustic instruments like guitars and ukuleles. The wood's acoustic properties contribute to the instrument's sound quality.

Kitchenware: Mango wood is utilized in making kitchen utensils like cutting boards, serving bowls, and spoons. The wood's hardness makes it suitable for food preparation and serving.

Panels and Plywood: Mango wood is also used to manufacture panels and plywood. These products find applications in interior decoration, wall paneling, and furniture making.

Packaging Material: Mango wood can be converted into packing materials like wooden crates and pallets for transportation and storage purposes.

properties such as antibacterial, antioxidant, anticancer, antidiabetic, hepatoprotective, and anti-inflammatory activities.

Industrial Applications: Apart from its medicinal properties, *Mangifera indica* finds extensive use in the food industry. Mango puree and essences are employed in various food products like nectar, beverages, jam, jelly, leather, ice cream, and baby food. Mango puree, in particular, is commonly utilized in the beverage industry. Mango pulp and mango concentrate are primary processed products derived from mangoes.

Processing Challenges and Potential Uses in Wood-based Industries: While working with *Mangifera indica* wood, there are some common processing challenges to be mindful of. These include drying, machining, preservation, gluing, and grading. Proper techniques and tools should be employed to overcome these challenges and ensure the quality and usability of the wood. Besides, yellowing of wood is also a common problem in some of the planks thereby causing non-uniform colour in the product. Despite these challenges, *Mangifera indica* wood holds great potential as a raw material for various wood-based industries. Its strength, durability, and workability make it well-suited for furniture making, including doors, windows, flooring, tables, chairs, and cabinets. In the construction industry, it can be utilized for structural framing, flooring, and roofing due to its robust nature and ability to withstand adverse conditions. Furthermore, the wood's strength and durability make it suitable for producing packaging materials like crates and pallets. Its attractive grain and colour also lend themselves well to the creation of decorative items such as figurines, bowls, and vases. Additionally, *Mangifera indica* wood can serve as an energy source for fuel production.

Overall, the mango tree plays a crucial role in the socio-economic and cultural fabric of India, making it an essential part of the country's agricultural and rural landscape. *Mangifera indica* is a versatile tree with multiple applications and immense potential in various wood-based industries. It's worth noting that the utilization of mango wood is not limited to India. The wood is also sought after in other countries for similar purposes, contributing to the global trade in timber and wood products. However, sustainable practices must be emphasized to ensure responsible harvesting and management of mango wood resources to protect the environment and maintain the ecological balance.

Melia azedarach Linn.

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INTRODUCTION

Melia azedarach Linn, commonly known as Chinaberry Tree, Lilac Tree, Persian Lilac, or Pride of India, is a native species of South Asia, including Iran, India, and southern China. It has been introduced and naturalized in tropical America, spanning from Mexico to Argentina. The tree exhibits a wide distribution across India, with regional names such as Ghora Neem in Assam, Bakarjam in Bengali, and Bakain in Hindi. Its ecological range extends to Indonesia, Northern Australia, Africa, North America, Tropical South America, and Southern Europe. Additionally, it has been established in the Philippines, the United States, and various African and Arab nations.

Tree Description:

Melia azedarach is an attractive deciduous tree, ranging in size from small to medium, and can grow up to 45 meters in height. It features a spreading crown with sparsely branching branches, and its bole develops fluting as it matures. Often used as an ornamental avenue tree and occasionally as a shade tree in coffee and tea plantations, it thrives in the sub-Himalayan region up to 2000 meters above sea level. The tree exhibits toughness and drought resistance. The wood of *Melia azedarach* is reddish or pinkish brown, lightweight, and suitable for furniture, veneering, and sporting goods. Its bark undergoes a transformation from smooth and greenish-brown in youth to fissured and grey as it ages.

Propagation and Regeneration:

Melia azedarach has natural and artificial methods of propagation. In natural conditions, it regenerates prolifically through seed dispersal during rainfall. Artificial propagation can be achieved through

Picture depicts (a) *Melia azedarach* plant (b) flowering stage and (c) fruits of the plant

cuttings, root suckers, direct sowing, and transplanting seedlings from nurseries.

SUITABILITY IN AGROFORESTRY SYSTEMS:

Variability in Form and Morphology:

Melia azedarach, also known as Bakain, exhibits variations in form and morphology depending on the region of growth. Trees cultivated in plantations differ significantly from those found in the wild. In un-irrigated plantations in India, 6-year-old trees were observed to lack tap roots, with lateral roots found at an average depth of 76.0 cm and weighing around 1.3 kilograms per tree. The first-order lateral roots were found to grow horizontally within 4 cm of the soil surface. Bud explosion and new leaf development typically occur in late February, with the majority of growth happening during the dry months of March to May. The tree primarily reproduces through seeds, although it can also sprout from root buds, and sexual reproduction is more common in undisturbed environments.

Role in Environmental Health:

Due to its fast growth, Bakain plays a crucial role in improving environmental health. It produces an average of 3.19±0.90 t/ha of leaves containing about 12.10±2.21% crude protein. Studies on agroforestry systems based on *Melia azedarach* have shown a significant increase in soil pH and electrical conductivity under ten-year-old trees, indicating its potential for acid soil reclamation. Implementing agroforestry systems based on *Melia azedarach* can be an effective strategy for improving the livelihoods of local communities.

Agroforestry Systems and Economic Benefits:

A closely monitored study on a rain-fed *Melia azedarach*-based agroforestry system in Dharwad, on medium black clay soil, revealed positive results. Soybean crops (JS-335) were cultivated in the interspace between *Melia azedarach* rows during the kharif season. The agroforestry system showed significantly higher net returns and benefit-to-cost ratios, especially with the 5m x 4m spacing. This indicated that the agroforestry system was suitable for planting on bunds, canals, and nala. Additionally, the wood waste of *Melia azedarach* is ideal for heating purposes, and to rrefaction can further increase its calorific value. The rapid growth, high stem quality, and moderate canopy shadowing effect make *Melia azedarach* recommended for agroforestry development. However, it is not recommended to establish *Melia azedarach* alone in saline soil, as it may not thrive under such conditions.

In conclusion, Bakain or *Melia azedarach* has proven to be suitable for agroforestry systems, offering environmental benefits, improved soil conditions, and economic advantages. Its rapid growth and versatile uses make it a valuable species for agroforestry development.

ANATOMICAL FEATURES:

The bark of mature bakain trees has distinct anatomical characteristics. The outer zone of the bark, called rhytidoma, consists of alternating strips of dark brown cork cells and dead secondary phloem. The cork cells are compressed and have a nearly rectangular shape, forming multiple layers. The secondary phloem, also compressed and multilayered, lacks prominent cork cambium and secondary cortex. Below the rhytidoma, there is a wide zone of secondary phloem containing sieve tubes and compound sieve plates.

The phloem parenchyma, found within the secondary phloem, has oval to irregular-shaped cells with thin walls. These cells are colorless and contain intercellular spaces. The phloem rays, which are structures that extend radially across the phloem, are 2 to 5 cells wide. Rosette and prismatic calcium oxalate crystals are present in both the phloem parenchyma and ray cells. Additionally, there are a few very small, simple round to oval starch grains measuring 5 to 11 in diameter, typically with 2 or 3 components.

In a study on 8 years old *M. azedarach* trees, Juhany (2011) reported that, the fiber length of the wood varied among trees, ranging from 0.742 to 0.797 mm. Fiber length increased from the pith to the bark, ranging between 0.62 and 0.92mm. Specific gravity showed minor variation among trees but increased

from the pith to the bark, ranging between 0.366 and 0.432. The proportion of heartwood accounted for approximately 70% at the base of the tree, but decreased to 63.32% at breast height. Significant variations in the proportion of sapwood were observed between the base and breast height, as well as among different trees. The breast-height cross section of *Melia azedarach* trees exhibited an area of 84.3 cm^2 for sapwood, compared to 102.3 cm^2 at the base. However, the proportion of sapwood was greater at breast height.

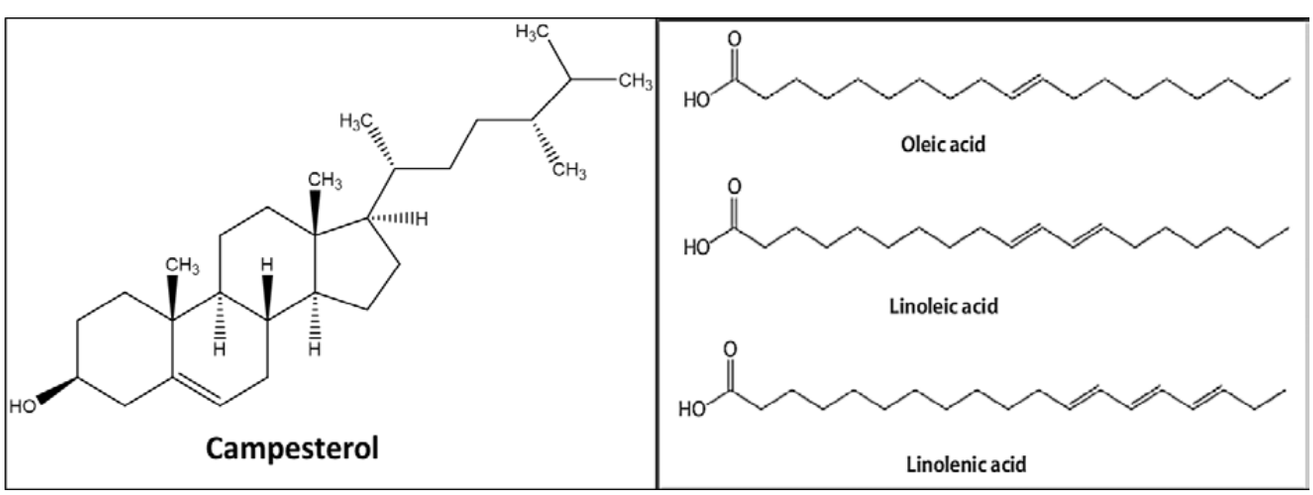
In summary, the anatomical features of bakain's mature bark include distinct layers of cork cells and dead secondary phloem, the presence of sieve tubes and compound sieve plates, and specific characteristics of phloem parenchyma, phloem rays, and starch grains.

CHEMICAL CONSTITUENTS AND MEDICINAL PROPERTIES:

Preliminary phytochemical screening of *Melia azedarach,* showed the presence of number of organic molecules i.e., terpenoids, flavonoids, steroids, acids, anthraquinones, alkaloids, saponins, tannins. The bark of bakain contains various chemical compounds, including terpenoids and limonoids such as 7a-acetoxy-14β,15β-epoxygedunanl-ene-3-o-β-d-glucopyranoside, 12-acetoxyamoorastatin, amoorastatin, fraxinellone, 12-hydroxyamoorastatone, 3-hydroxy eupha-7,24-diene-21,16-olide, kulactone, kulinone, kulolactone, methylkulonate, a-pinene, β-pinene, a-terpinene, and aterpineol. It also contains flavonoids like 4',5-dihydroxyflavone-7-o-u-l-rhamnopyranosyl-(1-4)-β-d-glucopyranoside, as well as anthraquinones like 1,3,5,8-tetrahydroxy-2-methylanthraquinone-8-me ether, 3-o-α-l-rhamnopyranoside, 1,5-dihydroxy-8-methoxy-2-methyl-anthraquinone-3-o-α-l-rhamnopyranoside, and 1,8-dihydroxy-2-methylanthraquinone-3-O-β-D-galacto pyranoside.

The wood of bakain also contains terpenoids and limonoids, such as melianin-a and melianin-b. Additionally, the seeds of bakain contain terpenoids and limonoids like 3β,7α-dihydroxy-21,23-epoxy-apotirucalla-14,24-diene-21-one and meldenin. Steroids like campesterol, cholesterol, stigmasterol, and fatty acids like linoleic acid, linolenic acid, and oleic acid are also present in the seeds.

In summary, bakain exhibits a diverse chemical composition in its bark, wood, and seeds, with the presence of terpenoids, limonoids, flavonoids, anthraquinones, steroids, and fatty acids. These chemical compounds contribute to the unique properties and potential applications of bakain in various fields. The following table compiles the traditional usage of the various parts of the plant.



Some important chemical compounds present in the wood and bark of Melia azedarach

Plant Parts	Traditional Uses
Bark	Antidiarrheal, de-obstruent, diuretic, rheumatic pain, and used in fever to relieve thirst, nausea, vomiting and general debility, loss of appetite, stomach ache. Bark decoction is used as a remedy for fever aches and pains. Bark paste is used to treat piles, used as lotion on ulcers, syphilitic.
Stem	Used for gonorrhoea, treat malaria and to expel parasitic worms.
Seed	They are bitter, expectorant, anthelmintic and aphrodisiac and are useful in helminthiasis, typhoid fever, pain in the pelvic region and scrofula.
Whole plant	Used to stimulate hair growth, treat eruption of scalp.

