IWST

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Vol. 1, Issue 2, July - September 2020

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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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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Dehradun - 248 006
Phone:- +91-135-222 4814, +91-135- 2755221,

WOOD POLYMER COMPOSITE

A Technology from IWST

- The technology provides an opportunity to replace up to 50-60% plastics by environment friendly natural fibers.
- Any type of woody material like lops and tops, branches, wood waste, saw dust, bamboo, lantana, jute, coir, etc. can be used for this purpose.

These composites have a wide range of applications like light structural components, interiors (wall cladding), garden and outdoor products, injection molding products like hangers, pens, pencils, pen stands, trays, and other utility products.

The advantages of using wood polymer composite material:

- Cost effective compared to virgin thermoplastics
- Superior in strength and stiffness than plastics
- Dimensionally stable
- Recyclable and environment friendly than virgin plastics

For further details, please contact :
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Babul Supriyo
Union Minister of State
Ministry of Environment, Forest & Climate Change
Government of India

बाबुल सुप्रियो
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पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
भारत सरकार

FOREWORD

Wood has been used by mankind since the beginning of human civilization. During the transition between Neolithic and Bronze Ages, very early wheels were made of wood, with holes in the core for the axle. In ancient times, wood was used for fuel, agricultural implements, bullock carts or camel carts, housing, handicrafts, etc. It now finds use in furniture making, building structures and other applications.

Ministry of Environment, Forest and Climate Change, Government of India has been promoting the production and use of wood. The Central Public Works Department has recently lifted the ban on the use of wood in construction. This will create demand for wood-based industries that would boost the local economy, especially in rural areas, generate employment and encourage farmers to bring degraded areas under tree cover, thus augmenting the production of a multitude of ecosystem services for the benefit of the country.

Institute of Wood Science and Technology (IWST), Bengaluru (an institute under the Indian Council of Forestry Research and Education) has been working on development of emerging technologies for wood-based industries for sustainable use of wood. The institute has a one-of-its-kind training centre (Advanced Woodworking Training Centre) to conduct certificate and diploma courses in the area of woodworking to attain global competitiveness by using state of the art machinery. The institute has recently come out with its first publication **"Wood is Good: Grow more, Use more"** to share the scientific knowledge and success stories with all stakeholders. The magazine has generated a lot of interest and created awareness among wood users and industries about the latest developments in wood utilization.

I sincerely hope the second issue of this quarterly magazine of IWST will further bring researchers, academicians and wood-based industries together on a platform to share their success stories and achieve global competitiveness. I also hope that the next issue of the publication will dwell upon different aspects of furniture manufacturing as the Government of India has identified furniture among 20 sectors where India can meet the domestic demand and simultaneously become a 'global factory in the world'.

(Babul Supriyo)

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CONTENT

Popular Articles

TESTING AND TRAINING SERVICES @ IWST

Testing Services

- Identification of wood
- Physical properties of wood tests (Specific Gravity/Density of Wood, Moisture Content, Shrinkage)
- Mechanical properties of wood (Static Bending, Compression Parallel to Grain, Compression Perpendicular to Grain, Tension Parallel to Grain, Tension Perpendicular to Grain, Hardness, Shear, Nail Holding Power, Screw Holding Power)
- Determination of calorific value of wood
- Thermo gravimetric analysis of lignocellulosic material
- Determination of penetration and retention of preservative in the treated wood
- Wood polymer composites
- Preservative solution analysis
- Proximate analyser (fixed carbon content, volatile content, ash content and moisture content)
- Estimation of percentage of Sandalwood oil and GC analysis of oil
- Distillation of essential oil and estimation of oil yield by hydro distillation method
- Identification services decay fungi/mould
- Supply of fungus culture per tube
- Testing of bio-efficacy of preservatives/ insecticides against borers
- Sandalwood farming and managing its health Consultancy
- Testing of wood preservatives/fire retardants
- Specific information by post

Short Term Training Courses (3/5 days)

- Bamboo: Tissue Culture
- Sandalwood: Tissue Culture Techniques
- Sandalwood: Seed Handling, Nursery and Plantation Technology
- Wood Seasoning and Preservation
- Sandalwood: Farming and Management of its Health
- Extraction and Quality Assessment of Sandalwood and other Essential Oils
- Wood Modification
- Field Identification of Important Timbers
- Clonal Propagation of *Melia dubia*
- Sandalwood: Establishment and Maintenance of Healthy Nurseries and Plantations
- Insect Pest Management
- Bamboo Agarbatti Stick Making

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The Indian Sandalwood: how IWST proposes to promote & popularise Sandalwood cultivation

When one hears the word 'Sandalwood,' they are automatically taken into a world of unique aroma and bliss, thinking about the perfumes, soap, garlands, handicrafts and so much more! That is the power of Sandalwood. The Indian Sandalwood (*Santalum album* Linn.) is a highly valuable and commercially important tree species, in fact, it is a true gift of nature. Since time immemorial Sandalwood has been intricately associated with our culture, heritage, folklore and scriptures. The aromatic heartwood and the essential oil obtained from it is extensively used by most of the major religions of the world. Among the 16 different species belonging to the genus, Santalum, *S. album* is considered to be a superior species due to its utilisation and value. The yellow coloured heartwood is dense, fine-grained and has tranquillising fragrance. This wood is a sought after material for handicrafts, wood sculptures and carvings. The essential oil obtained from the steam distillation of heartwood is used in perfumes and medicines. The precious oil has an indispensable role in perfumery as it is used as a base note because of its wood, balsamic and sweet smell. Due to its inherent fixative property, Sandalwood can prevent volatile molecules of different bases escaping. Not to forget, the joy sticks or Agarbatti made out of the wood shavings that is left over after distillation. Also, did you know? India was the major Sandalwood and oil producer in the world during 1980s.

Indian Sandalwood is a medium sized partially root parasitic tree that can grow even in harsh climatic conditions. It is found predominantly in the deciduous forests of the Deccan region. More than 90 % of the Sandalwood is distributed in the states of Karnataka and Tamil Nadu covering around 9,000 km^2 of which more than 70 % occurs in Karnataka. Management of Sandalwood in Karnataka dates back to as early as 18th century when King Tipu Sultan the erstwhile rule of Mysore declared

Sandalwood as a 'Royal tree' in 1792; because of which the tree became a state property and Sandalwood trade was monopolised. Though illicit felling and harvest was not prevalent during the earlier times, considering the increasing value for the wood in the market the trees were subjected to uncontrollable harvest in both Karnataka and Tamil Nadu. The global annual demand of Sandalwood was estimated at about 5,000 to 6,000 MT wood and around 100 to 120 MT oil. However, India which used to produce about 4,000 tonnes per annum in the 1960s gradually reduced to less than 1,000 tonnes by 1990s.

The International Union for Conservation of Nature - a global organisation aiming at nature conservation for enhancing sustainable development; categorised Sandalwood as 'vulnerable' and stated that improving its status is of utmost importance. Considering the dwindling population of Sandalwood, Governments of Karnataka and Tamil Nadu have relaxed the stringent policies which is very encouraging for Sandalwood cultivation.

There is an increase in extensive cultivation of Sandalwood both in areas where Sandalwood is naturally distributed and far away areas from its natural distribution. For instance, farmers and entrepreneurs from states like Gujarat, Rajasthan, Maharashtra, Telangana and Madhya Pradesh have also taken up Sandalwood cultivation. However, there are pertinent constraints such

Highlights of the proposed project

1. To help in capacity building of master trainees and field trainees through-out India
2. Dissemination of information on Sandalwood cultivation
3. Establishing Sandalwood based agro-forestry demonstration plots
4. Technology based support system (app based) for Sandalwood cultivation
5. To help in the supply of Quality Planting Material (QPM)
6. Documentation of knowledge like cultivation practices followed in different regions.

Approaches to address the comprehensive plan

The aim of the project is to meet the requirements of Training and Extension part of Sandalwood cultivation and achieve the target of encouraging Sandalwood cultivation throughout India. This project is in collaboration with all the ICFRE institutes and centre viz.

1. Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore
2. Institute of Forest Biodiversity (IFB), Hyderabad
3. Tropical Forest Research Institute (TFRI), Jabalpur
4. Arid Forest Research Institute (AFRI), Jodhpur
5. Forest Research Institute (FRI), Dehradun
6. Himalayan Forest Research Institute (HFRI), Shimla
7. Institute of Forest Productivity (IFP), Ranchi
8. Rain Forest Research Institute (RFRI), Jorhat
9. Centre for Social Forestry and Eco-rehabilitation (CSFER), Allahabad.

as training, extension, cultivation, protection, and lacuna in schemes and policy that are hindering the progress in Sandalwood cultivation. The erstwhile Sandal Research Centre which was established in 1977 was the only Centre in India to have carried out extensive and pioneering work on various related aspects related to Sandalwood. Subsequently this was merged with Forest Research Laboratory resulting in the formation of presently the Institute of Wood Science and Technology (IWST).

Considering the grave situation and to facilitate Sandalwood cultivation across the country IWST as a nodal agency in Sandalwood research has taken up a comprehensive plan to promote Sandalwood cultivation for upliftment of socio economic status of Indian farmers with a budget outlay of 17.405 crores.

The Institute will help in capacity building of both ICFRE and non-ICFRE institutes located in different regions of India. In the next three years, the target to train 150 field trainees across the country by the Master trainees is to be achieved.

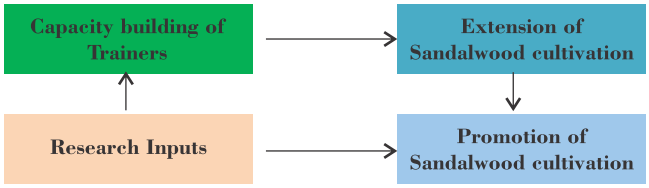
In training component the aim is to build capacity among the master and local/field trainers at State and National level. IWST will be responsible for training of master trainers selected from different parts of the country with the help of ICFRE institutes. In-turn, these master trainees will train the local/field trainers at their respective institutes. These field trainees, further will train prospective Sandalwood farmers across the country. Apart from this, IWST is also regularly conducts five days training programme on Sandalwood cultivation to all the stakeholders to enhance their scientific knowledge along with field inputs. The training provides a comprehensive exposure to the trainees from seed collection, seedling

production, plantation establishment, harvesting, marketing along with legal implications. IWST also plans to establish demonstration plots which helps to bring confidence to prospective cultivator.

The services of Van Vigyan Kendras and Krishi Vigyan Kendras are being utilised in developing one acre demonstration plots with different agroforestry models that are region specific. In extension component, the aim is extension of Sandalwood based agroforestry systems throughout the country with development and deployment of technological intervention like app based systems to help needy farmers with the correct answer at right time.

Also, development and distribution of information and Quality Planting Material (QPM) from different ICFRE institutes. Documentation of knowledge on cultivation practices and suitable host species along with establishment of demonstration plot will also be taken care. As a long term objective the institute is promoting Sandalwood cultivation throughout India by solving the legal/policy issues associated with Sandalwood cultivation and marketing.

The entire process of growing more Sandalwood can be summarised through this flow chart



IWST has envisaged this ambitious programme to fulfil the dreams and aspirations of Sandalwood growers which would not only help in conserving the Sandalwood but also in its sustainable utilisation.

IWST activities during July-September, 2020

Furniture: Trade, Testing and Certification

A webinar on *"Furniture: Trade, Testing and Certification"* was organized on 29th July 2020 in which 68 participants attended the webinar. Director IWST, Bangalore emphasised the need to establish furniture testing and certification infrastructure in the country in order to promote and produce competitive wood-based furniture products in which the country has a distinctive advantage.. Dr. S.R. Shukla discussed about the wood qualities of a timber species to be used in furniture applications and common wood species used for furniture artifacts. Mr. Safique Porbandarwala discussed about the potential of furniture industry in India and pointed out that organized as well as unorganized sectors are facing many challenges like: unavailability of seasoned wood, lack of new designs for furniture, shortage of skilled manpower, shortage of wood and other raw materials, shortage of new entrants in the sector. Mr. Rahul Mehta discussed about the status of furniture sectors in India, its trade, challenges and future. Mr. Vivin Agarwal discussed about the importance of design in the growth of furniture industries in India. Further, he spoke that prototyping, test marketing, promoting the product as brand associated with designer has very important role for further growth of this sector. At the end the Director IWST concluded the webinar and intimated the participants that this webinar is just a start and this type of webinar / discussion will be further organized for the welfare of the furniture sector and to establish 'Furniture Testing and Incubation Facility' at IWST.

Sandalwood: Seed Handling Nursery and Plantation Technology

A webinar on *"Sandalwood: Seed Handling Nursery and Plantation Technology"* was organized on 21st August 2020. Dr. M.P. Singh, Director, IWST explained about the need to encourage sandalwood cultivation throughout the country. Dr. P.V. Somashekar explained about sandalwood seed collection, processing of fruits, depulping of fruits for seeds, seed drying in shade, how to test seed quality, selection of seeds, season for sowing and subsequent transplanting, materials required for preparation of germination bed, management of bed, seed treatment by using Gibberlic acid (GA3), seed sowing, watering of seed bed after sowing and its maintenance, preparation of potting mixture for transplanting and addition of host plant, root trainers and potting media, explained about germination of sandalwood seeds. Dr. B.N. Divakara explained about the need for management of sandalwood plantation and what are all the points to be considered in management of sandalwood on farmlands such as

selection of site, site preparation, planting, selection of host, pruning, weeding and cleaning, assessing yield/growth etc. Dr. M.V. Durai, mentioned about management of sandalwood, host species, livestocks, and agriculture crops. Dr. R. Sundararaj explained in detail about the management of important insect pests in plantation with beautiful photographs and also stressed the use of any pesticide should be the last option in sandalwood cultivation. Dr. A. Muthukumar explained on diseases in sandalwood nursery like rot in seeds, damping-off/collar rot of seedlings, vascular wilt of seedlings, mildew diseases, infestation by nematodes, nutrient deficiency. Dr. K.T. Chandrashekar explained about the natural bio-fencing by banboo (thorny bamboo), community protection, solar fencing, protection from trained dog, two tier protection. Shri. A.H. Chandraprapha explained in detail about the present rules and regulations for sandalwood cultivation in Karnataka. Sri. H.S. Ananthapadmanabha explained about the estimated world production of sandalwood, official production, price trends per MT, actual growth in plantation, average production of heartwood in 15 years, pitting using augur, wrong method of pruning.

Development of Cross Laminated Timbers (CLT)

A Webinar on *"Development of Cross Laminated Timbers (CLT)"* was organized on 31st August 2020. Dr. S.S. Chauhan, initiated the seminar (webinar) by a welcome talk and he briefly explained the topic, scope and its importance. IWST is working on hardwood CLT which is showing better properties than most of the softwoods and a motivating factor as well. Mechanical testing and biodegradation of rubber wood CLT have been studied. CLT has also shown better dimensional stability than glulam and normal wood. Dr. R. Sundararaj suggested development of long lasting preservatives from durability point of view. He also highlighted environmental aspects of preservatives. Dr. Vipin Chawla from IPIRTI, Bengaluru put light on suitability of wood species and discussed importance of building codes and standards for CLT. Mr. Kedia and Mr Salman applauded the efforts and highlighted the market condition, awareness and acceptability among Indian markets. Director, IWST suggested to turn this concept in to an inter disciplinary approach where specialists from different fields can come together and provide their input to make it a successful journey. More and more involvements of people can lead it to the awareness campaign and soon India will be featuring a revolution in the construction sector by strengthening the concept of "Green building".

Prioritisation of Species for FGR Programme in IWST

A virtual workshop on *"Prioritisation of Species for FGR Programme in IWST"* was organised on 2nd September 2020. The purpose of the workshop was to prioritize the tree species for conservation of Forest Genetic Resources (FGRs) initiated under the project on National Programme for Conservation and Development of Forest Genetic Resources' funded by CAMPA-MoEF & CC New Delhi. About 13 experts from different fields (State Forest Department, Karnataka Medicinal Plant Authority, Ayurvedic College, Forestry College, FRLHT) participated and suggested more tree species in addition to the species proposed by the Institute based on their economical, conservation, medicinal and ecological importance. After deliberation it was decided to include the species suggested by the expert and also to formulate a committee to prioritize the species to be taken in the `First Phase of the Project'.

Safeguards Information System for REDD+ INDIA"

A consultative Webinar of all the stakeholders including state government departments of Karnataka, Andhra Pradesh and Goa, regional research institutions, agricultural universities and colleges, NGO and general public to give their comments/ suggestions on draft on "Safeguards information system for REDD+ India was held at IWST, Bengaluru on 16th September 2020. The meeting began with welcome address by Dr. M.P. Singh, Director IWST. Sh. A.S. Rawat IFS, Director General ICFRE made the inaugural address on REDD+ and proposed Safeguard information system (SIS). The PCCF (HoFF) Karnataka highlighted the REDD+ activities in the state Karnataka. Followed by PCCF (Working Plan) Andhra Pradesh presented his views and emphasized those criteria and indicators should be smart and understandable equally to all. The PCCF, Goa also gave his introductory remarks and raised the implementable issues with respect to his state. This was followed by two excellent presentations from Dr. Jagmohan Sharma IFS, member of the drafting committee and Dr. R.S. Rawat from Biodiversity and Climate change, ICFRE. Dr. Jagmohan Sharma presented an overview of Safeguards Information System and Dr. Rawat explained the concept of principle, criteria and indicators

(PCI) as per Cancun safe guards. There was detailed discussion about the presentation and each participant presented their view point. Finally there was a detailed discussion on PCI. The meeting concluded with vote of thanks by the Dr. Anurag Bhardwaj, Director, International Cooperation, ICFRE, Dehradun.

Training on Sandalwood Farming and Management of its Health

A Four days online training programme on "*Sandalwood farming and management of its health*" through WebEx was conducted at IWST Bangalore from 21st-24th September, 2020 in four different languages (Hindi, Kannada, Tamil and Telugu). Around 1040 participants (mainly farmers) registered and participated in the training programme (Hindi: 172; Kannada: 313; Tamil: 240 and Telugu:315). Various aspects such as benefits of cultivating Indian Sandalwood, sandalwood seed handling and nursery techniques, management of diseases in sandalwood nursery and plantation and good silvicultural practices for the best health of sandalwood, suitable plants for primary, intermediate and permanent hosts etc. were covered during the training programme. During training programme, many quarries such as were raised by the participants and all of them were answered except legal issues. Most of the participants requested IWST to conduct a webinar particularly related to legal issues in planting the sandalwood in the farm field, marketing of the product and protection aspects. Besides this, the farmers also expressed their interest to attend the training in physical mode. In this regard, it was assured that once the Covid Pandemic condition improves, the physical mode of training will be organised.

Research Advisory Group Meeting

The Research Advisory Group Meeting was organised on 29th September 2020 to discuss the new research proposals and also the ongoing research programmes. The meeting was attended by the Assistant Director General (Research & Planning), ICFRE along with Director IWST and other expert members from various organisations. The purpose of meeting was to get suggestions from expert members and modify the research programmes to meet end user/stake holder's requirement.

Hindi Pakhwada (14-28 September 2020)

The institute celebrated Hindi Pakhwada from 14th to 28th September 2020. During this fortnight, various activities were held to promote the use of official language in day-to-day activities of the institute. The closing ceremony was held on 30th September 2020 in which the Director, IWST distributed the prize to winner of various events. The Director in his concluding remarks emphasised the use of more and more Hindi language in official correspondences in the office.

THE INDIAN ACADEMY OF WOOD SCIENCE

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E-Mail: iaws.india@yahoo.com Website: http://www.iaws.org.in

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: ……..
Date: ……..

(Signature of the Applicant)

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. 5000
Foreign:		
Corporate	N. A.	US $ 2,500
Institutional	US $ 50	N.A.
Individual	US $ 20	US $ 200

(To be Photocopied for Use)

Indian plywood and panel industries: their journey of raw materials from forest produce to AgriWood

(Supporting Atma Nirbhar Bharat, Make in India and Vocal for Local)

M.P. Singh
Director- Institute of Wood Science & Technology and Indian Plywood Industries Research & Training Institute, Bengaluru
E-mail: dir_iwst@icfre.org

The inaugural issue of this magazine carried an article broadly outlining the issues for revival of wood based industries. It was emphasized that wood based industries need to be supported for augmenting raw materials, not only by promoting agroforestry but also by relaxing/liberalising ecosystem for transportation and processing of such timber. The concept of Agmark for agricultural goods can be extended to wood grown on farmer's lands, AgriWood. A project has been undertaken at IPIRTI to take this concept of AgriWood forward for realization and implementation as per Vocal for Local campaign of Government of India.

In the meantime, two important agricultural ordinances namely The Farmers (Endowment and Protection) Agreement on Price Assurance and Farm Services Ordinance 2020 and The Farmer's Produce Trade and Commerce (Promotion and Facilitation) Ordinance 2020 were promulgated; however, they did not include wood from agricultural practices within the definition of farming produce or farmer's produce of these ordinances. Representations were made by all major association bodies such as Federation of Indian Plywood & Panel Industry (FIPPI), The South Indian Plywood Manufacturers Association (SIPMA), All India Plywood Manufacture's Association (AIPMA) and Indian Paper Manufacturers Association (IPMA). Subsequently, these ordinances became acts duly notified by Ministry of Law and Justice on 27th September 2020.

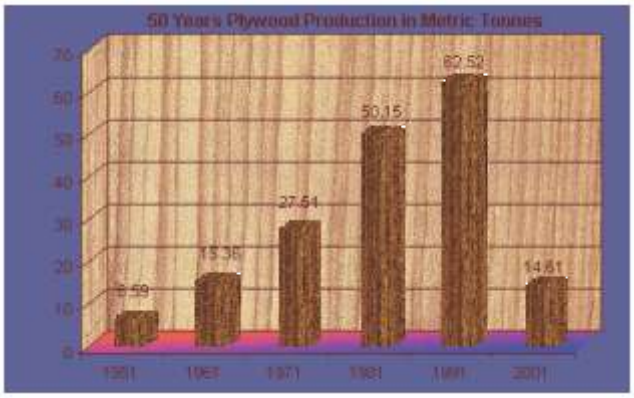
The present write up is based on detailed study done to understand the issues of plywood and panel industries especially raised in those representations for the supply or augmentation of wood from Agroforestry. First issue relates to the inclusion of wood obtained from agroforestry practices followed by farmers of the country within the definition of recently enacted agricultural acts. The second issue relates to exclusion of such timber grown by farmers on their agricultural lands and being used by plywood and panel industries from the definition of 'Forest Produce' under Indian Forest Act 1927. Before going into the merits of issues raised in their representations, it would be appropriate to give an overview of this sector especially with regards to the raw materials and their supply.

The journey of plywood industries in India though started well before independence but it could not prosper till India became independent. It was the demand of tea industry that started its journey in India in 1917. After 1947-48, the industry resorted to diversification of its products and block boards, flush doors, commercial plywood, decorative plywood, marine and aircraft plywoods, produced in Indian factories came into the market which were second to none in the world in quality and diversity of its products.

Industrial Licensing was governed by the Industries (Developmental and Regulation) Act, 1951 under which the wood-based industry was covered. There was no restriction of putting up plywood mill up to 1970. The only criteria were that the applicant was required to obtain an Industrial License which was being considered by the Ministry of Industry after consulting various Ministries. Ministry dealing with forest matters was being consulted for ascertaining sustainable raw material of timber for a particular project; the wood based industry was more or less in medium and large scale. During 1970, there was clear cut definition of small-scale sector and units having an investment of less than Rs. 7.5 lakhs in plant and

equipment were covered under the definition of small-scale sector which would be registered with the respective state director of industries. At that particular stage, some of the units with such investment got themselves transferred to small scale sectors. After the adoption of new Forest Policy in 1988, wood based industry was placed under Compulsory Industrial Licensing whether a small-scale unit or a large/medium unit, new undertaking or substantial expansion would require Industrial Licence. To understand the overall status of plywood industry in the country, the production of plywood in India given here below for 50 years from 1951 to 2001 on 10 years basis.

Due to Hon'ble Supreme Court Order on 12/12/1996,



the production activities were totally suspended in medium/large scale unit particularly in North Eastern Region as a result the production reduced drastically from 1997 and it came to 14.61 metric tonnes as compared to 62.52 metric tonnes in 1991, still there is no improvement. The phase wise development of this sector to appreciate the transformation undergone by these plywood and panel industries is given below:

Industry Phase I
(Prior to the landmark judgment in December 1996)

In the early 90's, the concentration of plywood companies was largely in the northeast, particularly Assam and Arunachal Pradesh, due to the proximity to huge forests resources there. The industry was mostly concentrated and largely dominated by organised industry players, which accounted for 60% of the industry size. The major organised players included Kitply Industries, National Plywood Industries and Anchor Plywood & Boards, while GIL and CPBI were marginal players at that time. The unorganised industry, which accounted for 40% of the industry size, was based in Bihar, West Bengal, Madhya Pradesh and Haryana. Yamuna Nagar, Haryana had few plywood units during the period, manufacturing cheap commercial grade plywood from agro-forestry / plantation timber.

