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Vol. 2, Issue 1, April - June 2021

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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सत्यमेव जयते

भूपेन्द्र यादव
BHUPENDER YADAV

FOREWORD

Bamboo is a wonder plant which is a fast-growing sturdy grass that can be important nature-based solution to a number of pressing global challenges, for livelihood development, green trade, climate change mitigation and environmental protection. A grove of bamboo release 35% more oxygen than an equivalent stand of trees. Because of this, planting bamboo is a great way to reduce the carbon footprint and address the challenges of global warming. Bamboo thrives in a wide range of climates and bamboo litter and root mass would help to conserve the soil and moisture to a great extant.

Apart from its ecological value, bamboo is an excellent raw material for furniture and construction industries. Moreover, bamboo can be harvested within four to five years whereas the hardwood species like Teak would take at least forty years to mature before they can be harvested. Bamboo's versatility as a substitute for hardwoods offers a great chance to reduce pressure on natural forests. Bamboo was termed as poor men's timber but perception about bamboo has changed gradually and now it is considered as a most sustainable alternative to wood which can match steel and plastic in strength and the elasticity. The government of India recently amended the Indian Forest Act, 1927, and the new changes can transform the bamboo sector. After amending Section 2(7) of the Act, bamboo is no longer a tree and felled bamboo too is not timber. So any bamboo grown in private or homestead land by millions of farmers does not require a felling permission or transit permission from any state forest department. The Prime Minister of India has rightly pointed out that, "thousands of small scale farmers and other livelihoods dependent on bamboo trade and cultivation will be positively impacted" by this amendment.

There are more than 1600 species which contribute in livelihood of more than 1 billion people. During last decades of 20th century more than 1500 uses of bamboo were highlighted which are increasing further with novel uses. Bamboos are being used in sectors like construction and housing, paper and boards, wood and furniture, food, energy, fibre and handicrafts. Presently in India, bamboo products are manufactured in cottage industries with traditional designs and low quantity production. Though there is a traditional domestic market, globally Indian bamboo products have to find a better market which has already been captured by Chinese, Vietnamese, Indonesian and Italian products. This sector needs

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premium products, process improvement, contemporary designs, appropriate testing and adoption of standard operational protocols, joineries and better finishing for global as well as mainstream domestic market .One may also explore the possibility of innovative Production Linked Incentive Scheme for promoting manufacturing of Bamboo based Products to upscale the utilization and development of this vast eco-friendly resource.

India has a great responsibility as it has committed itself to create an additional carbon sink of 2.5 to 3 billion tonnes of carbon dioxide equivalent by the year 2030. This also creates farmers to double their agricultural income by taking up bamboo based agroforestry along with regular farming. Institute of Wood Science and Technology, Bengaluru (an institute under the Indian Council of Forestry Research and Education) has been continuously striving to enhance the knowledge on adoption of emerging techniques and prudent utilization of wood and bamboo based materials. The institute has been successfully publishing a quarterly magazine "Wood is Good: Grow more, Use More" to disseminate the scientific information and applied knowledge in this sector. The magazine is widely circulated and it has generated great interest among concerned industries and end-users about the latest developments in wood science and technology. The present issue of the magazine is dedicated to various aspects of Bamboo as a promising resource in the construction and furniture industry. I hope that this popular magazine will act as a useful source of information to recognize and realise the country's potential and capture the domestic and export markets and sustained income to bamboo based farming community.

Date: 11.08.2021

(Bhupender Yadav)

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Sponsor Booth			
• Customised booth options • 10 documents/brochures & Videos • Video call and chat integrations • Business Cards • Customized Call to Action Buttons • WhatsApp integration • Meeting Lounge Access • Conduct up to 4 Webinars* • Branding during webinar • Branding across lobby	1,44,000	82,800	45,000

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The Mission envisages promoting holistic growth of bamboo sector by adopting area-based, regionally differentiated strategy and to increase the area under bamboo cultivation and marketing. Under the Mission, steps have been taken to increase the availability of quality planting material by supporting the setting up of new nurseries and strengthening of existing ones. To address forward integration, the Mission is taking steps to strengthen marketing of bamboo products, especially those of handicraft items.

Contact : Ms. T. Pooja Mobile: +91-900 899 6091 Email: t.pooja@jaatre.live

Going Live on "World Bamboo Day" on Sep 18th , 2021

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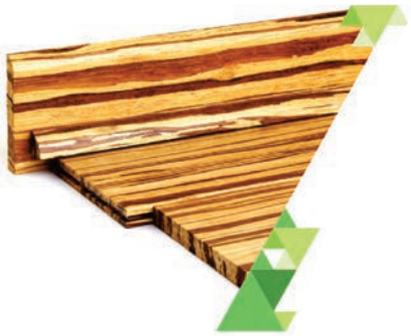

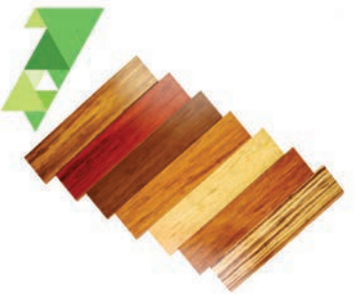

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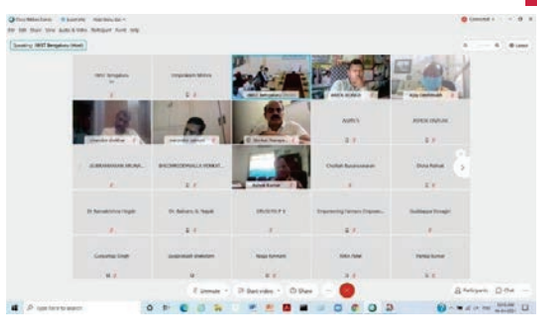
IWST Activities during April-June 2021

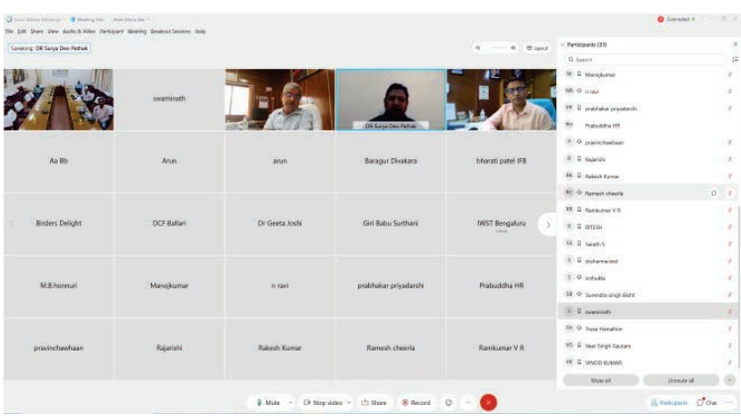
Azadi Ka Amrit Mahotsav (India@75) - Online Question-Answer Session on Propagation and Cultivation of Indian Sandalwood



Commemorating Azadi Ka Amrit Mahotsav (India@75), Institute of Wood Science and Technology (IWST), Bengaluru, successfully conducted an online open Question and Answer session on "Propagation and Cultivation of Indian Sandalwood" on 16th April 2021 under the chairmanship of Dr. M.P. Singh, Director, IWST. The programme was coordinated by Dr. A.N. Arunkumar and 128 participants from different parts of India had registered for this event and subject matter experts of IWST answered the queries of the participants on various aspects related to the topic.