PHYSICAL AND MECHANICAL PROPERTY:

A study conducted by Duong and Matsumura examined the variations in tangential shrinkage (αT), radial shrinkage (αR), and the tangential/radial shrinkage ratio (αT/αR) within the tree stems of *Melia azedarach* grown in different sites in northern Vietnam. The results showed that αT and αR gradually increased from the pith to the bark, displaying a consistent trend across both sites. In the radial direction, the αT/αR decreased significantly from 10% to 50% of the radial length from the pith, after which it approached a constant value towards the outer part of the stem. Transverse shrinkage showed minimal variation with height and did not exhibit statistical significance. The study also revealed a positive correlation between transverse shrinkage and basic density (BD), indicating that selecting wood with higher density may lead to increased transverse shrinkage. Furthermore, αT and αR exhibited significant positive linear relationships with both acoustic wave velocity (VL) and dynamic modulus of elasticity of the log (DMOElog).

Another study conducted by Duong and Ridley-Ellis (2021) investigated the potential of stress wave velocity (SWV) as a rapid and non-destructive method for estimating the mechanical properties of Melia azedarach wood. The authors reported that SWV in combination with wood should be employed to predict the mechanical properties of M. azedarach wood.

In summary, the physical and mechanical properties of *Melia azedarach* wood were analyzed, revealing variations in shrinkage, density, fiber length, specific gravity, and the proportion of heartwood and sapwood. These findings contribute to a better understanding of the characteristics and potential uses of *Melia azedarach* wood.

Utilization of *Melia azedarach* Wood in Various Industries:

Recent studies have explored the suitability of *Melia azedarach* wood for different industrial applications.Plywood and particleboard manufacturing are among the major sectors where *Melia azedarach* wood is used. Researchers have reported that plywood made from M. azedarach wood exhibits favorable properties for industrial applications. The wood has also been identified as a suitable raw material for pulp and paper production as well as particleboard manufacturing. Additionally, it shows promise for producing specialty items like sporting goods and compressed wood for shuttle blocks. In terms of durability, *M. azedarach* heartwood grown in India demonstrated resistance to white and brown rot fungi, although the natural durability of bakain wood varies depending on the test fungi and evaluation system used.

In Mexico, planted *M. azedarach* tree heartwood displayed high resistance to certain rot fungi. However, different studies have yielded contrasting results regarding the wood's natural durability. A study by Rahman et al. (2014) assessed the

effectiveness of *Melia azedarach* plywood (ghora neem) as an alternative raw material for the plywood industry. The physical and mechanical properties of ghora neem plywood were compared to those of shimul plywood (*Bombax ceiba*). Ghora neem plywood exhibited superior performance, with higher density, modulus of rupture (MOR), and modulus of elasticity (MOE) values compared to shimul plywood.

Further investigations by Iwakiri et al. (2012) explored the potential of *Melia azedarach* wood in the particle board industry. The researchers found that boards manufactured with *Melia azedarach* wood and urea-formaldehyde resin showed promising physical and mechanical properties. Increasing resin content in the internal and external layers improved water absorption and thickness swelling properties. However, the mechanical properties remained unaffected.

These findings highlight the versatility of *Melia azedarach* wood for various industrial applications, including plywood, particleboard, and specialty item manufacturing. The wood's favorable properties and performance make it a viable alternative in these industries.

CONCLUSION:

The wood derived from the bakain tree holds great potential as a utility timber for interior applications. It is valued for its moderate weight and strength, as well as its ease of drying, processing, and gluing. Reports consistently describe its appearance as highly attractive. As a result, bakain wood has been recommended as a suitable substitute for S*wietenia macrophylla* in various interior uses, including furniture, shop and office fittings, and other applications. In addition to its use in interior design, high-quality bakain logs have been successfully transformed into veneer. The wood can be sliced for decorative purposes or peeled for plywood faces and core stock. This versatility positions bakain wood as an important alternative within the engineered wood sector. Overall, bakain wood offers a promising solution for interior applications, thanks to its appealing characteristics and suitability for veneer and plywood production. Its availability as a substitute for other timber species further enhances its value in the woodworking industry.

Michelica champaca L.

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Scientific name – *Michelia champaca L.*
Family : Magnoliaceae
Vernacular names:
Hindi : Champa
Tamil : Sambagam
Assamese : Tita – sopa
Bengali : Champa, Champaca
Gujarati : Rae-champo
Kannada : Kola sampige, sampighi
Malyalam : Champakam
Marathi : Kud-champa Tree of *Michelica champaca L.*
Oriya : Champaka, Kanchanam
Punjabi : Champa
Sanskrit : Champaka
Telugu : Champakamu, champakam

Tree of *Michelica champaca L.*

Origin and Distribution

Michelia champaca, commonly known as Champak, is a tall evergreen tree that originates from India. It is widely distributed throughout tropical Asia, including the Western Ghats from Karnataka to Kerala. The tree is also found in the deep forest valleys cooled by perennial springs in the Tholkabada and Karampoda forests of Bihar. In addition to its natural occurrence, *Michelia champaca* is extensively cultivated in various regions of India and Burma. Notably, it thrives in the moister and almost evergreen type of Sal forests on rich soil in Bengal's Duars and even extends to the Abor country at lower elevations. There are reports of it growing to even larger dimensions in the Mishmi and Khamti hills.

Tree Characteristics

This magnificent tree exhibits a close, tapering crown composed of ascending branches, reaching a height of 33m or more. The clean, long cylindrical bole under ordinary forest conditions measures between 18 to 21m with a girth of 2.4 to 3.7m. Notably, the tree's form is excellent, boasting a clean and straight bole that is free from forks. There are records of a tree in the Balarangan hills of Mysore with a girth exceeding 1.5m.

Growth Behaviour

Michelia champaca is known as a light demander, showing increased vigor in saplings and poles grown under complete overhead light. In contrast, those grown in shade tend to have a less striking bole and crown, with possible production of numerous epichromic branches when suddenly isolated, such as in coppice coupes. The tree exhibits good coppicing ability and does not produce root suckers. In its natural habitat, drought is not common, but young plants on southerly aspects may suffer from moisture deficiency. The species is sensitive to fire and is more prone to damage by animals compared to other trees from its origin. It thrives in fast-growing conditions, particularly on moist, well-drained,

deep, and fertile soil. With its rapid growth rate, *Michelia champaca* can yield 18.25 m^3/ha per year by the age of just 8 years. Gambles wood specimens showed 20-30 rings per dm of radius, indicating a fair rate of growth.

Stability under Agroforestry System

Michelia champaca plays a crucial role in nutrient acquisition mechanisms within natural ecosystems. It has been found to act as an excellent nitrogen fixer due to colonization by Arbuscular mycorrhizal fungi (AMF) and dark septate endophyte (DSE). In various regions, it is utilized in agroforestry systems as a shade tree in tea plantations, intercropped with banana, areca, and other multipurpose tree species, and integrated into pineapple-cultivated areas (Panna and Highland, 2022).

The tree produces new leaves around March and bears large, scented yellow flowers singly at the base of leaves. The fruits ripen from August to September. Propagation is successfully achieved by planting out nearly one-year-old seedlings during the monsoon break of the following year. Due to damage caused by Urostylis punctigera, it is common to grow mixed plantations of *Michelia champaca*. West Bengal has successfully employed a mixture of Bischofia javanica and underplanting in fast-growing deciduous trees, while Assam has found success in planting under Terminalia myricarpa in older plantations. The fragrant flowers are distilled to obtain "champaca oil," extensively used in jasmine flower perfumes. Additionally, the aromatic "Sampanghi" oil of Tamil Nadu is also derived from the tree. In religious ceremonies, the flowers are worn by ladies in their hair (Troup, 1975).

As fa as tree improvement of this species is concerned, there have been no varieties or clones released by ICFRE or other institutions. However, research on tissue culture activity for essential oil production and plant regeneration through callus induction has been initiated.

Physical, Mechanical, Chemical, and Anatomical Characterization of the Wood

The narrow, white sapwood contrasts with the light yellowish brown to olive brown heartwood. *Michelia champaca* timber possesses a lustrous and smooth surface without characteristic odor or taste. It is light, soft, straight-grained, and easy to work with tools, finishing to a smooth and glossy surface. The wood exhibits distinct growth rings delimited by light lines of terminal parenchyma. It can be easily sawn and is excellent for producing veneers. The mechanical properties of this wood (in air dry condition) sourced from West Bengal has been presented in the following table.

Major Applications with Emphasis on Wood

The wood of *Michelia champaca* finds diverse applications, including light furniture, indoor works, Grade 1 commercial and moisture-proof plywood, tea chests, heavy packaging cases, superior boxes, battery separators, and pencils. It is considered a first-class wood for various purposes, such as joinery, carpentry work, cabinet making, ship and boat building, carriages, plows, and toys. The tree's

Species	Std. SG	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at E.L..	R	T	E	R	T	R	T
Teak	0.598	95.9	12534	27	16381	54.5	14017	9.7	5004	4959	4670	8.4	9.8	3.7	4.4
Champa	0.426	63.8	9563	23	16140	44.3	10349	6.8	3380	3736	4470	7.4	8.4	2.4	2.6

wood is also utilized for heavy construction and door panels, and it is known to be used for making drums in Mysore.

Processing Issues

The timber is moderately refractory and can be air or kiln seasoned without significant difficulty or degradation if handled properly. However, slight discoloration may occur during drying, and proper care is necessary to prevent cracking. *Michelia champaca* wood is generally not durable, although it can last for extended periods when used as posts or underwater. The heartwood exhibits very low treatment-side end penetration, indicating its refractory nature.

Potential Scope as Raw Material in Wood-Based Industries

In addition to its traditional medicinal use, the leaves of *Michelia champaca* are fed to silkworms, while the flowers yield essential oils used in perfumery. The heartwood, with its appealing olive-brown to dark brown appearance, holds potential in various wood-related industries. Its straight or slightly interlocked grain, fine to moderately fine and even texture, and distinct figure make it suitable for furniture, cabinetwork, carvings, turnery, pattern making, and cement-bonded wood-wool boards. Moreover, the wood's gross energy value makes it a viable option for fuel wood. India has recommended ring girdling trees about three years before felling to prevent warping and checking of the wood

Mitragyna parvifolia (Roxb) Kortha native economically important timber species

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INTRODUCTION:

Mitragyna parvifolia (Roxb) Korth an indigenous, medium to large deciduous tree species belonging to family Rubiaceae. It is commonly known as Kaim (Panwar and Tarafdar, 2006). It is native to India and Sri Lanka and grown widely for its potential use as timber and medicine. This species is found throughout the greater parts of India up to an altitude of 1300m, scattered in deciduous forest and grows best in well-drained soil. It is also found growing gregariously in low lying areas close to the river (Bhandari, 1990). The genus Mitragyna consist of ten species which are mainly distributed in tropical and arid/semi-arid parts of Africa, India, China, Bangladesh, Myanmar, Sri Lanka and south-east Asia (Govaertset al.2015). In India, the tree distribution is found in states of TamilNadu, Kerala, Karnataka, Andhra Pradesh and Uttar Pradesh. This species is credited with innumerable medicinal properties and is widely used by tribal people and other ayurvedic practitioners. The chemical constituents of the plant are pyroligneous acid, methyl acetate, ketones and aldehydes. (a) Habit. – (GPS, Co-ordinates - 11◦36'29.14",77◦01'29.34") (b) An inflorescence. c) Fruiting stage. Flowering Sequences (from bud to flower)

Tree characterstics: Flowering Sequences (From bud to flower)M.parvifoliais widely grown commercially in Indian Thar Desert (Shetty and Singh, 1991). It grows best in areas with annual daytime temperatures within the 20 - 35oC range, but can withstand temperature range of 5 - 47oC. It grows well in the mean annual rainfall in the 1500-2500 mm range, but can tolerate up to 3300 mm. Young trees withstand shade, whilst older trees are light demanding. It can grow in a wide spectrum of fertile soils and prefers a pH between 5.5 and 6.5 but tolerates between 4.5 and 7.5. The stem is erect and branching. Bark is light soft white/gray to grey/gray-black in colour, smooth and have thin irregularly scale when mature, fibrous; blaze pink, traversed by whitish rays; branchlets subterete. Leaves are simple, opposite and broadly obovate, dark green in color, smooth, rounded in shape, opposite in growth pattern, elliptic, obovate, apex rounded or acute, stipules large, interpetiolar, pink caducous. Leaves ovate, elliptic-oblong, 8 - 12.5 x 4 - 6.5 , base cuneate, trancate, rounded-subcordate, margin entire, obtuse, subacute at apex, glabrous; 7 - 8-pairs; petiole up to 2 cm long. Flowering and fruiting take place during March to August.Flowers are creamy white or yellow in colour, and grows in

ball-shaped cluster. The flowers are fragrant and peduncle with 2 small leaves at the base, calyx funnel-shaped, Corolla funnel-shaped, lobes 5, recurved, stamens 5, Ovary 2-celled, style white, exerted. Fruit/seeds develops as capsules, arranged in globose heads, each with 2-folicular cocci; seeds many, 2-3 mm long, ribbed, separating in to two cocci, brown; small, 10-ribbed., winged.