Industry Phase II (1996-2001)
The plywood industry almost came to a standstill with two major apex court judgements in 1996 and 1998:

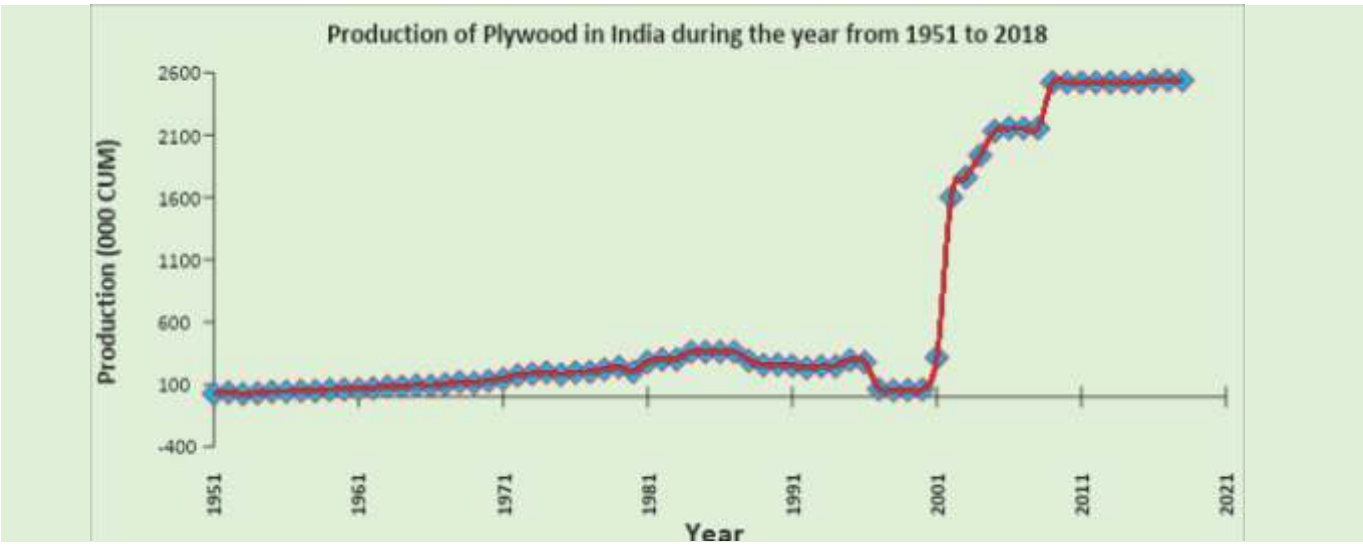
Ban on tree felling: The Hon'ble Supreme Court on December 12, 1996 in the landmark TN Godavarman versus Union of India case suspended tree felling in all 'forest' areas across the entire country. The court also interpreted the word 'forest' by its dictionary meaning. Prior to it, the word 'forest' was limited only to government declared forests, irrespective of whether it had tree cover or not. This ruling virtually paralysed wood-based industries - saw-mill, veneer and plywood factories - located in states like Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura due to inadequacy of raw material.

Suspending licences of wood-based industries: Less than two years after the first order in the Godavarman case, another order on January 15, 1998 suspended licences of all wood-based industries in the seven northeast states and ordered relocation of those industries to state-specified industrial zones, where they could be more closely monitored. This judgement was a big body blow to industry players located in the northeast, which were hoping that the ban on felling of trees would be lifted at some point in time. By virtue of this order, the court suspended all earlier licences given to saw mills and plywood industries in the northeast.

Industry Phase III (2001-2011)

The dynamics of the plywood industry changed completely with the Supreme Court rulings. Organised

players like CPBI and GIL shifted their factories to West Bengal and started looking to build their manufacturing base in States with close proximity to port (for imported timber) or plantation timber. Leading players like National and Kitply were particularly reluctant to this shift and instead started outsourcing products from unorganised players, resulting in their downfall. Large unorganised clusters in Bihar and Madhya Pradesh, prevalent prior to 2000, started shutting down units or reduce their scale of operations due to high operating costs, led by sourcing of raw material from distant states. With the industry gradually becoming dependent on plantation timber, small unorganised units started coming up in those states where plantation timber was available in abundance, resulting in scaling up of the so-called unorganised sector. Since then, the unorganised clusters started emerging in a big way in Haryana, Punjab and Uttar Pradesh in the north, Kerala and Karnataka in the south, Gujarat in the west and West Bengal in the east. However, with the emergence of dedicated players - GIL and CPBI - in the agro-forestry space and consistent shift happening from organised to unorganised plywood, the latter now accounts for over 75% of the industry, with Yamuna Nagar in Haryana being recognised as the plywood hub having more than 350 units. The production of plywood in India during the year from 1951 to 2018 is given in the figure below to drive further that there has been enormous increase in the plywood production and this is based on wood obtained from agroforestry.



Data Source: 1951 to 1984 by Directory of the IPIRI, May 1986, Bangalore & 1985 to 2018, FAOSTAT, 2020

Current Phase (2011-2020)

Today, this sector consists of around 3,300 units (small, medium and large units) scattered all over the country mostly in the rural and backward area. Out of these 3,300 units, nearly 3,200 units are in the unorganized sector, and has a market share of nearly 80% of the total panel production in the country. Production in these industries is done mostly by employing/engaging work force from nearby area. These units provide direct employment to more than 1 Million people and almost equal number of people is employed indirectly, mainly in rural India. However, expected growth in the sector depends upon the quality raw materials. This was expected to get boost with the promulgation of The Farmers (Endowment and Protection) Agreement on Price Assurance and Farm Services Act, 2020 and the Farmers Produce Trade and Commerce (Promotion and Facilitation) Act 2020. However, wood obtained from agricultural practices does find mention in either of the acts. The Farmers Produce Trade and Commerce (Promotion and Facilitation) Act 2020 does not leave any scope for any interpretational inclusion within the exhaustive definition of 'farmer's

History of wood based industries in the past

M.M. Mujeeb Rahman
Perumbavoor, Kerala

I would like to narrate brief note about past history of wood based industry. During the Period Maharajah of Travancore, the first plywood factory in Kerala came up in Kallai in 1937. Almost at the same time, the Mudickal Timber depot at Perumbavoor was started. The geographical features of the region, especially the thick forests surrounding the Periyar River in the nearby high ranges played crucial role in the growth of the wood related industries in Perumbavoor. After independence, the government started selling jungle and hardwood in open market by public auction through Mudickal timber depot. It helped the timber industry in Perumbavoor to flourish greatly.

Supreme Court of India to ban felling trees in any state without prior permission from the Union government. The verdict took place on 12 December, 1996.

Kerala State government imposed this rules and restriction before this. As a result, many saw mills were closed or converted to packing case manufacturing units. In 1980, owing to non-availability or shortage of softwood the entrepreneurs tried agro waste rubber wood in place of forest wood. The experiment proved successful. The availability of rubber wood boosted up veneer and plywood industry in Perumbavoor and adjacent places. Earlier, the veneer which was produced in Perumbavoor used to be sent to Gujarat, Maharashtra, Tamil Nadu, Andhra Pradesh and North Indian states for the production of plywood.

In Kerala, our main raw material for plywood manufacturing are plantation rubber wood, other soft wood/ and weed wood. The latex yielding period of plantation rubber wood is maximum 20 years, after wards for replantation purposes, this slaughter tapped rubber wood tree have to remove from premises. As, you may aware that Kerala is producing 90% of natural rubber wood in India. Mundakayam in Kerala had become the leading centre of rubber plantations. Moreover, this is not a seasonable yielding tree. Full calendar year, rubber wood is available in market. No quantity restriction to use rubber wood as raw material. Moreover in Kerala, Forest Department is giving license to function wood based units. Near about 500 trucks load reaches in Perumbavoor market situated in Ernakulum District. Comparatively prices are less, available its trunk/stems are near about same girth. These qualities attracts manufactures to use rubber wood as their raw material.

Fortunately we are not expecting deficit for rubber wood in immediate future because of its cycling cultivation. Kerala Forest Department collecting Soft wood/sap wood from reserve forest, are mainly using for making wood pulp for Newspaper industry. So, Raw material from forest department contribution for plywood industry is scant.

As shortly, it can be said that transformation helped rubber planters to obtain reasonable price for their rubber wood as well wood based units to get raw material incessantly.

Farmers don't find buyers for their short rotation tree species such as popular (e.g. Bihar) since there are no plywood or veneering units. Even in areas such as Punjab, Haryana and West Uttar Pradesh, there has been instances of acute lack of demand since no new industry or units can be licensed.

produce', however there is scope for inclusion of wood within the inclusive definition of 'farming produce' provided under The Farmers (Endowment and Protection) Agreement on Price Assurance and Farm Services Act, 2020.

The Farmers (Endowment and Protection) Agreement on Price Assurance and Farm Services Act, 2020 should include farm produced wood (AgriWood) under its ambit. This will surely help the issue to be resolved for the mutual benefits of farmers and the industries. Farmers are helping two important sectors plywood and panel industries and paper and pulp industries in providing wood by growing short rotation tree species as varied agroforestry practices. Otherwise, this will create demand for leasing forestlands for supply of raw materials for these two sectors.

Sub Mission on Agroforestry has not helped the cause of these industries, since there is serious local mis-match between demand and supply of wood between farmers and the industries. Farmers don't find buyers for their short rotation tree species such as popular (e.g. Bihar) since there are no plywood or veneering units. Even in areas such as Punjab, Haryana and West Uttar Pradesh, there has been instances of acute lack of demand since no new industry or units can be licensed.

Recently, National Green Tribunal (NGT) quashed a notice issued by the Uttar Pradesh government for establishing new wood-based industries in the state, saying hardly any timber will be available for these units. It also held that as "precautionary" principle of environmental law "State should therefore make an inventory, species-wise and district-wise, and also have species-wise consumption data of all the wood-based industries and their capacity to utilize them and not proceed with the present proposal till further exercise of making inventory and assessment of actual availability of timber/raw material is done. If new industries are allowed to open based on wrong estimation of availability of timber, it may result in clandestine supply of wood and illegal cutting of trees." As explained above, all panel industries have moved to plantation timber with limited choice for species and with short rotation of 4-5 years. Resultantly with no demand, farmers will move away from growing these crops resembling the chicken or the egg causality dilemma.

Contract farming agreements would provide suitable means to industries to harness assured supply of quality wood for their manufacturing supporting Atma Nirbhar Bharat and Make in India. Even new species like Melia dubia (composita) having great potential to improve panel products in India can be adopted by farmers and industries, which will even propel export of Indian panel products.

On the second issue regarding the exclusion of farm produced wood from the definition of 'Forest Produce' of Indian Forest Act 1927, there is need to take a comprehensive and contemporary view aiming at having an integrated Indian Forest Management and Conservation Act, which not only facilitates production from the forests while respecting biodiversity and community but also enables farmers growing wood on their farms to Double their income. The provisions and regulations put forward especially in the light of judgements of Hon. Supreme Court may be redefined to support Atma-Nirbhar Bharat, Make in India and Vocal for Local campaigns of Government of India.

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(Autonomous Body of Ministry of Environment, Forest and Climate Change, Govt. of India)

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Scope of the act on farming agreement for wood production on farmland

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Central government has recently brought some drastic reforms in agriculture sector. One of these reforms is in the form of 'The Farmers (Empowerment and Protection) Agreement on Price Assurance, and Farm Services Act, 2020' (MoL&J 2020) which is referred as farming agreement act hereafter. This act is also having a provision for connecting farmers to a platform for electronic trading and transport for conduct of trade and commerce of farming produce through a network of electronic devices and internet application. This reform, among many others, is suggested as a step forward for creating an ecosystem for opening up the agriculture sector and makes it competitive for the benefit of farmers and industry. This paper explores the scope and implications of this act on wood production and other related forestry origin crops on farmland.

In India, legally, there are two kinds of land viz., revenue land and forest land. There is different terminology used to refer the trees/wood grown on revenue land and wood obtained there from. These terms are trees outside forests (ToFs), farm forestry (FF), agroforestry (AF), tree based agriculture, extension forestry, social forestry, cropping land plantations, agrowood, agriwood, windbreaks/ shelterbelts, boundary plantations, road side plantations, canal side plantations, railway line plantations etc. Using any one of these terms limits, the scope of including wood from the entire wood produced on non-forest land and its interpretation/misinterpretation left to the individuals. Farmland grown trees or ToFs are better terms for overall understanding and interpretation of wood produce grown on revenue land. Even, if we use the term agroforestry plantations/wood, it does not include wood produced in pure plantations without integration of crops and others grown under various schemes on farm land as mentioned above. Based on the large number of overlapping production systems including fruit orchards producing wood on farm land, it is inferred that the term "farm grown plantation/wood" will be appropriate with wide coverage of trees grown on farm land by farmers. Presently, this is the dominant form of land use activity for production of the bulk of wood for industry. It is, therefore, suggested to use a term "farm grown wood" to cover most of the plantations grown on agricultural fields and to avoid any ambiguity in its interpretation.

The farming agreement act

The act seeks to provide an enabling environment for remunerative prices to the grower for his farm grown produce. It provides protection to both farmers and sponsors. No order of recovery can be issued in case of "force meijure"(damage to crop due to external events, including floods, drought, bad weather, earth quick, epidemic outbreak of diseases, insect pests and such other events which is unavoidable and beyond control of the parties entering into farming agreement). Farmers' land and his premises are kept outside the act and they cannot be mortgaged. The farming produce grown under the farming agreement is exempted from the application of any state act. There is also a practice of informal agreements of leasing land by farmers to others to grow crops on consideration of sharing farming produce or making payment mutually decided. This may

sometimes go against the sponsor -entering into a farming agreement with a farmer who has already given land to someone else for growing crops. The act protects the sponsor under its section 3(2) where it is provided that no farming agreement can be entered into by a farmer for a land having share cropper (a tiller or occupier of land who formally or informally agrees to give fixed share of crop or to pay fixed amount to the land owner for growing or rearing of farming produce).

The agriculture produce grown by farmers on their fields is designated as "farming produce" in the act. The definition of farming produce given under clause 2(h) of Chapter II enlists items like food stuffs including fruits and animal products consumed by human beings, fodder consumed by animals, cotton and its seed, and raw jute. Tree produce or those of any other forest origin crops like medicinal and aromatic plants, forest based oil yielding crops etc., grown on farm land is not specifically mentioned in the definition of farming produce. There are differing interpretations regarding covering produce of forestry origin crops including trees, if grown on farms, in this act. One school of thought is that the act intentions reasonably imply favorable to take care of/to include-cover items like tree produce including bamboos, medicinal plants/shrubs, herbs, aromatic plants grown on farm land by performing agriculture operations such as cultivation of land and/or, any process ordinarily employed by a farmer to render the produce raised or received by him fit to be taken to market. The argument suggested that the word farming produce has been used as such and the applicable meaning shall be exhaustive. The definition is inclusive which does not restrict the English meaning of the words 'farming produce'.

A classical case of bamboo being considered non forest produce when grown / found on farm land, whereas, is a forest produce when grown/found on forest land could be replicated for other species as well.

The second school of thought is that the present definition of farming produce in this act does not specifically include these items and hence a separate clause in the definition needs to be inserted with "produce of trees, shrubs and herbs grown on farm land". States may relax the transit and felling rules for such tree, shrub and herb crops those having overlapping occurrence in forests and grown on the farm land as has been done for number of tree species exempted in different states. A classical case of bamboo being considered non forest produce when grown/found on farm land, whereas, is a forest produce when grown/found on forest land could be replicated for other species as well. There is another reform in the form of act on trade and commerce where tree produce of some exempted species is specified under APMC laws in many states.

Another school of thought is related to a term "forest produce" which is defined under section 2(4) of the Indian Forest Act 1927 (IFA) that enlists different items related to trees and forests whether found inside or brought from a forest or not. Therefore, it is implied that a tree produce whether produced or brought from forests or from other land use including farm land is considered a forest produce and fall under the ambit of IFA. The provisions of IFA will still be applicable on such produce grown on farm land even after the act on farming agreement is promulgated. It is, therefore, suggested that an amendment is needed in section 2(4) of IFA to exclude produce of trees and other items of forest origin grown on farm land to avoid any ambiguity

and to permanently settle the issue which can then safeguard farmers' interest in growing such crops on their farm land. This will also increase the scope of most of the existing wood based industry (WBI) using raw material grown on farm land to declare them as agro based industry for drawing benefits related therewith.

Besides, some contradictions and confusion on interpretation whether farm grown wood could be considered within the ambit of this act, there is no doubt that this act provides; first time; detailed procedure and mechanism to enter into formal, written, and legally enforceable farming agreements between farmers and sponsors (industry and other entrepreneurs, service providers and Assayers -technical experts) for farming produce. There is also no confusion on the increasing role of the farming sector in production of industrial wood in addition to similarly grown other food crops on farm land. Therefore, it is inferred that the procedure and mechanism developed for entering farming agreements between farmers and other parties for crops enlisted in the definition of the farming produce will be similarly extended for wood production or other crops inadvertently left out or otherwise. It will formalize the agreements and provide legal backing for both the farmers and other parties involved in wood production and many operations related therewith.

Comparison of the provisions of this act with past agreements

The farming agreement also referred as contract farming, contractual arrangements, contract agreements etc. for growing timber and other forest crops on farm land which has been in vogue for the last over three decades. There are many versions of formal, and informal agreements including verbal ones between parties those may also include third parties growing trees on farmers' fields (Dhiman APAN 2012, Pratibhan et. al. 2010). A detailed account of formal and informal agreements between farmers and different parties in agroforestry is given by Dhiman (2014) who has defined it as "A written or verbal agreement/ arrangement that is legally or socially enforceable between the contracting parties to produce and supply/procure/trade specified tree/intercrop produce grown in agroforestry production system with or without services and/or credit extended to the growers".

A detailed account of formal and informal agreements between farmers and different parties in agroforestry is given by Dhiman (2014)

The lessons learnt on these agreements so far have been mixed. Besides, there being some very good aspects in these agreements those enabled establishing new tree crops of long production cycle, i.e., poplar, eucalypts, kadam, etc. on farm land, linking wood production with wood based industry, huge employment generation especially in rural locations where the development activities are not very significant, environment amelioration by creating sylvan landscape around monotonous cropping fields, saving natural forests by diverting pressure of wood production to non-forest land etc., there have been some negative exposures as well. There have been number of disputes for wood production and supply between sponsors and farmers, some of them are still pending in consumer forums and courts. There were also a very large number of defaulters who declined to supply tree produce to sponsors or tried to supply ungraded poor quality wood. A large number of cases decided after a long legal battle has largely been in favor of sponsors/company as the terms and conditions of these agreements were drafted by safeguarding their interests. The detailed mechanism outlined for new

farming agreements made in this act thus could be a relief to both farmers and sponsors. A comparison of mechanism, procedure, terms and conditions, dispute disposal, penalties etc given in old agreements already in vogue and those proposed in the new act is given in the table below.

Table-1: Comparison of old and proposed agreements for wood production on farm land

Activities	Old agreements	Agreements as per new Act
Period	Full or part of production cycle of crops including seasonal operations like planting tending and harvesting of trees	One full production cycle, with a cap of maximum five years but extendable further and terminated in-between with mutual consent of parties
Items	Wood, tree parts, medicinal plants, seedlings etc.	There is suspense on inclusion of tree produce, though mechanisms and procedure of registering agreements could be extended to these crops as well
Agreement timing	Largely beginning, but also during the production cycle and even on completion of production cycle, for logistic support & for sale of standing crop.	In advance of starting production.
Execution on	Stamp paper	Not clear, yet to be decided
Registration	Not done	With proposed State Registration Authority. Fees charged on registering such agreements as per existing provision may be a limiting factor.
Terms and conditions for price and quality	Mainly decided by the sponsor	A benchmark and transparent method suggested
Scope	All forms of written, verbal, legally and socially enforceable	Recognize only written forms
Provision for insurance and refinance	Yes, but largely depends on drafted terms and conditions, lacked in many informal agreements	Yes, provisions made. Terms and conditions need to be worked out
Quality control	Was decided by the sponsors	Through third party qualified "Assayers" to ensure impartiality and fairness.
Dispute readdress mechanism	Suggested through arbitrator which has been lengthy and time consuming.	Time frame fixed with different authorities. Time frame for settling prescribed as one month at each level.
Forum	Arbitrator, consumer and civil courts.	Conciliation Board, local SDM and Appellate Authority (Collector). Civil courts debarred for appeals on such matters. Passed orders shall have the status of Decree and enforceable under the Code of Civil Proceedings 1908. Fear of non-fare judgments from officers acting judicatures.
Punishment	Depends on interpretation of the forum/court.	Prescribed, 1.5 times the value of produce supplied to sponsor and equivalent of service cost to farmer.

The act also created a provision for qualified "Assayers" to monitor and certify the produce (wood in this case) or so delivered as per specified quality, grades and standards as per the terms and conditions of the agreement. This may strengthen the wood production protocol and also the quality of plantations. Assayers may also act as qualified resources to provide technical inputs to growers. This, however, may work more in favor of sponsors and factory owners as more of wood produce is likely to get rejected on the name of quality standards and any overhead payment to them would be built on wood cost that may affect returns to the farmers.

The mechanism for price fixation is suggested to be linked to the prevailing prices in specified APMC yard or electronic trading and transaction platform or any other suitable benchmark prices. Such price needs to be mentioned while executing farming agreement itself, and in case, such price is subject to variation then such agreement shall explicitly provide for a guaranteed price to be paid for such produce and a clear price reference for any additional amount over and above the guaranteed price including bonus or premium, to ensure best value to the farmer. Unlike agriculture crops, price fluctuation in wood prices is very high. Wood prices, like any stock, fluctuate on day to day basis, seasonally, annually and periodically. For example, poplar wood prices during the last two decades varied from around Rs. 300 per qtl to over Rs. 1200/qtl for oversize log grade. There is hardly any mechanism to forecast and predict this variation in advance and capture the estimated price during harvest of trees. If the wood prices during supply time are higher than those mentioned in the agreement, farmers will try to invoke the provisions of agreement for getting agreed price. However, in case of reverse situation when prices mentioned in the agreements are far below the prevailing prices then sponsor would like to avoid taking wood produce at that agreed price and that would be one of the main confrontations between the parties on the price front. There is a possibility of predicting these variations on the basis of trends in plantations and their harvest and capture such a variation in prices with some degree of accuracy but

When wood is in abundant supply; log grades, log measurement parameters, rejections based on straightness, stem circularity, bark thickness, moisture content etc. are tightened and relaxed when wood is in short supply.

that needs a lot of ground work and involvement of field level operators in doing so. In old agreements, there was a provision wherein a farmer can sell his produce to any other party if he gets better than agreed price, but there was no protection to the sponsor. In some ongoing agreements for wood production a provision is created for a price fixation committee that fixes the wood prices and its grade periodically to settle this issue. However, the present act does not provide this relaxation.

The real challenge would be in its implementation especially on acceptable quality, grade and standards of produce. These are though required to be clearly mentioned in the agreement, supply and receipt of wood of these grades would always remain a cause of conflict between the farmer and sponsor. Wood grades and quality are frequently changed based on demand and supply and hence mere their mention in agreement would be unrealistic until and unless followed in letter and spirit by both contracting parties. When wood is in abundant supply; log grades, log measurement parameters, rejections based on straightness, stem circularity, bark thickness, moisture content etc. are tightened and relaxed when wood is in short supply. Wood is presently traded on lump-sum basis (plantation); on selected tree basis; log grade wise viz., mix grade, oversize, undersize, sokta, pleva, billets, roots etc. Wood in many locations is sold on weight basis and in some locations on volume basis. Poplar is presently traded in around a dozen wood markets and

directly to large number of wood processing factories. Each location has its own definition of grades, sizes, deduction on log defects etc. It would mean that each location would need separate standardization of these grades and their specifications for implementation of the provisions of the act. Wood sometimes may meet physical parameters mentioned in agreements like log length thickness, straightness, knots, etc but may have some defects not visible on surface like moisture content, hidden knots, heartwood rot etc. and such disputes would be very difficult to settle.

Conclusion

Besides a few uncertainties, the act on farming agreement is a welcome step towards creating trust and confidence among farmers and sponsors for farming produce. There is no bar in applying the detailed legally enforceable and sound provisions and procedure of farming agreement on farm grown wood. There is an urgent need for creating awareness among the stack holders for realizing its benefits for farming produce that may also include farm grown wood. Field level operators and other stack holders need to take notice of the limitations being observed during its implementation and pin point them to the policy makers for making suitable amendments as and when required.

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Need for amendment of BIS standards in relevance with plywood quality made of plantation timber

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Manufacture of tea-chest was attempted in India during World War I; but was unsuccessful due to non-availability of suitable binding material. By 1940, urea formaldehyde came into use as bonding material of wood. As tea-chest, used to be imported from Europe, became non-available during World War II, Indian manufacturers again took an attempt to manufacture tea-chest using urea formaldehyde as adhesive and it was successful. After independence of India, commercial plywood was made and since then plywood industry did not have look back. Today, Indian manufacturers can make all grades of world class plywood. Simultaneously, national standards were developed to give guidelines to the manufacturers for making uniformly standard products and assure consumers with quality plywood.

Initially, preparation of standards was greatly influenced by British Standards and gradually amendments were brought in the standards depending on the Indian conditions of manufacture and end use of the products. However, in none of the specifications major modifications were done. Indian standards on plywood give brief guidelines on raw materials and manufacturing process while major emphasis is being given on the evaluation of the quality of the products. Product standard or the test values of different physical and mechanical tests done on different grades of plywood were based on plywood made with mature and most suitable timber procured from natural forest. At the beginning, there was no problem, as the entire raw material required for plywood manufacture used to come from virgin forest. But, since last twenty five years, plywood industry is totally dependent on 5 to 7 years old plantation timber. Obviously, strength of plywood made with immature and secondary timber species cannot match with plywood made with mature and primary forest grown timber.

The matter was discussed in several meetings of CED 20 of BIS. Minor amendments were brought about in one or two of the specifications and alternative test methods were suggested for some; for example, cyclic boil-dry test has been suggested as an alternative to glue shear tests in some specifications. But test values in any specifications were not changed as majority of committee members of the specifications were against doing so fearing dilution of the standards. In fact, systematic studies were also not done on plywood prepared by standard procedure and using standard glue and veneer from plantation timber.

IPIRTI, Bangalore, has been working on finding suitability of several secondary timber species of non-forest origin for manufacture of plywood and evaluated their physical-mechanical properties. Also plywood manufactured by plywood industries from plantation timber is regularly tested in IPIRTI laboratory. Test results of more than 10 years done by IPIRTI on mechanical properties on various grades of Plywood prepared from plantation timber were critically analysed to find out the gap between the test values obtained and the values set in BIS standards. It was observed that deviation of test values from values set in BIS standards are due to timber strength, construction of veneer in plywood making, poor adhesive, veneer quality and lack of adequate knowledge in plywood manufacture. When lower timber strength of

plantation timber is the reason, there is no choice but to change the values of mechanical properties of plywood set in BIS specifications. But if test values cannot reach the specified values of the BIS specification due to faulty construction or method of manufacture or poor adhesive, it is the manufacturers who have to come forward to improve their floor activities.