Webinar on Weeds to Wealth

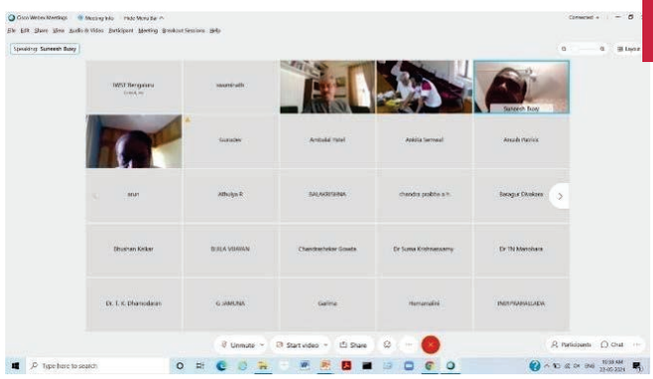
A webinar on "Weeds to Wealth" was organized by the Institute of Wood Science and Technology, Bengaluru on 23rd April 2021 under the Chairmanship of Dr. M. P. Singh, IFS, Director, IWST. Dr Siddappa Setty, Fellow and Convenor from Centre for Environment and Development, Ashoka Trust for Research in Ecology and Environment, Bengaluru delivered the lecture on the topic "Weed to Wealth". In his lecture he shared his past 27 years research experience on various aspects of *Lantana camera* - an obnoxious weed from Male Mahadeswara Hill and Biligiri Ranganatha Swamy Temple Tiger Reserve, in Karnataka and how livelihood opportunity was created using this weed. Using statistical data, diagrams and sate images very elaborately explained about the extent of spread of *Lantana camera* in India and Karnataka in particular and how rapidly it is spreading and occupying the major forest area, its effect on regeneration of native flora and fauna and on soil health. Further, he explained how this weed was utilized for livelihood support of tribal communities of BRT and MM Hills by making handicraft items, briquettes, particle board etc. about 50 participants were participated in the webinar including senior forest officials from Karnataka Forest Department, Director IPIRTI, Scientists and Forest officials from Institute of Forest Biodiversity, Hyderabad, ICFRE Dehradun, Forestry colleges and other sister organizations etc. The detailed discussion was held on methodology to be adopted for mapping of Lantana, uprooting / eradication of Lantana and to how we can make best use from it by preparation of handicraft items and value addition, briquettes and particle board preparation in a larger scale using improved technology and energy resource and also providing marketing link to the products including online marketing with the help of E-commerce giants.



Celebration of Biodiversity Day through Virtual meeting

A virtual meeting for the celebration of International Biodiversity Day was organized on 22nd May 2021 with the theme `***Forest Biodiversity Conservation, Development and Utilization: Way forward***' by the Institute of Wood Science and Technology, Bangalore. A total number of 80 participants participated in the event.

Dr. Suneesh Buxy, IFS, delivered his inaugural address. In his address he had mentioned about the timely need of conservation of biodiversity in forestry and steps taken by the Government. He pointed out that the Government of India is allocating lot of funds through various schemes including CAMPA for promoting research in the field of forestry and many of the State Forest Departments also came forward to release funds in this regard for biodiversity conservation aspects. He asked the Scientist and Researchers in ICFRE should also formulate projects in this line of research. Followed by, Dr. M.H. Swaminath, IFS, in his keynote address on ***"Biodiversity- Global and National Perspective"*** detailed the basics of biodiversity and new discoveries of flora and faunal diversity including microbes. He also mentioned about the activities undertaken globally in the subject to conserve the biodiversity of various ecosystem and the Acts enacted globally and nationally to conserve the same. Dr. Gurudev Singh, in his keynote lecture on "Biodiversity Conservation for sustainable Utilization" he stressed the need of conserving the biodiversity with various examples and his own studies conducted in the region of Western Ghats. He also mentioned the floral

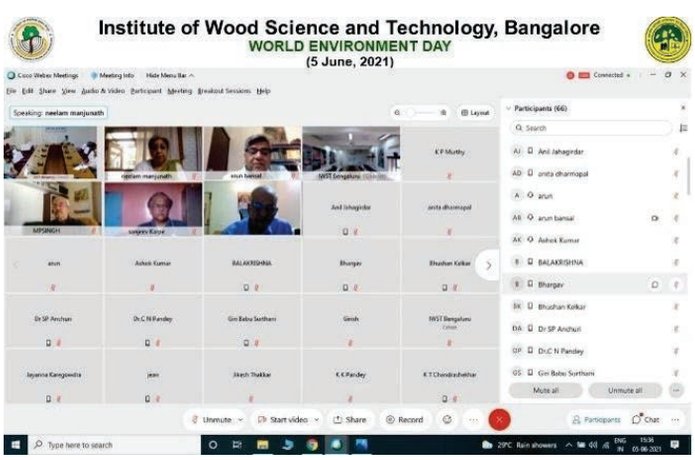


diversity in particular the forestry species and the variations exiting with in species level and its importance based on its utility. He has emphasized about the various threats existing to present genetic resources and the need of involvement of local community during raising of plantations and promoting the in-situ conservation.

Followed by the keynote address of Dr. M.H Swaminath and Dr. Gurudev Singh, the participants were interacted with their views and doubts. Scientists and officers from IWST expressed their views on conservation of various species and the scope of future studies in this line. Dr. Sudhir Kumar, DDG (Extension), ICFRE had given a note on the urgent need of biodiversity conservation and its protection in forestry ecosystem. Dr. M.P. Singh, Director, IWST, emphasized the need of conservation of biodiversity in forestry ecosystem, special attention to be given on endangered forestry tree species. He also pointed out that when promoting any species through in-situ conservation, their utility also to be looked in to.

World Environment Day

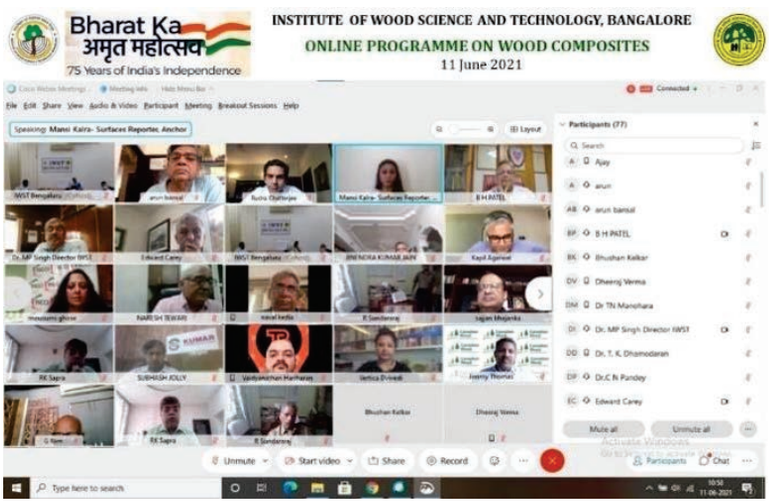
The Institute of Wood Science & Technology, Bangalore celebrated World Environment Day on 5th June 2021 through virtual mode with special emphasis on bamboo. A total of 70 participants from different parts of the country attended the programme. The programme was inaugurated by Shri A.K. Bansal, former Additional Director General, Ministry of Environment, Forest & Climate Change, Govt. of India, who talked about 'unlocking the potentials of bamboo sector in India'. Smt. Neelam Manjunath, Chairperson, Bamboo Society of



India, Karnataka Chapter, delivered the talk on 'mainstreaming bamboo in the construction sector'. Shri. Sanjeev Karpe, Founder Director, Konkan Bamboo and Cane Development Center (KONBAC), Kudal, Sindhudurg district, Mahrashtra, talked about 'bamboo as an inspirational material for furniture and construction industry'. Dr. S.R. Shukla, Scientist-G, IWST talked about 'bamboo – a wonder eco-material for utilization' and presented IWST technologies about use of bamboo in engineered form. Dr. K.P. Murthy, Vice Chairman, Bamboo Society of India, Karnataka Chapter, presented the research/engineering applications of bamboo as a key sustainable material'. Welcome Sir. The programme was concluded with address by Dr. M.P. Singh, Director, IWST. Saplings of various species