Flowering Sequences (From bud to flower)

Fruit variations of *Mitragyna parvifolia* across populations

Anatomical, physical and mechanical properties wood: *M.parvifoliawood* is pinkish-brown in colour, even grained, moderately hard and durable if not exposed to the wet condition. The wood is moderately heavy with a standard specific gravity of 0.558. The wood shrinks 3.3% is radial direction and 7.4% in tangential direction. The volumetric shrinkage is about 11.9%. The details of mechanical properties of this wood sourced from Hadwani and tested in air dry condition are presented in the following table. Most of the properties of this species are comparable to that of Teak.

Table. Mechanical properties of *M.parvifoliawood* (Source- Indian Forest Record-Vol. XVIII)

Species	Std. SG	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
		MOR	MOE	Max. drop (cm)	MOE	Max. C stress	MOE	CS at E.L..	R	T	E	R	T	R	T
Teak	0.599	95.9	12534	68.6	16381	54.5	14017	9.7	5004	4959	4670	8.4	9.8	3.7	4.4
M. parvifolia	0.558	81.8	9735	48.3	14561	49.7	10376	9.7	5115	5827	6894	8.5	9.8	1.7	4.3

The wood is moderately refractory to season (Class-B) and can be seasoned satisfactorily by using schedule V as recommended by IS1141-1993. The wood is easy to work and polishes well. A useful wood, esteemed for many purposes, used in construction, furniture making, agricultural implements, combs, cups, spoons, plates, carved articles and paper industries. The wood bark yields cordage fibers (Chatterjee et al., 1982; Anon,1998).

Uses

Mitragyna species are used medicinally as well as for their fine timber throughout the areas they grow. The bark and roots are used in the treatment of fevers and colic. The wood is esteemed for many purposes. It is used in construction, furniture making, agricultural implements, combs, cups, spoons, plates and for turned and carved articles.In traditional Indian medicine, bark and roots were used for treating evers

colic, muscular pains, stomach burning, poisoning, gynecological problems, cough and edema.Bark decoction is used for fevers. In some countries, it is marked as a "Yellow Gold"—as a kratom product or cheaper substitute for kratom. However, to kratom users, it fails in comparison in overall effects.

Status of tree improvement of the species:

Institute of Forest Genetics and Tree Breeding, Coimbatore conducted extensive field survey throughout Tamil Nadu and selected 92candidate plus trees of M. parvifolia based on growth superiority of tree height(TH), clear bole height(CBH), girth at breast height (GBH) and tress without any pest infestation and diseases. Location details of the selected superior trees of M. parvifloia can be obtained from IFGTB, Coimbatore.

Neolamarckia cadamba

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Fig 1: *Neolamarckia cadamba* tree Fig 2: Kadam tree lower trunk

Scientific name	*Neolamarckia cadambaor Anthocephalus cadamba*
Family	Rubiaceae
Kingdom	Plantae
Order	Gentianales
Type	Evergreen
Common names	Burflower-tree, laran, Leichhardt pine, Kadam, cadamba, common burflower, jabon, sukhothai, kalempayan
Native	India, Australia, China, , Indonesia, Malaysia, Papua New Guinea, Philippines, Singapore, Vietnam

Neolamarckia cadamba, also known as *Anthocephalus cadamba*, is a large tree with a broad crown and a straight cylindrical bole. It can reach heights of up to 45 meters with trunk diameters ranging from 100 to 160 centimeters. The tree may possess small buttresses and a broad crown. The bark starts off smooth and grey in young trees, but becomes rough and longitudinally fissured as the tree ages. It is becoming increasingly popular as a planted tree in the tropics, often used for avenues, roadsides, and in villages for both ornamentation and shade. The tree holds religious and cultural significance in India, Java, and Malaysia.

Cultivation Details:

Neolamarckia cadamba thrives in moister tropical climates at altitudes ranging from 300 to 800 meters. It prefers a mean annual temperature of approximately 23°C and is sensitive to frost. The tree grows best with a mean annual rainfall of around 1600 mm or more, although it can tolerate as little as 200 mm in dry areas. Well-drained soils are preferred, while leached and poorly aerated soils are not suitable. Older trees require good light conditions and can tolerate periodic flooding. Young trees typically experience rapid growth for the first 6 to 8 years and begin flowering around 4 years of age. When cultivated for timber, they are typically harvested at 10 to 15 years of age. The tree has good coppicing ability and its fragrant orange flowers attract insect pollinators.

Propagation:

Neolamarckia cadamba is best propagated through

seeds, which are sown in nurseries. Direct sowing is not very successful due to the small size of the seeds and their sensitivity to drought, excessive moisture, and direct sunlight. Epigeous germination begins in approximately 10 to 14 days during the rainy season. When the seedlings are 8 to 12 weeks old, they are transplanted to nursery beds or plastic bags. It is recommended to use a medium enriched with organic matter. After 6 to 7 months, when the seedlings are about 30 cm tall, they are ready for transplanting into the field. They can be planted bare-rooted with little loss in survival rate. Young seedlings require regular weeding as they are highly susceptible to weed competition. Two-month-old seedlings can be transplanted into nursery beds or polythene bags and retained before planting at the start of the monsoon season. Successful establishment is ensured by planting seedlings with their root balls.

Biology:

Birds and other animals aid in the dispersal of the edible fruit. The tree may start flowering at around 4 years of age. In Indonesia, flowering occurs from April to August, sometimes from March to November, while in India, it commences from December to July. The flowers are bisexual.

Timber:

Neolamarckia cadamba is becoming one of the most frequently planted trees in the tropics. The sapwood of *Neolamarckia cadamba* is white with a light-yellow tinge, which becomes creamy yellow upon exposure. The wood has a density of 290 to 560 kg/m^3 at 15% moisture content, a fine to medium texture, straight grain, low luster, and no characteristic odour or taste. It is easy to work with both hand and machine tools, cuts cleanly, provides a very good surface, and is easy to nail. However, the wood is rated as non-durable, with graveyard tests in Indonesia showing an average life of less than 1.5 years in contact with the ground. The wood of *Neolamarckia cadamba* can be easily preserved using open tank or pressure-vacuum systems. Juvenile Kadamtrees, harvested from forest plantations and converted into sawn timber, were studied for their physical and mechanical properties in air-dried conditions. The investigation revealed that the wood can be used as a substitute material for furniture components after necessary modifications to its properties. The timber possesses desirable characteristics for various applications. It is used in plywood manufacturing, light construction, pulp and paper production, boxes and crates, dug-out canoes, and furniture components. It yields pulp of satisfactory brightness and can be impregnated with synthetic resins to increase density and compressive strength.

Based on the strength properties, namely MOE and extreme fibre stress in Bending-Tension, the *N. cadamba* timber is classified as Group C structural category as given in the following table (MOE above 5.6 kN/mm^2 and up to 9.8 kN/mm^2 and bending-tension above 8.5 N/mm^2 and up to 12.0 N/mm^2) (National building code. 2016).

Safe permissible stresses for the Kadam species timber.

Scientific name	*Neolamarckia cadamba or Anthocephalus cadamba*
Family	Rubiaceae
Kingdom	Plantae
Order	Genti anales
Type	Evergreen
Common names	Burflower-tree, laran, Leichhardt pine, Kadam, cadamba, common burflower, jabon, sukhothai, kalempayan
Native	India, Australia, China, Indonesia, Malaysia, Papua New Guinea, Philippines, Singapore, Vietnam

Source: (National Building code of India, 2016).

Applications of *Neolamarckia cadamba:*

Neolamarckia cadamba is a valuable source of timber. Mature Kadam trees produce abundant wood, which is highly sought after. The wood is popular due to its affordability compared to other options such as mahogany and cedar. It is durable and used for manufacturing plywood and various types of furniture. The wood is widely utilized in the production of paper and paper products. Its pulp is used by paper manufacturers to create durable and cost-effective paper. This makes it a sustainable and economically viable choice compared to other sources. The pleasant fragrance of *Neolamarckia cadamba* flowers is highly preferred. Extracts from the tree are used in the production of perfumes and fragrances in India. Whether it's local perfumes or products from renowned brands, the Kadam tree flowers are used to create a sweet floral fragrance at affordable costs.

Suitability of Kadam Wood for Plywood: A Study on Fast-Growing Plantation Timber

This study aimed to assess the suitability of N. cadamba wood for plywood production. The research investigates the peeling process, drying characteristics, gluing properties, and shrinkage characteristics of the veneers, and compares the properties of plywood manufactured using Kadam veneers with general-purpose plywood standards.

The study involved peeling *N. cadamba* logs to produce surface veneers suitable for plywood manufacturing. The veneers were carefully dried to minimize potential degrades. Gluing and bonding properties were optimized using urea formaldehyde and phenol formaldehyde adhesives to meet the requirements of moisture-resistant (MR) and boiling water-resistant (BWR) grade plywood. The shrinkage characteristics of the veneers were analyzed prior to the veneering process. The resulting plywood properties were compared with those of general-purpose plywood specified in IS 303.

The investigation demonstrated that Type-B surface veneers of satisfactory quality could be produced by peeling *N. cadamba* logs. The veneers exhibited acceptable drying characteristics without significant degrades. The gluing and bonding properties were optimized using appropriate adhesives, ensuring compliance with the requirements for MR and BWR grade plywood. The shrinkage characteristics of the veneers were within acceptable limits. Plywood manufactured using Kadam veneers exhibited properties conforming to the standards specified in IS 303.

The study confirms the suitability of *N.cadamba* wood for plywood manufacturing. The fast-growing nature of *N.cadamba* makes it a viable alternative to conventional timber species for the plywood industry. The research findings highlight the potential of *N.cadamba* as a sustainable and economically viable resource for the production of plywood, contributing to the diversification of timber sources in India. The successful utilization of *N. cadamba* wood in plywood manufacturing can enhance the availability of locally sourced plywood materials and reduce dependence on imported timbers. Further research and development efforts should focus on scaling up the production and commercial utilization of *N. cadamba* plywood in the Indian plywood industry.

Fig- 1 Log being taken for debarking Fig -2 Log being loaded to Peeling lathe

Log being cut to veneer Peeling of veneer

Log being cut to veneer and collected Dried Veneer

Assembly of Glue coated veneer for Plywood Plywood from *N.cadamba*

Schima wallichii (DC.) Korth.

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Family : Theaceae
Synonyms : *Gordoniachilaunea* Buch. *Gordoniawallichii* DC.
Common Names: Schima, Needlewood, Simartolu, Mang tan, Voosithuoosc (Vietnam), Thalo, Champa dong, Bunnak (Thailand), Mi, Khaisou, Bounnak (Laos), Laukya (Myanmar), Schima (Papua New Guinea), Samak, Gatal-gatal (Malaysia), Medanggatal (Indonesia), Seru, Kelincipadi (Brunei Darussalam), Puspa (Indonesia), Ta lo (Thailand)

Origin and Distribution: Native to Assam, Bangladesh, Borneo, Cambodia, China South-Central, China Southeast, East Himalaya, Jawa, Laos, Lesser Sunda Is., Malaya, Myanmar, Nepal, Philippines, Sumatera, Thailand, Tibet, and Vietnam. It is found in E. Asia, including China, Indian subcontinent, Myanmar, Thailand, Malaysia, Indonesia, and the Philippines.

Tree Characteristics: *Schima wallichii* is an evergreen, medium to large-sized tree with a dense crown, typically growing to about 10-15 meters in height, but capable of reaching 47 meters. The cylindrical bole can be branchless for up to 25 meters, with a diameter of up to 125 cm. The tree's wood is valuable and collected from the wild. It is also used medicinally and as a source of tannins and oil. Schima is sometimes cultivated as a shade tree and for reforestation projects.

Growth Behavior: *Schima wallichii* prefers tropical climates and can be found at elevations up to 3,900 meters. It grows in a wide range of soils, including infertile ones. The tree is relatively fast-growing and can flower and fruit after four years. It can succeed in shaded conditions and has good survival rates for seedlings when planted out.

Suitability under Agroforestry Systems : *Schima* is used as a shade tree in coffee plantations and as a cover crop in other plantations. It is also used for reforestation and water conservation in catchment areas. Schima is planted in degraded woodlands and open areas alongside other species to restore native woodland and attract seed-dispersing wildlife.

Wood Characteristics: The wood of *Schima wallichii* has a basic density of 0.54 g/cm^3 and air-dry density of 0.62 g/cm^3. The details of other mechanical properties of this wood sourced from West Bengal and tested in air dry condition are presented in the following table (Source: Indian Forest Record, Vol. XVIII). Most of its mechanical properties are either comparable or better than that of Teak. It has good bending strength, stiffness, and shear strength, making it suitable for various applications in the wood industry.

Species	Std. SG	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
		MOR	MOE	Max. drop (cm)	MOE	Max. C stress	MOE	CS at E.L..	R	T	E	R	T	R	T
Teak	0.598	95.9	12534	68.6	16381	54.456	14017	9.7	5004	4959	4670	8.4	9.8	3.7	4.4
Schimawallichhi	0.539	98.6	13561	68.6	18802	52.7	13941	8.9	5760	5315	6583	12.2	15.1	9.6	6.6

Processing and Drying: The wood of *Schima* is easy to work with hand and machine tools, polishes well, and responds well to hand tools. The wood is moderately refractory to season (Class-B) and recommended to follow schedule IV for satisfactory drying (IS-1141-1993). Drying is moderately easy, but some care is needed.