In last 25 years, not only the industry has fully switched over to use of plantation timber, there have been many changes in the manufacturing processes of plywood in India. BIS specifications have not been tuned up with the changes that have occurred in the industry. Hence the gap between BIS standards and the quality of actual products made in the country is getting widened with passage of time. It is an open fact that certain BIS requirements such as thickness of face veneer, preservative chemical retention of 12kg/M^3 or bending strength test values are no more achievable with plywood made in India today. Still marking of plywood with BIS logo is going on.

The entire plywood industry has switched over to a process popularly called 'Glue Line Poisoning' (GLP) treatment.

At Institute Industry meet at Kolkata in December 2019 and at Bengaluru in January 2020, major plywood manufacturers put forth this point very emphatically that BIS standards for plywood should realistically conform to contemporary manufacturing practices prevalent in the country. All plywood manufacturers were encouraged to bring out the deficiencies in the present standards not being realistic and submit suitable draft amendment to existing standards for the consideration of CED 20 of BIS.

It is therefore urgently necessary that thorough review of all BIS specifications on plywood be done and revised on the basis of the actual quality plywood that can be made with the timber available in the country and using the best manufacturing practices and using quality resin. Based on the studies of the present status of the plywood industry in India, test results obtained from IPIRTI laboratory and study on the relevant BIS specifications, a few points have been sorted out where changes in the standards are necessary.

Preservative treatment

The method of treatment of plywood with preservative was formulated in line with the preservative treatment of solid timber. Methods like pressure impregnation, application of vacuum and high pressure and even alternate hot and cold dipping for longer period are too rigorous for plywood. Plywood is a composite panel where pieces of veneer are joined surface to surface by adhesive. Under rigorous condition of treatment as above, glue bond between veneers weakens and even disintegrates. Secondly, water soluble preservative cannot pass through the glue line in plywood and hence preservative chemicals do not pass from surface to inside of plywood. Only a small quantity of preservative enters inside through edges of plywood and mostly deposit on the surface of the board. Almost all plywood manufacturers have abandoned using pressure impregnation process. By simple hot and cold treatment, it is very difficult to attain a loading of 12 kg/m^3.

The entire plywood industry has switched over to a process popularly called 'Glue Line Poisoning' (GLP) treatment. In this process, preservative chemicals which resist attack of fungus, borer and termite are mixed with resin in the glue mix. During glue application, the preservative chemicals coat the glue core veneer and during pressing the same, along with glue, pass on to non-glued surface of veneer. Thus, all surfaces of veneers get coating of preservative and protected. The lethal doses of preservative chemicals have been worked out. The process is very easy for application. Market complain on bio-deterioration of treated plywood have been significantly decreased with the introduction of GLP.

The outer two surfaces which do not contain adhesive, remain untreated. Hence the finished board may be given final treatment with water soluble non-leachable preservative to get the final board fully resistant to all types of bio-deterioration. The type of chemicals and method of treatment and hence retention of chemicals

depends upon the grade of plywood and/or severity of exposure to which the plywood will be exposed to during service life.

Static Bending Strength: The mechanical strength properties of plywood were standardised for BIS depending on the test result obtained from plywood made with natural forest grown mature timber of selected species. At present, plywood is made from 5-7 years old plantation timber of secondary species. In strength properties, an immature timber of 5-7 years old is no match to the primary timber of 50-70 years old. Hence, Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) of any grade of plywood made with plantation timber cannot attain the value prescribed in BIS specifications.

To reach to ground reality, test results of plywood done in last 10 years at IPIRTI, can be critically analysed and the values obtained with plywood, made with ideal construction of veneer from plantation timber and manufacturing conditions, be compared with results on the same properties of plywood samples drawn from factories and conclusion drawn to fix values for MOR and MOE.

Flatness: Most of the veneer from immature logs of plantation origin cannot be dried flat. Plywood made with such veneer shows tendency to warp specially when cut to pieces. This creates lot of problem in furniture making or other uses. Technology is now available for drying and plywood manufacture to get flat board. Keeping in mind the necessity of the end users, this test has to be added as a physical property of the finished plywood.

Face veneer Thickness: For making shuttering grade plywood as per IS 4990, minimum face veneer thickness will be 1.2 mm. For marine grade plywood, face veneer should be minimum half the thickness of that of the adjacent glue core veneer. Due to high cost of face veneer, no plywood industry abides by the norms given by BIS. In fact, face veneer thickness used in plywood manufacture, even for higher grade plywood, is 0.25 mm to 0.30 mm. This is the major reason that total veneer thickness along the face grain is always less than the total veneer thickness across the face grain. This leads to lower value of MOE and MOR along the face grain than that across the face grain.

There is little chance that industry will, in future, use higher thickness face veneer lest it costs higher. Keeping this fact in mind, alternative veneer construction for plywood manufacture has to be evaluated so that total veneer thickness along the grain of the face veneer is higher than that across the face grain. This will serve the purpose without escalating the veneer cost.

Tensile Strength: As explained under static bending test, the value prescribed in BIS specifications cannot be obtained due to poor strength of low density and immature plantation timber which is being used at present for making even higher-grade plywood and hence test values needed to be reviewed.

Glue Shear Strength (GSS):

There is no doubt that glue shear strength pertains to bond strength between faces of two adjacent veneers through adhesive. With good bond and low density, immature plantation timber, failure on shear will be with wood rather at glue line. Even by using the best available timber, GSS never attains the desired value as per BIS Standards. To overcome this problem, either of the following may be adopted:

Value of GSS may be reduced based on actual value obtainable from plywood made with plantation timber.

GSS test may be replaced by cyclic test of alternate boiling for 8 hours and drying at 60 0C for 16 hours in all grades of plywood. Total no of cycles to be performed will depend on the grade of plywood. Bond quality may be evaluated by knife test.

For the same reason, as explained above, GSS value after mycological test may be changed based on actual test value or test method may be changed.

Load Bearing Strength: As explained under static bending test, the value prescribed in BIS specifications cannot be obtained due to poor strength of low density and immature plantation timber which are being used at present for making even higher-grade plywood and test values needed to be reviewed.

Thickness Swelling: Plywood used under marine condition and for shuttering and form work, remain in water contact for long period when in use. Very often non-prescribed low-density veneers are used in manufacture of marine or shuttering plywood due to the non-availability of high density or BIS prescribed species. If, during manufacture, plywood is properly densified, it will not absorb water on long exposure, otherwise soft and spongy veneer may absorb water and swell, affecting glue bond and joint fixed by hardware. Since most plywood in India is manufactured with timber of plantation origin, both low and medium density, this additional test is necessary to ensure required performance at the users' end.

Formaldehyde Emission Test

Formaldehyde is a gas and its inhalation causes health hazard. Continuous inhalation of formaldehyde can cause headache, sneezing, nausea, vomiting and fever. Long exposure to formaldehyde may lead to serious pulmonary disease. When the wood based panel industry throughout the world is showing concern about formaldehyde emission in the work place and panel products where formaldehyde-based resin is being manufactured and used in product, Indian plywood manufacturers are silent on this issue. No control over emission of formaldehyde has three serious consequences : 1) formaldehyde emission at the work place in the factory causes health hazard to the workers dealing with formaldehyde and resin manufacture, 2) end users of the panel products made with formaldehyde based resin would be subjected to health problem on long exposure to such products, and 3) export of wood based panel products made with formaldehyde based resin will require emission certificate if the country of import follow emission norms.

Central and state Pollution Control Boards have various regulations over harmful emission and effluents from manufacturing units, but silent over emission of formaldehyde in formaldehyde-based resin manufacturing units. BIS has not yet fixed any norms and limit on the emission of formaldehyde from plywood products made with formaldehyde-based resin.

It is urgently necessary that BIS include in all its specifications on plywood and other wood-based panel products limit of formaldehyde emission and its testing method. IPIRTI, Bangalore, is fully equipped with to undertake testing of formaldehyde emission by Perforator and Chamber method. Plywood factories can establish testing facilities by Perforator or Desiccators methods which are very cheap, fast and simple.

Way forward

Standards on a product is prepared based on test results of the same made with definite raw material(s) under standard process and aims to meet all end use requirements. No product standard is universal, nor everlasting. Standards need to be updated and amended if there is change in any of the related parameters such as raw material, manufacturing process or end use requirement. In last 25 years. plywood industry has seen many changes – raw material (from mature forest timber to short rotation plantation timber), method of manufacture (veneer composition, preservative treatment, process parameter) and also end-use requirement (formaldehyde emission). In the above discussions, only a few parameters pertaining to IS:303, IS:710 and IS:4990 have been mentioned. Other specifications on wood-based panel products also require thorough study and subsequent amendment. It is in the interest of all that these corrective steps to amend the specifications are given due priority lest this gap between the standards and actual products does not further widen.

The Indian standard marking is voluntary by nature and manufacturers are free to opt or not to opt for IS certification, out of about 3300 wood-based panel industries, very few industries have opted for BIS certification. Standards play a significant role in sphere of quality level, quality assurance, quality advancement and trade. Markets require realistic, easily achievable and contemporary standards in order to efficiently align the expectations of buyers and sellers. This may also encourage more and more MSME plywood manufacturers to register with BIS for its product licenses and improve supply of standard products to the consumers.

Indoor concentration of formaldehyde from panel products and its impact on environment

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In spite of the introduction of modern materials in recent times, wood continues to be one of the most widely used raw material for diverse industrial and structural applications. The wood composites are categorized as plywood, particle board (PB) and medium density fiber board (MDF). In India, plywood constitutes largest share and is dominating the other panel products.

Plywood industry as on today consists of 100 large and medium size industries and over 3238 SSI units. Out of 3300 industries, nearly 2500 are in the un-organised sector which holds market share of 60-65% nearly of the total panel productions. There are 65 particle board units and 9 MDF industries producing materials worth Rs.25,000 crores per annum. The market size of plywood in India is 6.3 million cum, particle board 1.8 million cum and medium density fibre board is 1.2 million cum with the market share of 68%, 19% and 13% respectively. The CAGR expected for the panels ranges from 10 -22%.

It has been estimated that the present demand for industrial wood in India is 90 million cum, while the present consumption reported is 50.1 million cum (survey in 2017). The projected demand by 2022 for plywood is 18 million cum, particle board, 1.5 million cum, veneer 0.60 million cum and MDF 16.10 million cum. The demand for the panel products is always in growing trend. Simultaneously, there is growing concern on the safe quality of the products being marketed and used. In our county, all the wood composites are manufactured using the synthetic resin adhesives of phenolic and amino. Formaldehyde is the cross linking compound used for making phenolic and amino resins. The phenolic resin requires less formaldehyde for cross linking. Hence, the panels bonded with phenolic resin releases negligible level of free formaldehyde and may not impose any harm to the environment.

Amino resins require an excess of formaldehyde for cross linking and it always has a tendency to release small amount of free formaldehyde when comes in contact with moisture. Although the emission of formaldehyde is mainly due to higher formaldehyde content kept in the resin during manufacturing process and it is also the fact that it cannot be eliminated completely due to the condensation reaction of Urea Formaldehyde resin requiring an excess of formaldehyde for further reaction process during the curing of resin. However, the total formaldehyde content/emission in the panels can be minimized by addition of higher quantity of second urea which would react with the unreacted formaldehyde that may be present during the reaction. Also, addition of suitable absorbing agents to the resin during manufacture reduces the formaldehyde content/emission from panels.

The volatile organic compounds emission especially formaldehyde from wood and wood based composites bonded with amino resin is a typical health hazard associated during the production process and at the time of end use of these products. Formaldehyde concentrations from panel products varies depending on the adhesive formulation and process of manufacture. Formaldehyde is a gas which on inhaling at higher levels are found to be carcinogenic leading to the poor indoor air quality for the customers/users. Formaldehyde affects people in various ways. When present in the air at levels at or above 0.1 ppm, acute health effects can occur including watery eyes, burning sensations in the eyes, nose and throat; nausea; coughing; chest tightness; wheezing; skin rashes; and other irritating effects. Colds, flu, and allergies can cause symptoms similar to some of those produced by exposure to formaldehyde. Formaldehyde has caused cancer in laboratory animals and may cause cancer in human. There is no known threshold level below which there is no threat of cancer. The risk depends upon amount and duration of exposure. Some people are very sensitive to formaldehyde while others may have no noticeable reaction at the same level of exposure. Sensitive people can experience symptoms at levels below 0.1 ppm. It has also been reported

by Chen, et al that high concentration of formaldehyde is toxic on the nervous system, immune system, and the liver. Extensive research has been conducted on the issue of formaldehyde emission from wood-based panels during the last decade. The formaldehyde emissions are mainly from three sources: (1) formaldehyde compound in wood material, (2) residual free formaldehyde of the formaldehyde-based resin that is not involved in the reaction, and (3) formaldehyde released by the structural degradation of the wood-based panel used. Among them, the residual free formaldehyde in the panel is the main source of indoor air pollution especially from particle board and MDF given in Fig. 1 and 2 respectively.

The World Health Organization (WHO) recommends that the limit of formaldehyde content in exposure in human inhabitant should not exceed 0.05 ppm. Since risks of emission of formaldehyde form pressed wood products are more where bonding agent is amino formaldehyde resin, many countries has banned manufacture of such resin. Even where such resins are being manufactured and used for bonding wood, lot of care is being taken to minimize residual formaldehyde in the product otherwise finished products are being coated or overlayed to minimize emission of formaldehyde from the products. Most of the developed countries and many developing countries has set up National Standard or follow International Standards to control formaldehyde emission from panel products used in respective countries.

Fig. 1. Particle board cut edges

Fig. 2.Medium Density fiber Board (MDF)

Test methods for determination of free formaldehyde

Zhu et al. has reported that the testing methods of formaldehyde as three categories: total amount testing method such as perforation; static emission testing method such as desiccator; and dynamic emission testing method such as chamber. The chamber method is widely used in the United States and Germany. In the EU standards, chamber, gas analysis, and perforation methods are used. In Japanese standards, the desiccator method is used. According to Chinese mandatory national standard GB 18580-2001, MDF and PB are tested by perforation method, and plywood and block board are tested using the (9–11) L desiccator method. For the desiccator method, a 40L desiccator is usually used to test the laminate flooring and parquet. If there is a controversy for the result, an arbitration method is used using a 1 m^3 chamber.

The list of methods being used for determination of formaldehyde release are as given below

- Desiccator method according to JANS 16 and ASTM D5582 (Fig. 3 a)
- Perforator method according to EN 120 (Fig 3b)
- Gas analysis method according to EN 717-2
- Flask method according to EN 7173

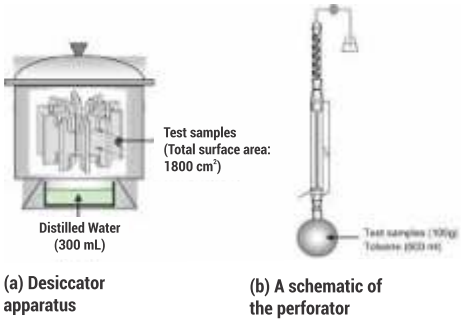

Fig. 3. (a) Desiccator set up and (b) perforator test set up

- Dynamic Micro chamber method according to ASTM D 6007.
- Chamber method as per EN-717-I
- Large Chamber Test method as per ASTME1333-96(2002).
- Small chamber method ASTM D 6007-02

Each testing method has its own advantages and disadvantages. The chamber method (Fig. 4) is more close to the practical application in terms of temperature, relative humidity, loading rate, air exchange rate, and air velocity on the sample surface. The chamber body is large and the testing time is long.

The unit and value of formaldehyde limit indicators of all levels are different due to different testing methods. The units of formaldehyde content and emission are mg/100 g, mg/L, mg/m^3, and mg/m^2.h, corresponding to different test methods. The unit of formaldehyde content in wood-based panel is mg/100 g that refers to the formaldehyde content per 100 g wood-based panels, using the perforation test method. Three units mg/L, mg/m^3, and mg/m^2·h are used for the formaldehyde emission. The unit mg/L corresponds to the desiccator method, which is related to temperature, specimen area, dryer volume, water volume, and collection time. The unit mg/m3 corresponds to the chamber method related to the temperature and humidity, loading rate, ventilation, sampling port, sample size, sampling time, and analysis methods. The unit mg/m^2·h corresponds to the gas analysis method. Each country has their own limits, coupled with the testing conditions, the difference between the pretreatment methods, and the type of panel.

Despite the achievements and progress in meeting industry benchmarks, formaldehyde emissions impacting indoor air continue to be aggressively regulated. The California Air Resources Board (CARB) recently established a new set of product emission control measures. CARB's two-step process tightens allowable formaldehyde emissions from raw composite wood panels (particleboard, medium density fiberboard and hardwood plywood) and all products constructed out of them (such as flush doors).

Fig. 4. Small chamber of 1 M3 established at IPIRTI for steady state formaldehyde emission

Factors attributing to emissions in panel products

The formaldehyde emission from wood and wood based panel products may vary depending on the raw materials viz., wood species, the adhesive used and the overlaying/coatings provided on the surface. Also it is dependent on the temperature and humidity during the time of use of the product. Generally at lower temperatures and humid zones the emission will be higher. The formaldehyde emission value depends on the temperature, humidity, the air velocity and the air exchange rate and more specific to the moisture content of the product.

Emission of formaldehyde is mainly due to higher formaldehyde content in the resin manufacturing process, it cannot be eliminated completely due to the fact that condensation reaction such as Urea Formaldehyde resin requires an excess of formaldehyde for further reaction process leading to curing of resin. However, the total formaldehyde content/emission in the panels can be minimized by addition of higher quantity of second urea which would react with the unreacted formaldehyde that may be present during the reaction. Also addition of suitable absorbing agents to the resin during manufacture reduces the formaldehyde content/emission from panels.

The higher the moisture content of raw material (veneer, particles and fibres), the greater is the emission of formaldehyde. This is evident from the reaction mechanism of Urea formaldehyde resin that some amount of formaldehyde always remains in the final resin. This free formaldehyde when comes in contact with moisture will again try to form formaldehyde chains and releases more to atmosphere. Higher temperature or longer hot pressing time will reduce the amount of formaldehyde emission, but increase the cost. Usually, the formaldehyde emission of thicker panel is lower than the thinner one because of more energy absorption.

Emission of formaldehyde is always higher when the product/panels are new. This is mainly due to the presence of excess formaldehyde in resin used during the panel processing which tends to escape. The escape in the initial levels will be more which continues to decline with time eventually decaying to negligible levels. The emission of

formaldehyde is comparatively higher in particle board and Medium density fiber board than that found in plywood. This is mainly due to the process employed in manufacture. Generally in plywood the alternate layers of veneer is glue coated whereas for particle board and medium density fiber board each and every particles/ fibres needs to be uniformly coated with adhesive to achieve good bond integrity. Generally, the formaldehyde emission of particle board made from low-density wood is higher than those made from high-density species. Medium density fiber board uses more adhesive than PB, which causes higher initial formaldehyde emission of Medium density fiber board than PB.

Since people today spend most of their time at home or in an office, long-term exposure to VOCs in the indoor environment can contribute to health issues. Hence, it is pertinent to move towards safe products which release less volatile compounds to atmosphere and qualifies the limits indicated in the following Table.

Test Method	Country	Specification standards	E0 value	E1 value	E2 value
Perforator Method EN 120	Europe	Wood based panel specification EN 13986	-	≤8.0 mg/100g	>8.0 to ≤30 mg/100g
Gas Analysis Method EN 717-2	Europe	Wood based panel specification EN 13986	-	≤3.5 mg/m^{2}h	>3.5 to ≤8mg/m^{2}h
Chamber Method EN 717-1	Europe	Wood based panel specification EN 13986	-	≤0.124 mg/m^3	>0.124 mg/m^3
Desiccator Method AS/NZS	Australia	Fibre board specification AS/NZS 4266.16:2004 1859.2:2004	≤ 0.5mg/litter	≤ 1.5 mg/litter	>1.5 ≤ 4.5 mg/litter
Desiccator Method JIS A 1460	Japan	JIS A 5905 & 5908	F* or E2 F** or E1 F*** or E0 F**** or super E0	≤ 4.5 mg/litter	≤ 1.5 mg/litter or 6.5 mg/100 g or <0.10 ppm ≤ 0.5 mg/litter or 2.5 mg/100 g or 0.01-0.08 ppm ≤ ≤0.3 mg / litter or 1.5 mg / 100 g or 0.008-0.01ppm
Large chamber ASTM 1333 A208.1&2 (PB & MDF)	USA	E1333 LARGE CHAMBER	≤ 0.3 ppm (class not mentioned)		

The Regulated products emission standards beginning June 1, 2018 under CARB for Hardwood Plywood – Veneer Core is 0.05 ppm of formaldehyde while for Hardwood Plywood – Composite Core it is indicated to be 0.05 ppm of formaldehyde. The carb limits to 0.11 ppm of formaldehyde for Medium-Density Fiberboard and 0.13 ppm of formaldehyde for Thin Medium-Density Fiberboard. For Particleboard the limit set is 0.09 ppm of formaldehyde. The graphical representation is indicated in Fig 5. The limits indicated during the year 2011-2012 are continued in 2018 standards.

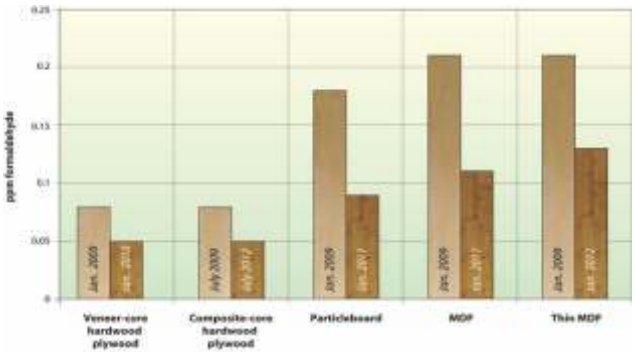

Fig. 5. CARB allowable formaldehyde emissions standards

In order to comply with increasingly stringent requirements, the industry has to develop strategies to minimize formaldehyde emissions. Four major approaches that can be adopted to minimize the emissions are (1) reduction of formaldehyde content in resin formulation, while attempting to maintain adhesive performance, (2) addition of formaldehyde scavengers to resin or wood particles, having the negative effect of consuming formaldehyde prior to resin cure, (3) implementation of surface treatments after board production, and (4) use of alternative adhesive systems with Formaldehyde Emissions from Wood-based Panels with reduced or no emissions. All the above factors need to be worked out considering its impact on product cost and/or performance.

Thermal modification: an eco-friendly processing technique to produce value-added wood products

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Background

Thermal modification is processing technique where wood is subjected to high temperature treatment (150-250°C) for certain duration under inert or vacuum environment. Thermally modified wood exhibits enhanced dimensional stability, decay resistance and darker brownish colour. Depending on required level of changes in wood properties and product performance, process parameters can be adjusted. Important process parameters include temperature, duration, atmosphere, species, thickness, initial moisture content and defects present in the wood. Thermally modified wood provides an economically viable alternative to the conventional tropical timbers having darker coloured heartwood associated with higher durability. The wood quality of most of the plantation grown wood species can be upgraded using this method. Thermally modified wood can be used for different applications. In recent years, this technique has attracted considerable attention worldwide. Wood species having low commercial value as such can be heat treated and improved, providing a new source for timber industry.

Process and its significance

During last few years, good amount of work has been carried out in this Institute on thermal modification of wood and bamboo. Thermal modification of plantation grown wood was successfully carried out using different temperature profiles under controlled ambient environment. A microprocessor controlled heating chamber was used for thermal treatment of wooden planks (Fig. 1). Various physical, mechanical properties and durability of thermally modified wood were evaluated as per applied Indian standards and compared with unmodified controls. Thermal treatment of wood was found to improve the dimensional stability, moisture/water repellency and resistance against attacks biodegrading agents. Appearance and all the way through dark brownish colouration of heat treated wood give a whole new look which rivals many tropical hardwoods. This technique provides value-addition to fast grown plantation timbers towards improved utilization

Fig. 1 Microprocessor controlled heating chamber used for producing thermally modified wood in the laboratory

Techno-economic viability

Technology of heat treatment process has a huge growth potential due to gradual banning of chemically preserved wood in many part of the world for environmental reasons. Heat treatment of fast grown plantation woods grown abundantly in the country is a market with untapped potential. For processing the plantations woods, this Institute is in position to provide technical know-how on thermal treatment technology as an affordable, domestically-sourced and eco-friendly technique to produce alternative to scarce and highly priced primary/imported timbers for different applications. This technology provides potentially profitable market for species which are generally not very profitable in terms of their overall wood quality point of view. A medium to large size thermal treatment plant of wood may be established by interested industry for large scale production of thermally modified wood.

Commercial opportunities

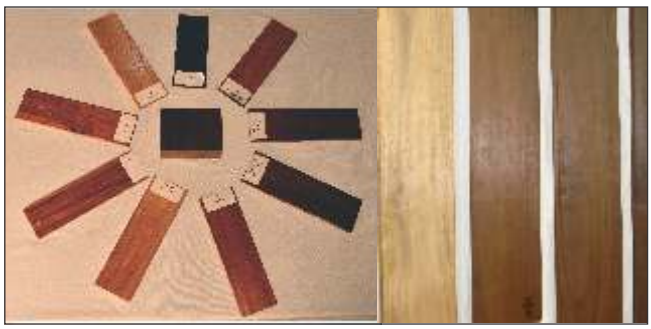
Heat treatment is a promising technique to enhance the dimensional stability, moisture resistance and durability of wood. Heat-treated wood may be considered

as an ecological alternative to chemically impregnated or high priced imported timbers. As shown in Fig. 2, thermally modified wood has been found suitable for different products such as wall cladding, siding, light furniture items, flooring and door/window shutters etc. As thermal modification of different wood has shown extremely encouraging results, it is quite useful towards upgrading certain properties of poor grade species.