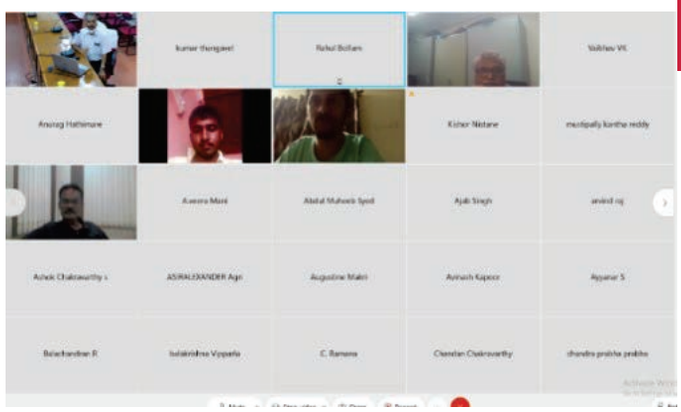
(Sandalwood, *Ficus mysuransis, Multingia calabura* and *Azadirachta indica*) were also planted in the campus during this occasion.

Azadi Ka Amrit Mahotsav (India@75) - online programme on Wood Composites



The Institute of Wood Science and Technology, Bangalore organised an online programme on Wood Composites as part of Celebration of Bharat Ka Amrut Mahotsav. This programme was second in this series. The purpose of this event to tell public about the present status and utilization aspects of wood composites in out country. A total of 80 participants from various organisations and industries took part in the programme. The programme was inaugurated by Mr. Sajjan Bhajanka, Chairman, Century Plywood and President, Federation of Indian Plywood & Panel Industry (FIPPI) who spoke about the present status of panel industries in India. Mr. Rudra Chatterjee, Chairman, Furniture Committee, Federation of Indian Chambers of Commerce and Industry (FICCI) and Mr. Edward Carey, CEO, Manor and Mews spoke about 'Wood composites for furniture making in India'. Mr. Vaidyanathan Hariharan, Executive Member of Wood Technology Association, delivered a lecture on 'Role of adhesives in wood composites & formaldehyde emission parameters. Dr. S.K. Nath, former Joint Director, Indian Plywood Industries Research & Training Institute (IPIRTI), Bangalore delivered a talk on 'Panel products from plantation timber and amending BIS standards. Dr. Jimmy Thomas, Forestry Innovation Consulting India Pvt. Ltd. (FII), Bengaluru talked about wood composites for structural uses. Mr. Mahadev Chikkanna, Founder & CEO, Spectalite, Bangalore spoke about wood plastic composites as promising green-composites for furniture, automotive and other industries. The programme was concluded with the remarks by Dr. M.P. Singh, Director, IWST Bangalore.

Training on Sandalwood Farming and Management of its Health



One day online training on "Sandalwood farming and management of its health" was organized on 30th June 2021 for the benefit of farmers to grow sandal wood in a more healthy and sustainable way. Experts from various divisions gave lectures on different aspects of sandal wood farming. About 250 participants from various states attended the training through WebEx and YouTube. The programme was inaugurated by Dr. M.P Singh, Director, IWST. The first session was on 'Basics and benefits of cultivating Indian sandal wood' by Dr. R Sundararaj, HOD, Forest Protection Division. He enlightened the paricipants with basic concepts of sandalwood farming and shared his practical experience and knowledge with sandal wood farmers. Dr. N. Ravi gave lecture on 'sandal wood seed handling and nursery techniques 'in which he mentioned about processing of sandal wood fruits and seed quality testing. Lecture on 'Management of diseases in sandalwood nursery and plantations, was given by Dr. A. Muthukumar where he explained about various diseases affecting each stage of sandalwood, their symptoms and control methods. Dr. M.V. Durai made presentation on 'Plantation technology in sandal wood-based agroforestry system'. He described about various planting techniques and various agroforestry systems. Dr. B.N. Diwakar gave an important lecture on 'Economics of growing sandal wood'. He provided information about the cost of cultivation of sandal wood and the returns that one can expect from sandal wood in a long run. The final interesting lecture on 'Good silvicultural practices for the best health of sandal wood' was given by Dr. R. Sundararaj. He also emphasized about the harmful effects of injudicious pruning to the farmer with good photographs. There was an interactive session at the end, where the participants raised their queries, for which the experts gave suitable solutions.

Bamboo: a sustainable resource for building an Atmanirbhar Bharat

Suresh Prabhu
Member of Rajya Sabha,
Government of India, New Delhi

The coronavirus epidemic has wreaked havoc on the global economy, and the Indian economy has not come out unscathed. The lockdown dealt a double whammy to the economy, one due to the closing down of all economic activities and two, due to the flight of labour from cities back to rural areas. The large-scale reverse migration of rural populations from cities and industrialized, agricultural & horticulture belts across the country has created immense pressure on the rural economy, that is already dealing with issues of unemployment and under-employment. The government has responded to the distress of the returning migrants by expanding MNREGA works to ensure that they have some work on hand. But a significant majority of these returning migrants are skilled and semi-skilled labour having worked in the industrial & construction industry and service industries like hospitality, logistics, retail as well commercial agriculture and horticulture. MNREGA is unable to offer them opportunities that allow them to utilize their skills and earn livelihoods and can at best be an emergency provision. It was in fact the lack of adequate employment opportunities in their villages and towns that had led to the migration of these populations in the first place.

The time is now opportune to turn the crisis of rural under-employment caused by COVID into an opportunity to rejuvenate the rural economy across the country to build an 'Atmanirbhar' Bharat. We must remember that India was a strong and self-reliant economy in ancient times. The pre-industrialised Indian economy saw a vibrant global mercantile trade where products made by local artisans using natural raw materials had great demand. We must draw lessons from this great economic heritage to grow our footprint in the global market. As we march on this redesigned trajectory in economic growth, we must walk the path of sustainable development, building climate resilience through mitigation and adaptation processes.

Bamboo is one natural indigenous raw material that can play a key role in the rejuvenation of the rural economy impacting, both, the agricultural sector and industrial sector.

Bamboo is one natural indigenous raw material that can play a key role in the rejuvenation of the rural economy impacting, both, the agricultural sector and industrial sector. It is the most environment friendly plant on this planet, being one of the highest carbon sequesters amongst all the floral species. It grows rapidly, matures within a few years and re-grows after harvesting without the need for replanting, making it a perennial 'renewable' resource. Bamboo is also a very effective natural resource to control soil erosion, raise the water table and improve fertility of even the most degraded soils. Bamboo can thus play a key role in combating desertification by restoring degraded lands and protecting forests. Most Bamboo species form an evergreen canopy, shedding leaves all year round and this too contributes to improving soil health. It can be easily integrated into agriculture by growing it on farm boundaries and farmland as well as non-agricultural land including wastelands and degraded lands, and in homesteads. Bamboo thus provides farmers a perennial income, allowing for annual harvests at any time of the year offering them a robust and dependable supplement to an otherwise relatively fickle agriculture.

Bamboo, a woody grass is a versatile material with an aesthetic appearance and lends itself to the manufacture of furniture, lifestyle and interiors products and is increasingly being used to replace timber. The tensile strength of Bamboo is also being harnessed to reduce the use of steel, a high embodied energy resource, in industries like construction and has the potential to generate exponential employment, on-site and

off-site, in the construction industry.