Major Applications and Usage: The wood of *Schima wallichii* is used in various wood-based industries, including construction, including door and window frames, furniture, railway sleepers, firewood as well as for paper pulp. It is suitable for plywood production and wood-wool boards. The bark is a source of tannins and used for dyeing, and the seed contains oil. Additionally, the tree has medicinal uses, and the leaves are used as fodder in some regions. Its versatility and valuable wood properties make it suitable for a wide range of applications. It's worth noting that while *Schima wallichii* offers valuable wood and potential medicinal benefits, sustainable harvesting and conservation practices are crucial to ensure the continued existence of this species and its ecosystems.

Swietenia macrophylla King

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INTRODUCTION:

Swietenia macrophylla King, commonly known as mahogany, is a highly esteemed tree renowned for its desirable characteristics in the international market. With attractive appearance, excellent dimensional stability, ease of working, and natural durability, mahogany wood has been extensively used for various purposes since the 17th century. This article provides valuable information about the origin and status of mahogany, its distribution, and the description of the tree. It also highlights the establishment of large-scale plantations in Southeast Asian countries to ensure a sustainable supply of mahogany wood.

Botanical name: *Swietenia macrophylla* King
Family: Meliaceae
Trade name: Mahogany

Origin and Status:

Mahogany trees have gained worldwide recognition due to their exceptional qualities. Over 200 species belonging to 35 families have been referred to as "mahogany" at different times. For trade purposes, mahogany trees are generally categorized into three groups: Genuine (Swietenia sp.), True (Khaya sp.), and mixed mahogany (Toona sp., Entandrophragma sp., etc.). The genuine mahoganies, including Swietenia macrophylla, hold significant economic importance for their native countries. Honduran mahogany, native to regions with abundant rainfall in southern Mexico, Central America, Colombia, Venezuela, the Amazon Basin, eastern Peru, and northern Bolivia, is one of the highly valued species. However, due to over-exploitation and the inclusion of genuine mahogany species in the CITES list, large-scale artificial plantations have been established in Southeast Asian countries such as Indonesia, Fiji, Philippines, India, and Sri Lanka since 1988 to ensure a consistent supply of mahogany wood.

Distribution:

Genuine mahogany species were introduced from Jamaica and Honduras to the Royal Botanic Garden in Kolkata, India, in 1795 and 1872, respectively, primarily as ornamental trees. Subsequently, they were introduced as avenue trees and timber species

in various parts of India. Kerala, with over 1283 hectares of mahogany plantations, holds the largest area of mahogany plantations in India. Under the World Bank project, a total of 1735 hectares of mahogany plantations were established in Kerala from 1987 to 1999. The Social Forestry wing of the Kerala State Forest Department has distributed lakhs of mahogany seedlings to farmers for planting in their homesteads. Farmers and tree growers in Kerala, Tamil Nadu, Karnataka, and Maharashtra are cultivating Honduran mahogany on a large scale in block plantations, agroforestry systems, and as avenue trees due to its fast growth, short rotation, and high market price. The government has included mahogany species in the exempted tree lists to encourage its cultivation outside forests.

Description of the Tree:

Honduran mahogany is a majestic evergreen tree that briefly sheds its leaves during the summer. It typically grows to a height of 30-40 meters with a girth of 3-4 meters, although in favorable conditions, it can reach heights of up to 60 meters with a girth of 9 meters. The straight and cylindrical trunk has a clear bole height of 20-25 meters and is buttressed at the base. The bark is grayish-brown, ranging from fairly smooth to somewhat rough, and flakes off in patches. The paripinnate leaves are initially long and green or reddish, turning dark green and shiny as they mature, reaching up to 20 centimeters in length. Inconspicuous flowers appear in small open clusters among the leaves, typically during February-March, almost a year later. These sweet-scented flowers are greenish-cream in color, approximately 0.8-1.0 centimeters across, arranged in narrow supra-axillary panicles. The fruits, known as capsules, resemble large, inverted clubs, measuring 12.5 × 7.5 centimeters and possessing a woody texture. Cuban mahogany closely resembles Honduran mahogany in most aspects, except for the size of leaves and fruits, as well as branching patterns, which differ when grown in wider spacing.

Mahogany in wet and dry site

Honey bees in Flowers

Growing Mahogany Trees: Environmental Conditions and Seed Collection

Environmental Conditions:

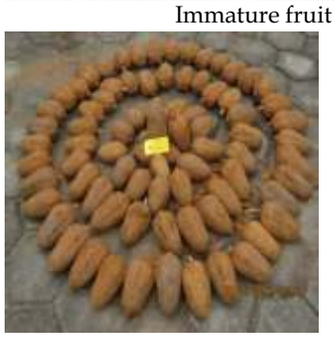
Mahogany trees thrive in various soil types, but they achieve the best growth in deep, fertile soil on well-drained slopes, particularly in regions with abundant rainfall. Interestingly, timber from less moist regions is reported to be of higher value. While mahogany can grow at elevations up to 1300 meters, the optimal growth is observed up to 900 meters. Compared to true mahogany, Honduran mahogany is less demanding in terms of soil and climate requirements. On the other hand, Cuban mahogany exhibits better growth when provided with suitable soil and climate conditions. Ideally, mahogany trees prefer a warm and moist climate, with temperatures ranging from 21 to 35 degrees Celsius and an average annual rainfall between 1000 and 2000 millimeters. They can also be grown as understory trees in teak plantations. However, mahogany is highly sensitive to frost, and plants grown in open areas, such as Dehra Dun, are often susceptible to frost damage.

Fruiting and Seed Collection:

The quality of seeds plays a crucial role in producing high-quality seedlings for planting. To obtain good quality seeds, they can be collected from identified seed trees, seed production areas, or seed orchards. Mahogany trees typically flower in February, with seeds ripening from February to March. After about 11-12 months of flowering, the fruit reaches maturity. Mature fruits are collected between November and April, when they turn whitish-brown and begin to naturally split open. To facilitate seed release, the mature pods are sun-dried for 2-3 days until they longitudinally dehisce, allowing the seeds to be released. Each fruit contains around 25-30 viable seeds, with approximately 2000-2200 seeds weighing 1 kilogram. It's important to note that the viability of the seeds decreases after two to three months of exposure to open air, but if stored in closed containers mixed with sawdust, they can retain their viability for up to a year.

Immature fruit

Mature fruit



Drying fruits

Seeds arrangement in fruit

Processed seeds

Nursery and Seedling Production of Mahogany

Mahogany trees can be propagated through various methods such as direct seed sowing, transplanting, and stump-planting. Among these methods, transplanting has shown the best results. Here is a step-by-step guide to nursery and seedling production:

1. **Seed Preparation:** After freshly collecting the seeds, soak them in cold water overnight. After decanting the water, allow the seeds to dry in shade for 15 minutes before sowing.
2. **Seed Sowing**: Spread the prepared seeds uniformly on sand-beds. Then, broadcast a layer of fine sand or soil over the seeds, with a thickness of approximately 1 centimeter to cover them. Regular watering is required after sowing.
3. **Germination:** Seed germination typically begins on the 15th day after sowing. However, the speed and percentage of germination may vary depending on the seed source and site conditions. The germination percentage can also vary with the age and location of the seed source. The peak time for germination is usually observed between 15 to 20 days after sowing.
4. **Transplantation:** Once the seedlings reach the 2nd leaf stage, they can be transplanted from the nursery bed into polybags. These container seedlings are then maintained in the nursery for approximately 6 months before they are ready for out-planting.
5. **Seed Treatment:** To protect against soil-borne insects and improve germination percentage, seed treatment with either a 10% BHC or 10% methoxychlor solution is recommended. Soak the seeds in the solution for 3 hours before sowing to ensure effectiveness.

By following these steps, successful nursery and seedling production of mahogany can be achieved, providing a strong foundation for future plantation and growth.

Mother bed

Seedlings in mother bed

Container filling with media

Transplanting seedling from bed to polybags

Seedling transplantation

Seedlings in green house

Seedling hardening

Vegetative Propagation of Mahogany

Vegetative propagation is a method used to ensure that the desirable traits of the mother tree are fully transferred to its progenies. Two common techniques for vegetative propagation of mahogany are stem cuttings and grafting. Here are some key details:

1. **Stem Cuttings:** Stem cuttings are taken from selected mother trees and treated with a rooting hormone such as 2000 ppm IBA (Indole-3-butyric acid) to promote root development. This treatment has shown maximum rooting percentage and longer root length in the cuttings. The cuttings are then planted in a suitable growing medium and provided with appropriate moisture and care to encourage root formation.
2. **Grafting:** Grafting is another method used for producing clonal seedlings with desired traits. Cleft grafting, in particular, has shown promising results for mahogany. In this technique, a scion (a shoot or bud from the desired mother tree) is inserted into a cleft made in the rootstock (a young plant with established roots). The scion and rootstock are then joined together and secured. With proper care and management, the graft union will develop, resulting in a clonal seedling.

By employing these vegetative propagation techniques, it is possible to replicate the desired traits of the mother tree and produce genetically identical offspring. This can be advantageous for maintaining specific traits, such as timber quality, growth rate, and disease resistance, in mahogany plantations.

Cuttings at poly- tunnel

Sprouted cutting

Rooted cutting

Grafted seedling

Establishing a Mahogany Plantation

When establishing a plantation of Honduran mahogany, it is important to consider its intended purpose, whether it be for timber production, shade, avenue trees, or border trees. Additionally, incorporating agroforestry practices can enhance the overall productivity and diversity of the plantation. Here are some key points to consider:

1. **Purpose and Inter-cropping:** Honduran mahogany is commonly cultivated for various purposes, and inter-cropping can be implemented to maximize land utilization. Common intercrops include pumpkin, maize, sugarcane, banana, fodder grasses, chili, and leafy vegetables. These intercrops can provide additional economic benefits while the mahogany trees are growing.
2. **Spacing:** The recommended spacing for timber production in block plantations is 2×3 meters, 3×3 meters, or 3×4 meters. This spacing allows for optimal growth and development of the mahogany trees while ensuring efficient land utilization. For agroforestry purposes, a wider spacing of 4×4 meters is recommended to accommodate the intercrops and provide sufficient sunlight and space for their growth.
3. **Growth Rate:** *Honduran mahogany* has a rapid growth rate and performs well in favorable conditions. Compared to Cuban mahogany, it tends to thrive better in the Indian climate. With proper care, including adequate water, nutrients, and maintenance, the growth rate can be further enhanced, leading to quicker establishment of the plantation.

By considering the plantation's purpose, incorporating inter-cropping techniques, and selecting appropriate spacing, a well-planned and managed Honduran mahogany plantation can achieve both economic and environmental benefits. It is essential to monitor and provide the necessary care to ensure the successful establishment and growth of the plantation.

Agroforestry model (mahogany + rainfed crops)

Block plantation

Plantation Management and Timber Yield

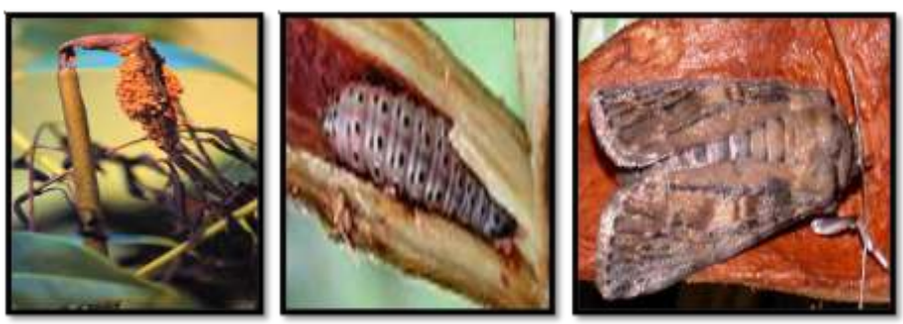
To ensure the successful growth and optimal timber yield of a Honduran mahogany plantation, effective management practices need to be implemented. Here are key management considerations:

1. **Weeding and Fertilization:** Weeding and hoeing should be carried out four times at six-month intervals during the first two years after planting. Line weeding or ring weeding (around the seedling) are recommended methods. Applying a dose of 75-100 grams of NPK fertilizer per plant in a ring around the seedlings after planting can reduce susceptibility to shoot borer damage and promote healthy growth.
2. **Pruning and Thinning:** Pruning is typically not required for Honduran mahogany, as it naturally grows straight with a narrow crown. However, pruning may be necessary to remove dead and diseased branches, reducing the risk of disease and pest infestations. Pruning is usually done during the first three years, preferably just before the rainy season. Thinning, which involves selectively removing trees to improve the growth of the remaining ones, is recommended. The timing and frequency of thinning depend on the initial stand density and site quality.
3. **Growth Statistics and Timber Yield:** The growth rate of Honduran mahogany varies based on site conditions, initial spacing, and age. At 11 years old, the annual height growth is approximately 1.5 meters and the diameter growth is around 1.3 centimeters. Maximum timber yield per hectare has been recorded in wide spacing plantations in Palakkad, Kerala. Factors such as density, site quality, and age of the plantation play a significant role in enhancing timber yield. Depending on site quality, medium-quality sites can produce a volume mean annual increment (MAI) of 19.7 cubic meters per hectare per year, reaching up to 493 cubic meters per hectare in 25 years. With a rotation age of 30 years, stands in moderate sites can attain a mean height of 24.4 meters, mean diameter of 35.4 centimeters, and total volume of 583 cubic meters per hectare, including thinning.
4. **Insect Pests:** Honduran mahogany is susceptible

to various insect pests, including defoliators, borers, and sap-suckers. The sapwood is particularly vulnerable to powder post beetles (Lyctus sp.). The shoot borer (Hypsipyla robusta) is the most significant pest, causing damage to the leading shoots of plants and hindering their growth. Extensive pruning until three years after planting, planting repellent trees around the plantation, or establishing mixed plantations can help control the threat of shoot borers. Additionally, the application of a 0.5 percent lead arsenate paste solution has been reported to provide some control.