Improved quality of heat treated wood makes it an excellent solution for growing wood furniture and flooring markets. Heat treated wood species of higher density may be used for flooring and other applications. Furniture manufacturers may have the opportunity to enter in the market by offering at much lower prices than traditionally used teakwood or imported furniture. Attractive furniture items can be produced from relatively lower-cost heat treated wood, which could win a significant market share from traditional woods, metal and plastic furniture. Similarly, high density and higher strength wood species may be a better choice to be used in building and construction applications such as doors and window frames and shutters etc. after adopting appropriate treatment process.

A few challenges

IWST has been working on developing the heat treatment process for value-addition of different timber species. Various processing parameters of these wood species have been optimized in laboratory using a small heat treatment chamber. However, this process needs to be tested at pilot scale before large scale production by wood processing industry. No open source information is available about commercial operations of treatment plants in the country for producing thermally modified wood.



However, recently a few timber merchants have started importing the heat treated European woods such as Beech, Ash, Pine etc. for meeting the demand of consumers from different sectors. The real challenge comes in marketing heat-treated woods as viable alternate to conventional timbers. Sometimes, the consumer perceptions that should help sell heat-treated products may work against them. It would require a significant marketing effort to change the old patterns, but it can be done by changing the mind-set of the end users. If these things can happen and the message that thermally modified wood is a technologically viable alternate to conventional timbers can be spread to the stakeholders and consumers, then wood-based industries may find it economically viable to pursue and adopt business opportunities for the growth of furniture, building and construction sectors.

Summary

Thermal modification of wood is one of the treatment techniques for value addition to fast grown plantation species. It is a totally 'green' process with absolutely no chemicals added during treatment process. Thermally modified wood is being specified 'across the board', where dimensional stability, durability and darker brownish colour are the priorities. The process is simple, chemical free and offers a viable alternative to relatively costly and scarce tropical hardwoods. The heat treated woods are found suitable for different lifestyle products such as furniture, flooring, wall cladding etc. It can easily be sold as 'greener' substitute and simple "chemical free" labelling would be enough to set it apart from chemically treated wood. IWST has developed thermal treatment process for plantation woods and bamboo, the technical know-how is ready for transfer to the industry to scale up. This process is therefore very useful to the timber processing and products industry for manufacturing various value-added wood products from fast grown timbers.

Protection of wood by chemical modification

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Wood is one of the widely used structural materials. It is a preferred material because of properties such as high strength, light weight, good insulation and aesthetic appeal. However, being a biological material, it suffers from weathering and bio-degradation particularly when used outdoors. Chemical modification (acetylation) provides a non-toxic treatment solution for low durability timbers. It has outstanding dimensional stability, improved durability and superior UV resistance. It improves weathering resistance and coating performance significantly and considered ideal for outdoor applications

Degradation of wood exposed outdoors

The scarcity of the conventionally used primary timber species like Teak has necessitated use of fast growing plantation timbers. Unfortunately, most of the plantation timbers have low natural durability and require preservative treatment to increase their service life when used outdoors. Particularly, the sapwood of these species has a low durability. Unprotected wood because of its biological nature is susceptible to deterioration due to following factors (Feist and Hon 1984; Rowell 2006; Evans 2012):

- Dimensional changes due to absorption/ desorption of moisture
- Biodegradation due to microorganisms
- Degradation due to solar UV radiation

When wood is exposed to natural weathering, physical and chemical changes occur which result in discoloration, roughening, cracking, damage of microstructure affecting its properties. Such deterioration also occurs underneath clear finishes, affects coating adhesion, and contributes to premature coating failure (Fig. 1).

Fig. 1 Weathered wood and coating failure

The problem of biodegradation is resolved by using traditional biocides preservatives (containing for example: creosote, arsenic, zinc, copper, chromium, etc.). These preservatives are known to make an adverse impact on environment, particularly due to the leaching of arsenic, copper and chromium into the environment. There has been growing environmental and legislative pressure on the use of traditional biocide based wood preservatives. Therefore, alternative options which are more environmentally friendly treatments are being explored. One means of achieving this, which does not rely on metal-containing wood preservatives, is the chemical modification of wood (Rowell 2005; 2006; Hill 2006). This process can enhance properties of low durability woods as a substitute for certain high value species in different applications for outdoor applications. The process also help in climate change mitigation by enhancing carbon locking period in wood.

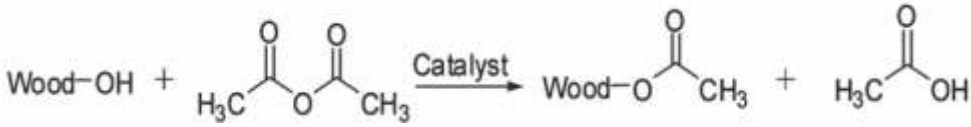
The vulnerability of low durability timber used for domestic and other industrial purposes can be effectively managed by altering wood chemistry. The properties of any materials can be changed by changing its chemical structure. Wood contains an abundance of free hydroxyls groups, which absorb and release water according to changes in the climatic conditions resulting in swelling or shrinkage. Affinity of wood towards moisture also makes it susceptible to bio-agents. In chemical modification these free hydroxyl groups are replaced by hydrophobic groups. This reduces the ability of the wood to absorb water, rendering the wood more dimensionally stable and durable.

Wood modification technology

Chemical modification is an effective method of timber wood protection. The wood is reacted with chemicals, as against traditional method of injecting them with chemicals, inside a protected chamber. As part of the modification, the wood is reacted with modifying reagent (e.g., acetic anhydride) at elevated temperature to change the molecular structure of its cell wall components. The modification alters the water absorbing components

(hydroxyl groups) of cell wall components (lignin, cellulose and hemi-cellulose) in the wood with water resistant (hydrophobic groups) ones by forming covalent bonds (Rowell 2005).

The process of chemical modification involves impregnation of swan wood with a chemical reagent (acetic anhydride). The impregnated wood is then heated at 100-120°C for 2 to 6h, depending upon the desired level of modification. The level of modification is characterized by weight percent gain (WPG). A WPG in



Benefits of modified wood

Moisture absorption and dimensional stability

Chemically modified wood has good hydrophobicity and reduced equilibrium moisture content (EMC) of wood (Rowell 2006; Prasad and Pandey 2012; Giridhar et al. 2016). The extent of dimensional stability is estimated by evaluation of Anti-swelling efficiency using volumetric swelling/shrinkage coefficient. Modified wood has an outstanding dimensional stability (reduced swelling and shrinkage) (Fig. 2). Anti-swelling efficiency depends upon degree of modification.

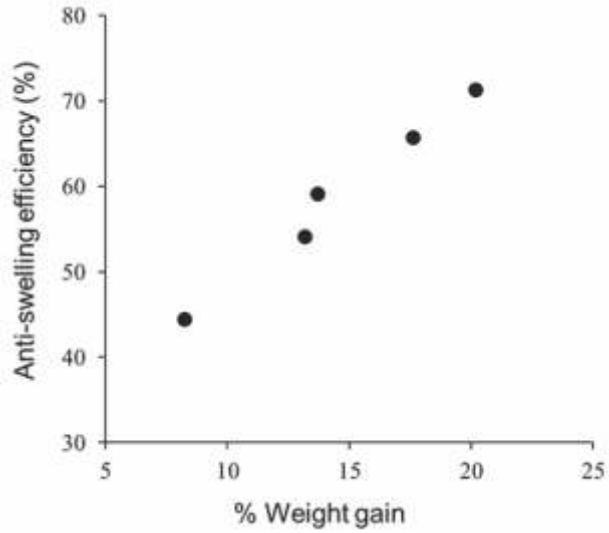


Fig. 2 Dimensional stability of modified rubberwood

Weathering resistance

Chemically modified wood has superior UV resistance therefore natural appearance of wood is retained for longer duration under outdoor use. UV resistance of modified wood can be evaluated in the laboratory conditions by exposing unmodified and modified wood to accelerated weathering tester. UV-stabilization effect of rubber wood chemically modified using isopropenyl acetate (IPA) is shown in Fig. 4. Unmodified wood showed rapid colour changes (photo-yellowing) due to degradation of wood polymers, particularly degradation of lignin upon exposure to UV light. Chemical modification of wood polymers is effective in reducing light induced colour darkening at wood surfaces; modified wood exhibits some photo-bleaching of wood surface (Giridhar and Pandey 2016). Modification also improves thermal stability of wood to some extent.

Biological resistance

Modified wood is more durable and has good resistance against decay fungi and termites. It is indigestible to insects and micro-organisms. Fungal growth observed in unmodified wood is inhibited in modified wood (Fig. 3). Chemically modified wood exposed to brown rot and white rot fungi shows a significant reduction in weight loss as compared to unmodified wood, indicating effectiveness of modification in inhibiting decay.

Unmodified wood Modified wood

Fig. 3 Rubberwood specimens exposed to white-rot (Tremetes hirsuta) after 16 weeks of exposure.

Fig. 4 UV stability of rubberwood modified with IPA. Photograph showing changes in color of (a) unmodified (left side panel) and (b) modified rubber wood surfaces (right side panel) after 250 h UV light exposure in QUV accelerated weathering tester.

Modification improves coatings adhesion and enhances

life of paints and varnishes under outdoor exposure (Vollmer and Evans 2013; Pandey and Srinivas 2015). Very high dimensional stability and improved UV stability of modified wood makes modified wood weather resistant. The chemical modification of wood is very effective in restricting degradation of paints and performance of coating can be remarkably improved by chemical modification of wood substrate prior to coating (Fig. 5).

Fig. 5 Enhancing coating life by substrate modification. Performance of opaque (a) and transparent (b) PU coating on acetylated wood after 1 year of natural weathering. Left specimen is unmodified wood and right specimen is modified wood.

Other benefits

Chemically modified wood has no significant adverse impact in the strength properties of wood. It is non-toxic

Fig. 5

and can be safely reused and recycle.

Applications of modified wood

Because of its good dimensional stability, UV and decay resistance, modified wood is excellent for outdoor

Fig. 4

applications such as decking, window frame and doors, garden furniture, cladding. Since there is no adverse impact on mechanical properties, it is also suited for structural applications.

Opportunities and challenges

Chemically modified wood is appropriate to address the global outcry against the use of hazardous chemicals as wood preservatives. Modification usually results in an increase in the cost of the timber. However, if long term benefits of modified wood are considered (its good dimensional stability, increased service life and paint retention etc.), the product is economically viable. At present, chemically modified wood is not produced in India. However, imported modified pine wood is available in Indian markets. There is opportunity for production of chemically modified wood in India.

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Wood Technologist Association (WTA) is India's apex non-government organisation of plywood & other wood-panel based industries, providing a unique platform for all stakeholders: Government - Research Institutions-Industry-Machine Manufacturers-Technologists-Agroforestry Farmer, to interact and introduce path-breaking measures for progress of the industry.

WTA strives to make true the vision of Hon'ble Prime Minister Shri Narendra Modi of making wood-sector "Atmanirbhar" and for past 12 years has been relentlessly pursuing the cause of its stakeholders, addressing their key issues and seeking suitable policy-changes with Government agencies (MoEFCC, FRI, IPRITI, FIPPI, IWST and others).

WTA, led by President: Shri S.C. Jolly & a team of professionals' technologists / field-experts, also collaborates with international wood chambers / associations for mutual co-operation & adoption of best practises in the industry. WTA has organised host of conferences, seminars, training workshops, awareness campaigns and industry mets for taking forward initiatives of the industry.

WTA is a member of:

- Bureau of Indian Standards (BIS) CED-9 CED-20 Committees.
- President WTA (Shri S.C. Jolly) is a Member of Managing Committee of FIPPI.
- President WTA (Shri S.C. Jolly) is a Member of Steering Committee of IPRITI.
- President WTA (Shri S.C. Jolly) is a Member of Steering Committee of IPRITI.
- President WTA (Shri S.C. Jolly) is a Life Member of IWST, Bangalore.
- WTA, since the past decade, is in continuous dialogue with Ministry of Environment, Forests & Climate Change (MoEF&CC) and made representations to their Hon'ble Ministers: Shri Jairam Ramesh, Shri Anil Madhav Dave, Dr. Harsh Vardhan and recently to SHri Prakash Javdekar for bringing forth relevant issues of plywood industry.
- WTA submitted memorandums to MoEF&CC on various occasions for considering demands of the industry / Stakeholders for driving suitable policy-changes like reduction in GST, lease of barren-land to farmers for enhancing green cover by plantation drives, research & development on Melia Dubia as substitute of face veneer, foreign currency savings through reduction in imports, transportation subsidy and similar issues. Recently on WTA's perusal, the e-Transport facility for farmers was agreed upon by Government of India.
- WTA and FRI (Dehradun) collaborated under Green India Mission to organize industry institute Farmer meets at Ludhiana (Punjab), Yamunanagar (Haryana) and Pantnagar (U.P.)
- WTA's key role in agroforestry was explained to Shri C.K. Mishra (Secretary, MoEF & CC) by Shri Manoj Gwari (Secretary, WTA) at a meet organised at forest Research Institute, Dehradun
- WTA hosted international delegations from Malaysia, China and Ghana for partnership dialogue with Indian Plywood Business Groups. In a recent visit of Sarawak Timber Association from Malaysia, WTA coordinated and organized their meetings with IPIRTI and other agencies
- WTA under aegis of Shri S.C. Jolly, started the National WhatsApp Group: "Agroforestry" bringing together key decision making administrators, leading industrialists and other subject matter experts, during the COVID times for suggesting and implementing the way forward for overcoming challenges being faced. The patronage and active participation of all members including Additional Secretary Dr. Alka Bhargava, Dr. Arun Rawat (DG, ICFRE & DIrector,FRI), Dr. M.P. Singh (Director IPIRTI & IWST), and other eminent personalities (Industry Association heads, senior - Industrialists & Technical experts) has brought out innovative & viable solutions.
- WTA participated and organised multiple webinars in which leading subject experts shared views / opinion about how to tackle the problems being faced by each stakeholder
- WTA (Shri G. Rajput, V.P) participated in R & D work with Senior Scientist Shri D.P. Khali, FRI.
- WTA organized numerous hands on trainings with the industry for aspiring Technologists
- WTA assists in Industry placement of Technologists pan-India as per their skill set.

WTA in coming times, endeavours to take forward the best interest of Indian Plywood Industry!!

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Potential of coconut stem wood for utilization in wooden furniture sector

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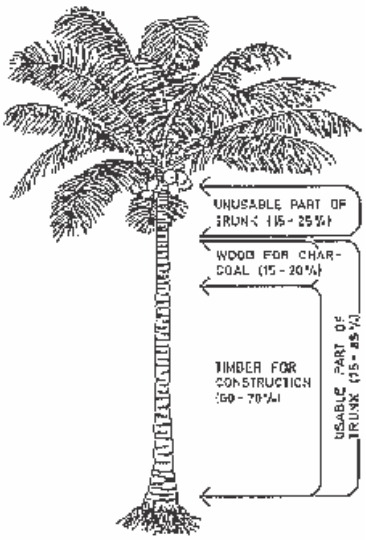
The whole Asia-Pacific region has an estimated number of senile coconut trees of about 371.3 million or 111.4 million cubic meters of sawn coconut wood, based on an average sawn lumber recovery of 0.3 cubic meter per tree. 20-22% of the total number of trees in the country are estimated to be senile and are due for felling and replanting. The possibility of utilizing the coconut palm wood on a commercial scale must be recognized as an impactful investment. The opportunity to look for non-forest or indigenous wood material and to conserve natural forests in countries where the coconut palm is grown, could led to a serious consideration of utilizing coconut stem wood furniture. The huge number of old and senile palms in coconut growing countries, especially in Asia and the Pacific, as well as the wide-spread disease, root-wilt, along with serious natural disasters like hurricanes affecting coconut farms necessities urgent large-scale replanting. It has been widely recognized that the most effective way of disposing the felled trunks is to convert them to saleable wood products; as otherwise increasing the inoculum strength and environmental issues can adversely affect the agricultural sector. Coconut wood can thus be a promising material for the manufacture of furniture.

The cylindrical trunk of coconut tree reaches a height of 20-25 meters or more with an average diameter of 30-40 cm, sometimes reaching up to 1 meter at the base. A tall variety of palm which contains timber of commercially utilizable value up to a height of about 3 m from the base and is estimated to contain at least 0.15 m^3 of high density wood suitable for furniture. At a very conservative estimate, based on prevailing market rate, each palm would fetch a minimum of Rs. 7500 from timber alone.



USABLE PARTS OF A COCONUT PALM

One of the components of the project for the promotion of coconut cultivation in the country by the Coconut Development Board of the Government of India is to replant the senile and unproductive disease affected palms in a phased manner with high yielding palms, has the estimation that around 16700 senile palms may be needed to cut and remove per year per districts. The wood of all the palms cut and removed all over the country needs to be to be effectively utilized; this could be a resource for alternative non-conventional furniture wood.

Strength properties of Coconut stem wood in comparison with other conventional timbers

Species	Static Bending		Compression parallel to Grain
	Modulus of Rupture (MOR, N/mm^2)	Modulus of Elasticity (MOE, N/mm^2)	Maximum Compressive Stress (MCS, N/mm^2)
Albizia odoratissma (Safed seres)	144	14500	79
Artocarpus heterophyllus (Jackwood)	81	10100	50
Artocarpus hirsutus (Anjili)	97	12200	62
Tectona grandis (Teak)	96	12200	53
Terminalia paniculata (Laurel)	112	14300	64
Cocos nucifera (Coconutwood)	93	15900	57

Comparison of wood properties of Teak and Coconut wood

Property	Teak	Coconut Stem Wood
Basic Density (kg/m^3)	750	820
Hardness (N)	4740	8430
MOR (MPa)	97	89
MOE (GPa)	12	11
Crushing Strength (MPa)	55	66
Shrinkage (%)		
Radial (R)	2.6	5.5
Tangential (T)	5.2	5.5
Volumetric (V)	7.2	9.2
T/R	2.0	1.0

Efficient processing and utilization of coconut trunks are aimed at solving technical and socio- economic problems especially when the coconut farmer decides to replant his senile palms. Being a monocotyledonous plant, its anatomical, physical, chemical and mechanical properties are different from the conventional woods. Hence, processing techniques and equipment including appropriate machinery have been developed, modified and improved to process coconut wood more efficiently and produce comparatively good quality furniture. The conveniently straight and branchless stems, and their nearly uniform volume and dimension allow the use of comparatively light and simple tools and equipments for felling and transportation. Logging operation in a coconut plantation is therefore easier and cheaper than logging under forestry conditions in mountainous steep terrains.

In sawing coconut logs, the most important factors in selecting the milling equipment are profitability and ability to be relocated if this is required; simplicity of design to avoid breakdowns which are difficult to repair in isolated situations; ease of operation as skills of operators will often be limited; an inexpensiveness as the industry is often situated in poorer and underdeveloped areas. Different type of mills have been tested at the Zamboanga Research Centre in the Philippines and the Timber Industry Training Centre in New Zealand and information gathered could provide a guide to the selection of mills for different conditions. These mills include the medium-size portable sawmill, a larger transportable sawmill, light/general purpose portable sawmill, a mini mill, a breast bench with light weight carriages and a chainsaw with guide attachments. Problems of sawing coconut logs are similar to the ones encountered by saw millers when using high density species of tropical hardwoods.

It has been established that no importer is prepared to make a commitment to purchase large volumes of coconut

wood unless both quality of material and reliability of supply are guaranteed. Uniform grading standards for coconut wood are therefore highly desirable. A system of grading coconut wood and the mechanics of its implementation and control should be established in the producing countries. The mechanism for quality control should not restrict efficient management but should aim to protect and foster the interests of the country, the coconut wood industry, and its customers. Quality control of coconut wood starts during the logging operation. Coconut wood should be graded hard, intermediate or soft, corresponding to high, medium and low density: high density is above 600 kg/m^3; medium density between 400 - 600 kg/m^3; and low density less than 400 kg/m^3. Because of the widely varying density of material within each log, and the difficulty of differentiating these by superficial inspection after sawing, it is essential that a grading, sorting and identification system be established to track the wood from different parts of a log and from different logs along the length of a tree; this should start in the plantation at the time of felling. Systems of this sort have been designed and are implementable. The high density wood is recommended for furniture making as well as for other structural applications. Other portions of wood could find suitable end-use applications in an integrated approach.

Another important phase in coconut wood utilization is machining or the process of cutting and milling the wood into various shapes and patterns with the use of woodworking machines. Lumber production from coconut trunk has been commercialized in the Philippines since early 1970's. One of the most efficient processing technique is the chainsaw-table saw lumbering system. Round coconut trunks are sawn into halves or smaller dimensions as in flitches using a 10HP chainsaw at the cutting site. The flitches are transported to the lumber yard for re-sawing into desired dimension using a table saw. The table saw may be stationary or mobile-type with 20 HP diesel engine. The saw blade is circular and the diameter is around 500 mm. The chainsaw-table saw lumbering system is designed for rural application. It involves relatively unskilled labour and the processing system may not be capital intensive. The preference of using chainsaw over mounted portable or stationary sawmills is its low investment cost and complete portability by a single operator. Mounted portable sawmills, although could be operated near the raw material source, require a number of personnel. The use of stationary sawmills or portable ones, although efficient in terms of lumber recovery, is as yet very limited because of prohibitive initial investment combined with the potential for irregularity of raw material supply.

Coconut is not naturally durable when used in situations favorable to attack by decay fungi and wood boring insects particularly in ground contact and exposed to the weather. The low natural durability can be overcome by the application of suitable preservative treatment, for which appropriate prescriptions and dose rates that have been developed. Choice of treatment depends on hazard level and cost which can be borne. The treatment schedules of the different processes have been established for coconut wood through a series of laboratory experiments, field and service tests of treated materials.

Treated wood needs to undergo seasoning (drying) process to minimize if not completely avoid dimensional problems in its utilization. Dried wood with a moisture content of around 12 to 10% only are approved for furniture manufacture. The common drying methods include air drying wood under shed, forced-air drying, solar kilning, and dry kilning. Depending on weather conditions, 25- 50mm coconut boards take 1-5 months to air dry to attain equilibrium moisture content of around 20%. Drying schedules have been worked out for kiln drying coconut wood to avoid the observed drying defects such as internal collapse, cupping, twisting, wrap, checks & splits, etc.

Good quality finish for coconut wood involves sanding the surface to remove the knife marks and produce a smooth surface. The use of mechanical sanders instead of manual sanding facilitates finishing the surface of the wood.

Coating involves the sequence application of stain, filler, sealer and top coating materials such as lacquer, polyurethane, polyester and oil finish to enhance the natural beauty of the grain, colour and figure of coconut wood furniture. Usually two or more coats of finishes are applied to coconut wood to improve the appearance and quality of furniture.

Properly treated and seasoned coconut wood is an excellent and cheap raw material for furniture manufacture. The wood hard is with low shrinkage; with different shades of brown, with dark-brown veins has a characteristic texture and grain desirable for elegant furniture with attractive natural appearance. There is no distinguishable separation between the sapwood and heartwood. The older vascular bundles located on the outer perimeter of the tree trunk gives the palm good strength and elasticity. It has good resistance to indentation and abrasion. Coconut wood has a unique appearance and has a good decorative value. The timber will dry uniformly and without much cross-sectional distortion. The timber is thus suitable for modern (knock-down) & conventional designs. With effective product promotion, quality high-value furniture from coconut wood can have a potential share not only in the domestic but also in the world markets.

Constraints & Remedies

Constraints	Remedies
Very high density wood at the periphery of trunk; saw gets out of the sawline. Fine substances similar to sand (silica) will rapidly blunt the blade	Tungsten carbide (TC) or Stellite tipped machineries & Tools
Difficult to nail; splits are common	Pre-drilling
Sawn Lumber – 25-50 mm thick sizes only. Trunk once formed does not increase in diameter with age	Glued Lamination of wood
Untreated freshly cut limber can be easily attacked by moulds and staining fungi. Dry wood could be attacked by insects/ termites	Grading, Preservative Treatment & Seasoning (air drying or Kiln drying)

Consumers and retailers are yet to be convinced about the quality and strength of coconut wood, which is comparable to conventional wood coming from natural forest or other plantation trees. With the world concern about environment and depleting forest resources, using senile palm wood as an alternative source to replace indigenous forest timber for furniture needs for modern day living is a logical move towards commercial venture. Furniture made from coconut wood are exotic, eco-friendly and possess unique natural appearance and color which can fetch premium prices in the niche market.

The Asian and Pacific Coconut Community (APCC) member countries occupy more than 10 million hectares of coconut in the world and an average 15 percent of the coconut palms are old and senile trees which could be a high potential source of supply for coconut wood. The tree usually continues to bear fruit until it reaches around 60 years of age after which the yield declines even when one applies fertilizers. The normal life span of coconut tree can

be from 70 to 80 years. Thus, a coconut tree is ready for harvesting wood after 60 years and at this age, the wood is said to reach its highest quality. Nevertheless, the potential source of coconut wood depends very much on the level of maturity of coconut plantations and also government policies with regard to coconut area expansion and replanting programs. The availability of senile coconut palms in coconut producing countries can provide good indication on the supply side of the wood.

AGRO FORESTRY

RURAL EMPLOYMENT

TECHNOLOGY

GROWTH with SUSTAINABILITY

Sustainability is at the core of India's Paper industry. Paper is one of the most environmentally sustainable products as it is biodegradable, recyclable and is produced from sources which are renewable and sustainable.

Paper Industry is not only conserving the environment but also regenerating natural resources. Through the agro-forestry initiative of the Indian Paper Industry, more than 1.2 million hectares of land has turned green and thousands of jobs in rural India have been created.

Of the total demand for wood by India's Paper Industry, over 90% is sourced from industry driven agro-forestry. The industry is wood-positive, that is, it plants more trees than it harvests. Pioneering work has been carried out by the industry over the last three decades in producing tree saplings (e.g. Eucalyptus, Subabul, Casuarina, etc.) which are disease and drought resistant and can be grown in a variety of agro climatic conditions. Substantial amounts have been spent by the industry on plantation R&D, production of high quality clonal saplings, technical extension services and hand holding of marginal farmers.