The International Bamboo and Rattan Organisation (INBAR), is a multilateral development organisation that promotes environmentally sustainable development using Bamboo and Rattan. It has 46 Member States. Its unique set-up makes INBAR an important representative for Member States. With over 40 of its Member States from the Global South, INBAR has played an especially strong role in promoting South-South cooperation for the last 20 years. Since its founding, it has been making a real difference to the lives of millions of people and environments around the world, with achievements in areas such as: raising standards; promoting safe, resilient Bamboo construction; restoring degraded land; capacity-building; and informing green policy and Sustainable Development Goal objectives.

In 1998, when I was Union Minister for Environment and Forests, India became a signatory to the INBAR treaty. My Ministry took the initiative to start Bamboo promotion in our country. I also facilitated to establish a not-for-profit organization, Konkan Bamboo and Cane Development Centre (KONBAC), in my constituency, Sindhudurg district of Maharashtra in 2004. KONBAC in partnership with International Network for Bamboo and Rattan (INBAR) focused on the development of Bamboo as a key resource for catalysing an inclusive green economy. One of the key strategies pursued by KONBAC was to work towards positioning Bamboo as a pro-poor credible alternative to timber providing the rural poor and small land holders an opportunity to participate in and benefit from the US$100+ billion wood products market. The second important strategy was to leverage Bamboo's off-farm economic value and opportunity to realize the considerable environmental benefits that it's growing offers.

KONBAC manufactures not only furniture and interior accessories, but also constructs entire building structures made entirely from Bamboo, both in India and abroad. Over the last seventeen years, it has succeeded in changing the perception of Bamboo from being a 'poor man's timber' to a 'rich man's choice' as a credible alternative material of high-quality wood that is currently being used for furniture and construction. This has helped move Bamboo up the value ladder as a material of choice for the environmentally conscious community and for those consumers who seek novelty.

Today, KONBAC has developed a self-sustaining institutional ecosystem and has a fully developed facility for designing, prototyping and productionizing marketable Bamboo products for domestic and international markets. It has also put in place mechanisms to link poor Bamboo producers to larger lucrative markets and has emerged as a model that is being emulated elsewhere in India and abroad. These interventions have provided an income to thousands of people over the last seventeen years. It has also led to the greening of the environment through the plantation of Bamboo. The KONBAC experience demonstrates that the Bamboo sector has the potential to offer exponential entrepreneurship and employment opportunities to rural populations like farmers, youth and women in farm based and non-farm enterprises.

In 2020, I conceptualized the India Bamboo Forum (IBF) as a stakeholder forum of the leaders of the Bamboo sector to bring together stakeholders from across the Bamboo sector to both, spur the replication of their achievements and address the systemic gaps that inhibit the growth of the Bamboo sector, and keep it from holding its place as the driver of the green economy generating exponential livelihoods.

Today the IBF has a membership of 70 bamboo sector leaders across the Bamboo value chain; like farmers, foresters, entrepreneurs, architects, designers, contractors, R & D organisations, skilling institutions, academic organisations, policy makers, bankers, machinery suppliers, and primary & secondary producers. Our resolve is to provide opportunities to all these stakeholders to come together on one platform to share, deliberate and resolve the challenges faced by the Bamboo sector. I am honoured to share that IBF founder member and Director, KONBAC Mr Sanjeev Karpe is a member of INBAR's Bamboo Construction Task Force that supported the International Organization for Standardization (ISO) to develop a new standard on structural design with bamboo pole ISO 22156:2021 which applies to the design of bamboo structures whose primary load bearing structure is made of round bamboo. This standard will encourage stakeholders in the building and construction industry to mainstream Bamboo in residential,

institutional and industrial structures for up-to ground plus one structures. Demand for Bamboo as a raw material will have an exponential impact on the Bamboo ecosystem. It is my firm belief that Bamboo has the potential to make India truly 'Atma Nirbhar'- locally produced, processed, manufactured, and providing incomes to local communities by ushering a new Green Revolution.

Bamboo has the potential to be a key driver for agro-industrialisation due to its low dependence on high-technology or infrastructure, its easy availability in the rural areas and availability of local labour. Further, Bamboo clusters can be developed as hub and spoke models with technology enabled and high skill processes being undertaken at the hub and primary processing undertaken at the village level. This dispersed model of production can lead to exponential employment opportunities for rural communities across the country.

This humble grass, also known as green gold, not only has the potential of rejuvenating the rural economy but is also a key resource for building climate resilience and catalyzing an inclusive green economy in India.

THE INDIAN ACADEMY OF WOOD SCIENCE

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

APPLICATION FOR MEMBERSHIP

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

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

Place: ……..
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)

Unlocking the potentials of bamboo sector in India

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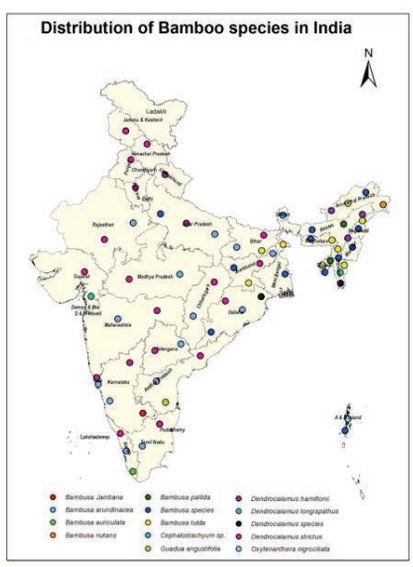
Introduction

Bamboo, the wonder grass, is one of the most important plants used by people all over the world. It belongs to Poaceae or Gramineae; a large family of flowering plants known as grasses that includes the cereal grasses viz. rice, wheat, maize, barley, millets. Bamboos contribute to the subsistence needs of over a billion people in sub-tropical and tropical regions, particularly in Asia and the Pacific. In several regions and states of India, bamboo has been an integral part of people's lives and cultural ethos. Due to its versatility and uses, it is often called "green gold", "poor man's timber", "friend of the people", "even cradle to coffin timber".

It is the fastest-growing woody plant and can grow up to 0.9-1.2 meters/day. Bamboo yields biomass faster than many fast-growing tree species. Bamboo is nature's own engineering material, weight by weight stronger than steel. That is why it is excellent raw material for manufacturing re-engineered products that are both, environment and people friendly alternates to traditional wood products and their substitutes made from metals and plastics. Bamboo has been rightly projected as a natural renewable fiber material of the 21st century having considerable latent potential to contribute significantly towards economic growth, employment generation, and the rehabilitation of vast degraded lands. While contributing to the achievement of India's NDCs and Bonn Challenge, bamboo sector has potential in meeting 6 SDGs related to poverty, affordable and clean energy, sustainable communities and cities, responsible consumption and production, and life on land.

Bamboo resources



India has large bamboo resource, both in terms of diversity and extent, represented by 136 of the total 1,250 species of bamboo in the world, and about 16 million hectares of bamboo-bearing forests (22.47% of its forest cover), which was 50% of reported bamboo resources in Asia and 30% of reported bamboo resources in the world (FAO, 2007). Considering its importance, Forest Survey of India (FSI) has started including a separate chapter on bamboo resources in biennial reports on forests. From these reports, the bamboo-bearing forest area has increased from 13.96 Mha in 2011 to 16 Mha in 2019. Major bamboo forests are in NE States and Madhya Pradesh, Chhatishgarh, Maharashtra, Andhra Pradesh, Karnataka, and Odisha.

The figure shows distribution of natural bamboo species in the Country. Based on their properties and inherent characteristics matching with end uses, 16 bamboo species, both in natural forests and cultivated, were identified to be of commercial importance under the National Mission on Bamboo Applications (NMBA). Very recently, in 2020, National Bamboo Mission (NBM) has zeroed on to 10 species, namely *B. tulda, B. Bambos, B. cacharensis, B. polymprpha, B, nutans, D. asper, D. hamiltonii, Thyrostachys oliveri, Melocanna baccifera*, as commercially important and required by the industry.