Shoot borer infested tree in Burliyar, Tamil Nadu in 2017

By implementing effective plantation management practices, including weeding, fertilization, pruning, thinning, and pest control measures, Honduran mahogany plantations can thrive, leading to optimal timber yield and sustainable growth.



Symptom, borer and adults of shoot borer (www.entnemdept.ufl.edu/creatures)

Management of Heartwood Borer (*Apate monachus)* in Honduran Mahogany Plantations

The heartwood borer, also known as the shot-hole-borer (*Apate monachus*), has been identified as a potential pest causing significant damage to young Honduran mahogany trees. The infestation of this pest was first observed in a 3-year-old mahogany plantation in Anaikatty, Coimbatore, Tamil Nadu, India in April 2016.

The damage caused by the heartwood borer is characterized by small holes in the trunk, through which the shot-hole-borer enters and constructs tunnels within the wood. As it feeds on the wood, it produces a substantial amount of sawdust. To effectively manage this pest, mechanical control measures can be employed when infestations are sporadic.

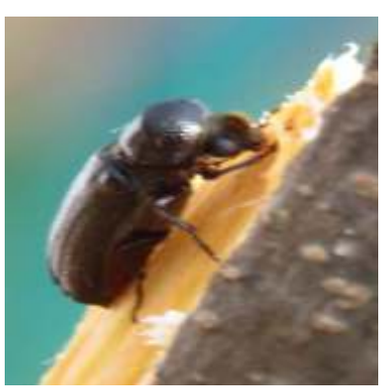
Additionally, natural enemies such as species of Sclerodermus and other braconid species, like Glyptodoryctes, may provide valuable assistance in controlling the heartwood borer population. These natural predators can help reduce the pest's impact on young mahogany trees.

Implementing appropriate control measures, including mechanical methods and leveraging natural enemies, can aid in managing the heartwood borer infestation and protecting the health and growth of Honduran mahogany plantations.

Management of Leaf Spot and Leaf Malformation in Honduran Mahogany

Honduran mahogany (*Swietenia macrophylla*) is susceptible to certain fungal diseases that can affect the health and appearance of the trees. Leaf spot is a common disease caused by fungi, including *Botryodiplodia theobromae, Colletotrichum gloeosporioides,* and *Pestalotiopsis adusta.* These fungi can lead to the development of spots on the leaves, affecting their overall vitality.

Tunnels in infected tree



Adult, Shot-hole-borer

In addition to leaf spot, another fungal infection known as leaf malformation can occur in young seedlings of Honduran mahogany. The causal organisms responsible for this condition are *Fusarium mexicanum* and *F. pseudo circinatum*. The presence of these fungi can cause abnormal growth and malformation of the leaves in affected seedlings.

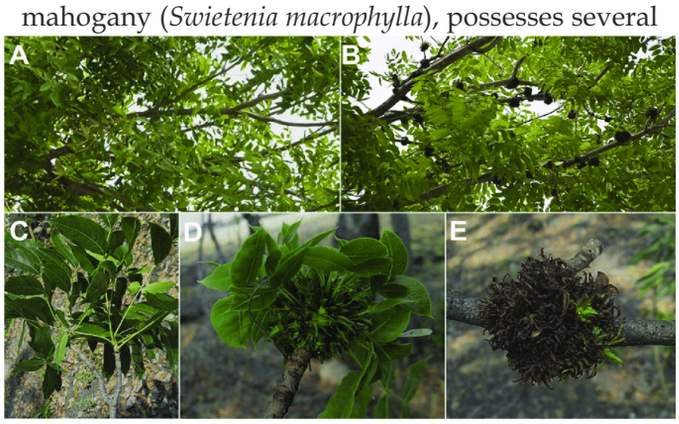
To effectively manage these diseases and minimize their impact on Honduran mahogany plantations, certain strategies can be employed. These include:

1. **Cultural practices:** Implementing good cultural practices, such as proper sanitation, removing and disposing of infected plant material, and maintaining optimal growing conditions, can help reduce the spread and severity of fungal diseases.
2. **Fungicide applications:** In cases where the diseases are severe or recurring, targeted fungicide treatments can be applied as recommended by local agricultural or forestry authorities. It is important to follow the instructions and guidelines for proper application and safety precautions.
3. **Disease-resistant varieties:** When available, selecting disease-resistant varieties or strains of Honduran mahogany can help mitigate the risk of infection and reduce the impact of these fungal diseases.

Regular monitoring of the plantation for early detection of disease symptoms, combined with prompt management measures, can help protect the health and productivity of Honduran mahogany trees, ensuring their long-term viability and sustainability.

Properties and Utilization of Mahogany Wood

Mahogany wood, specifically Honduran mahogany (*Swietenia macrophylla*), possesses several unique properties that make it highly sought after in various industries. The heartwood of the tree exhibits a range of colors, starting from yellowish-white to salmon pink when freshly sawn. Over time, with exposure to air and light, the wood develops a rich golden brown hue. One distinguishing characteristic of mahogany wood is its high natural lustre. The grain patterns can vary, with straight or interlocked grains that give rise to figures such as fiddle-back, blister, stripe, swirl, crotch, and mottle. The wood has a uniform texture and is devoid of any odor or taste.



Malformation in Honduran mahogany (Santillán-Mendoza et al. 2018)

In terms of physical properties, mahogany wood is moderately hard and heavy, with a weight of approximately 560 kg/m^3. Growth rings are distinct, and both true and false rings can be observed. It is important to note that the quality and characteristics of Indian mahogany wood may differ from Central American mahogany, with the former exhibiting superior weight, hardness, and resistance to splitting, but inferior strength, stiffness, and figure.

When it comes to wood density, plantation-grown mahogany wood shows variations based on age and site conditions. Young plantation wood (<40 years old) has a mean density that is 16.3% lower than older plantation wood (>40 years old). Similarly, the density of mature plantation wood is 11.5% lower than that of natural forest wood. The density of mahogany wood can vary depending on the region, ranging from 420-660 kg/m^3 in Honduras, 470 kg/m^3 in Puerto Rico, and 510-570 kg/m^3 in Asian countries.

Mahogany wood is known for its ease of seasoning through both air and kiln methods. However, air seasoning may lead to fine surface cracks, which can be prevented through careful handling and proper stacking of sawn material. Kiln-drying can be done rapidly without significant degradation. In terms of workability, mahogany wood is highly regarded by wood craftsmen, known for its ease of working and ranked among the top 25 American hardwoods. It is suitable for various applications, including veneer production. The wood glues well, and its decay resistance is generally higher compared to other mahogany species.

Identification of mahogany wood can be done through various characteristics. Ripple marks on flat-sawn surfaces are typical of Swietenia species, distinguishing them from other woods labeled as

mahogany. African mahogany may lack growth rings and rarely exhibit ripple marks. Philippine mahogany has distinct resin canals appearing as white lines and lacks dark-colored deposits found in true mahogany. Advanced techniques like NIRS and Partial Least Squares for Discriminant Analysis have also been successfully employed to differentiate mahogany wood with a high degree of accuracy.

Laughing budda

Chitra veena

Flooring with mahogany

Mahogany kitchen cabinet

Mahogany wood holds significant value in the market. Prices for different grades of mahogany timber can vary, with Grade-I and Grade-II timber priced at Rs. 23,205/m^3 and Rs. 12,881/m^3, respectively, according to Kerala Forest Department rates. In the international market, sliced veneer (export quality) and sawn wood (export quality) are priced at US$ 1743/m^3 and US$ 1570-1655/m^3, respectively. Based on these prices, the predicted timber yield and income per hectare in a rotation period of 15-30 years can range from 200-501 m^3/ha and US$ 3,14,000-8,29,155/ha (equivalent to Rs. 2.38-6.3 crore), respectively.

Mahogany wood finds extensive utilization in various industries due to its medium density, attractive reddish or pinkish color, ease of working, excellent finishing qualities, dimensional stability, and durability. It is commonly used in construction, plywood production, high-grade furniture and cabinet making, as well as for paneling, framing, flooring, automobile bodies, interior trim of boats, radio and phonograph cabinets, musical instrument bodies, moldings, and other ornamental applications. The United States and the United Kingdom are major importers of mahogany wood, while Peru and Brazil are the largest exporters globally

Ethno-botanical Uses of Mahogany

Mahogany (*Swietenia macrophylla*) is rich in phytochemicals, with various parts of the tree, including the leaves, seeds, fruits, and bark, containing valuable compounds. The seeds and leaves are particularly abundant in alkaloids, terpenoids, and carbohydrates. The leaves, as well as the central fruit axis, have a high tannin content. Specific compounds isolated from the seeds include swietenine ($C_{32}H_{40}O_9$, m.p. 272-76°C), a neutral and non-bitter principle, and swietenolide ($C_{27}H_{34}O_8$; m.p. 218-22°C), a bitter and hygroscopic component.

The seeds of mahogany yield approximately 50% clear, yellow, and bitter-tasting fatty oil. The oil contains six types of fatty acids, namely palmitic, stearic, arachidic, oleic, linoleic, and linolenic acids. Linoleic and oleic acids make up more than 50% of the fatty acids in the seed oil.

In ethno-botanical practices, genuine mahogany is often regarded as a "cure-all medicine" and the "Queen of Plants" due to its wide-ranging medicinal applications. It is traditionally used to address common ailments such as diabetes, arthritis, rheumatism, gout, diarrhea, fever, malaria, cough, and high blood pressure. The seeds, in particular, are employed for managing conditions like high blood pressure, hypertension, diabetes, and malaria. Additionally, crushed seed decoctions are utilized for treating skin ailments and wounds.

In certain Amazonian and Bolivian ethnic groups, mahogany seeds are even used to induce abortion. Furthermore, the seeds have been employed in the treatment of cancer, amoebiasis, coughs, chest pains, and intestinal parasitism. The seed oil shows promise as a moderate drying oil and is also used in soap-making.

The ethno-botanical uses of mahogany reflect the rich traditional knowledge and cultural practices associated with this remarkable tree. Further research into its phytochemical constituents and their potential benefits may reveal additional applications for this valuable plant.

Thespesia populnea (L.) Soland. ex Correa

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Thespesia populnea, commonly known as Portia tree, is a small evergreen tree with a height ranging from 6 to 10 meters (20 to 33 feet). It is characterized by a short, frequently crooked trunk and a large, thick crown. The tree bears yellow hibiscus-like flowers and glossy green, heart-shaped leaves. It is also referred to by various vernacular names such as Gajahanda, Paras-piapal, Parsippu, Bendi in Hindi, and Parisha, Pursa, Porsung, Kallal, Karvarachu, Gangareni, Gangaravi, Gangaregu, Galgaiovi in Telugu, among others.

Origin and Distribution:

Thespesia populnea is believed to have originated in the Asian tropics or along the coasts of the Pacific and Indian Oceans. It thrives in warm coastal regions and is found in regions spanning from the east coast of Africa and South and Southeast Asia to Melanesia, Micronesia, and Polynesia. The tree has become naturalized in tropical regions worldwide, including Africa and the Caribbean. It is commonly found along the coastal regions of the Indian Peninsula and may also grow wild in Cuttack, south Kanara, Malabar, the Godavari and Mahanadi Deltas, and the Andaman Islands. Additionally, it can be found in the Sundarbans in West Bengal.

Tree Characteristics: A twig with flower and fruit *Thespesia populnea* is an evergreen tree with an average height of 6 to 12 meters. It has a broad, dense crown and often exhibits a crooked stem. The tree grows in short twists and turns with numerous limbs, resulting in lumber typically found in short lengths. The clear bole height is around 2 to 2.5 meters, and the girth at breast height ranges from 0.6 to 1.2 meters. The leaves are heart-shaped, glossy, and green, resembling poplar leaves, measuring approximately 15 cm by 6 to 10 cm. The flowers are bell-shaped, bisexual, and axillary, with five overlapping, broad, and rounded petals. They are yellow, 5 to 7.5 cm long, and feature a maroon or purple patch at the base of each petal. The outer surface of the petals is covered with star-shaped hairs. The flowers change color throughout the day, transitioning from yellow to shades of red, purple, or pink.