Indian Paper Manufacturers Association

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Present status and challenges of wood science and technology education in India

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This article summarizes the present status and challenges of academic programmes in the field of Wood Science and Technology (WST) in Indian universities and other institutions, with special emphasis to post graduate education. Though the WST education has been running since several decades in India, there is very slow improvement in terms of the number of institutions offering this programme, when compared to many other professional courses. Now there are only 7 institutions in the country for the wood technology programmes including diploma, post graduate diploma and post graduate courses. There is scope for more institutions to enter into this field. Institutions having expertise and facilities for training activities on improved, better and efficient utilization of wood and other lignocellulosic materials, may be encouraged to start suitable academic programmes in WST. Timely update of the current curricula followed at present by the institutions should be done with rigorous discussions with industries, government authorities and academics in order to improve the quality of wood technology professionals. The curriculum should be at par with those of developed nations so that the graduates could be familiar with the global trends. The government should support the organizations engaged in novel and practical methods of collaborative academic programmes with the objective of improving the quality of education in the field like the one being practiced in Dual Mode recently in Kerala. Regarding the job opportunities, the wood-based industries including the furniture units should facilitate the recruitment of wood technologists, considerably reducing the number of candidates employed from non-technical professions for managing their manufacturing and quality control facilities. In order to ease many of the aforementioned challenges, efforts are needed to prod the Central Government for the establishment of a statutory body under the Ministry of Science & Technology, with more authority to coordinate/monitor and promote all institutions and industries associated with the research and training activities in the field of wood science and technology.

Introduction

The field of study which consists of the physical, biological, and chemical makeup of wood is called wood science and it covers the underlying principles of wood preservation and wood processing. The application of various scientific disciplines inclusive of forestry, physics, chemistry, biology, engineering, etc. to the wood preservation, processing, etc. is the wood technology. It also includes biotechnology, quality control and waste management too.

Wood science and technology course in India promotes interactive learning methods. During the postgraduation, students get chances to broaden their knowledge and explore their possibilities. The course includes local field visits, industrial tour, and in-plant (industrial) training, aside from routine theory and practical classes. Local field visits increase interests and create more positive feelings toward that topic. Industrial tour across the country and industrial trainings provide opportunities to learn practically through interaction. During the in-plant training period, the students visit the industry and get insights regarding the working environment. The training which lasts from more than a month improves their entrepreneurial ability, helps to come across real problems, and to find proper solutions. The industrial exposure to the students helps them to develop their career in high-tech industrial requirements. Toward the end of the study period, each student is required to do a project work independently. This will help to deepen and extend the knowledge of the chosen topic, helps to solve problems with confidence, and strengthens the student for large and complex research projects.

History, objectives and present status

The history of Wood Science in India could be traced back to the teaching of the subject to the trainee Forest

Officers at Forest Research Institute, Dehradun under the British administration and the field was then referred to as Forest Science. However, the starting point of a formal Wood Technology education was the diploma level course initiated in 1982 by the Government Polytechnic College, Kannur under the patronage of Sri Kaderkutty Sahib, the Founder Managing Director of The Western India Plywoods Ltd, with the objective of producing technical manpower in the field suitable for working in plywood and other wood-based industries in the country. Later in 1991, the course was renamed and restructured as Diploma in Wood and Paper Technology. In 1996, the first Post graduate programme in Wood Technology was introduced under the aegis of FRI, Dehradun with the following objectives:

- To develop technically qualified wood technology professionals with sufficient knowledge and skills
- To provide true industrial training exposure to the youth and there by pave the way for greater employability in wood-based industries
- To prepare the human resources which enable and encourage the young professionals to take up 'start-up' wood-based enterprises
- To equip the professionals with new innovative research and technology to extend high quality technical services to the industries

Though the WST education has been running since several decades in India, there is very slow improvement in terms of the number of institutions offering this programme, when compared to many other professional courses. Now there are only 8 institutions in the country for the wood technology programmes including diploma, post graduate diploma and post graduate courses (Table.1). As stated above, a career in wood science and technology in India begins with the diploma level course. Matriculates with science and mathematics background are eligible for this 3 years course. Graduates with physics, chemistry, biology, mathematics and engineering subjects are eligible for the post graduate programmes. Further, there are several specialization subjects like wood waste utilization, plywood, fibreboards, etc. However, access to wood science and technology education at all levels has widened significantly over the last two decades. Hence, human resource development (HRD) in wood science and technology sector has become so important for better understanding and management of forest and agricultural resources. It is also necessary to introduce the wood technology subject at all levels in village schools and colleges because they produce a good quality education from childhood.

Table.1: Institutions/Universities offering Wood Science &Technology courses in India.

No.	Course	Institution/University	Address
1	M.Sc. Degree in Wood Science & Technology (2 years)	Forest Research Institute Deemed University	Dehradun, Uttarakhand
2	M.Sc. Degree in Wood Science & Technology (2 years)	Dr. Yashwanth Singh Parmar University of Horticulture and Forestry	Solan, Himachal Pradesh
3	M.Sc. Degree in Wood Science & Technology (2 years)	Kannur University	Kannur, Kerala
4	M.Sc. Degree in Forestry (Wood Science) (2 years)	Kerala Agricultural University	Thrissur, Kerala
5	P.G. Diploma in Wood and Panel Products (1 year)	Indian Plywood Industries Research & Training Institute (IPIRTI)	Bangaluru, Karnataka
6	Diploma in Advanced Woodworking (1 year)	Institute of Wood Science & Technology (IWST)	Bangaluru, Karnataka
7	Certificate Course in Wood Product Designing & Development (4 weeks)	Institute of Wood Science & Technology (IWST)	Bangaluru, Karnataka
8	Diploma in Wood and Paper Technology (3 years)	Government Polytechnic College	Thottada, Kannur, Kerala
9	Diploma in Wood Technology (3 years)	Kashmir Government Polytechnic Gogji Bagh, College	Srinagar, Jammu & Kashmir

Diploma and postgraduate diploma courses: In India, the Government Polytechnic College, Kannur is conducting a three-year diploma course in the field of Wood and Paper Technology with the objective of imparting professional training to the students with regard to processing technologies for efficient utilization of wood. The subjects covered by this course include: forest and forestry, raw materials for wood and paper industries, wood seasoning and preservation, saw milling, veneering, manufacture of wood products like particle board, MDF, value added products like mouldings, cornices, skirtings, deckings, etc; plywoods, blockboard, flushdoor, synthetic resin manufacturing, pulp and paper manufacturing, specialty papers and boards, interior design engineering, etc. The job opportunities are in interior fields, estimation, interior design and drawing, particle board and MDF industries. There is great demand for the diploma holders in Wood and Paper Technology and all the students are placed through campus interview arranged by placement cell.

There is great demand for the diploma holders in Wood and Paper Technology and all the students are placed through campus interview arranged by placement cell.

The Government Polytechnic College, Srinagar has recently introduced the second diploma course in Wood Technology in the country under the World Bank Technical Education Project-III to impart technical education to the students. A special workshop is under construction for conducting the practical sessions where all modern machinery required in wood based industry will be installed with the financial assistance of World Bank.

The Bangaluru-based Institute of Wood Science and Technology (IWST) is conducting two programmes: a Diploma course in advanced woodworking and a certificate training course in Wood Product Designing and Development for individuals, students, carpenters, persons working in wood-based industries. The training programmes address the skill development in the area of woodworking to attain global competitiveness by using state of the art machineries and on completion of the courses; the trainees will be able to handle advanced woodworking machines for product development.

Another Bangaluru-based institute i.e., Indian Plywood Industries Research and Training Institute (IPIRTI) is conducting a Postgraduate Diploma course in Wood and Panel Products Technology for young science and engineering graduates who are selected on all India merit basis. The major part of this one-year training programme involves the actual transfer of skills through hands on experience at the pilot plant of the Institute simulating the factory conditions. Trainees are also exposed to actual industrial environment through study tours. To develop communication skills amongst the trainees, seminar presentation and project works are also organized. The main objective of the course is to prepare the trainees to shoulder various responsibilities in the wood based industries. The course also aims at imparting professional knowledge and skills with regard to processing technologies for efficient utilization of wood through conversion into engineered wood and a variety of panel materials/products viz. plywood, particle/fibreboard, block board, flush door. It includes processing technology on bamboo-mat based panel products and adhesive technology. Standardization aspects with respect to quality management and BIS certification are dealt with in details. Working knowledge on use of computers and internet is also imparted. Emphasis is given not only to theoretical background of various technologies but also acquaintance with wood panel processing machinery and training imparted on operation of machinery in laboratory and pilot plant scale.

Postgraduate courses: The Master in Wood Science and Technology programmes of FRI, KAU, Dr. Y.S. Parmar University of Horticulture and Forestry and Kannur University aim to provide opportunity to the students wishing to pursue professional careers in science and technology of wood as natural resource and to make themselves aware about the problems related to wood as basic material to manufacture various useful products. The programme is designed to provide the students with specialized knowledge and skills in the properties, manufacture and utilization of wood and related biomaterial products and also to improve the qualitative, quantitative and futuristic aspects of students. The structure of the curriculum is developed to synthesize

multi-disciplinary knowledge in the biological and physical science of wood and its industrial application. Emphasis is also given to provide a fundamental education in the properties of wood basics of wood anatomy, chemistry, physics, mechanics, as well as processing knowledge and techniques to manufacture solid and composite wood products. The students are also expected to improve their capacities as leaders and managers through study tour, industrial attachment and excursions and other opportunities. Human Resource Management and Marketing and Enterprise Development are also the part of syllabus to build their entrepreneurial skills and aptitude.

Challenges and future prospects

1. Syllabus, teaching methodologies and lab facilities:

To begin with, the need of amendments in syllabus has been the greatest challenge. Since four decades, the world wood science has changed a lot and we are still in the same course designed in the1990s. Important changes are necessary in the current curricula to meet new challenges for educating the future students in wood science. The syllabus is more theory oriented.

Current curricula of post graduate courses should be amended to meet new challenges for educating the future students in wood science. The curriculum should be at par with those of developed nations so that graduates could be familiar with the global trends. Timely update of the curriculum should be done with rigorous discussions with industry experts, government authorities, and academics. Through the continued effort to shape the curriculum to be consistent with changing industry needs, the demand for the graduates will be very high. A core under standing of wood science, building technology, business, and emerging technologies such as engineered wood products contribute to their career success (Damery et al, 2007).

The university has been very flexible in distributing license/ affiliation to academic institutions without fulfilling criteria about physical infrastructures and sustainability. Some of the institutions are operating without proper and complete set of faculties, classroom, and laboratories. The teaching methodologies in many institutions are of the spoon-fed type. Students totally rely on lecture notes.

There should be regular monitoring of academic institutions to check if the operation of pilot plants, laboratories, and faculties are in place. Students should develop the habit of consulting different reliable sources to deepen their knowledge. Teaching faculties should encourage the use of student journals, motivate students for writing-to-learn assignments, practice cooperative and collaborative learning techniques, accommodation of varying learning styles, and methods to enhance problem-solving abilities and critical-thinking skills.

2. Research Culture:

Research culture is lagging in academic institutions due to the lack of qualified manpower and well-structured laboratories. Each institution should have a separate research unit for its faculties, and should encourage them to participate in research and publication process. Research can be done in a collaborative manner too. After completing preliminary studies, the sample may be micro-analyzed in sophisticated laboratories of foreign universities. This will help to upgrade the research status of both the institutions. It is also necessary to have a close cooperation with specialists from related branches of science and engineering in order to increase the potential of wood as a material and also to develop the scientific, technical skills and knowledge of the student community (Gardner et al, 2005).

3. Industry tie-up:

Lack of cooperation among academia and industries makes it difficult when it comes to conducting in-plant trainings and internships. This might be due to the flooding of interns from all academic backgrounds, be it science based or others. Lack of uniformity in pay scale motivates the mobility of fresh graduates from industries. This turnover has been a headache for industrialists.

4. Inter-teaching:

Inter-teaching has been found as a novel approach to facilitate students of wood science. It is a 20- to 30-min student-to-student discussion which includes reciprocal peer tutoring,

cooperative learning, and problem-based learning. Lectures should be accompanied by hands-on or visual explanations. More emphasis should be given to practical demonstrations and that may be performed in wood industries itself. But there must be mutual understanding among them.

5. Interaction with industrialists:

All institutions should arrange regular interactive sessions with industrialists or wood technologists

Fig. 1. M.Sc. WST students of FRI University interacting with Mr. Subhash Jolly, President of the Wood Technologist Association of India

from leading industries as practiced by FRI University, Dehradun, for the benefit of the students in deepening their understanding of the present industrial scenario. Fig.1 shows one of the interactive programmes organized by FRI University on 23rd August, 2018 for the students of M.Sc. WST. During this one-day session, Mr. Subhash Jolly, President of the Wood Technologist Association offered various tips to the students for succeeding and excelling in wood-based industries from his experience in the field of wood technology, especially from his association with various plywood manufacturing units in India.

6. Placement Cell:

- To help the students in finding suitable employments in their chosen field, there should be regular placement cells in institutions consisting of a placement officer and representatives of students from respective programmes. The functioning of the placement cell of FRI Deemed University as summarized below is an excellent model for adopting by other institutions.
- FRIDU will prepare students profile cum placement brochure every year and will send invitation to various companies/ organizations for placement.
- After confirmation from companies/ organizations, suitable date for placement/ interview is decided as per mutual convenience. The companies/ organizations can ask for the resumes of students and has the liberty to shortlist them. The list of shortlisted students is to be mailed to the placement cell of FRIDU by the companies/ organizations at least 7 days prior to the campus selection date.
- The companies/organizations are required to also keep an extended shortlist prior to visiting the campus for interviews as some students shortlisted by them may already get placed before the campus selection date assigned to the company.
- The final results of campus selection/ interviews should be submitted to placement cell FRIDU within 7 days along with a waiting list. After declaration of the results, companies/ organizations need to send offer letter/ joining letter to selected student through placement cell FRIDU within 2 weeks.

Novel restructuring attempts

During the last decade, in order to meet the recent challenges for educating the students, the institutions offering the wood technology courses in India have attempted to restructure the academic programmes to help unlock the potential of the students by focussing on quality teaching on the lines followed by the institutions abroad(Table.2). Realizing that Industry-Academic partnership is a strategic necessity in today's challenging global knowledge economy, one of the institutions has entered into a collaborative academic programme of 'Dual Mode' as practiced in Germany and other European countries. The alliance to this effect was signed with Kannur University and announced in the year 2015. This 'Dual Mode' is a joint programme consists of theoretical classes for six months in the Kannur University and six months of in-plant training at the WIP in an academic year. As part of this unique initiative, the students get substantial practical exposure through hands-on experience on various processes employed in the wood processing units of The Western India Plywoods Ltd. Following are some of the highlights of this programme:

Certificate from Industry: Students get the M.Sc. degree in Wood Science &Technology from the University and a certificate by The Western India Plywoods Ltd, after the

Table 2 Major restructuring of Wood Science & Technology programmes in India

No.	Institution/University	Attempts to restructure the programmes
1	FRI Deemed University	Separated wood technology from the original PG degree programme on Forestry in 1996
2	IPIRTI	Major restructuring of the course is in progress in 2020
3	Institute of Wood Science & Technology (IWST)	Course started in 2018 and later redesigned short-term courses of 4 weeks duration
4	Dr. Y.S. Parmar University of Horticulture and Forestry	Renamed and restructured degree
5	Kannur University	Course started in 2008 and later entered into a collaborative academic programme of 'Dual Mode' with a leading Wood-based Industry in 2015
6	Kerala Agricultural University	Under ICAR, it has a full-fledged Forestry College and in 2010 started a Dept. of Wood Science.
7	Govt. Polytechnic College, Kannur	Course started in 1982 as Diploma in Wood Technology and Renamed and restructured in 1991 as Wood and Paper Technology
8	Govt. Polytechnic College, Srinagar	New course funded by a World Bank Technical Education Project

Fig. 2. M.Sc. WST students of Kannur University during a field study trip to Periya, Wayanad

completion of 2 years.

Scholarship: WIP pays scholarships of Rs 5000/- per month to each of the 24 students of the first year and 24 students in the second year (a total of 48 students in an academic year).

Field study tour: Field visits to the captive plantation sites of the industry and nearby forest areas are arranged to learn to identify trees with the help of field guides, use of crosscut saws and other logging tools and plantation management techniques, continuous assessment of students' performance during the training sessions by qualified R&D team and end semester project and dissertation works under the guidance of technical experts (Fig.2).

Training session by experts: As part of the training programme, interactive sessions between the the students and the experts in the field who visit the company for technical or business purposes are also arranged by WIP. For instance, a special session with Dr.R.N.Kumar, former Head of R&D and renowned wood polymer technologist was organized for the 2018-20 batch was conducted on 4th July, 2019 (Fig.3). In a very lively and interesting way, Dr.Kumar shared his experience in the field of wood technology with the students. He also discussed various ongoing research activities the world over in the field of wood and lignocellulosic composites both in industries and academic institutions. He also shared the memories and reminiscences of his experience in the field of wood drying and wood adhesion with the world renowned wood scientist, Prof.Kollmann in the Institute for Wood Research and Wood Technology, University of Munich, Germany. The narration of his interactions with the Malaysian students in the Department of Wood Paper and Coatings, Universiti Sains Malaysia, Penang, Malaysia was useful. During his talk, he also a training session in

Fig. 3. M.Sc. WST students of Kannur University interacting with Dr. R.N. Kumar, renowned wood polymer technologist

the Plywood factory and a special session on Quality Management Systems at WIP offered useful tips to the students for excelling in their studies as well as their professional life in future. There was an enthusiastic response from the students who asked a number of questions.

The R&D Division plays an active role both in coordinating the activities with the industrial units as well as extending all the facilities of the in-house Unit for practical training. The syllabus for the course was so designed by the R&D team under the expert guidance of Dr. R.N. Kumar that the students will have expertise in saw milling operations, plywood and compreg manufacturing, synthetic resin manufacturing, manufacturing of fiberboards (softboard, hardboard and pre-compressed press board) and block boards and flush doors. During this training period, the students also get exposure in management, accountancy, marketing, materials procurement, safety, standardization, etc. and are therefore ideally suited for employment in the wood-based industries both in our country and abroad. They also become resourceful with entrepreneurship potential to take up 'start-up' programmes in the production of wood-based panel products and furniture.

Conclusions and recommendations

In the U.S, Wood Science and Technology education in what has traditionally been called wood science or forest products has been plagued by low enrolments for decades (Armstrong et al, 2013). But the problem faced by India is the very slow progress in terms of the number of institutions offering this programme, when compared to many other professional courses. At present, there are only 7 institutions in the country for the wood technology programmes including diploma, post graduate diploma and post graduate courses. There is scope for more institutions to start the WST course. State Agricultural Universities, Government Polytechnic Colleges and Institutions like IWST, Bangalore, KFRI, Thrissur, etc. having expertise and facilities for training activities on improved, better and efficient utilization of wood and other lignocellulosic materials, may be encouraged to start suitable academic programmes in WST. Urgent changes in the academic curricula of on-going wood technology courses are imperative in order to provide a profound technology education to the students, which has to create the intellectual backbone of tomorrow's forest-based industries and a knowledge-based society as well (Teischinger, 2010) and it should be done with rigorous discussions with industries, government authorities and academics to improve the quality as well as the employability of the wood technology professionals.

At present, there are only 7 institutions in the country for the wood technology programmes including diploma, post graduate diploma and post graduate courses.

Some ideas and suggestions arose during the above discussion are listed here in no particular order of significance, as recommendations for the overall improvements of the WST programmes in the country:

- Introduce the subject at graduation level (B.Sc. WST degree course) under the crown umbrella of ICFRE at FRI, Dehradun and at different research institutes and colleges.
- Encourage novel attempts by institutions and extend Government support to the efforts to collaborate with other institutions or industries within the country.
- Similarly, international cooperation among the wood technology institutions in South Asian countries may be started based on bilateral agreements, covering the exchange of teachers for shorter or longer stays and students for summer practices. This type of cooperation as one of the possible ways to improve the forestry educational system was financially supported by the parties of agreement and has been working well in central and eastern European countries. The bilateral contacts led not only to the development and improvement of educational systems, but they resulted in good international cooperation in research programs, and common publication of scientific papers and textbooks (Paule and Scheer, 2005).
- Fill various teaching posts in universities to empower

the education and encourage extending short duration Adjunct faculty positions for industry experts with proper relaxation in their age or educational backgrounds

- Professionals associated with Wood Technologist Association, India should work together with others-industry members of IPIRTI Society, research institutions and those in the regulatory and public policy communities for better training and employment for young wood technologists. Regarding the job opportunities, the wood-based industries including the furniture units should facilitate the recruitment of wood technologists, considerably reducing the number of candidates employed from non-technical professions for managing their manufacturing and quality control facilities.
- Efforts are needed to prod the Central Government for the establishment of a statutory body under the Ministry of Science &Technology, with more authority to coordinate/monitor and promote all institutions and industries associated with the research and training activities in the field of wood science and technology.

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Wood seasoning: the first step in value addition

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Wood seasoning is one of the most fundamental processing for increasing the service life of timber and its products. The process is often overlooked by many wood based industries which ultimately affects the quality and performance of the final product. Unseasoned timber is prone to develop several defects like end-splitting in planks, surface cracking, shape deformation, fungal degradation, etc. (Fig.1 & 2).

Water is essential for tree growth and this water is transported from roots to leaves through wood as the conducting channel. Therefore, wood from a freshly cut tree will have substantial amount of moisture present. In many fast grown tree species, the amount of water may be more than the amount of wood (on weight basis). Mostly sapwood of a tree contains more moisture than heartwood. High amount of moisture in wood is highly undesirable when it is used in sawn form.

For the satisfactory performance of timber, it is essential to season wood. If left unattended, wood tends to loose moisture on its own over a period of time and tries to reach to a moisture content which is in equilibrium to the surrounding environment. However during this process, it also tends to develop defects which can affect the recovery of good quality sawn timber. If the seasoning process is not properly carried out, defects generated during the moisture loss can devalue the timber.

Wood seasoning is primarily a process of removing moisture from wood in a controlled manner such that the resulting material attains moisture content which is equilibrium with the environmental conditions without any undesirable defects. In addition to reduce defects, seasoning also adds lot of value to the timber in terms of high strength as seasoned timber is typically more than twice as strong as wet timber, improved nail and screw holding strengths, dimensional stability, easy gluing and finishing, easy to handle as seasoned wood is much lighter than wet wood, better electrical and thermal insulation, etc. It is also to be noted that for preservative treatment using vacuum and pressure process, wood needs to be dried to about 30% moisture content (fiber saturation point) in order to allow chemical to penetrate inside wood. Seasoned wood is also resistant to fungal degradation as fungal activity requires high moisture content in the substance (generally above 20% moisture content). Considering the numerous advantages seasoning process offers, it should be mandatorily implemented by the wood based industries.

Fig. 1. End cracks in sawn slabs and logs of wood

Fig. 2. Cracks and fungal growth in poorly seasoned wooden products

Historically, air seasoning was extensively practiced by the wood workers and carpenters. The method mainly depends on the natural process of drying of wood but with certain code of practices like proper stacking of wood, having effective ventilation for efficient air flow within the stacked timber, protection from direct exposure to sun light and rains during seasoning process and prevention of faster drying from the ends (along the grains) of planks.

For stacking, well seasoned heartwood stickers of uniform thickness are placed across the timber layer for uniform air circulation. The stickers should be accurately aligned above one another in the vertical direction to

prevent bending under an eccentric load and allow uniform drying. The distance between stickers depends on the species and its thickness. Too close spacing of stickers will hamper the free flow of air result in slow drying whereas too far spacing may lead to warping in timber. Generally, spacing between the stickers is kept about 60 to 75 cm. The combination of atmospheric temperature, relative humidity and air velocity are the determining factors for the seasoning rate. One of the major limitations of air seasoning is that none of these factors are controlled, overall seasoning process very time consuming. This makes it less attractive and uneconomical for industrial scale operations for mass production.

In the present day scenario, when large scale production of wood based products has to be carried out at industrial scale, air seasoning methods is far from being practical. In order to hasten the seasoning process, kiln seasoning has evolved. The kiln seasoning is done in a chamber where wood is stacked and the main driving force required for removing moisture i.e. temperature and relative humidity are controlled. The forced circulation of air is performed by means of the reversible fans of proper capacity mounted in the seasoning chamber. Reversible fans are used to reverse the direction of dry air at a regular interval to get uniform drying through-out the stack. Steam or electrical energy is used to dry air. The dry air passed through the wood stack carrying moisture along with it resulting in faster drying of the wood. There are number of options available for kiln seasoning namely solar seasoning kiln, steam heated kiln, thermic-fluid heating based kilns, electrical heated kilns, dehumidification kilns, etc. Conventional seasoning kilns commonly use temperatures of 38oC to 68oC and air velocity through the load is generally between 0.6 and 1.5 m/s. Steam heated kilns are the most popular and are suitable for all kinds of wood. A schematic diagram of a steam heated kiln is shown in Fig. 4

Solar seasoning is one attractive option for drying of timber with appreciably accelerated rate compared to air seasoning and at reduced seasoning costs compared to conventional steam/electrically heated kilns. It is also one of the most energy efficient ways of drying wood operated during day light hours and effectively be used as a pre-dryer for slow drying timber species. The selection of site and direction of the kiln is very critical for efficient operation and harnessing the maximum solar energy for the kiln. A number of designs are available for fabricating a solar kiln however the greenhouse type of design is very popular and easy to fabricate. The schematic diagram of a solar seasoning kiln is shown in Fig. 5.