Government of India (GoI) has amended the Indian Forest Act in 2017 and omitted bamboo from the definition of tree/timber. Bamboo is included in the definition of MFP in the Schedules Tribes and other Traditional Forest Dwellers (Recognition of Rights) Act, 2006. To

facilitate seamless transport of timber, bamboo and other forest produce MOEF&CC has launched an online portal of national transit pass system for issuing transit permits. It is being piloted in two states — Madhya Pradesh and Telangana.

Traditional Bamboo Uses

Bamboo utilization continues to be an integral part of the culture and socio-economic scenario in many parts of the country. Multiple uses of bamboo integrate several sections of the society in the national economy. These sectors include: bamboo collectors; craft persons who use bamboo for making value added handicraft products, mats, furniture etc.; traders or intermediaries who facilitate transfer of primary processed bamboo materials and products to larger markets or industries; and industrial establishments converting bamboo into manufactured products such as paper, panels, bamboo wood etc. Due to light weight, good tensile strength, and being an almost a ready-to-use natural constructional material bamboo has been a favoured material for rural housing, scaffolding in urban constructions, and pandals for marriage parties and religious functions. Due to the ease of splitting, bamboo has been used in weaving mats and baskets required in agriculture, and for other essential household items. There are some communities in various states like Medars in Karnataka, Basods in Madhya Pradesh, Beteras in Odisha, Korku in Madhya Pradesh have traditional skills in bamboo-crafts. Some artisans, e.g. in Tripura, have special skills in making fancy articles from the epidermal layer of bamboo culms which fetch higher price due to better durability and aesthetics. Total number of bamboo artisans, who earn their livelihood making baskets, mats and a variety of containers and other articles of bamboo for sale, is estimated to be 2 million (ISFR, 2019), which is about 30% of the total number of artisans in the country.

In the North Eastern states, Odisha, Karnataka etc. local people use fresh shoots of several species of bamboo to prepare bamboo prickles and food supplements. Fresh bamboo shoots are called khorisa and bah gaj in Assamese, "hen-up" in Karbi in Assam, kanile or kalale in parts of Karnataka and kardi in Odisha. Bamboo shoots are low in calorie and fat, but have high nutritional value, are rich in vitamins, cellulose and amino acids. In some areas, bamboo culms are also used for cooking rice, called bamboo rice, and for preparing special dish of roasted meat.

Bamboo poles/splits are used as supports in several horticulture and vegetable crops, viz. banana, citrus, grapes, tomato, etc. in many states and this use is having an increasing trend. Mature bamboo culms are also used to make trellis, stakes and shade supports in betel vine cultivation. One species, *Thyrsostachys oliveri*, is used for making fishing rods, javelins etc.

Banslochan (also called tabasheer), a microscopically fine siliceous matter within the inner nodes of some bamboo species, has been used in ayurveda preparations for cough, asthma and also as an aphrodisiac. Other parts of bamboo — roots, leaves, sap — are also used to treat several ailments like cough, bile, fever, swelling, cuts, ring worms, bleeding gums.

Management of bamboo forests

Management of bamboo forests in the country focused on the major industrial use of bamboo i.e. paper manufacturing. National Forest Policy in 1988 brought a paradigm shift in the management of forests in the country as it envisaged forest-based industry to raise the raw material, preferably by establishment of a direct relationship between the factory and the individuals who can grow the raw material. Consequently, long-term leases of bamboo areas given to paper mills were discontinued. Gradually, the paper industry shifted to fast-growing wood species grown by farmers under agro/farm forestry, including hybrid/clonal eucalyptus and Casuarina, agro waste and imported pulp. Annual consumption of bamboo in paper and pulp industry has reduced to a meager 0.3 million tons. Reduced demand for industrial bamboo from paper industries resulted in bamboo forests getting neglected, leading to their deterioration.

In recent years, sizeable bamboo forests have been recognized as community forest resources under FRA 2006 along with management responsibilities with the Gram Sabha.

Bamboo processing technologies

In the wake of reducing timber supplies from forests, several environment and people-friendly technologies have been developed for manufacturing innovative products from bamboo viz (i) wood-substitutes - bamboo mat board (BMB), bamboo mat veneer composite (BMVC), Laminated Bamboo Lumber or bamboo laminates, bamboo strand lumber, bamboo compressed wood, (ii) housing-construction products - bamboo mat corrugated sheets (BMCS) for roofing and bamboo corrugated ridge cap (patent No. 653/MAS/2001).

IPIRTI, a premier organization of MoEF&CC, has been on the forefront in developing bamboo composites and transferring the technology from lab to the industry and some technologies have been commercialized (Bansal et al., 2002; Bansal and Zoolagud, 2002; Bansal and Prasad 2004, Bansal et al., 2013). Other organizations involved in the development/demonstration of similar products include RV-TIFAC, Bangalore. It is important to note that bamboo composites have lower emissions and have low embedded energy compared to similar products of steel and plastics in carbon emissions audit studies underway at IPIRTI as a part of Life Cycle Analysis (LCA) (Sujatha et al., 2014). Indian Standard Specifications have also been developed for several bamboo composites and technologies.

Bamboo based housing

A comprehensive bamboo housing system has also been evolved at IPIRTI Bangalore in collaboration with TRADA Technology of UK and has been used in demonstration houses and eco-tourism in several parts of the country (Bansal et al. 2001). IIT Delhi has also developed bamboo-based constructions in collaboration with NMBA. The strength properties of bamboo-grid wall, bamcrete (bamboo concrete), bamboo panel door, bamboo corrugated roofing sheets, fire resistance etc. have been extensively tested and documented to enhance user confidence. Several NGOs, other organizations, including KONBAC/CIBART, and industries have been associated with the construction of prefab bamboo houses in disaster relief works in earthquake/flood prone areas.

The latest National Building Code of India (NBC 2016) covers bamboo in Part 6 — Structural Design —Sub Section 3B which describes general principles in designing buildings with bamboo and bamboo composite and mentions precautions and design limitations of bamboo constructions. The Delhi Schedule of Rates in July 2012 included some bamboo products in construction: Bamboo Mat Board conforming for wall paneling, wall cladding, false ceiling, partitions; BMCS and BMRC for roofing; Bamboo Wood for flooring, door/window frames, and paneled/glazed shutters for doors/windows. Ministry of Tourism has advised Railway Board, ITDC, all central agencies implementing schemes of Ministry of Tourism, andall State Tourism Development Corporations for using bamboo related items in building works to promote bamboo. Similarly, Ministry of Rural Development in collaboration with IIT Delhi and UNDP has developed a compendium "PAHAL" of housing design typologies using local materials in 15 states, some of which incorporate use of bamboo and bamboo-based construction materials. In November 2018, MoRD issued guidelines for use of bamboo and bamboo-based construction materials in PMAY-G. *However, bamboo and its products are yet to be recognized by the construction industry in the country, due largely to lack of awareness about bamboo and engineered bamboo products as construction/structural material among architects and engineers.*

New Bamboo Products

Considering the vast potential of bamboo as a renewable natural resource, it is necessary to look for newer industrial uses of bamboo, in addition to qualitative improvement in current technologies and uses through continuous R&D and their promotion. Some of the new and emerging bamboo products include bamboo lumber (Mutha Industries, is already making bamboo wood (Epitome Bamboo Wood Products), Bamboo furniture, Bamboo shoots: Bamboo Vinegar, activated carbon (used for cleaning water, air purification. It is also used in air purification, health/beauty products), Bamboo charcoal, bioenergy from bamboo, Bamboo fabric, Bamboo ethanol (a bamboo based ethanol plant is under establishment by Numaligarh refineries in Assam), and utility products like Bamboo water bottles, bamboo tiffin, reusable cutlery, reusable

bamboo straw, toothbrush, pen, pencils, pen stand/holder, bamboo cotton buds, mobile amplifier, and bamboo jewelry. There are a few successful industries related to bamboo composites namely Kerala Bamboo Corporation BMB, Timpack Burnihat for BMCS, and Mutha Industries, Tripura.