A twig with flower and fruit

Growth Behaviour: Bark

Thespesia populnea thrives in moist to wet lowland tropics and warm subtropics, typically at elevations of up to 150 meters. It can tolerate temperatures as high as 35°C and occasional light frosts as low as 4°C. The tree prefers environments with yearly daily temperatures ranging from 20 to 30°C. It can tolerate annual precipitation of up to 5,000 mm but prefers 1,000 to 3,000 mm. *Thespesia populnea* thrives in full sun and prefers well-drained soils that retain moisture. It exhibits a strong tolerance for salinity and is well-suited to arid environments. The height growth rate slows down as the tree reaches 7 to 10 years of age, averaging 50 to 150 cm per year during the initial years. The stem diameter increases by 1 to 3 cm per year.

Suitability under Agroforestry Systems:

Thespesia populnea has been cultivated in domestic home gardens, particularly in coastal areas. It is frequently planted as a coastal windbreak due to its ability to thrive in sandy, salty soils and its high resistance to wind and salt spray. The tree is commonly used as a living fence in regions such as Kerala and Karnataka in India, as well as in the Pacific Islands, to control coastal erosion. It has also been planted to support vanilla plants. The tree's chippings have been used as green manure.

Genetics and Tree Improvement:

The stem of *Thespesia populnea* often exhibits a crooked appearance, limiting the availability of long lengths of timber. However, no systematic tree improvement program or variability studies have been conducted for this species. In 2011, the Institute of Forest Genetics and Tree Breeding initiated a systematic tree improvement program for Thespesia populnea, selecting 139 plus trees with desirable form traits from Tamil Nadu, Kerala, and Puducherry. Selection criteria included tree height, clear bole height, girth at breast height, straightness, and freedom from pests and diseases. Stem straightness and absence of pests and diseases were given significant importance during the selection process. The selected cuttings underwent root formation in a polytunnel, achieving a rooting percentage of 60%. Rooted cuttings were subsequently hardened in a shade house. A clonal multiplication area (CMA) was established to produce clonal plantlets, which can be used for the establishment of clonal seed orchards to produce high-quality seeds. The South Pacific Regional Initiative on Forest Genetic Resources (SPRIG), CSIRO Forestry and Forestry Products in Canberra, Australia, has designated *Thespesia populnea* as a priority species for genetic study and conservation. Research on the creation of a germplasm bank and selection of superior trees is necessary.

Physical, Mechanical, Chemical, and Anatomical Characterization of the Wood:

The wood of *Thespesia populnea* exhibits a diffuse porous structure with indistinct growth rings. The vessels are medium to small, mostly solitary or in radial multiples of 2, 3, or more. The parenchyma is

Bark

diffuse to diffuse in aggregate, forming an irregular reticulum with rays. The rays are fine and occasionally moderately broad and storied.The bark thickness ranges from 0.3 to 0.8 cm.Thespesia populnea wood has a weight ranging from light to medium, with a density of 400 to 770 kg/m^3 at 15% moisture content. The heartwood is smooth and dark crimson in color, with a medium to fine texture.

The physical, mechanical, and chemical properties of the wood are as follows: Density: 770 kg/m^3, Specific gravity: 0.55 to 0.89, Strength as a beam: 722, Stiffness as a beam: 92, Suitability as a post: 101, Shock-resisting ability: 182, Retention of shape: 78, Shear: 131, Hardness: 124, Refractoriness: 91, Nail or screw-holding property: 109 (Comparative suitability as timber with teak taken as 100).

Shrinkage is minimal after seasoning, and the wood seasons well. Despite its wavy grain, the timber is easy to saw and work with. It exhibits resistance to insect attacks. The wood of Thespesia populnea is fairly durable, with the heartwood being refractory to treatment. Working properties include satisfactory sawing, good workability with hand tools and machines, smooth finish, and the ability to take a good polish.

Major Applications with Special Emphasis on Wood: Thespesia populnea wood is easy to saw and work with, yielding a smooth finish and accepting polish well. It is used to make small canoes, furniture, agricultural equipment, and wooden footwear. In Kerala, the wood is highly prized for its resistance to splitting. It exhibits high resistance to termites when dry. The wood is also suitable for carving figurines, tools, bowls, and plates. It finds applications in furniture, toys, shuttles, shelves, tool handles, and other textile accessories. Additionally, it is used to make food containers, split drums, and cabinetry. Thespesia populnea wood also serves as a source of fuel.

Medicinal Uses:

Root extracts of *Thespesia populnea* are used externally to treat scabies, psoriasis, and other skin conditions. Traditional medicine employs heartwood for treating skin conditions. Bark decoctions are used to treat skin diseases, and a combination of ground bark and coconut oil is administered for skin conditions. Bark extracts have been found to possess hepatoprotective and antioxidant properties. Leaf extracts are used for inflamed and swollen joints. Flavonoids extracted from the flowers have demonstrated antibacterial properties, as well as anti-hepatotoxic and anti-steroidogenic properties. The fruit of Thespesia populnea contains a viscid, yellow juice that is used to treat various conditions such as psoriasis, gonorrhea, ringworm, migraines, fistulas, sprains, and warts. Fruit extracts also have wound-healing properties. Seed extracts are used for pregnancy prevention by the Irular tribal community of Anaikkatty Hills, Kerala.

Social Benefits:

Thespesia populnea has cultural and social significance. It is considered a sacred tree and is often grown near temples in various Pacific Islands. The tree also serves as a living fence. The foliage can be used as fodder, and the hard, fibrous bark, which contains up to 7% tannin, is used for making ropes. All parts of the plant, including the seeds, are utilized for traditional medicines. The fruit extract is also used as a coloring agent.

Potential Scope as Raw Material for Different Wood-based Industries: Thespesia populnea wood finds applications in furniture, tool handles, boat and shipbuilding, mathematical, engineering and drawing instruments, carts and carriages, and wooden footwear.

In conclusion, Thespesia populnea, with its desirable characteristics and versatile applications, holds potential as a valuable species for various wood-based industries. Its cultural significance, medicinal uses, and social benefits further enhance its value. Continued research on genetic studies, tree improvement, and the establishment of germplasm banks can contribute to the conservation and sustainable utilization of this species.

Toona ciliata M. Roem

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INTRODUCTION

Toona ciliata, commonly known as the Toon tree, is a deciduous tree native to Southeast Asia, including India, Nepal, Bangladesh, Myanmar, and parts of China. It is a medium to large-sized tree with a straight trunk and a broad, spreading crown. The *Toona ciliata* tree is valued for various uses such as timber, medicine, culinary, ornamental etc

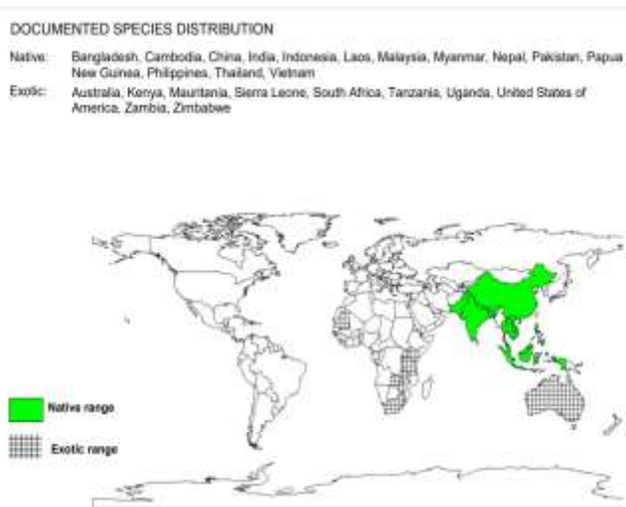
Scientific Name : *Toona ciliata* M. Roem
Family : Meliaceae
Syn. Cedrelatoona Roxb. ex Rottler & Willd. (1803)

Vernacular names:
English : Australian red cedar, Indian cedar
Hindi : Mahanim
Sanskrit : Nandivriksha
Tamil : Tunumaram

Common Name: Red cedar, Toon or Toona, Australian red cedar, Burma cedar, Indian cedar, Moulmein cedar, Queensland red cedar. The synonymous name 'cedrela' is derived from the Latin 'cedrus', referring to the cedar, owing to its scented wood.

Tree of *Toona ciliata* M. Roem

Origin and Geographic Distribution: *Toona ciliata* is native to tropical Asia and Australia. It has been extensively cultivated in subtropical and tropical regions worldwide as a shade tree, prized for its fast growth. Notably, it is widely planted in tropical Africa, Madagascar, Mauritius, and the Hawaiian Islands. Although once heavily harvested, often unsustainably, during the 19th and early 20th centuries, large trees are now scarce, and the species is essentially commercially extinct. The availability of this timber is currently limited.



Ecology: *Toona ciliata* thrives in subtropical climates and can be found in both primary and secondary forests, favouring moist habitats such as ravines, stream banks, and swamps. It shows optimal growth in fire-protected savannahs, abandoned cultivation areas, and small gaps within forests. However, it does not thrive well in dry hillslopes.

Biophysical Limits: *Toona ciliata* prefers the moist to wet tropics and subtropics, growing at elevations between 400 and 2,800 meters above sea level. It thrives in areas where daytime temperatures range from 18°C to 34°C but can tolerate a broader range of 8°C to 48°C. Regarding rainfall, it prefers a mean annual precipitation between 1,100 and 3,000 mm, but it can tolerate levels between 750 and 4,500 mm.

Description of Tree: *Toona ciliata* is a deciduous or nearly evergreen, monoecious medium-sized tree that can reach heights of 25 to 35 m. The trunk can have a clear bole up to 22 m and a diameter of 50–100 cm, with exceptional cases reaching up to 60 m in height and 3 m in girth. The crown is rounded, spreading, and dense, sometimes with buttresses at the base. The bark starts as dark grey or reddish-brown, becoming rough and exfoliating in irregular woody scales as the tree matures. The inner bark is brown to reddish and fibrous. Leaves are alternate, imparipinnate, 30-50 cm long, with 11-29 lanceolate or ovate-lanceolate leaflets. The inflorescence is a much-branched, drooping or sub-erect terminal panicle up to 55 cm long, with unisexual, fragrant (honey-scented) flowers that are cream-colored. Fruits are ellipsoid to obovoid green capsules, turning brown when mature and dehiscing to release numerous winged seeds.

Biology: The leaves of *Toona ciliata* fall during autumn (late March) and regrow in spring (early September). Trees start producing flowers and fruits after approximately 6 years. Flowering occurs in early to late spring, with small, white, tubular-shaped flowers that are functionally unisexual. The flowers are pollinated by bees and moths. Fruits ripen about three months after flowering, and the seeds are wind-dispersed and light in weight. Seed germination is epigeal, and seedlings have opposite, 3-foliolate leaves with lobed or toothed leaflets.

Management: Propagation of *Toona ciliata* is mainly done through seeds, root suckers, and occasionally wildlings. The seeds have a relatively short storage life at room temperature but can remain viable for an extended period at low temperatures. Adequate spacing, regular weeding, and early thinning are essential for successful growth. Coppicing and pollarding are common management practices. The species is sensitive to fire and drought during its early stages of growth.

Growth: *Toona ciliata* is a rapid-growing species that thrives in high light conditions, including the understorey of rainforests. It prefers medium to heavy soils with good drainage and rich organic content. It is not well-suited for wet, compacted, or poor sandy soils. The heartwood of the tree is pale red to reddish-brown, with a cedar-like odor. The wood is lightweight to medium-weight and has moderate shrinkage rates. It is relatively easy to work with and takes paints and polishes well. However, it can be susceptible to warping and cupping during drying. The wood is moderately durable but vulnerable to termites and dry-wood borers.

Insect-Pest and Disease problems: *Toona ciliata* is susceptible to attack by the cedar tip moth. The cedar tip moth lays its eggs on the tree's leading shoot, allowing the larvae to burrow into the stem. This causes dieback. Leaf blight caused by *Phytophthora* has been reported from forest nurseries in India. In many regions *T. ciliata* plantations are severely damaged by attacks of tip moth (*Hypsipyla robusta*), which may attack young shoots, flowers, fruits, and seeds. Tip moth and some other pests may cause seed losses of up to 97%. *T. ciliata* has been used successfully in South-East Asia for enrichment planting and was then much less severely attacked by tip moth than when seedlings were planted in the open. The shoot borer H*ypsipyla grandella* attacks *Toona ciliata* worldwide. In the 1970s in several areas of Malawi many *Toona ciliata* trees showed die-back of the branches, locally resulting in 80% mortality. It has been suggested that Fusarium sp. was the causal

organism.

Genetic improvement: *Toona ciliata* is much sought after for its timber in its natural distribution area and has become scarce in many regions. It has been suggested that there is much genetic variation in *Toona ciliata* over its large natural distribution area. In many parts of Brazil genetic improvement and clonal production has been taken up for the species.

Uses: *Toona ciliata* is highly valued for its red-coloured timber, which is lightweight, moderately hard, tough, and durable. It finds various applications, including boat building, cabinet making, furniture, decorative plywood and veneer, musical instruments, panelling, and building materials. Historically, it was prized for lightweight racing boats and dinghies. Additionally, different parts of the plant have medicinal uses, and the flowers are used in dye production.