However, understanding the fundamental concepts involved in wood seasoning is very important for

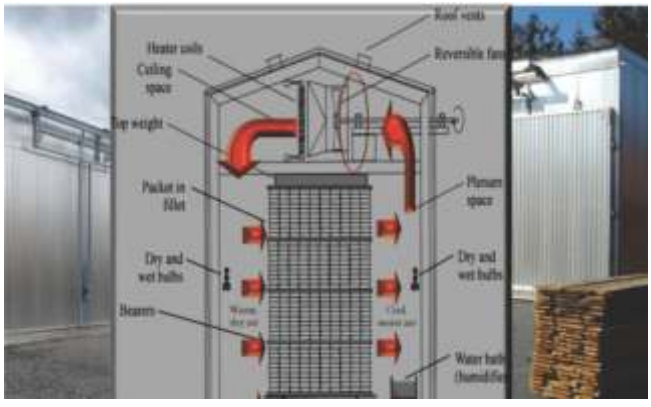

Fig. 4. A schematic diagram of overhead fan steam heated kiln

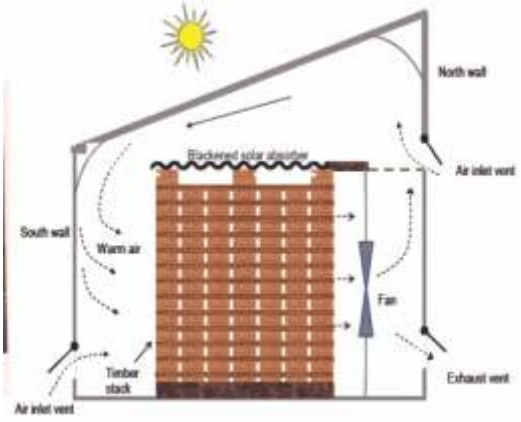

Fig. 5. Schematic diagram of solar seasoning kiln

economical and efficient seasoning. This knowledge of these concepts allows kiln operators to control the seasoning parameters desired for specific situations. While wood seasoning it is very critical to know that what level of moisture content and quality in seasoned wood is desired. Kiln seasoning needs to ensure that the seasoned wood has correct moisture content; there is very little variation in moisture content between the planks within a stack; moisture content within the plank is uniform; seasoned wood is free from surface checks, warping, end-splitting, fungal or chemical stains and there is no colour change. The possible seasoning defects are shown in Fig. 6.

Optimum conditions have to be used to avoid such degrades while seasoning timber. Seasoning too fast or too slow can results in different types of degrades. For example faster drying or seasoning can lead to surface checks and cracks in timber whereas slower drying can provide favourable environment for fungal growth which can ultimately result in discolouration. Proper control of relative humidity is very important in efficient seasoning of wood. Higher temperature and lower relative humidity (RH) at the beginning of the kiln seasoning process can result in excessively fast drying that may develop drying stresses in wood. While fixing these parameters due consideration should be given to the species to be dried, initial moisture content, and thickness of the timber. Different wood dry at a different drying rate and are prone to varying magnitude of drying related degrades. Species like sal, axlewood, eucalyptus, ebony, oak, jamun require lot of care during seasoning as they tend to develop seasoning defects and needs to be seasoned very slowly. These species are classified as highly refractory species for seasoning. Whereas, species like teak, toon, shisham, bijasal, paduak, silver oak, gurjan, rubberwood, rosewood, white cedar show moderate tendency to crack and split during seasoning are classified as moderately refractory species. These species can be seasoned with relatively faster rate that highly refractory species. Most of the low density timbers and permeable timbers like pines, mango wood, fir, semul, poplar, spruce, etc. can be seasoned at a faster rate and then do not exhibit significant degrades after seasoning.

The major economic drivers for wood seasoning are seasoning time, energy requirement and extent of degrade in the seasoned wood. Both time and energy requirement

Fig. 6. Defects in timber due to improper seasoning

has direct bearing on the cost of seasoning whereas degrades is linked with quality of the material. Wood seasoning is one of the most energy intensive operations product manufacturing and it is estimated that about 60-70% energy of the total energy required for timber processing is consumed in seasoning operations. This can have a large bearing on seasoning cost. Any changes made in seasoning process to reduce the energy consumption and the seasoning time can have a significant impact on the cost of production as a whole. Considering cost factor in seasoning operations, many times industry overlooks the proper seasoning practices and timber is dried at faster rate with little consideration to degrade and quality of the dried wood. In India, standards for kiln seasoning of wood of different species are already in existence (IS 1141:1993) and need to be followed for quality seasoning of timbers. The standards clearly specify the seasoning schedules i.e. the temperature and relative humidity conditions to be used during seasoning of different species. These sets of conditions are called "Kiln Schedule". It is very much necessary to follow these schedules to achieve the final moisture content of timber. Kiln seasoning applying proper schedule not only results in uniform moisture but also yields quality material with least defects. Once timber is properly seasoned, it must be stored, manufactured, and warehoused at humidity conditions that are at or slightly below the expected in-use humidity conditions. Failure to adhere to these basic principles will result in serious economic losses for the manufacturing firm.

To avoid manufacturing problems with the finished product, especially warping, splitting and checking. The final moisture content may vary depending on the environmental conditions where the timber has to be used. The moisture content for several wood products to be used in areas with different annual average relative humidity in India has been recommended and is given in Table 1.

Table 1: Recommended moisture content of wood

Applications	Final Wood Moisture content (%)			
	Area –I (Average RH < 40%)	Area-II (Average RH between 40-50%)	Area-III (Average RH between 50-67%)	Area –IV (Average RH > 67%)
Agricultural implements	12	14	16	16
Automobile bodies				
50 mm and above thickness	10	8	12	10
thinner than 50 mm	14	12	14	12
Doors and windows				
more than 50 mm thickness	10	8	12	10
Less than 50 mm thickness	14	12	16	14
Furniture and cabinet making	10	12	14	15
Shuttles and bobbins	8	10	12	12
Sports goods	10	12	14	16
Ship and boat building	12	14	16	18
Handles	12	12	14	15
Toys, carved items, pencils	8	10	12	12

(Source – Pandey and Jain, Wood Seasoning Technology, ICFRE publications, 1992)

Industries must follow proper seasoning practices to produce quality material in order to produce high quality end products. Many times, poor seasoning results in devaluation of the products and also rejection by the consumer. These also contribute to short life of the products and considerable economic loss to the manufacturer and consumer.

Advanced seasoning technologies

With the technological advancements, wood processing technologies are going through a transformation and new technologies have emerged for reducing time without compromising on quality of the material. Dehumidification based wood seasoning, vacuum seasoning, dielectric heating based seasoning methods have evolved over a period of time.

Dehumidification drying

Dehumidification drying is based on removing moisture from the air through either condensation or absorbing through a desiccant chemical. The condensation type dehumidifier kiln consists of an evaporator (heater) and a condenser both placed inside the chamber. Moisture evaporated from timber by hot circulating air is continuously sucked through the dehumidifier and get condensed. During the condensation process, latent heat is generated which maintains the temperature of air circulating inside the chamber resulting in lower energy consumption. Whereas in desiccant based kiln, the desiccant need to be dried at frequent intervals to keep the desiccant capacity. Though the dehumidification method is an attractive method to produce quality dried material particularly for hardwoods the system design is very critical in efficient seasoning.

Vacuum Drying

Vacuum seasoning was developed almost a century ago, but its popularity has grown substantially in recent times where need to reduce drying time is the prime factor. It can be used in small-scale operations. Moisture removal from wood is rapid as water boils at much lower temperatures in vacuum and it also produces good quality material, higher cost and criticality in designing of the kiln makes it unattractive among wood processors. Operating costs are usually three to four times higher than costs for dehumidification kilns and capital costs are also much higher.

High-Frequency and Microwave Heating

Dielectric heating has received significant attention in

recent past for drying of agriculture produce, disinfestations of grains, food processing, etc. due to its higher efficiency, easy controlling and environmentally friendly nature. Dielectric heating includes both radio frequency (RF) waves and microwaves. The technology has been extended to wood drying in many developed countries with commercial acceptance. RF based drying has been found to be effective particularly for thicker sections of hardwood species. Moist wood being a dielectric material when exposed to an electric field, the electrostatic charges in the wood begin to oscillate. These oscillations give rise to heating due to friction from the oscillating charges. Since energy is transferred by the interaction between the high frequency electric field and the responsive components in the substance, heat is generated throughout the volume of the body. Because of the volumetric nature of the heating, it avoids case hardening and other surface damage, which is a major concern in conventional kiln drying of timbers. In India, dielectric heating based wood drying is still at infancy and

A microwave wood dryer

recently an all India coordinated project on processing of wood using dielectric heating has been initiated. This project aims at comprehensive study on potential of DH based wood systems for a range of processes involved in wood processing.

MDF: THE NEW-AGE PLY

Association of India Panel Board Manufacturers (AIPM), is a non-profit organisation consisting of members who are manufacturers of MDF, HDF, Particle boards with and without pre-lamination, Laminated Flooring etc. with different grades and international-national norms like E0, E1, E2 and other standards. All members are encouraging agroforestry farmers as key raw material.

The Association members are continuously researching & adapting new techniques towards product advancement. Currently AIPM is working on modifying BIS standards to maximise usage of MDF boards with the help of IPIRTI.

AIPM is catering to the increasing urbanisation, demand for ready-made furniture, produced with engineered panels like MDF, which is growing rapidly and gradually replacing plywood.

Today's discerning consumer with a busy lifestyle, is looking for interior products which save time, are convenient to use, and are cost-effective, while being stylish. They want functional homes and furniture.

AIPM has been enlightening the trade about the usage of MDF ever since it forayed into the MDF production.

AIPM plans to organize the Carpenter meets frequently across the country to educate carpenters on the benefits of MDF and the tools required to work with it & enhance their skills and improve their livelihood opportunities by bringing professionalism in the field.

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ASSOCIATION OF INDIAN PANEL BOARD MANUFACTURERS

Melia Dubia Cav.: as multipurpose tree species and quality industrial raw material

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In India, wood based industry is the major users of wood produced by growing trees outside forests (ToF), on private and community lands. The Indian wood based industry imports wood substantially to meet ever increasing domestic demands. The Global Agricultural Information Network reported that that India's total import of forest products during 2017 was equal to US $ 2193 Million, of which maximum import was realized for logs (US $ 1206 Million) followed by lumber (US $ 368 Million). The import of medium/high density fireboards and veneer was calculated to US $ 326 Million. It is also a fact that in last seven years India's import of wood and wood products has substantially increased from Rs. 168.95 to Rs. 328.20 billion. Factually, India is one of the largest importers of wood, which has consistently been increasing over the years from worth Rs.1,500 Crore in mid-eighties to Rs. 50,000 Crore per annum presently.

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The bulk of wood as industrial raw materials globally derived from ToFs covering an area of around 9.13 million ha, which is about 2.70 % of geographical area. Therefore increasing domestic production of wood is essentially required to reduce imports, and enhance contribution of indigenous trees. In India nonetheless, forest conservation policies have limited supply of wood from natural forests, and presently about 82 % of wood is supplied from ToF. Owing to a large amount of wastelands, there is a huge scope of increasing area under agro and farm forestry. Further, increasing productivity of planted forests would be a sustainable option for fulfilling ever growing demand for wood in the country. It is obvious that so much of the gap between demand and supply presently persists, which can be brought down substantially by increasing area of planted forests with quality planting stocks with specific end uses. Such practices are extremely important globally for conservation of natural resources and play an increasingly important role in climate change, and are also expected to reduce price of forest products by 23-37 %. During 2015, total planted forests were 290 million ha of which Asia had a share of 129 million ha, and implementation of National Agroforestry Policy (2014) it is expected that area under agroforestry would grow further and substantially.

Though fast growing trees like Eucalyptus, Casuarina and Populus are promoted by wood based industries in recent past, most of these species have poor productivity owing to poor planting stock and narrow genetic base. The Deccan Chronicle highlighted that Kerala Forest Department has decided not to replant water sucking species like Acacia and Eucalyptus at places where these trees have been felled for pulpwood and replace them with more efficient species like Melia dubia. Moreover, majority of exotics originate from a very small genotypes/population/germplasm, and therefore bear narrow genetic base which have cascading impacts on genetic improvement and productivity. In India, for example, Eucalyptus was derived from one small stand / population during early introductions to Nandi Hills which was a real cause of concern with very narrow genetic base. It is perhaps the only reason that productivity of Eucalyptus has not commensurated with resources poured-in on genetic improvement and field deployment. Moreover limited productive clones, derived from germplasm that was originally established exclusively by Forest Research

Institute and Colleges, Dehradun in coordination with Uttar Pradesh Forest Department, were multiplied ruthlessly without crediting to stake holders by numerous private companies resulting to serious infestation of devastating gall insect (Leptocybe invasa). This infestation was proven to be epidemic, purely disconcerted to narrow genetic base.

Melia dubia Cav. (*Syn. Melia composita Benth.*)

Melia dubia Cav. (Syn. *Melia composita* Benth.), commonly known as Malabar Neem, Burma Dek or Gora Neem, attains an average height of 20-30 m and of 1.2 to 1.5 m with cylindrical straight bole reaches upto ~ 9 m or even more.The species is most commonly found in tropical moist deciduous forests of Sikkim, Eastern Himalayas, North Bengal and Upper Assam, and also occurs in deciduous forests of Northern Circars, Khasi Hills of Meghalaya, Hills of Odisha, Nallamalai Hills and Western Ghats from South Kanara Southwards. It is an economically and industrially important tree speciesaswell realized source of timber, pulp and plywood, and is also a source of biologically active compounds of medicinal importance. There was a need to employ tree improvement for further betterment of the species including selection of plus trees / elite trees, setting up of breeding programme, evaluation of wood of specific genotypes for end products like ply, paper and so on.

A series of products are manufactured from the wood of *M. dubia*, and is also valued for high quality timber which is resistant to termite and fungus. The wood is used for production of quality plywood in a short period, and timber is chiefly used for furniture, agricultural implements and house construction. The species is undoubtedly an alternative source of raw material for producing pulp and paper, and in fact paper of this tree has been recorded to demonstrate excellent strength and brightness. In Sri Lanka, wood is also used for making outriggers of native boats, and also finds suitability as source of quality bio-energy, especially for biomass gasification to generate producer gas and in lime kiln.

In view of above, Indian Council of Forestry Research and Education (ICFRE) decided to initiate research work on genetic improvement and other associated fields including deployment of superior genotypes of this multipurpose indeginous tree species. Accordingly in 2004, Forest Research Institute, Dehradun initiated a pilot project on *M. dubia* Cav., and results of this pilot project were very encouraging to implement another follow-up project in 2008. The research outcomes and interpretations of these two pilot projects encouraged formation of first ever 'All India Coordinated Project on Genetic Improvement of *M. composita*' in forestry in 2011 with following objectives,

- To identify promising genotypes and provenances through selection and field evaluation
- To field evaluate different progenies and clones for growth performance and productivity
- To characterize different genotypes for morphological, anatomical, physiological, biochemical and pulping traits
- To establish micro and macro propagation protocols for rejuvenation of adult genotypes and commercial production of clonal planting stock
- To analyze seed and seed characteristics including germination and impact of seed quality on field performance
- To study reproductive biology and synthesize intra and inter specific hybrids for productivity and utility enhancement
- To standardize DNA based tools for application of biotechnological interventions and enforce marker assisted selection to improve the productivity
- To analyze status of genetic diversity based on morphological and molecular markers
- To develop silvicultural practices for pure and mixed plantations, and also development of suitable agro-forestry models
- To study important insects and diseases, and screening of resistant / tolerant genotypes for insect, disease, salinity and drought
- To establish breeding populations for various end uses and future breeding and biotechnological programme

Economic importance

M. dubia could play a complementary role as one of the most potential pulpwood species and fetches handsome price in the market with low maintenance expenditure. Even if planted in rows along the field bunds, about 60 trees can be planted per acre, which will fetch an income of about Rs. 2 lakh in sixth year of planting. On the other hand, planting of 300 to 400 trees per acre will give a minimum profit for Rs. 1 lakh per year from an acre. Under good maintenance and controlled irrigation from sixth year onwards trees with about 100 cm GBH and clear bole of 5 to 7 meters can fetch upto Rs. 4000 to Rs. 5000 per tree depending on soil depth and quality. It is an important species for agroforestry as inter-cultivation can easily be done with regular annual crops during first three years and thereafter selected crops could well be grown.

The Hindu, May 25, 2011 reported that *M. dubia* is a money spinning tree of short duration as a tree with more than 16 inches of girth can easily be sold for about Rs. 2000 as an end product for matchbox industry. In fact, veneer industry would fetch more price than matchbox industry. Since there is a total mismatch between demand and supply for wood under veneer industry, block planting of 300 to 400 trees per acre can ensure a profit of about Rs. one lakh per year or even more.

Further to compensate ever increasing demand for wood and also to reduce pressure on native forests, it is essential of produce more quality on less land by planting highly productive trees. The newspaper further emphasized that 'one of the main problems that farmers face today is decreasing income from an acre per year against sudden increase in value of agricultural lands due to newly formed rural roads, mushrooming of industries and concrete dwellings'. Thus, the easiest way to increase income is to plant certain tree varieties such as *M. dubia* which fetches handsome price in market with assured buybacks and low expenditures on maintenance. Moreover, micro site improvement technique in Ayalur Watershed Area to improve soil texture and nutrient uptake under irrigated conditions has enabled *Melia* tree to yield 5-7 cubic feet timber, profiting farmers to fetch handsome money of around 15 lakhs / hectare of land after six years.

Wood properties

Though M.dubia has been identified as potential source of raw material for manufacturing of quality ply and pulp, age at which species becomes amenable to such uses has not been assessed properly. Nonetheless, wood variations in Melia at age gradations from one to five years were studied, and analyzed physical, chemical and strength properties of wood including bulk and basic density, holocellulose and lignin content, pulp yield and kappa number analysis. It was found that fifth year wood dominated higher pulp yield (50.00%) and moderate kappa number (22.00) exhibiting superiority in terms of tensile index, burst index and tear index of bleached paper. The relationship between morphological variability and wood quality traits was also established for *M.dubia* by assessing heartwood proportion, basic density, stiffness and shrinkage properties

In a major myth, it was considered that the wood of *M.dubia* has a tendency of splitting ends after harvest, and therefore can't be used for peeling and furniture making. The Forest Research Institute, Dehradun therefore investigated on this aspect and found that such splitting doesn't take place with *M.dubia*, however is a persisting problem with *Melia azedarach*. The species therefore has greater potential for plywood industries to reduce pressure on few tree species based raw material like Eucalyptus and populous, and microscopic features of *M.dubia* are presented below (Table 1)

Table 1. Microscopic characterization of Melia species

Axial parenchyma	Scanty vasicentric
Deposits	Gum
Fibres	Septet fibres present
Ground tissue fibers	Fibres with simple to minutely bordered pits
Growth rings	Boundary distinct
Helical thickening in vessel element	Throughout body of vessel element
Inter-vessel pits: arrangement and size	Alternate, bordered, minute-4-μm or less (1-1.5)
Perforation plates	Simple
Porosity	Ring-porous
Ray width	Larger rays commonly 4- 10 seriate
Rays	Fused
Rays per mm	12 or more/mm
Rays: cellular composition	All ray cells procumbent
Solitary vessel outline	Circular to oval
Tangential diameter of vessel lumen	200 μm or more
Vessel arrangement	Radial pattern
Vessel groupings	Radial multiples of three or more and also solitary
Vessel ray pitting	Simple to minutely bordered pits

The assessment of suitability of the species for manufacture of plywood, gluing and bonding properties was investigated using adhesives (urea formaldehyde and phenol formaldehyde), and it was investigated that species meets essentially required parameter of moisture resistant (MR) and boiling water resistant (BWR) grade ply. The investigations at Forest Research Institute, Dehradun proved suitability of thirteen genetically distinct progenies of *M. composita* for ply manufacturing using urea formaldehyde adhesives for general purpose interior grade by meeting IS specification.The plywood made from Progeny No. FRI/MD/104 was found to be most appropriate in terms of modulus of rupture and modulus of elasticity alongand across the grains, followed by Progeny No. FRI/MD/028,FRI/MD/075 and FRI/MD/076. The ply made of progeny FRI/MD/028 and FRI/MD/076 was most suitable in dry and wet state glue shear strength to the extent of 200 kg/inch^2, which was almost double the threshold level of 100 kg/inch^2 (Table 2 and 3). The species therefore has a potential to become a natural alternate raw material for plywood industry.

Table 2. Moisture content and density of plywood prepared using various progenies of *M. dubia*

	Moisture content (%)				Density (gm/cm^3)			
Progeny No.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
FRI/MD/013	13.25	1.22	9.73	14.94	0.52	0.05	0.46	0.61
FRI/MD/020	12.53	0.50	11.42	13.34	0.51	0.04	0.44	0.57
FRI/MD/024	13.26	1.71	8.54	14.89	0.50	0.02	0.47	0.54
FRI/MD/028	12.53	0.50	11.69	13.31	0.52	0.02	0.49	0.57
FRI/MD/032	12.93	1.67	8.50	14.88	0.52	0.03	0.46	0.60
FRI/MD/064	13.10	1.15	10.23	14.74	0.50	0.01	0.48	0.53
FRI/MD/069	12.47	0.50	11.38	13.82	0.51	0.03	0.46	0.57
FRI/MD/075	13.33	1.12	10.11	14.94	0.52	0.02	0.50	0.55
FRI/MD/076	12.59	0.71	11.43	13.95	0.52	0.03	0.48	0.56
FRI/MD/104	12.90	0.84	12.07	14.54	0.52	0.02	0.50	0.55
FRI/MD/114	12.85	1.20	9.69	14.93	0.51	0.04	0.44	0.59
FRI/MD/115	13.14	1.03	11.86	14.92	0.52	0.02	0.49	0.57
FRI/MD/128	12.48	0.98	11.30	14.49	0.52	0.03	0.48	0.59
Mean	12.88	1.10	8.50	14.94	0.52	0.03	0.44	0.61

Table 3. Glue-shear strength of plywood prepared using various progenies of *M. dubia*

Progeny No.	Glue Shear Strength (kg)							
	Dry State				Wet (60 ± 2°C for 3 h) State			
	Mean FL (kg)	SD (kg)	Min. (kg)	Max. (kg)	Mean FL (kg)	SD (kg)	Min. (kg)	Max. (kg)
FRI/MD/013	119.89	19.94	85	162	120.03	19.40	87	185
FRI/MD/020	113.50	28.93	82	179	118.36	23.37	87	170
FRI/MD/024	126.56	22.39	91	179	114.47	18.82	76	165
FRI/MD/028	143.75	36.82	85	196	134.50	21.66	98	172
FRI/MD/032	119.50	18.04	89	158	103.72	12.27	73	128
FRI/MD/064	111.03	19.95	82	154	105.33	23.63	74	171
FRI/MD/069	118.92	25.65	85	176	130.25	40.93	82	209
FRI/MD/075	140.33	27.86	89	195	117.78	24.52	76	175
FRI/MD/076	139.81	34.89	84	224	140.00	39.92	78	235
FRI/MD/104	124.86	28.34	82	191	123.17	33.46	73	185
FRI/MD/114	115.56	23.24	80	181	107.61	25.38	65	164
FRI/MD/115	142.31	25.64	106	215	125.14	27.44	77	191
FRI/MD/128	131.08	33.07	83	198	130.42	28.05	75	186

The species has also been found to be suitable based on physical and chemical properties for utilization in plywood industries. Rahman et al. (2014) examined various properties like density, modulus of rupture (MOR), modulus of elasticity (MOE), etc. of Melia and compared that with Bombax ceiba, already available plywood source in market of Bangladesh. In conclusions Melia was found to be far superior to *B. ceiba* with higher density (541.00 kg/m^3), greater MOE and MOR (3950.01 N/mm^2 and 58.33 N/mm^2, respectively).

Melia in Agroforestry

The agroforestry concept is basically depended on establishment of interface between agriculture and forestry. Agroforestry is a management system based on natural resources such as trees and farms which integrate to establish a new sustainable and economically beneficial scheme. In agroforestry, forest based economically important trees are grown with crops in farms. It is a fact that farmers / growers are not willing to invest resources in tree species that are governed with stringent permit systems, and therefore species which are exempted from government permissions and licenses on growing harvesting, transportation and marketing are preferred.

The Forest Research Institute, Dehradun has played a significant role in exemption of *M. dubia* (Syn. *M. composita)* along with many other species from the list of species exempted from necessary permit / license to grow and harvest. A list of 20 important multipurpose tree species have been provided which are excepted at national level from restrictions related to harvesting, transportation and marketing grown under agroforestrysystems as per following (Table 4).