Government Initiatives

GOI has launched a series of initiatives starting from 1999 resulting in two national missions namely NMBA under the Ministry of Science & Technology, and NBM under the Ministry of Agriculture during 2005-07. NMBA was subsumed in the North East Centre for Technology Application and Reach (NECTAR) in 2012.

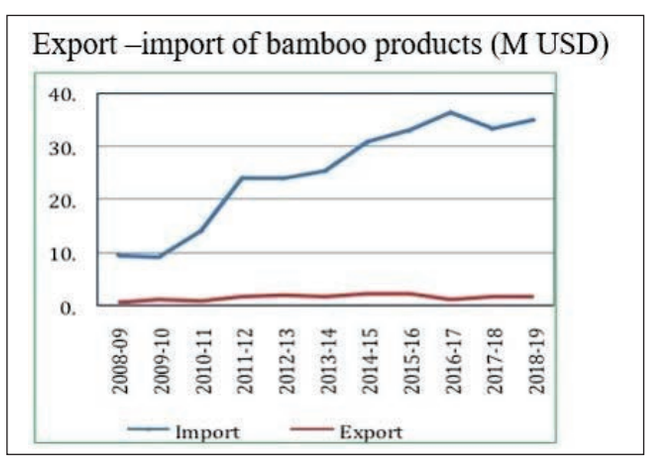
NMBA funded R&D for developing/evolving standard protocols for bamboo processing technologies and facilitated the establishment of several bamboo-based industries in various parts of the country. However, it is a matter of serious concern that the enterprises established/supported under NMBA have been closed due to various reasons, including lack of working capital, non-availability of bamboos (suitable species), problem of waste utilization and this necessitates an in-depth and diagnostic analysis. Primary activity funded by NBM was enhancing the resources in forest areas and plantations in private land. At present, it is continuing as Restructured NBM and seeks to strengthen the complete value chain of bamboo to boost bamboo-based industry, both MSME and high-end with a concomitant ripple effect on rural economy. Establishment of several bamboo processing industries viz. seasoning & treatment plant, carbonization plants, furniture making units, shoot processing units, corrugated sheets/floor tiles units, bioenergy extraction and activated carbon units, ethanol gasifier plant in addition to bamboo depots / bazaars / rural haats, and handicrafts /cottage industries across the country through the participating states have been approved. Funding, up to 50% for private manufacturing units is routed through credit-linked back-ended subsidy.

In addition to the activities under RNBM, bamboo-related works are also being undertaken under other central/state schemes/projects/funds, including Green India Mission, CAMPA and Externally Aided Projects. However, information of such interventions is not being compiled at the national level.

One serious bottleneck in the establishment of bamboo industries is the non-availability of technical specifications of various machinery and equipment required for manufacturing different intermediary/ end products and their suppliers in India. In many cases entrepreneurs have to rely on consultants who facilitate sourcing of technology and bamboo machinery from China or Hong Kong, which are not very suitable for many Indian bamboo species as they have been designed for processing moso bamboos found in China.

Export and import of bamboo products

It is a matter of concern that India, despite huge bamboo resources, continues to be importer of bamboo products with very little exports. Following Table/Graph depicting India's import and export value of bamboo products suggests that bamboo sector presents immense opportunity for growth of export from India, while also reducing imports.



Considering the adverse impact of growing imports of bamboo agarbatti sticks, in 2019, the Ministry of Commerce placed the import of raw agarbatti sticks under "Restricted" category. Further in June 2020, GOI increased the basic duty on bamboo sticks from 10% to 25% to encourage use of domestic bamboo under the 'Aatma Nirbhar Bharat Abhiyan' and provide jobs locally to migrant workers who returned to their homes due to the Covid19 pandemic, beside benefitting.

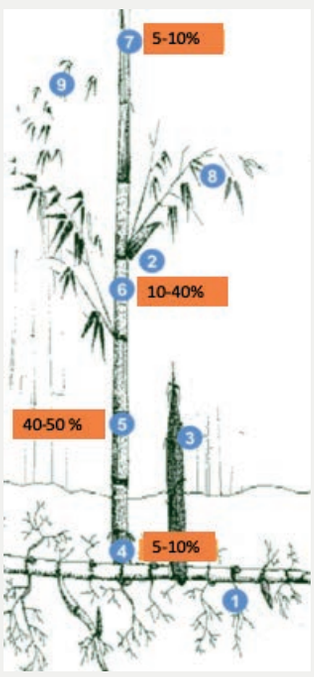
Way forward

It is evident that the development of the bamboo sector in India has immense potential in addressing three major national / regional / state concerns while contributing towards the achievement of India's

climate change related commitments, namely ecological security through conservation of forests through timber substitution, efficient carbon sequestration, **Food, fiber, shelter and energy security** through bamboo based agro-forestry system, **Livelihood security** through generation of additional employment in resource augmentation and processing. For the fullest utilization of bamboo and unlocking its potential in contributing to national growth, it is necessary various parts of bamboo culms are put to optimal use following the concept of circular economy, and economy of scale so as to maximize economic gains.

Considering the tubular structure of bamboo culms, and that while transporting bamboo lot of air is to be transported and the fact that any single bamboo industry generates lot of utilizable waste, adoption of the concepts of putting circular economy is absolutely essential for optimal utilization of whole culms. To achieve this, it is necessary that special bamboo processing zones are set up in the vicinity of available bamboo resources and potential bamboo plantation areas for economically important species. It is felt that the establishment of a dedicated statutory body on the lines of Tea/ Coffee /Rubber /Coconut Boards under the MOEF & CC will go a long way in strategic planning for the development of bamboo sector in the country. It will help in integrating the efforts and fostering synergies between various schemes of different ministries/ departments of Government and advise them for harnessing the full potential of bamboo.

Potential uses of various parts of bamboo culm



Sl. No.	Culm Part	Potential uses (vary with species)	Current uses
9	Leaves	Manure, fodder, medicines	Manure, fodder
8	Twigs	Brooms, cloth	Brooms
7	Top part	Toothpicks, chop sticks, As part of bamboo poles & for scaffolding	Bamboo sticks (for horticulture & Vegetables)
6	Upper middle	Blinds, mats, carpet toothpicks, chop sticks Handicraft	Bamboo poles (for horticulture & vegetable), handicraft
5	Lower middle	Flooring, laminated furniture	Scaffolding, Housing
4	Base	Charcoal	Fuel/Not used
3	Shoots	Vegetable	Vegetable
2	Sheath	Handicraft	Not used
1	Rhizomes	Handicraft	Handicraft
	Left over & waste from processing of other parts	Fiber board, charcoal, pulp, lumber pallets (fuel)	Firewood for household & small-scale industry

Followings are some of the activities that need to be taken up on priority:

1 A district-wise survey of bamboo stocks outside forests (in private lands) proposed by FSI under NBM should be done species-wise covering all species. Species wise-information is important since some bamboo products require specific characteristics in terms of wall thickness, inter-nodal length, node-wall etc.

2 Similarly, a detailed survey of bamboo resources in forests is also required, since major bamboo resources are in forest areas despite limitation of species and current low productivity. It should comprise species-wise areal extent, clump density and vitality, regeneration status and

preparation of geo reference and GIS compatible maps usable for strategic planning.

3 Diagnostic study of the operational status of CFCs and industries already set up to understands the recipe of success and causes of failures so as to replicate the successes and evolve action plan to avoid pitfallsand minimize failures.