Nutritive and Medicinal value: Various parts of the plant are used medicinally throughout its geographical range. Leaves were palatable to sheep, has good nutritive value, contains 13–14% crude protein and 14–22% crude fibre. An ethanol extract of the heartwood showed anti-ulcer, gastro-protective and analgesic activities in tests with rats. The bark is a powerful astringent, febrifuge, tonic, and antiperiodic. It is used to treat chronic dysentery and wounds. Bark extracts have insect-repellent activity. The flowers are used to stimulate menstrual flow in women. The fruits yield aromatic oil. The wood is used for shiitake mushroom culture. Several limonoids have been isolated from *T. ciliata*. The tetra nortriterpenoid cedrelone showed antifungal activity.

Prospects: Despite its commercial extinction in many regions due to unsustainable harvesting, *Toona ciliata* remains a valuable species for agroforestry systems and reforestation projects. Sustainable management practices are essential to preserve this valuable species and continue to benefit from its various uses. However, due to its superficial root system and susceptibility to pests and diseases, it may be more practical to consider other species with similar wood properties, such as Entandrophragma and Khaya species, for some regions.

Wood Properties:

The heartwood is pale red to reddish brown, darkening to dark red-brown on exposure, usually distinctly demarcated from the greyish white to pink sapwood. The grain is usually straight, sometimes interlocked, texture rather coarse and uneven. The wood has a cedar-like odour. The wood is lightweight to medium-weight, with a density of 330–600 kg/m^3 at 12% moisture content. The rates of shrinkage are usually moderate. The wood may be liable to warping and cupping during drying, particularly in thin planks. Close spacing of stickers and weighting of stacks is recommended. Boards 25 mm thick take 1–3.5 months to air dry. Once dry, the wood is moderately stable in service. For wood of South African origin at 12% moisture content, the modulus of rupture is 76 N/mm^2, modulus of elasticity 8900 N/mm^2, compression parallel to grain 42 N/mm^2, shear 7 N/mm^2, Janka side hardness 3650 N and Janka end hardness 5330 N. The wood is easy to saw, cross-cut and plane, and the planed surface is smooth; it takes a good polish. Some material tends to produce a woolly finish and the use of sharp tools is therefore recommended. Mortising, turning, and sanding give moderate results, boring sometimes poor results. Nailing is easy, but the nail-holding capacity is moderate. The gluing properties are rated as good. The wood peels well and the veneer is of good quality and has a nice figure. The veneer can be glued to produce good-quality plywood. The wood is moderately durable, susceptible to termite and dry-wood borer attacks. The heartwood is usually resistant to impregnation with preservatives, but the sapwood is permeable. Wood dust may irritate the respiratory organs and skin.

MECHANICAL PROPERTIES OF IMPORTANT TIMBER SPECIES

Michelea champaka

Species	Location	Condition	SG based OD weight and	MC at test	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
			Vol. at test		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at .. E.L	R	T	E	R	T	R	T
Tectona grandis	Burma and Malabar	AR	0.611	13.9	95.9	12534	27	16381	54.46	14017	9.68	5004	4959	4670	8.41	9.75	3.72	4.41
M. champaka	Kurseong Bengal	AR	0.441	8.8	63.77	9563	23	16140	44.26	10349	6.79	3380	3736	4470	7.37	8.44	2.37	2.62

Schima wallichhi

Species	Location	Condition	SG based OD weight and	MC at test	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
			Vol. at test		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at .. E.L	R	T	E	R	T	R	T
Tectona grandis	Burma and Malabar	AR	0.611	13.9	95.9	12534	27	16381	54.46	14017	9.68	5004	4959	4670	8.41	9.75	3.72	4.41
Schima wallichhi	Buxa Bengal	AR	0.619	13.5	98.62	13561	27	18802	52.71	13941	8.92	5760	5315	6583	12.23	15.16	9.61	6.55

Artocarpus chaplasha

Species	Location	Condition	SG based OD weight and	MC at test	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
			Vol. at test		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at .. E.L	R	T	E	R	T	R	T
Tectona grandis	Burma and Malabar	AR	0.611	13.9	95.9	12534	27	16381	54.46	14017	9.68	5004	4959	4670	8.41	9.75	3.72	4.41
Artocarpus chaplasha	UP	AR	0.592	12.2	78.08	9390	19	15720	45.16	8225	10.16	5182	5760	6405	10.37	10.27	2.55	4.24

Acrocarpus fraxinifolius

Species	Location	Condition	SG based OD weight and	MC at test	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
			Vol. at test		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at .. E.L	R	T	E	R	T	R	T
Tectona grandis	Burma and Malabar	AR	0.611	13.9	95.90	12534	27	16381	54.46	14017	9.68	5004	4959	4670	8.41	9.75	3.72	4.41
Acrocarpus fraxinifolius	Malabar, Madras, Coimbatore	AR	0.863	9.9	110.79	13355	49	-	54.64	13755	12.41	11498	10275	9541	13.03	13.72	3.58	7.48

Alstonia scholaris

Species	Location	Condition	SG based OD weight and	MC at test		Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N) Shear		
			Vol. at test		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at .. E.L	R	T	E	
Tectona grandis	Burma and Malabar	AR	0.611	13.9	95.90	12534	27	1638	54.46	14017	9.68	5004	4959	4670	
Alstonia scholaris	North Mangalore, Madras	AR	0.333	11.6	42.26	-	19	-	24.13	6432.80	2.89	1668	1957	2402	

Haldina cordifolia

Species	Location	Condition	SG based OD weight and	MC at test	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
			Vol. at test		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at .. E.L	R	T	E	R	T	R	T
Tectona grandis	Burma and Malabar	AR	0.611	13.9	95.90	12534	27	16381.94	54.46	14017	9.68	5004	4959	4670	8.41	9.75	3.72	4.41
Haldina cordifolia	South Coimbatore, Mangalore	AR	0.536	12.9	91.90	11762	23	13265	56.95		8.48	3825	5182	6049	7.92	8.58	3.17	4.20

Casuarina equisetifolia

Species	Location	Condition	SG based OD weight and	MC at test	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)	
			Vol. at test		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at .. E.L	R	T	E	R	T
Tectona grandis	Burma and Malabar	G	0.598	51.8	78.84	11534	35	15051	40.74	13.35	7.27	4648	4581	4070	7.2	8.06
Casuarina equisetifolia	Puri (Bengal, Orissa)	G	0.693	59	71.77	11224	49	15995	32.09	11045	6.79	1415	1570	1405	10.79	11.79

Cedrella toona

Species	Location	Condition	SG based OD weight and	MC at test	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)	
			Vol. at test		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at .. E.L	R	T	E	R	T
Tectona grandis	Burma and Malabar	AR	0.611	13.9	95.90	12534	27	16381	54.46	14017	9.68	5004	4959	4670	8.41	9.75
Cedrella toona	Dehradun (UP)	AR	0.435	32	55.15	7701	17	11086	31.50	5584	4.72	3269	3625	3692	7.79	-

Chukrasia tabularis

Species	Location	Condition	SG based OD weight and	MC at test	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
			Vol. at test		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at .. E.L	R	T	E	R	T	R	T
Tectona grandis	Burma and Malabar	AR	0.611	13.9	95.90	12534	27	16381	54.46	14017	9.68	5004	4959	4670	8.41	9.75	3.72	4.41
Chukrasia tabularis	Buxa, Bengal	AR	0.595	13.2	82.32	10817	36	17105	47.36	11210	10.82	5560	6071	6627	10.75	11.65	3.30	5.06

Mangifera indica

Species	Location	Condition	SG based OD weight and	MC at test	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
			Vol. at test		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at .. E.L	R	T	E	R	T	R	T
Tectona grandis	Burma and Malabar	AR	0.611	13.9	95.90	12534	27	16381	54.46	14017	9.68	5004	4959	4670	8.41	9.75	3.72	4.41
Mangifera indica	Puri (Bengal & Orissa)	AR	0.590	12.6	87.42	10879	26	13313	42.91	10528	9.13	4870	4848	6116	8.85	9.54	3.61	2.17

Mitragyna parvifolia

Species	Location	Condition	SG based OD weight and	MC at test	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
			Vol. at test		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at .. E.L	R	T	E	R	T	R	T
Tectona grandis	Burma and Malabar	AR	0.611	13.9	95.90	12534	27	16381	54.46	14017	9.68	5004	4959	4670	8.41	9.75	3.72	4.41
Mitragyna parvifolia	Haldwani (UP)	AR	0.581	8.6	81.77	9735	19	14561	49.74	10376	9.68	5115	5827	6894	8.48	9.75	1.65	4.30

Artocarpus hirsutus

Species	Location	Condition	SG based OD weight and	MC at test	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
			Vol. at test		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at .. E.L	R	T	E	R	T	R	T
Tectona grandis	Burma and Malabar	AR	0.611	13.9	95.90	12534	27	16381	54.46	14017	9.68	5004	4959	4670	8.41	9.75	3.72	4.41
Artocarpus hirsutus	South Coimbatore	AR	0.613	14.6	72.05	9962	26	12707	41.33	10810	8.58	5449	5226	6249	-	9.27	2.41	4.30

Duabanga sonneratioides

Species	Location	Condition	SG based OD weight and	MC at test	Static bending (MPa)		Impact bending (MPa)		Comp. Parallel to grain (MPa)		Comp. Per. to grain (MPa)	Hardness load in (N)			Shear (MPa)		Tension (MPa)	
			Vol. at test		MOR	MOE	Max. drop (inch)	MOE	Max. C stress	MOE	CS at .. E.L	R	T	E	R	T	R	T
Tectona grandis	Burma and Malabar	AR	0.611	13.9	95.90	12534	27	16381	54.46	14017	9.68	5004	4959	4670	8.41	9.75	3.72	4.41
Duabanga sonnera tioides	Kurseong Bengal	AR	0.433	13.6	62.84	8735	22	10714	32.12	9873	3.48	2491	2980	3491	915	8.30	2.58	2.30

Trade Statistics-Wood and Wood Products (HS-Code-44)

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Statistics of Import and Export of Wood and Wood Products in India During Jan-March 2023

S.No.	HS-Code	Commodity	Value in million USD		
			Import (Imp)	Export (Exp)	Trade Balance (Exp-Imp)
1	4401	FUEL WOOD, IN LOGS, IN BILLETS, IN TWIGS, IN FAGGOTS OR IN SIMILAR FORMS; WOOD IN CHIPS OR PARTICLES; SAWDUST AND WOOD	0.52	0.05	-0.47
2	4402	WOD CHRCL(INCL SHL/NUT CHRCL) W/N AGLOMRTD	1.46	11.74	10.28
3	4403	WOOD IN THE ROUGH, WHETHER OR NOT STRIPPED OF BARK OR SAPWOOD, OR ROUGHLY SQUARED	235.78	1.26	-234.52
4	4404	HOOPWOOD SPLIT POLES PILES PICKETS AND STACKOF WOOD POINTED BUT NOT CUT TO LENGTHWSE WOODEN STICKS CHIPWOOD	0.05	0.10	0.05
5	4405	WOOD WOOL; WOOD FLOUR	0.29	0.00	-0.29
6	4407	WOOD SAWN OR CHIPPED LENGTHWISE, SLICED OR PEELED, WHETHER OR NOT PLANED, SANDED OR ENDJOINTED, OF A THICKNESS EXCEEDING	118.45	1.76	-116.69
7	4408	VENER SHET AND SHETS FOR PLWD (W/N SPLICD)AND OTHR WOOD SAWN IN LENTH SLICD/PEELD W/N PLANED OR FINGR JTD THIKNES <= 6MM	66.82	9.49	-57.33
8	4409	WOOD(INCL STRIPS,FRIZS FOR PARQT FLORNG NT ASEMBLD) CONTINUSLY SHAPED(TONGD GROVD V-JTD ETC) ALONG ANY EDGS/FACS W/N P	8.85	3.02	-5.83
9	4410	PARTCLE BORD AND SMLR BORD OF WOOD OTHER LIGNUS MATRLS W/N AGLOMRTD WITH RESIN OR OTHR ORGNIC BINDG SUBSTS	7.72	1.49	-6.23
10	4411	FIBR BORD OF WOOD OR OTHR LIGNEUS MATRLS W/N BONDED WITH RESIN/OTHR ORGNIC SUBSTS	26.62	16.89	-9.73
11	4412	PLYWOOD, VENEERED PANELS AND SIMILAR LAMINATED WOOD	35.49	17.81	-17.68
12	4413	DENSIFIED WOOD, IN BLOCKS, PLATES, STRIPS, OR PROFILE SHAPES	1.37	0.44	-0.93
13	4414	WOODEN FRAMES FOR PAINTINGS, PHOTOGRAPHS, MIRRORS OR SIMILAR OBJECTS	0.21	2.85	2.64
14	4415	PCKNG CASES,BXES,CRTS,DRMS AND SMLR PCKNGS OF WOOD; CBLE DRMS OF WOOD; PALLET, BOX PALLETS AND OTHR LOAD BOARDS OF WO	1.97	3.12	1.15
15	4416	CASKS, BARRELS, VATS, TUBS AND OTHER COOPERSPRODUCTS AND PARTS THEREOF, OF WOOD, INCLUDING STAVES	1.00	0.02	-0.98
16	4417	TOOLS, TOOL BODIES, TOOL HANDLES, BROOM OR BRUSH BODIES AND HANDLES, OF WOOD; BOOT OR SHOE LASTS AND TREES, OF WOOD	1.06	4.30	3.24
17	4418	BUILDERS JOINERY AND CARPENTRY OF WOOD, INCLUDING CELLULAR WOOD PANELS, ASSEMBLED FLOORING PANELS, SHINGLES AND SHAKES	12.77	3.78	-8.99
18	4419	TABLEWARE AND KITCHENWARE, OF WOOD	3.85	13.03	9.18
19	4420	MARQUTY AND INLAID WOOD;CASKETS/CASES FOR JWELRY/CTLRY AND SMLR ARTCLS STATUETS AND OTHR ORNAMTS OF WOOD NT FALLNG I	0.66	4.59	3.93
20	4421	OTHER ARTICLES OF WOOD	9.24	45.03	35.79
Total	**44**	**WOOD AND ARTICLES OF WOOD; WOOD CHARCOAL**	**534.18**	**140.77**	**-393.41**