Table 4. Exempted tree species for growing, harvesting, transporting and marketing under agroforestry

Name of State	Exempted Species
Andhra Pradesh	*Mangifera indica, Casuarina equisetifolia, Acacia nilotica, Syzygium cumini, Psidium guajava, Azadirachta indica, Anacardium occidentale, Cocus nucifera, Ficus religiosa*, Eucalyptus and Subabul
Bihar	Poplar, *Eucalyptus, Anthocephalus cadamba, Mangifera indica, Bombax ceiba, Gmelina arborea*, Litchi, Phoenix and Bamboos, except *Dendrocalamus strictus*
Gujarat	*Eucalyptus, Casuarina equisetifolia and Prosopis juliflora*
Jharkhand	*Acacia nilotica*, Subabul, Bamboos, Cane, *Shorea robusta, Tectona grandis, Pterocarpus marsupium, Boswellia serrata and Terminalia elliptica*
Karnataka	*Eucalyptus*, Casuarina, Subabul, Rubber, Coconut, Arecanut, Orange, *Erythrina, Gliricidia, Sesbania* and Silver oak
Kerala	A total of 61 species permitted, and some of the important species are *Pongamia pinnata, Hevea brasiliensis, Ailanthus excelsa, Mangifera indica, Garcinia cambogia and Terminalia spp.*
Madhya Pradesh	*Eucalyptus, Casuarina, Subabul, Poplar, Pithocellobium dulce* and *Prosopis*
Maharashtra	*Acacia nilotica, Leucaena leucocephala, Prosopis, Eucalyptus, Moringa, Phoenix, Sapota, Acacia auriculiformis* and *Poplar*
Odisha	*Bambusa nutan, B. vulgaris, B. tulda, Samania saman, Eucalyptus hybrid, Acacia auriculiformis, Cassia siamea, Casuarina equisetifolia* and *Silver Oak*
Punjab and Haryana	*Eucalyptus, Ppoplar* and *Melia composita*
Tamil Nadu	*Grevillea robusta, Eucalyptus spp., Casuarina equisetifolia* and *Leucaena leucocephala*
Uttar Pradesh	*Poplar, Eucalyptus, Subabul, Casuarina, Ailanthus spp., Gmelina arborea, Grevillea robusta, Morus alba, Anthocephalus cadamba, Melia composita, Acacia spp., Albizia spp., Borassus flabeliformis, Butea monosperma, Tamarindus indica* and *Grewia oppositifolia*
Uttarakhand	*Poplar, Eucalyptus, Melia composita*

*M. dubia i*s investigated as a promising agroforestry species among many others identified which can be easily incorporated under farm systems. It can be planted as inter-crop with coconut, groundnut, black gram and green gram. Performance of Melia as a bund plant for species like Casuarina, banana, drumstick and sugarcane is also found rewarding. Species is also running in good health with mango orchards and as a shade tree for coffee and tea plantation, also supported tomato and turmeric cultivation

There is variety of crops are grown with Melia under agroforestry systems such as chilli, turmeric, papaya, melon, foxtail millet and sugarcane through inter-cropping with fine productivity, marking Melia as a good agroforestry species. Its performance successfully increases in bunding plantation and can give maximum yield within four years. M. dubia is extensively cultivated with mulberry and in a few sample sites as well as with horticulture crops like mango, sapota, banana and coconut

Genetic analysis

The genetic parameters of any trait are an important tool to predict amount of genetic gain expected from genetic material. A character is influenced by genes as compared to environments for analyzing magnitude of inheritance of quantitative traits. The knowledge of heredity and environment to the fullest extent gives opportunity to understand role of heredity among quantitative traits.

The investigations at FRI, Dehradun on variability

estimates of different parameters indicated existence of wide range of variation among progenies at different geographical locations. The traits like collar diameter (CD) and diameter at breast height (DBH) showed high variance at genotypic level than varying environments. The similar pattern was also supported by higher heritability and genetic gain for various traits. Though expression of CD and DBH was depicted to be controlled by genetic make-up, geographical variations of climatic and edaphic factors were clearly found to influence expression of growth parameters.

Variations among progenies are commonly used to calculate degree of genetic control for particular trait. During current investigation, variability estimates of different parameters indicate wide range variation among progenies at different geographical locations. The traits like collar diameter (CD) and diameter at breast height (DBH) show high variance and coefficient of variability at genotypic level than varying environments. The similar pattern was also supported by higher heritability and genetic gain for various traits under investigations. So it is clearly depicted that the expression of CD and DBH was more controlled by genetic make-up of the progenies. However, sites had clear influence on expression of growth parameters to great extent with varying climatic and edaphic factors.

Productivity

The field data recorded for seven year old Melia was analyzed and found to significantly influence various characters. The height for all 105 progenies across varied from 716.67 to 1619.03 cm with a mean value of 1094.89 cm, collar diameter varied from 11.47 to 31.00 cm with mean value of 20.42 cm, diameter at breast height (DBH) varied from 8.67 to 25.73 cm with an average value of 16.24 cm, clear bole height (CBH) varied from 363.33 to 890.00 cm with mean value of 637.46 cm and number of branches varied from 2.00 to 4.67 with a mean value of 2.93. The values for other two parameters viz. straightness and branching behaviour were awarded objectively which varied from 2.00 to 4.00 with an average value of 3.37 and 2.33 to 4.33 with an average of 3.32, respectively, and the improvement was recorded to be very substantial (Table 5).

The total index value varied from 0.00 to 95.50 with an average index value of 49.12. The ten genotypes were identified and screened based on total index value and diversity status. In this fashion, ten top ranked progenies were selected and named appropriately. These identified

genotypes were later released for commercial cultivation in different regions of Northern India as per the laid procedure of release that has been approved by the Ministry of Environment, Forests and Climate Change, Government of India, New Delhi.

The per tree volume of recommended varieties varied from 0.10 to 0.25 $m^{3.}$ with an average value of 0.17 m^3 (Table 5). The same was extrapolated on m^3ha-1yr-1, which varied from 23.19 (RITU) to 55.83 (SHARAD) with an average value of 34.57 m^3ha-1yr-1.The productivity of the released varieties over mean of all evaluated varieties was also calculated (Table 6). The varieties were accordingly recommended for various regions of Haryana, Punjab, Uttar Pradesh and Uttarakhand (Table 6 and 7).

Table 5: Comparative assessment of released varieties with genotypes evaluated and net gain achieved

Static	TRAITS Height (cm)	CD (cm)	DBH (cm)	CBH (cm)	Str.	NB	BB	Per tree volume (m^3)	Productivity (m^3ha-1yr-1)
Released Varieties Mean	1342.53	27.55	21.80	741.89	3.91	3.46	3.55	0.17	34.57
Evaluated Population Mean	1094.89	20.42	16.24	637.46	3.37	2.93	3.32	0.08	12.64
% Improvement Mean	22.00	34.92	34.23	16.38	16.02	18.08	6.92	112.50	173.49

Table 6 : Productivity of ten released cultivars at seven years of age

		TRAITS								
Cultivar No.	Commercial Name	Height (cm)	CD (cm)	DBH (cm)	CBH (cm)	Str.	NB	BB	Per tree volume (m^3)	Productivity (m^3ha-1yr-1)
FRI/MD/235	Sharad	1433.33	31.00	25.73	790.00	3.67	4.33	3.33	0.2513	55.83
FRI/MD/349	Shashi	1618.17	29.26	24.38	779.10	3.69	2.94	3.51	0.2546	40.41
FRI/MD/032	Bahumukhi	1233.33	28.67	23.33	666.67	3.33	2.33	3.00	0.1791	39.79
FRI/MD/232	Varsha	1216.67	28.33	22.67	616.67	3.67	4.67	3.00	0.1670	37.11
FRI/MD/241	Kartik	1521.40	28.88	22.93	892.54	6.41	5.09	6.11	0.2124	33.71
FRI/MD/075	Kshitiz	1233.33	28.00	21.33	740.00	4.00	3.33	3.00	0.1504	33.43
FRI/MD/262	Amar	1619.03	28.91	21.33	880.55	3.69	2.94	3.51	0.1960	31.10
FRI/MD/231	Megha	1216.67	25.33	19.13	650.00	3.67	2.67	3.00	0.1203	26.73
FRI/MD/256	Dev	1366.67	22.33	17.20	890.00	4.00	3.67	4.00	0.1096	24.36
FRI/MD/261	Ritu	966.67	24.80	19.93	513.33	3.00	2.67	3.00	0.1044	23.19

Table 7. Superiority (%) of ten released varieties over population mean

		TRAITS								
Cultivar No.	Commercial Name	Height (cm)	CD (cm)	DBH (cm)	CBH (cm)	Str.	NB	BB	Volume	Productivity
FRI/MD/235	Sharad	30.91	51.83	58.42	23.93	8.77	47.75	0.36	215.64	341.90
FRI/MD/349	Shashi	47.79	43.31	50.11	22.22	9.32	0.09	5.63	219.86	219.86
FRI/MD/032	Bahumukhi	12.64	40.40	43.65	4.58	-1.12	-20.44	-9.67	124.95	214.94
FRI/MD/232	Varsha	11.12	38.77	39.54	-3.26	8.77	59.12	-9.67	109.80	193.73
FRI/MD/241	Kartik	38.95	41.42	41.13	40.01	90.00	73.64	83.89	166.79	166.79
FRI/MD/075	Kshitiz	12.64	37.13	31.34	16.09	18.66	13.66	-9.67	88.97	164.56
FRI/MD/262	Amar	47.87	41.59	31.29	38.13	9.32	0.09	5.63	146.15	146.15
FRI/MD/231	Megha	11.12	24.07	17.79	1.97	8.77	-9.07	-9.67	51.12	111.57
FRI/MD/256	Dev	24.82	9.38	5.89	39.62	18.66	25.02	20.43	37.70	92.78
FRI/MD/261	Ritu	-11.71	21.46	22.72	-19.47	-11.01	-9.07	-9.67	31.09	83.53

Conclusion

Since India is under tremendous pressure to meet growing demand for wood and wood products, there is an urgent need to search for alternate species which are required to be evaluated and recommended for commercial cultivation. It is also not out of context to mention that indigenous species would always have better advantages than that of exotics. *Melia dubia* Cav. is one such alternate species with immense potential under ply, timber and pulp industries.

Big-leaf Mahogany: a promising tropical timber for wood based industries

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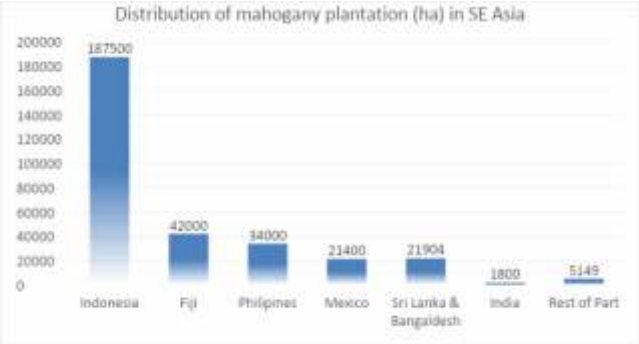
Introduction

The mahogany wood has unique reputation in the international market due to its desirable characteristics such as attractive appearance, good dimensional stability, carpenter's friendly, excellent finishing qualities with high durability. The name "mahogany" has been commonly accepted for the wood since the 17th century. In general, the mahogany timber is frequently sold in the market in the origin of country as Honduran mahogany, Mexican mahogany, Brazilian mahogany or Peruvian mahogany. The term "true mahogany" is sometimes used to distinguish it from other woods that are not belonging to genus Swietenia. According to Melville (1936), nearly 200 species of 35 plant families have been called as mahogany in one time or another. However, mahogany trees are generally grouped into three groups viz., Genuine (*Swietenia sp.*), True (*Khaya sp.*) and mixed mahogany (Toona sp., Entandrophragma sp., etc.) for the purpose of trade. Both genuine and true mahogany species are suitable for commercial plantation. Among all, big-leaf mahogany/Honduran mahogany (*Swietenia macrophylla*) is fast growing highly prized tropical commercial timber species. It is naturally distributed in Mexico, Central America, Colombia, Venezuela, the Amazon Basin, Peru, and Bolivia. As the reduction of big-leaf mahogany population in its native range and inclusion of all genuine mahogany species in CITES list, large scale artificial plantations have been established in South East Asian countries, especially in Indonesia, Fiji, Philippines, India, Sri Lanka during 1988 onwards. The largest plantation area of mahogany is found in Indonesia followed by Fiji and Philippines.

Distribution

Big-leaf mahogany was introduced from Jamaica and Honduras in the Royal Botanic Garden, Kolkata in 1795 as ornamental. It has been introduced as an avenue tree in West Bengal and has also been introduced into forest



plantations in many other parts of India including West Bengal, Bihar, Orissa, Mysore, Tamil Nadu Kerala and Maharashtra. However, it is well established only in Kerala, West Bengal and Tamil Nadu. The tree is found as far north as Dehra Dun at low elevations, usually in the rain- forests or the moist deciduous forests with a rainfall of 150-500 cm. It was first planted in 1879-81 in small groups in gaps of teak-plantations in Tamil Nadu and Kerala states. However, its cultivation was discontinued due to heavy damage caused by shoot-borer. It was tried again in 1886-96 as under-planting in teak plantations at a spacing of 15 m × 15 m. But it was again damaged severely by deer. During 1988 – 1992, it has been under-planted in pure plantations of Teak in Kerala, just after the final thinning when Teak is 30-40 years old. Among all Indian states, the Kerala has largest area of mahogany plantations (>1283 ha). A total of 1735 ha of mahogany plantations are established under the World Bank project in Kerala during 1987 to 1999. The Social Forestry wing of Kerala State Forest Department distributes of lakhs of mahogany seedlings to the farmers to plant in their homesteads in Kerala. Now–a-days, farmers and tree growers are cultivating big-leaf mahogany in the farm lands and forest lands in large scale in the form of block plantation, agroforestry and avenue tree in Kerala, Tamil Nadu, Karnataka and Maharashtra due to its fast growth, short rotation, and high price. The Government has included mahogany species in the exempted tree lists to promote its cultivation in Tree-out-side-Forests (ToFs).

Environmental conditions

Big-leaf mahogany grows in a variety of soils and the best growth is found in deep, fertile soil on well drained slopes in regions where rainfall is abundant. However, timber from the less moist region is reported to be more valuable. It grows well at elevations up to 1300 m (Kothagiri, Tamil Nadu) but best growth is found up to 900 m. Further, the big-leaf mahogany is less exacting than the true mahogany. Further, the S. mahagoni is regards both soil and climate for best growth. The big–leaf tree is suited to laterite soils, which is not suitable for Teak cultivation. In North Bengal, I t is doing well on the soil where Sal is growing. Mahogany tree appears to thrive best in a warm moist climate with the temperature ranging from 21 to 350C and mean annual rainfall from 1000–2000 mm. It is a moderate shade-bearer and can be grown as an under storey in Teak plantation after mid-rotation age when the final crop of Teak is widely spaced. It is very sensitive to frost and plants raised in the open in Dehra Dun are most often killed due to frost.

Maturity and collection of seed

Mahogany trees flower annually in the month of February. Seeds ripen from February to March and fruit attains maturity in 11-12 months after flowering. From phenotypically superior pest- disease free trees, mature fruits (capsules) are collected during November - April when fruit become whitish brown in colour and they begin to dehisce. The mature pods dry for 2-3 days in the sun to dehisce longitudinally to release seeds. A fruit contains 25-30 viable seeds and 1 kg seeds have 2000-2200 seeds. The seeds lose their viability after two or three months, if expose to the open air, but may retain it for a year if kept mixed with saw dust in closed containers.

Seedlings in mother bed

Seedlings in green house

Methods of regeneration

The big-leaf mahogany tree produces abundant seeds, almost annually, since the age of 8-12 years. Seedlings come up plentifully under the mature seed–bearers; but dense overhead shade is detrimental to their growth. Opening of the canopy over young regeneration is beneficial, when it attains 1.8 m height. Mahogany can be propagated through direct sowing, transplanting and stump-planting in which the transplanting gives best results. Direct sowing gives good results only on rich soil in a very humid climate provided lateral shade is available, as the young seedlings cannot bear the direct sun. The seeds are sown at the commencement of the rains, with their wings removed and covered with a thin

Description of tree

Big-leaf mahogany tree is a beautiful, lofty, evergreen tree and leafless for small brief period during summer. The leaves shed and new flesh shoots growth happens simultaneously in dry sites. It usually grows 30-40 m in height and 3-4 m in girth, but in very favorable localities it may attain a height up to 60 m and 9 m girth. The trunk is straight and cylindrical, with a clear bole height of 20-25 m and buttressed at base (Fig. 3). The bark is greyish brown, fairly smooth to some-what rough, flaking off in patches. Leaves are paripinnate, long green or reddish when young, dark green and shining when mature, up to 20 cm long. The inconspicuous flowers are borne in small open clusters among the leaves; these appear during February-March, nearly a year later. The flowers are greenish cream color, 0.8-1.0 cm across, sweet-scented, in narrow supra-axillary panicles. The capsules (fruits) are like a large, inverted club, 12.5 × 7.5 cm and very woody.

layer of earth. The sowing is done either in lines 1.8 m apart or in worked patches 1.8 m×1.8 m, with 4-6 seeds in each patch. About 27 kg of seeds are required per ha for line-sowing and 9 kg per ha for patch-sowing. Under this method, both nursery grown- and wild seedlings are directly transplanted in the field before just start of monsoon after 4-months (~ 16cm height) and no pricking out is necessary. Natural seedlings from forests about 10-15 cm tall can also be transplanted into root trainer/polybags and subsequently used for out-planting. In Bengal, ball-planting of 4-month-old seedlings gave 100% success and planting of 9-month-old plants during winter month is was also very successful. Stump-planting of seedlings during the second rains, though successful, does not give as good results as transplanting.

Quality planting stock production

Freshly collected seeds are subjected to over-night soaking in cold water and are dried in shade for 15 minutes after decanting the water before sowing. Then, seeds are spread on sand-beds uniformly and fine sand/soil is broadcasted over the seeds for about 1 cm thickness to cover. After regular watering, seed germination starts on 15th day from date of sowing. The speed of seed germination and germination % varied between seed source and site conditions. The maximum seed germination percentage (100%) was recorded in the seed source of Pudukkadu (Tamil Nadu), Kannur (Kerala), Mysore and Bangalore (Karnataka). The lowest seed germination percentage was recorded in seed source of Punjab (2%) and Tiruvarur (3%). Peak time of germination was observed 15-20 day after seed was sown. At 3rd leaf stage, seedlings are transplanted from nursery bed into polybags. The container seedlings are maintained for about 6-months for out-planting.

Establishment and management of plantation

Big-leaf mahogany is being cultivated for timber, shade, avenue tree and in agroforestry systems. In mahogany based agroforestry systems, pumpkin, maize, sugarcane, banana, fodder grasses, chilli and leafy vegetable are common intercrops. The recommended spacing is given below:

- Seedlings are planted at 2×3 m or 3×3 m or 3×4 m for block plantation for timber production.
- In the open (invariably attacked by the borer, Hypsipyla robusta) at an espacement of 3×3 m.
- Planting spacing in secondary-growth forest is 3×3 m.
- In taungya system, the recommended espacement is 4×4 m and field-crops being raised for about two years.

Big-leaf mahogany can be successfully established under teak at mid-rotation age in Tamil Nadu and Kerala. The big-leaf mahogany grows rapidly and thrives better in India than small-leaf mahogany (S. mahogani). Under favourable conditions, the rate of growth is very fast. During the first 2 years, weeding and hoeing are required 4 times at every 6 months interval. Either line weeding or ring weeding (in a 1m diameter around the seedling) is recommended. Usually, a dose of 75-100 g NPK per plant in a ring around the seedlings is applied after planting. Replanting can be done twice during the rotation. First replanting normally takes place in the rainy season at 1 month after planting to replace any dead seedlings and second replanting is at the end of the second year.

As big-leaf mahogany have habit of the growing erect with straight stem and few branches, normally pruning is not required. However, pruning may be required, if there are any dead or un-productive branches, and it also reduces the risk of disease and pest infestations by reducing relative humidity. Pruning is usually done for the first 3 years. Best time for pruning is just before the rainy season preferably during dormant season (winter). Thinning is normally done to improve the growth of remaining trees with an acceptable form. Diseased/pest-infested trees, deformed or poorly shaped trees and suppressed trees removed. First thinning is applied in around 5-10 years, depending on site quality and initial stand density. The number of thinning required in a rotation depends on initial stand density and site quality. Interval between thinning is 5-10 years. Multiple thinning is suggested for closer spaced stands (3×3 m; 2×3 m). For stands with high initial planting density (2×3 m), four thinning in a rotation is recommended. For 3×3 m spacing, 2 - 3 thinning appears to be essential whereas in a wider spacing (4×4 m), one thinning is recommended.

Growth statistics

The rate of growth varies with site conditions, initial spacing and age. The annual height growth and diameter of 11-year-old plantation was 1.5 m and 1.3 cm whereas in 17-year-old plantation, the mean diameter growth was same as in 11-year-old plantations. In the Palgat forest division (Kerala), the timber yield of 14, 24 and 32 year old big-leaf mahogany plantation was 30.2, 140.8,178.2 cu.m/ with density of 551, 227 stems per ha, respectively. Thus, optimum density, site and age of plantation are having important role in enhancing timber yield.

Rotation period and timber yield

Mahogany plantations are predicted to reach maximum mean annual increment (MAI) and volume of 38.1 m3/ha/year and up to 572 m^3/ha in 15 years in the best sites, respectively and the medium-quality sites produce a volume MAI of 19.7 m^3/ha/year with volume up to 493 m^3/ha in 25 years. If the rotation is set to 30 years, stands can attain a mean height of 24.4 m and a mean diameter of 35.4 cm and produce total volume 583 m^3/ha including thinning in moderate sites. Thus, the estimated total timber volume is between 200.5-501.6 m^3/ ha with MAI of 7.7–19.3m3/ha/year in rotation age of 15-30 years.

Pests and diseases

There are 23 pests are reported, of which most are defoliators, borers and sap-suckers. However, the shoot-borer (*Hypsipyla robusta*) is the only serious pest of mahogany in the sub-tropical and tropical regions. The larvae attack the leading shoots of plants, causing multiple branching and stunting of the saplings and retarding their development, but seldom cause their death. Shoot borer is generally high on the poor soils when the trees are exposed to wind. It is difficult to control due to short duration of external life of the larvae. However, it is reported that threat of shoot borer can be controlled by extensive pruning until 3 years after planting and prevention of arrival of adult moths for laying eggs by planting repellent trees around the plantation or by raising mixed plantation. Further, it reported that it can be controlled to some extent by application of a solution of 0.5 per cent lead arsenate paste.

Recently, a heartwood borer (*Apate monachus*, *Coleoptera: Bostrychidae*) has been reported in in 3-years-old big-leaf mahogany plantation in Anaikatty, Coimbatore, Tamil Nadu (India) in April, 2016 by Durai and others (2019). It is another potential pest causing severe damage in young mahogany trees. The pest damage is characterised by a small hole in the trunk, from where the shot-hole-borer enters constructing tunnels, and producing lot of saw dust while feeding the wood. Mechanical control measures may be adapted to control this pest when the pest infestations are sporadic. Natural enemy, *Sclerodermus* species and other braconid species (*Glyptodoryctes*) may also be helpful to control this pest.

Properties of wood

When freshly sawn, the heartwood ranges in color from

yellowish-white to salmon pink, but after exposure to air and light its color changes to a rich golden brown. For example the wood of Peru and Brazil tends to be darker color and slightly heavier than that of Central America. A characteristic feature of mahogany wood is its high natural lustre. The grains may be straight or interlocked, and grains irregularities produce a wide variety of such figures as fiddle-back, blister, stripe, swirl, crotch, and mottle. Texture is uniform, and the wood is without odour or taste. Most mahogany samples falls either in very resistant or resistant category. The presence of ripple marks on flat-sawn surfaces will generally separate Swietenia species from the other woods called mahogany. The woods most closely resembling true mahogany in gross appearance are the West African mahogany (*Khaya Ivorensis*).

Adult borer

Tunnels in infected tree

The wood is moderately hard and heavy (weight 560 kg/m^3). The mean density of young plantation wood (<40 years old) is 16.3% lower than older plantation wood (>40 years old). Likewise, the density of mature plantation is 11.5% lower than that of natural forest. The density of mahogany wood of Honduras and Puerto Rican is 540 kg/m^3 and 470 kg/m^3 whereas in Asian countries (Hawaii, Fiji and Philippines), it is ranged from 510-570 kg/m^3. The density of mahogany wood of Indian origin is 551 kg/m^3. Growth rings are distinct, both true and false rings occur. The Indian mahogany is superior quality with

respect to weight, hardness and resistance to splitting and is inferior for strength, stiffness and figure when compare with Central American mahogany. The total tangential and radial shrinkage of young mahogany trees (<40years old) are 83 and 44% respectively higher than those of natural forests. Similarly, the total tangential and radial shrinkage of older mahogany trees (>40 years old) is 54 and 40% respectively higher than those of natural forests. The longitudinal MOE of forest timbers ranged from 9490 to 13020 MPa with mean of 10960 MPa. However, the MOE of plantation timbers are not significantly differ from that of naturally grown timbers. The MOR values of plantation timbers are significantly differ from that of naturally grown mahogany timbers. Timber is easy to season by both air- and kiln seasoning. The fact that mahogany is a very easy wood to work has been known to wood craftsman for many years. The machining properties of big-leaf mahogany wood are highly comparable with that of 25 American hardwoods. The quality of big-leaf mahogany wood is comparable to that of teak wood with respect to specific gravity, weight, stiffness, shock resisting, retention and refractoriness.

Timber value

As said earlier that the Kerala state has largest area of mahogany plantations in India. The Kerala State Forest Department (KFD) has notified schedule rates for mahogany timbers periodically. As per the KFD schedule rates during 2004-2006, the mean price of Grade –I and Grade II of mahogany timber is Rs. 23,205/m^3 and Rs. 12,881/m^3 respectively. The scheduled rates of Grade –I and II of mahogany for 2013-14 and 2014-15 is 38,290/m^3 - and 15,430/m^3, respectively. In the international market, the price of sliced veneer- export quality and sawn wood-export quality is US$ 1743/m^3 and US$ 1570 -1655/m^3. If the price of sawn wood of mahogany timber (6 ft. length) is US$ 1570 -1655/m^3 in 2020 considered, the predicted timber yield and income per ha in 15-30 years rotation is 200 - 501 m^3/ ha and US$ 3,14,000 – 8,29,155 /ha (equivalent to Rs. 2.38- 6.3 crore), respectively.