4 Redefining bamboo management prescriptions to facilitate working of bamboo forests to produce appropriate raw materials for different end products, with the introduction of other local/preferred species.

5 Identification of most suitable industry-specific bamboo processing zones, so as ensure complete and optimal utilization of entire bamboo culm (through the right mix of processing units), considering the current availability of different species, potential of growing industry-specific bamboo species, traditional human skills in the locality. Focus should also be on reducing imports, and for that these areas need to develop into replicable models.

6 Awareness programmes targeting various end-use sectors, viz. housing and construction, including engineers and architects, handicraft, furniture, transport, food, renewable biomass energy, air/water purification and bamboo growers.

7 Development of industry-specific technology adoption model in the form of model DPRs, including detailed and technical specifications of machinery and equipment and their suppliers. The benefit cost analysis needs to be based on LCA.

8 Facilitating development/manufacturing of bamboo processing machines and improved tools required for various industries.

9 Evolving plantation models for different regions in states and financial/technical support for adopting bamboo plantation as an important economic activity.

10 Forest and chain-of-custody certification of selected bamboo forests and private plantations with a view to enhance exports. It is noteworthy that India specific and internationally bench marked sustainability standards for forest management have already been developed by NCCF endorsed by Programme for Endorsement for Forest Certification (PEFC) and can be used for certification of bamboo forest. Private bamboo areas can also be certified under the NCCF's sustainability standards for ToF, which is the first such standards in the world.

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Need for production linked incentive (PLI) scheme for bamboo products

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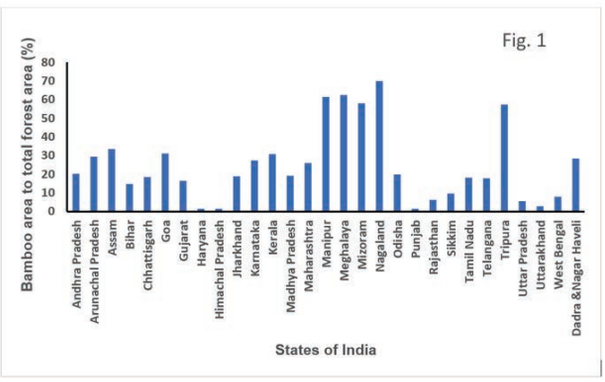
Keeping in mind India's fast-paced development, intersectoral transformation by rejuvenating the rural economy is the need of the hour to improve the standard of living in the country. The 'bamboo' sector has huge potential to play a key role in the country's development.

India with its diversified agroclimatic zones and growing conditions is ideal for bamboo cultivation. India State of Forest Report 2017 by Forest Survey of India stated that bamboo bearing area in India is ~15.69 million hectare with a standing stock of 189 million tons (Fig. 1). However, it is unclear to what extent these areas overlap with wildlife and protected areas set aside for conservation purposes. India, along with China and Myanmar, accounts for 80% of the total bamboo area in the world. India has diversified bamboo species, and harbours 136 bamboo species as per National Bamboo Mission. However, India's share in global bamboo trade and commerce is a mere 4%, though it contains 45% of the bamboo growth.

Fig. 1



Bamboo has diverse uses, such as for fibre, food, fuel, construction & engineering materials, panel products, handicrafts, charcoal, musical instruments, medicinal products, paper, flooring, screens, and is also emerging to be of use in automobile and aircrafts, etc. Climate change being a pressing issue, bamboo has been accepted for its significant role in carbon sequestration potential. Therefore, bamboo is globally recognised as one of the most important non timber forest products and has several sobriquets such as 'green gold,' 'poor man's timber,' 'material of the future,' 'friend of the people' and 'cradle to coffin timber'.

Considering its unique attributes, bamboo has diversified stakeholders such as state forest departments, local communities, artisans, industry, and civil society organisations. Each of these sectors has varied views and interests and different measures of success and failures. This fundamental issue has resulted in disagreement among the stakeholders and led to problems that hinder in arriving at concrete solutions.

A few inherent obstacles in the way of bamboo cultivation are a cause for concern. Knowledge on gregarious flowering and fate of those clumps, reproductive behaviour and life cycle, and the population dynamics is limited or absent. The management of bamboo clumps in terms of harvesting and culm congestion is yet to be standardized. While harvesting mature bamboos, longer time interval results in clump congestion which causes formation of twisted culms. This poses substantial hardship, even leading to poor culm growth and increased possibility of mortality of mother clumps.

Bamboo is a perishable commodity after harvest, and lack of proper perseveration techniques and necessary supply chain management also impacts its harvesting process. This has a cascading impact on the industry. Several challenges arise, such as inconsistent supply of bamboo as a raw material, marketing of products, production of new designs, and lack of skilled manpower. Most importantly, testing and certification of products that is satisfactory to international customers is absent. Therefore, involvement in developing the bamboo industry does not present an encouraging scenario to the corporate sector in India. All these issues have been the weakness of bamboo both as a species and as a product.

Government of India launched a series of initiatives from 1999, resulting in two national missions, namely National Mission on Bamboo Applications (NMBA) under the Ministry of Science and Technology and National Bamboo Mission (NBM) under the Ministry of Agriculture during 2005-07. NMBA had limitations leading to its abandonment. NBM is ongoing, with renewed emphasis on strengthening the entire value chain to promote bamboo-based industry. However, only a handful of bamboos-based industries have come up in the country to increase the demand of bamboo and bamboo products, raising apprehensions in the minds of cultivators. This is in spite of several studies related to bamboo popularity that significantly mention that the

enthusiasm for bamboo cultivation is enormous.

What is the PLI Scheme? Why was it introduced?

Let us understand the possibility of PLI Scheme for bamboo products.

Production-Linked Incentive or PLI is a scheme that aims to give companies incentives on incremental sales (over FY 2019-20) of products manufactured in domestic units. The scheme invites foreign companies to set up units in India. However, it also aims to encourage local companies to set up or expand existing manufacturing units and also to generate more employment and cut down on the country's reliance on imports from other countries.

Previously, the PLI Scheme was for select sectors such as mobile phones and allied equipment manufacturing, pharmaceutical ingredients and medical devices. In recent times, the scheme has been expanded. Government has approved the Production Linked Incentive (PLI) Scheme for White Goods (Air conditioners and LED Lights) to be implemented over FY 2021-22 to FY 2028-29 with a budgetary outlay of Rs 6,238 crore. Ministry of Food Processing Industries, GoI vide its notification dated 02.05.2021 also approved the Central Sector Scheme – "Production Linked Incentive Scheme for Food Processing Industry (PLISFPI)" to support creation of global food manufacturing champions commensurate with India's natural resource endowment and support Indian brands of food products in the international markets with an outlay of Rs.10900 crore. The incentive under the scheme would be paid for six years ending 2026-27. Thus far, Government has also extended the PLI scheme to cover sectors such as telecom, electronics, textiles, specialty steel, automobiles and auto components and solar photo-voltaic modules. Details are provided under product category specific PLI Scheme approved and notified by the respective ministry or departments of the central government having jurisdiction over the products category.

The purpose of widening the PLI Scheme is:

- To protect identified product areas;
- To introduce non-tariff measures that make imports more expensive;
- To acknowledge the relevance of exports in overall growth strategy but focus more on the domestic market;
- To promote manufacturing at home by offering production incentives and encourage investments both from within and outside; and
- To support creation of global manufacturing champions and strengthen select Indian brands for global visibility and wider acceptance in the international markets.