Source-Data compilation based on data in Ministry of Commerce and Industry, Govt. of India

Top 10 country wise Import and Export of Wood and Wood Products in India During January-March 2023

HS-Code	Rank	1	2	3	4	5	6	7	8	9	10	Top 10	%@	Others	Total
4401	*Country (8)*	VIETNAM SOC REP	CHINA P RP	GERMANY	FRANCE	ROMANIA	U S A	NETHERLAND	TAIWAN						
	Import	0.25	0.08	0.07	0.06	0.02	0.02	0.01	0.01			0.52	100.0	0	0.52
	Country (4)	BHUTAN	BANGLADESH PR	FRANCE	U ARAB EMTS										
	Export	0.02	0.01	0.01	0.01							0.05	100.0	0	0.05
4402	*Country (2)*	INDONESIA	SRI LANKA DSR	CHINA P RP	BHUTAN	HONG KONG	SEYCHELLES								
	Import	0.49	0.48	0.28	0.18	0.01	0.01					1.45	100.0	0	1.45
	Country (18)	BHUTAN	NETHERLAND	MALDIVES	U K	DENMARK	NEPAL	SAUDI ARAB	TURKEY	U ARAB EMTS	DOMINIC REP				
	Export	11.17	0.16	0.06	0.05	0.04	0.04	0.04	0.03	0.03	0.02	11.64	99.1	0.11	11.75
4403	*Country (53)*	URUGUAY	MALAYSIA	ECUADOR	ARGENTINA	AUSTRALIA	SURINAME	GHANA	BRAZIL	U S A	PAPUA N GNA				
	Import	40.59	32.2	22.19	20.76	17.37	14.34	13.52	12.97	10.58	8.74	193.26	82.0	42.53	235.79
	Country (7)	CHINA P RP	U ARAB EMTS	QATAR	ISRAEL	MALDIVES	JAPAN	KOREA RP							
	Export	1.08	0.06	0.05	0.02	0.02	0.01	0.01				1.25	100.0	0	1.25
4404	*Country (2)*	CHINA P RP	TAIWAN												
	Import	0.04	0.01									0.05	100.0	0	0.05
	Country (5)	MEXICO	NEPAL	NETHERLAND	U ARAB EMTS	U S A									
	Export	0.04	0.03	0.01	0.01	0.01						0.1	1000.0	0	0.01
4405	*Country (4)*	VIETNAM SOC REP	CHINA P RP	HONG KONG	GERMANY										
	Import	0.14	0.09	0.03	0.02							0.28	100.0	0	0.28
	Country (3)	NEPAL	NETHERLAND	U K											
	Export	0.0006	0.00007	0.001								0.00167	100.0	0	0.00167
4407	*Country (62)*	GERMANY	INDONESIA	MALAYSIA	BENIN	SWEDEN	MYANMAR	BRAZIL	TOGO	U K	U S A				
	Import	28.34	6.68	6.63	6.1	5.88	5.55	5.51	5.49	4.31	4.21	78.7	66.4	39.75	118.45
	Country (12)	ITALY	U ARAB EMTS	LITHUANIA	QATAR	U S A	KUWAIT	BAHARAIN IS	MALDIVES	NEPAL	MAURITIUS				
	Export	0.98	0.16	0.11	0.1	0.09	0.08	0.06	0.06	0.04	0.02	1.7	98.3	0.03	1.73
4408	*Country (31)*	GABON	INDONESIA	CHINA P RP	MYANMAR	ITALY	HONG KONG	VIETNAM SOC REP	MALAYSIA	SPAIN	GERMANY				
	Import	22.54	20.64	8.82	3.8	1.52	1.21	1.14	0.84	0.72	0.69	61.92	92.7	4.88	66.8
	Country (14)	NEPAL	BANGLADESH PR	CANADA	CHINA P RP	ITALY	SPAIN	U S A	CZECH REPUBLIC	U ARAB EMTS	JAPAN				
	Export	3.44	1.9	1.49	1.26	0.54	0.42	0.27	0.04	0.04	0.03	9.43	99.3	0.07	9.5
4409	*Country (18)*	INDONESIA	ESTONIA	CHINA P RP	SINGAPORE	BRAZIL	RUSSIA	MYANMAR	SWEDEN	ROMANIA	THAILAND				
	Import	2.65	1.71	1.42	1.03	0.71	0.67	0.19	0.17	0.05	0.05	8.65	97.6	0.21	8.86
	Country (9)	ITALY	U S A	GERMANY	U K	BELGIUM	SPAIN	FRANCE	NEPAL	U ARAB EMTS					
	Export	0.99	0.93	0.29	0.26	0.16	0.16	0.13	0.04	0.02		2.98	100.0	0	2.98
4410	*Country (15)*	THAILAND	FRANCE	MALAYSIA	GERMANY	BHUTAN	BANGLADESH PR	CHINA P RP	SPAIN	ROMANIA	U S A				
	Import	3.19	1.87	1.09	0.51	0.5	0.18	0.1	0.1	0.06	0.04	7.64	99.1	0.07	7.71
	Country (17)	NEPAL	SAUDI ARAB	SRI LANKA DSR	U S A	KENYA	KUWAIT	PHILIPPINES	BHUTAN	MOZAMBIQUE	SEYCHELLES				
	Export	0.44	0.32	0.2	0.15	0.07	0.07	0.05	0.04	0.04	0.03	1.41	94.0	0.09	1.5
4411	*Country (27)*	THAILAND	VIETNAM SOC REP	MALAYSIA	CHINA P RP	INDONESIA	GERMANY	ITALY	ROMANIA	NEW ZEALAND	BELGIUM				
	Import	7.75	6.22	4.73	3.35	0.81	0.73	0.66	0.43	0.36	0.34	25.38	95.4	1.22	26.6
	Country (42)	U ARAB EMTS	U S A	SAUDI ARAB	KUWAIT	MALAYSIA	SRI LANKA DSR	NEPAL	QATAR	CANADA	BAHARAIN IS				

	Export	11.29	0.81	0.59	0.51	0.51	0.49	0.39	0.37	0.34	0.26	15.56	92.3	1.3	16.86
4412	***Country (29)***	NEPAL	CHINA P RP	INDONESIA	RUSSIA	VIETNAM SOC REP	MALAYSIA	MYANMAR	BRAZIL	ITALY	TAIWAN				
	Import	9.94	7.38	6.75	2.86	2.66	2.63	1.21	0.27	0.27	0.27	34.24	96.4	1.28	35.52
	Country (49)	U ARAB EMTS	BHUTAN	SAUDI ARAB	NEPAL	OMAN	U S A	THAILAND	BAHARAIN IS	IRAQ	SEYCHELLES				
	Export	4.09	2.02	1.93	1.71	1.71	0.85	0.71	0.39	0.37	0.33	14.11	79.1	3.73	17.84
4413	***Country (9)***	ITALY	GERMANY	NETHERLAND	POLAND	CAMEROON	SRI LANKA DSR	CHINA P RP	TURKEY	U S A					
	Import	0.61	0.36	0.11	0.09	0.07	0.07	0.04	0.01	0.01		1.37	100.0	0	1.37
	Country (10)	ISRAEL	U ARAB EMTS	SAUDI ARAB	NEPAL	BAHARAIN IS	BANGLADESH PR	KUWAIT	NETHERLAND	U K	VIETNAM SOC REP				
	Export	0.2	0.08	0.06	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.42	100.0	0	0.42
4414	***Country (5)***	MALAYSIA	CHINA P RP	U S A	SPAIN	THAILAND									
	Import	0.07	0.06	0.03	0.02	0.01						0.19	100.0	0	0.19
	Country (24)	U S A	NETHERLAND	SPAIN	U K	SAUDI ARAB	CANADA	U ARAB EMTS	BRAZIL	AUSTRALIA	GERMANY				
	Export	1.7	0.18	0.12	0.12	0.11	0.08	0.06	0.06	0.05	0.05	2.53	90.4	0.27	2.8
4415	***Country (19)***	SWEDEN	THAILAND	LITHUANIA	SOUTH AFRICA	GERMANY	LATVIA	POLAND	U ARAB EMTS	U S A	BAHARAIN IS				
	Import	0.45	0.33	0.32	0.25	0.21	0.12	0.05	0.04	0.04	0.03	1.84	93.4	0.13	1.97
	Country (35)	U S A	U K	SAUDI ARAB	BELGIUM	FRANCE	TAIWAN	NETHERLAND	SPAIN	CHINA P RP	GERMANY				
	Export	0.83	0.26	0.2	0.19	0.15	0.15	0.13	0.13	0.1	0.1	2.24	73.4	0.81	3.05
4416	***Country (5)***	U S A	FRANCE	BELGIUM	CHINA P RP	NEPAL									
	Import	0.62	0.35	0.01	0.01	0.01						1	100.0	0	1
	Country (1)	U S A													
	Export	0.02										0.02	100.0	0	0.02
4417	***Country (2)***	VIETNAM SOC REP	CHINA P RP												
	Import	0.73	0.04									0.77	100.0	0	0.77
	Country (28)	GERMANY	U S A	DENMARK	NETHERLAND	KOREA RP	U K	NORWAY	FINLAND	RUSSIA	FRANCE				
	Export	1.11	0.75	0.35	0.26	0.23	0.21	0.19	0.14	0.14	0.12	3.5	83.1	0.71	4.21
4418	***Country (27)***	CHINA P RP	MALAYSIA	GERMANY	THAILAND	INDONESIA	ITALY	FRANCE	AUSTRIA	DENMARK	VIETNAM SOC REP				
	Import	2.97	2.05	1.74	1.33	1.09	0.85	0.48	0.44	0.27	0.17	11.39	89.1	1.4	12.79
	Country (39)	NEPAL	U S A	BHUTAN	U K	TANZANIA REP	U ARAB EMTS	MALDIVES	MAURITIUS	ITALY	MOROCCO				
	Export	1.09	0.45	0.33	0.25	0.19	0.19	0.16	0.14	0.08	0.07	2.95	79.7	0.75	3.7
4419	***Country (6)***	CHINA P RP	THAILAND	RUSSIA	MALAYSIA	FINLAND	ITALY								
	Import	3.57	0.1	0.08	0.05	0.01	0.01					3.82	100.0	0	3.82
	Country (45)	U S A	NETHERLAND	U K	POLAND	U ARAB EMTS	FRANCE	ISRAEL	AUSTRALIA	SWEDEN	DENMARK				
	Export	7	1.04	0.91	0.4	0.36	0.33	0.3	0.3	0.29	0.26	11.19	86.3	1.77	12.96
4420	***Country (9)***	CHINA P RP	INDONESIA	HONG KONG	SWITZERLAND	THAILAND	MALAYSIA	GERMANY	ITALY	TURKEY					
	Import	0.23	0.18	0.07	0.05	0.05	0.03	0.01	0.01	0.01		0.64	100.0	0	0.64
	Country (37)	U S A	CANADA	U ARAB EMTS	SAUDI ARAB	U K	AUSTRALIA	GERMANY	NETHERLAND	SPAIN	TURKEY				
	Export	2.56	0.23	0.18	0.17	0.16	0.15	0.13	0.12	0.1	0.07	3.87	84.9	0.69	4.56
4421	***Country (18)***	CHINA P RP	RUSSIA	GERMANY	MALAYSIA	VIETNAM SOC REP	IRAN	INDONESIA	ESTONIA	HONG KONG	ECUADOR				
	Import	8.08	0.25	0.17	0.14	0.12	0.1	0.09	0.04	0.04	0.03	9.06	98.2	0.17	9.23
	Country (71)	U S A	NETHERLAND	U K	SAUDI ARAB	GERMANY	AUSTRALIA	CANADA	U ARAB EMTS	FRANCE	SPAIN				
	Export	31.27	3.42	2.51	2.36	2.25	1.87	1.74	1.59	1.55	1.22	49.78	85.3	8.6	58.38

(Within parenthesis showed that total number of involved countries), @ i.e. percentage share of top 10 countries in total

Source-Data compilation based on data in Ministry of Commerce and Industry, Govt. of India

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