Particulars	Average of 3 years (2004-2006)	2007-2009	2013-2015	2020
Indian market-Kerala (Rs.)				
Mahogany IB logs	23,205.00	25,530.00	38,290.00	
Mahogany IIB logs	12,881.00	14,170.00	15,430.00	
International Market ($)				
Export sliced veneer	-	-	-	1743
Export sawn wood	-	-	-	1570 -1655

(Source: www.forest.kerala.gov.in, www.itto.org)

Uses

Mahogany wood is a medium-weight timber with reddish or pinkish colour, having attractive appearance, can be worked easily with hand tools and has excellent finishing qualities with high dimensional stability and durability. It polishes well and does not crack or bend. It is used for construction, plywood, high-grade furniture and cabinet making and also suitable for panelling, framing, flooring, automobile bodies, interior trim of boats, radio and phonograph cabinets, bodies of musical instruments, mouldings and other ornaments. USA and UK are leading importers of mahogany wood and Peru and Brazil are the largest exporters in the world. Genuine mahogany is tapped as “cure-all medicine” and “Queen of Plant” as it is used for common illnesses viz. diabetes, arthritis, rheumatism, gout, diarrhoea, fever, malaria, cough and high blood pressure. Seeds are traditionally used for high-blood pressure, hypertension, diabetes and malaria. Crushed seed’s decoction is used to treat skin ailments and wounds. Amazonian Bolivian ethnic groups use seeds to induce abortion. Seeds are used for treatment of cancer, amoebiasis, coughs, chest pains and intestinal parasitism. The seed oil appears to be useful as a moderate drying oil, and also in soap-making.

www.ilma.org.in

INDIAN LAMINATE MANUFACTURERS ASSOCIATION

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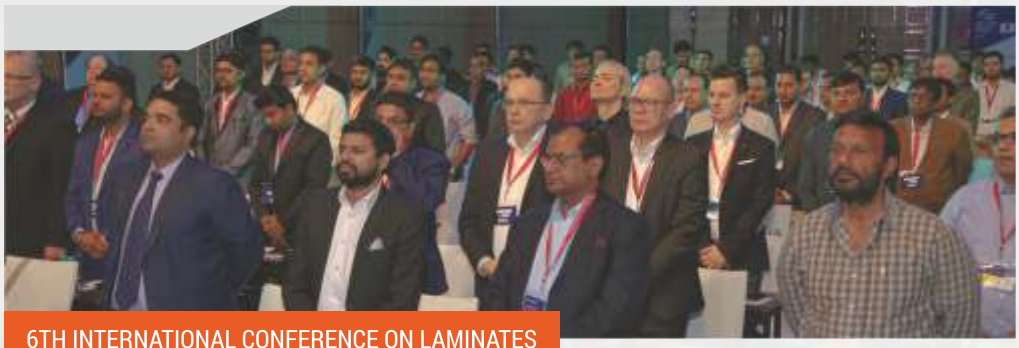

6TH INTERNATIONAL CONFERENCE ON LAMINATES

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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Acrocarpus fraxinifolius Wight & Arn.: a potential timber resource for furniture and other wood-based industries

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The government of India has so far identified 20 sectors including furniture industries where India can meet domestic demand as well as become a global supplier (Chakraborty, S. Business Standard July 23, 2020). India despite having skilled carpenters and artisans, traditional knowledge and design continues to import furniture and wood products. But now with the focus of the government various t department are giving attention towards the updating the existing policies, regulations in supporting the wood-based industries of the country to become the world furniture hub, so that mass manufacturing can take place at competitive prices. Furniture and other wood based industry have great potential for growth, employment opportunities and export potential. It is estimated that the Indian domestic furniture market will expand at a CAGR of 12.91% during the period of 2020-2024. (Jha, 2020, Trade Promotion Council of India). Currently, China is the leading exporter of furniture followed by Germany, Poland, Italy and USA. Furniture sector in India is under-developed. The key factors for the rapid increase in demand for furniture and other wood based products are growth of housing sector with wooden interiors and floors, commercial construction and also increase in income levels to adopt global lifestyle options. The modernization of wood based industries with machine and technology, availability of locally grown raw materials, technically qualified and experienced work force will help the growth of this sector as it has huge export potential also. But wood and wood based industries are facing shortage of raw materials and depend mainly of import of wood logs/sawn timbers. Therefore, India to become competitive and world manufacturing hub in furniture and other wood based industries, it is most important to ensure sustainable supply of wood. Without the sustainable source of wood, all the activities and efforts can't make any success in furniture and allied wood sectors. Therefore, the focus on supply of locally grown wood to the sector is necessary. To meet the growing demand of wood, raising plantations of fast growing tree species is best alternatives of the forest based timber species. Thus, to achieve the sustainable source of supply of wood, lesser known and fast growing tree species that can provide good quality wood should be identified, and need to be grown. *A. fraxinifolius* is a good candidate for timber plantations as it has suitable wood properties to be used in furniture and other wood based industries. Also it is easy to raise in the nursery, its survival after planting is generally very high and it grows fast. It usually develops a single and clear bole, making it suitable for pole production also.

About the species

A. fraxinifolius, a member of sub-family Caesalpinioideae of Fabaceae family, is a large deciduous, fast growing species, commonly known as Mundani, pink cedar and shingle tree, having its natural habitat in the evergreen forests of Western Ghats, chiefly on hill slopes up to 1220 m. It is grown for shade in coffee and tea plantations, sometimes also in timber plantations and as

windbreak. It is softwood and fast growing species with high survival percent with volume of wood produced after 4 years 10,663.37 cm^3 and the mean annual increment of biomass was 2,625 cm^3 per year (Bhat et al. 2002). Based on their studies using survival rate, mean annual increment of collar diameter, height and volume, the rank sum for *A. fraxinifolius* was found as 62, which was highest in 16 species studied and recommended it for afforestation and plantation purposes. Further the high growth was registered in cool soils and with good sun exposure and a yield of 47.5 m^3/ha/ year was observed (Martínez et al. 2006). Kumar et al. (2014) studied the effect of diameter and plant spacing on growth of A. fraxinifolius under mid hill conditions of Himachal Pradesh. The overall growth performance of the species was best at 3 m × 3 m spacing. The tree height, bole height, basal area, stem volume,

crown height, crown width and crown area increased significantly with increase in diameter as well as with spacing. This tree species is suitable for social forestry as well as agroforestry (Nath et al., 011).

Wood properties

The heartwood is pale pinkish, bright red to reddish brown with darker streaks, distinctly demarcated from the pale yellowish sapwood. The grain is straight to slightly interlocked, sometimes wavy, texture coarse and even. The wood is lustrous. Proximate analysis of wood revealed the percentage of cellulose, hemicellulose, lignin, ash, moisture and extractive contents as 35.40, 29.72, 24.71, 0.74, 7.06 and 9.43 percent respectively, The basic density of wood and fibre lumen width were reported as 437.45 kg m^{-3} and 8.59 µm respectively (Anbu, 2014). The wood density and consequently, the wood properties may vary with respect to place and age of the tree as in India, it 437.45 kg m^{-3} (Anbu, 2014) while in USA the basic specific gravity was 587 kg m^{-3} (Simpson 1996). The wood possesses the working properties as easy to saw and work. Due to resin, teeth of saw often get clogged; finishes well, takes good polish. Colour of sapwood yellowish to greyish-white, heartwood light pinkish or reddish-brown, hardness is soft to moderately hard, weight is moderately heavy, 690 kg/m^3 at 12% moisture content. The bending strength (modulus of rupture-MOR) and bending stiffness (modulus of elasticity-MOE) of air dry wood were found to be 1,119.8 kg/cm^2 and 154,500 kg/cm^2 respectively (Nazma et al. 1981).

Durability

A. fraxinifolius wood registered reasonably good life of 9 years in durability performance treated with creosote. The treated wood deteriorated 60 % at the end of 17 years (Rao et al. 1998). The outer and inner decay class of heart wood of *A. fraxinifolius* was reported as class III, also the durability class of field testing of wood was III (Sundararaj et al. 2015). The studies on the heartwood of 12-year-old *A. fraxinifolius* tree revealed as non-resistant to the action of *Laetiporus sulphureus* fungus, according to Findlay criteria, while the sapwood corresponds to the perishable group and classified pink cedar wood as half-heavy (Suirezs et al. 2015). Untreated wooden stakes of this species were reported as very perishable against termite and non-durable against fungi. However, CCA treated timber stakes was found to be durable (10-15 years) (Desalegn et al. 2007).

Uses of wood

Wood of *A. fraxinifolius* is mainly used for making particle boards, plywood, building and construction, packing cases, shingles, honey bee boxes, etc. (Parthiban et al. 2019). This tree species is also reported to have potential for timber production as well as shade tree under coffee and cardamom plantations (Radhakrishnan et al. 2010). Firmino et al. (2015) described that it produces a reddish-brown hard wood which may be used for construction, furniture and pulp production. Nazma et al. (1981) described the properties and uses of *A. fraxinifolius*. wood as it is mostly used for poles and fence posts; building construction; tool handles; heavy backing cases, crates; tea chests; general purpose plywood (Class I); flushdoor shutters; blockboards; core and face veneers; lorry and bus bodies. The classification of A. fraxinifolius wood based on their seasoning behavior and refractoriness was Class B and kiln schedule was III (Anon. 1993). Further, Suirezs et al. (2015) mentioned that due to its less natural durability and apparent specific weight characteristics, it can be used in furniture and interior constructions.

Uses in panel products

(i) Particle Board

The quality of panels made using wood of *A. fraxinifolius* were evaluated using European standards (Trianoski et al. 2011), density (EN 323:2002f), moisture content (EN 322:2002e). Mechanical properties analysed were static bending (EN 310:2002a) and internal bond (EN 319:2002d). The experimental results were compared with the requirements of EN 312 (2003) standards. The Average values of board density, compaction ratio and moisture content were 0.75g cm^{-3}, 1.65 and 10.22 respectively. Average values of water absorption were 19.17 and 52.53% and thickness swelling as 13.02 and 24.58% after 2 and 24 hrs respectively). Bending strength properties of the particleboard were 18.19 MPa (MOR) and 2.13 GPa (MOE)) while internal bond strength was found to be 1.50 MPa. Panels produced using wood of *A. fraxinifolius* exhibited higher average values than the requirements outlined in the EN 312: 2003 Standard. The minimum internal bond value prescribed in the EN 312:2003 Standard is 0.35 MPa and hence internal bond is also higher than the standard.

(ii) Plywood

Parthiban et al. (2019) studied the properties of plywood made by *A. fraxinifolius* and found that all the required properties were satisfactory and within the prescribed limits. The recovery of veneer from the A. *fraxinifolius* exhibited 63.19% which is very good for making the plywood. The plywood was tested positive at the 72-h boiling test. Wood quality studies in terms of wood density and shrinkage for plywood were 607.0 $kg/m^3$and 6.44% respectively. The plywood properties in terms of the flexural strength (MOR,), stiffness (MOE), were 43.5 N/mm^2 and 4357.50 N/mm^2 respectively. The water absorption (%) and thickness swelling (%) were found to be 21.0% and 4.2% respectively. The *A. fraxinifolius* wood exhibited higher veneer yields coupled with acceptable shrinkage, and therefore this species can play a vital role in plywood production. Plywood properties revealed that tested positive for the boiling test. The mechanical properties of plywood such as MOE and MOR showed that the plywood made out of the wood exhibited accepted values. As per the list of species for plywood manufacturing in IS 4990 (Anon. 2011), the wood of *A. fraxinifolius* can be used in manufacturing of plywood.

Conclusions

A. fraxinifolius is fast growing species and widely planted within and outside its natural area of distribution. The heartwood is pale pinkish, bright red to reddish brown and medium-weight. The wood is reported to be suitable for indoor construction, furniture, fence posts, beehives, boxes, packing cases, roof shingles, veneering, plywood, particleboard and other wood based industries.

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Usage of wood: the most sustainable material

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Wood application in India

Since ancient times in India, wood has been used for many applications such as building structures, bridges, furniture, etc. However, consumption of wood was in sustainable manner as the source of wood was almost perennial. With colonization, World Wars and post-independence agricultural reforms, unsustainable harvest of wood continued for a long period. However, formulation of the National Forest Policy (NFP) in 1988 put timber logging secondary to biodiversity conservation. The Policy further envisaged to relieve the existing pressure on forests for the demands of railway sleepers, construction industry (particularly in the public- sector), furniture and paneling, mine-pit props, paper and paper board, etc. through substitutes of wood. These substitutions have come in the form of materials, which are non-renewable and having more Carbon foot prints. The concepts of climate change and life cycle assessments were not in vogue then. In 1993, Central Public Works Department had banned to use Wood in their construction across the country. Then in 1996, the Honourable Supreme Court of India passed an order that led to a complete ban on felling of trees or timber logging in government forest areas, except those with approved Working Plans.

Wood substitutes

By 1990s, the market for wood substitutes had started growing and this gained momentum due to the ban on wood usage and timber logging. Wood substitutes can be wood-based or non-wood based. In the past three decades, we have witnessed transformation where wood substitutes, whether wood-based or non-wood based, have taken the industry by storm and have become synonymous with building material. Gone are the days when furniture was meticulously crafted with wood. Today, MDF (Medium density fibre board) or Particle board are the most common furniture materials used and have become household terminology. So is the fact that to a layman, building construction means concrete 'pillars and mould' (representing RCC framed structure with columns, beams and slab). By industrializing construction sector, the capital has also diverted from artisan to industry.

Growth of non-wood based substitutes has greatly changed construction practices leading to energy intensive substitutes such as concrete, steel, aluminum, PVC, Ferro-cement, etc. in large and small construction works. These substitutes depend on non-renewable sources of raw materials and include polluting, energy-intensive and carbon-generating methods of production. Non-renewable resources such as Iron and Manganese ore are needed to produce steel, bauxite is needed to produce Aluminum, limestone for cement and petroleum for plastics. Apart from that, the embodied energy of these materials are very high such as 330 MJ for Aluminum Sheet vs 4.1 MJ for air-dried sawn timber. (IFC India Construction Materials Database Methodology Report)

The production process is so energy intensive that same quantity of Aluminum sheets consumes 69 times more energy than soft wood timber (200.47 million BTU for Aluminum sheets, 50.32 million BTU for steel sheet, 8.77 million BTU for concrete blocks whereas only 2.91 million BTU for softwood timber per tonne) (India environment portal article 'The See saw approach' 1994).

On the other hand, Wood based substitutes are generally made from agro-wastes such as bagasse, rice husk and cotton stalk or from wood that cannot be used as timber, such as twigs and small branches. India has a thriving range of industries for semi-processed and value-added timber products, pulp and

paper, plywood, veneer, wooden furniture as well as wooden handicrafts. Substitutes such as Particle board, MDF boards, laminates, hardboard, cork, bamboo, etc. find application in furniture making, flooring and other construction related uses.

Life cycle costs and carbon footprint of building materials

With the climate change as an impending threat to the future of the planet, it is time to reconsider our material and resource usage in construction sector which currently leads to almost 32% of global final energy usage and 19% of energy-related greenhouse gas (GHG) emissions (IPCC fifth assessment report, Chapter 9). Life cycle emissions or equivalent Carbon footprint is a measure of the direct and indirect GHG emissions associated with all activities in the life cycle of a product, good or service. Below-mentioned is the comparison of life cycle emissions of wood versus wood substitutes, both wood based and non-wood based.

Full-lifecycle assessment shows high GHG reduction potential in wood products as wood is renewable, biodegradable material which consumes lesser energy in manufacturing. Making wood based substitutes with the waste generated in wood processes helps biomass substitution.

Even after wood has been converted into another

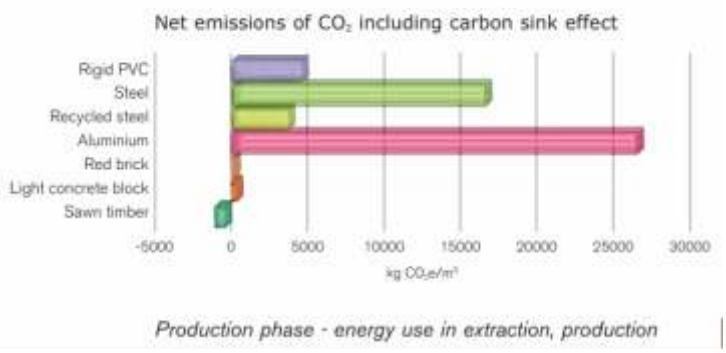


Fig 2: Comparison of CO_2 production phase (energy use in extraction and production) of different materials (net CO_2 emissions including carbon sink effect) (Source: Tackle Climate change:Use Wood, Pg 34)

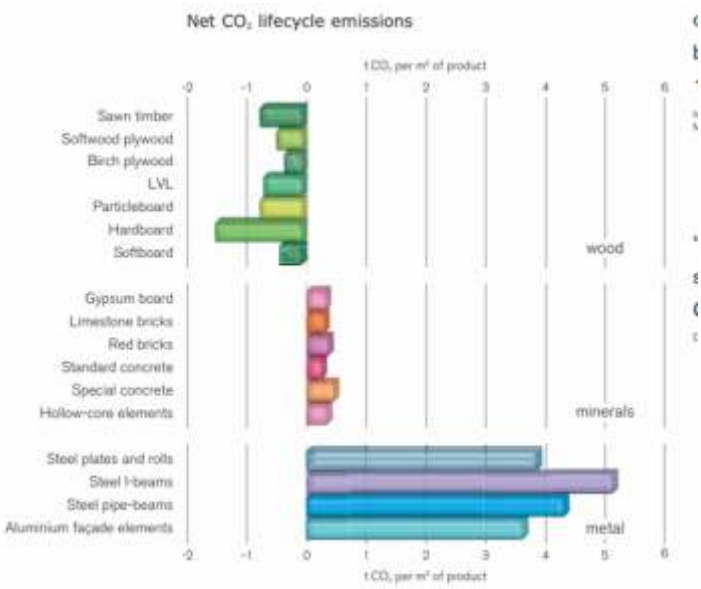


Fig 1: Net CO_2 Lifecycle Emissions (Source: Tackle Climate change:Use Wood, Pg 38)

product, it continues to store Carbon within and hence even at the end-of-lifecycle of the product, it remains a long term Carbon store. Apart from this, trees will also contribute to Carbon sequestration (fixing of Carbon in trees and its retention in wood products) and hence wood products create a significant net sink and Carbon store. Thus usage of wood and wood products will largely help offset CO_2 emissions of construction industry.

Use of wood products is a greener alternative to more fossil fuel intensive materials. Usage of a cubic metre (m^3) of wood instead of construction materials like concrete, blocks or bricks results in the significant average of 0.75-01 tonne CO_2 savings. The combined effect of Carbon storage and substitution means that 01 m^3 of wood stores 0.9 tonne CO_2 and substitutes 1.1 tonne CO_2 - a total of 2.0 tonne CO_2. Wood's unique end of life property such as recyclability and of energy gain makes for emissions-neutral energy recovery and low energy recycling. It can be recycled into by-products such as sawdust, chips, particleboard, panel products and can be used as a substitute for fossil fuels, providing a renewable energy

Other building products	CO_2e g/kg	CO_2 uptake g/kg
Aerated Concrete Block, Europe	442	-
Reinforced Aerated Concrete Block, Europe	511	-
Aluminium extrusion profile, Europe	2264	-
Aluminium sheet, Europe	2980	-
Ceramic Tile, Finland	613	-
Stainless Steel, Cold Rolled	3778	-
Copper Sheet, Europe	973	-
Copper tube, Europe	981	-
Copper wire, Europe	788	-
Crushed stone, Europe	14	-
Float Glass, Europe	1230	-
Gravel 2/32, Europe	3	-
Gypsum plaster, Germany	243	-
Gypsum stone, Germany	3	-
Lightweight Concrete Block, Europe	240	-
Polyethene (LDPE), Europe	2130	-
Pre-cast Concrete 20/25 (Europe)	121	-
Sand 0/2 (Europe)	2	-

Fig 3: Carbon footprint for other building products

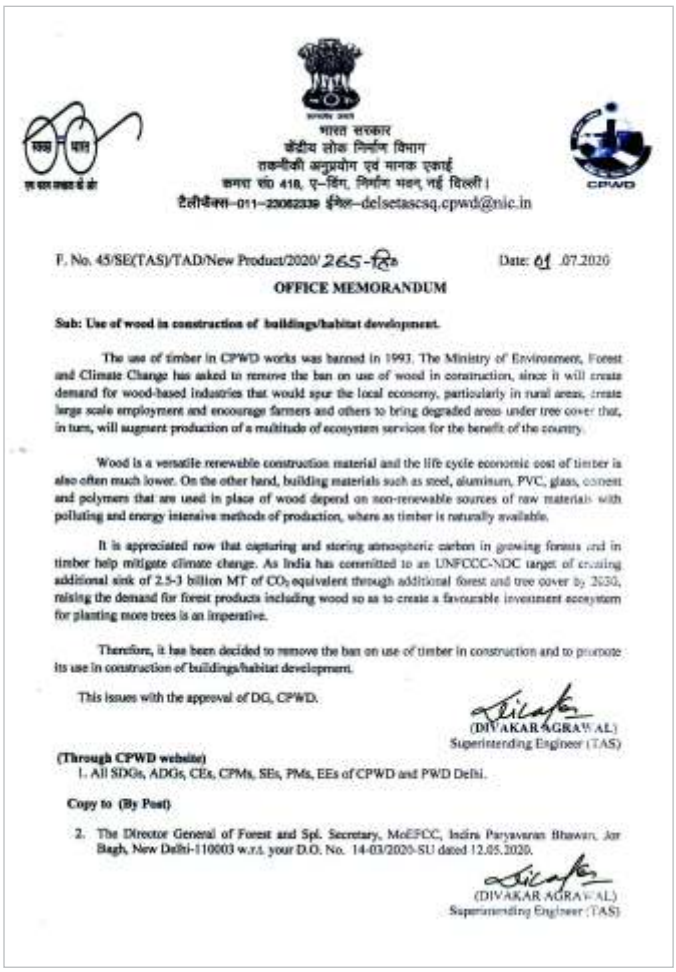
source. Overall, Forestry and wood products can make a significant positive contribution to the country's Carbon balance.

The above figures show that timber is the most sustainable material to be used and hence we must capitalize on these CO_2 savings by using a greater proportion of wood products, using wood products with a longer life, and substituting wood and wood-based products for energy-intensive materials in construction industry.

Since wood is a versatile renewable construction material and the life cycle economic cost of timber is also often much lower, MoEFCC took up the matter with CPWD and requested to lift the ban on use of timber in construction of buildings and habitat projects. In July 2020, CPWD removed the ban on use of timber in construction and decided to promote its use in construction of buildings and habitat development.

Wood Product	CO_2e g/kg	CO_2 uptake g/kg
Shipping Dry Timber - Finland	87	1505
Shipping Dry Timber - Sweden	13	1502
CLT - Germany	362	1611
CLT - Italy	408	1610
Dried Timber (Coniferous) - Germany	119	1637
Dried Timber (Deciduous) - Germany	167	1636
Special Dry Timber - Finland	108	1639
Timber, Fresh - Germany	49	1182
Timber, Fresh - Finland	44	1184
Glued Laminated Timber - Sweden	109	1730
Planed Timber - Germany	152	1638

Fig 4: Carbon footprint for timber products (Source: Carbon Footprint for Building Products, VTT technical research Center, Finland, Pg 24)



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टैलीफैक्स–011–23062339 ईमेल–delsetascsq.cpwd@nic.in

F. No. 45/SE(TAS)/TAD/New Product/2020/265-हि Date: 01.07.2020

OFFICE MEMORANDUM

Sub: Use of wood in construction of buildings/habitat development.

The use of timber in CPWD works was banned in 1993. The Ministry of Environment, Forest and Climate Change has asked to remove the ban on use of wood in construction, since it will create demand for wood-based industries that would spur the local economy, particularly in rural areas, create large scale employment and encourage farmers and others to bring degraded areas under tree cover that, in turn, will augment production of a multitude of ecosystem services for the benefit of the country.

Wood is a versatile renewable construction material and the life cycle economic cost of timber is also often much lower. On the other hand, building materials such as steel, aluminum, PVC, glass, cement and polymers that are used in place of wood depend on non-renewable sources of raw materials with polluting and energy intensive methods of production, where as timber is naturally available.

It is appreciated now that capturing and storing atmospheric carbon in growing forests and in timber help mitigate climate change. As India has committed to an UNFCCC-NDC target of creating additional sink of 2.5-3 billion MT of CO_2 equivalent through additional forest and tree cover by 2030, raising the demand for forest products including wood so as to create a favourable investment ecosystem for planting more trees is an imperative.

Therefore, it has been decided to remove the ban on use of timber in construction and to promote its use in construction of buildings/habitat development.

This issues with the approval of DG, CPWD.

(DIVAKAR AGRAWAL)
Superintending Engineer (TAS)

(Through CPWD website)
1. All SDGs, ADGs, CEs, CPMs, SEs, PMs, EEs of CPWD and PWD Delhi.

Copy to (By Post)

2. The Director General of Forest and Spl. Secretary, MoEFCC, Indira Paryavaran Bhawan, Jor Bagh, New Delhi-110003 w.r.t. your D.O. No. 14-03/2020-SU dated 12.05.2020.

(DIVAKAR AGRAWAL)
Superintending Engineer (TAS)

ADVANCED WOODWORKING
TRAINING CENTRE

Advanced Woodworking Training Center (AWTC) started in 2003 as an Indo-Italian joint project between Institute of Wood Science and Technology (IWST), Bengaluru, Italian Trade commission (ICE) and the Italian Woodworking Machinery and Tools Manufacturer's Association (ACIMALL). The Centre, presently being run by IWST, is regularly offering throughout the year following two advanced wood working training courses.

A. One Year Diploma Course in Advanced Woodworking

B. Certificate Course in Wood Product Designing and Development
Level 1 : Conventional Wood working and Finishing (4 Weeks)
Level 2 : Product Designing and Development on CNC Router (4 Weeks)
Level 3 : Product Designing and Development on PYTHA 3D (2 Weeks)

Aim of the Course: To enhance the skill in the area of woodworking to attain global competitiveness by using state-of-the-art machineries. Upon successful completion of trainin, the trainees will be able to handle advanced woodworking machines for product development. The centre will also liaison with wood based industries for placement.

Target Group: Individuals / Students / Carpenters / Persons working in wood based industries.

IWST is a premier research institute under the aegis of Indian Council of FOrestry Research and Education (ICFRE), of the ministry of Environment, Forests and Climate Change, Government of India. Being the only institute in the country dedicated to the cause of Wood Science & Technology, the institute is recognized as Center of Excellence in Wood utilization. With a specialized team of scientists, the institute is carrying out frotier research in wood identification, processin, wood composites, wood modification, wood protection, wood energy, wood quality assessment and tree improvement.

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