Illustration- Production Linked Incentive Scheme for Food Processing Industry:

The scheme has three broad components. The first component relates to incentivising manufacturing of four major food product segments viz. Ready to Cook/ Ready to Eat (RTC/ RTE) including millet-based foods, Processed Fruits & Vegetables, Marine Products & Mozzarella Cheese. The Second component is for incentivising Innovative/ Organic products of SMEs across all the above four food product segments including Free Range - Eggs, Poultry Meat & Egg Products. The third component relates to support for branding and marketing abroad to incentivise the emergence of strong Indian brands

There are three categories of applicants with different criteria of sales and investment namely,

- **Category-I:** Applicants are large entities who apply for Incentive based on Sales and Investment Criteria. Applicants under this category could undertake Branding & Marketing activities abroad also and apply for Incentives under the scheme. There is minimum criteria of sales (RTE/ RTC- Rs 500 crores, Processed Fruits & Vegetables- Rs 250 crores, Marine- Rs 600 crores, Mozzarella Cheese- Rs 150 crores) and investment (RTE/ RTC- Rs 100 crores, Processed Fruits & Vegetables- Rs 75 crores, Marine- Rs 50 crores, Mozzarella Cheese- Rs 25 crores) for different product segments.
- **Category-II:** SMEs Applicants manufacturing innovative/ organic products who apply for PLI Incentive based on Sales. and further eligibility is (i) Udyog Aadhar/ Udyami Registered; (ii) Minimum Sales of Rs 1 crore during 2019-20 for each of the innovative/ organic products proposed to be incentivised; (iii) Applicant for Organic Product shall be registered with APEDA for the organic product proposed to be incentivised.
- **Category-III:** Applicants applying solely for Incentive for undertaking Branding & Marketing activities abroad with (i) Only Indian Brands are covered for selling food products completely manufactured in India; (ii) Branding & Marketing shall be undertaken either by the Applicant directly or through its subsidiary or any other Agency.

It is the need of the hour to formulate an innovative PLI scheme at the earliest for bamboo products so that doubts of bamboo cultivators due to market uncertainties are assuaged and production increases. This will result in these products becoming cost competitive domestically and internationally as compared to similar products made from other materials. This will boost rural economy, create employment and help in mitigating the global concern of climate change. India, being blessed with a large bamboo area, should utilize the advantage it has to become a global leader in bamboo products.

Green Gold: *a key to Aatmanirbhar Madhya Pradesh*

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Bamboo has been traditionally used for food, fodder, crafts, and most commonly as a natural building material. Owing to its strength, resilience, flexibility, and versatility, it has transitioned from being a poor man's timber to the rich man's gold. It has attracted a plethora of applications across various product categories including wood substitutes and composites, construction and structural uses, industry wide demand/utilization in pulp and paper, charcoal, bio fuel, fibres and fabric, cosmetics medicine, beverages and various other segments.

The crop has attracted global attention as a sustainable wood alternative since the late 90's. The National Bamboo Mission (NBM) has recognized its potential as a resource to fuel social and economic development in harmony with the environment. As per the 2018 State of India's Environment report, it is capable of creating 516.33 million man days of work every year across the country. India houses more than 136 species of bamboo spanning across 13.96 million hectares that makes around 45% of the world's bamboo forests, but its share in the global market for bamboo based products is a meagre 4%. The major reasons identified for this lag in harnessing full potential of this asset include:

- scanty and irregular supply of bamboo,
- low productivity and degradation of bamboo forests due to poor management and harvesting practices,
- lack of information and awareness,
- shortage of advanced processing and value addition units,
- And a dilapidated marketing infrastructure among others.

Madhya Pradesh State Bamboo Mission (MPSBM), the implementing agency of the NBM in the state was commenced with the vision of promoting and facilitating bamboo-based development in a holistically sustainable manner to address these multi-faceted issues by adopting a dynamic, holistic, and scientific approach to the entire bamboo production-to-consumption system. It focuses on establishing integrated chain of plantations, processing and value addition units, and strengthening the forward and backward linkages across the bamboo supply chain by providing direct and indirect financial and technical assistance to all the stakeholders along it. It adopts a Cluster-based approach to carry out the following activities in 20 clusters formed across the state.

Establishment & accreditation of nurseries is being done for increasing the availability of Quality Planting Material (QPM) across the state. Financial assistance up to 50% of the project cost with the indicative upper limit of Rs 50 lakh, Rs 16 lakh, and Rs 10 lakh is provided to Hi-tech, big and small nurseries respectively in the private sector under the Credit linked back ended capital subsidy scheme of the NBM. As yet, 6 Hi-tech and 5 small nurseries have been set up. Furthermore, to ensure that plants being produced in the nurseries are properly identified at the species level, and are of superior pedigree, accreditation of nurseries based on a thorough assessment and listing of NCS-TCP (The National Certification System for Tissue Culture Labs) certified tissue culture labs is done. This assessment is carried out by a team of technical experts authorized by the NBM based on a checklist containing detailed information on production & management system, infrastructure, and other

quality parameters. Based on this, the nurseries are accredited. A total of 44 government & private nurseries have been accredited and 4 tissue culture labs have been listed.

Year	No. of beneficiaries	No. of plants	Area of plantation (in ha)
2016-17	6,712	15,07,590	3,768
2017-18	16	21,444	53
2018-19	1,752	9,26,779	2,316
2019-20	1,264	5,40,093	1,350
2020-21	3,597	14,73,356	3,520

There has been a huge impetus on promoting large scale plantation in private agricultural lands with the dual objective of doubling farmers' income while increasing the supply of bamboo for consumption by the enterprises. Up till now, a total of 11,007 ha of agricultural lands have been covered under bamboo plantation of various species namely *Dendrocalamus strictus, Bambusa bambos, Bambusa balcooa, Bambusa tulda,* and the like, with the current year's target being 4,450 ha. In addition to this, bamboo plantations in forest areas are being promoted with the aid of MGNREGA scheme. This is being implemented through a tripartite arrangement between the Forest department, JFMCs (Joint Forest Management Committees), & SHGs (Self-help groups). Under this scheme, 1 ha, comprising of 625 plants of bamboo, is being allotted per family in the forests, for plantation work and maintenance. They benefit both from the wages as well as the income earned from the harvest by retaining the usufruct rights. In the past two years, 3,710 ha have been covered under bamboo plantation in this manner.

Furthermore, setting up of bamboo-based enterprises in the private sector is being incentivized with credit linked back ended subsidy ranging from 25-50% of the project cost as per the norms of the NBM scheme. As a result of this, numerous such enterprises pertaining to carbonization, processing & value addition, waste management in primary processing, handicrafts, furniture making, incense

stick making, and activated carbon products are being set up in the state. From 2018-19 to 2020-21, financial assistance was provided to 42 bamboo based enterprises in the government sector and 49 such units in the private sector. These include 4 LBIs (Livelihood Business Incubators) each at Harda, Chhindwarra, Balaghat, and Seoni districts. The idea behind these units is:

- To support viable innovative bamboo based enterprises,
- To transplant & harden successful business models through field pilot projects,

- To facilitate initial funding (soft loans & relevant networking),
- To facilitate capacity building & training of entrepreneurs
- To provide exposure of entrepreneurs to local buyers, investors, experts, etc.

Owing to such efforts, private sector entrepreneurs are encouraged to venture into bamboo based industries, a recent example of it being the establishment of Processed Engineered Bamboo Board (PEBB) unit at Dewas, Madhya Pradesh.

Madhya Pradesh is home to a huge population of traditional bamboo artisans. To sustain and promote their livelihoods, establishment and up-gradation of Common Facility Centres (CFCs) across the state has been actively taken up by MPSBM. These centres provide the common infrastructure installed with modern machinery and equipments required for manufacturing & processing activities by these artisans. A total of 9 CFCs have been at various locations across the state namely Baihar, Garra, Timarni/Rahatgaon, Poama/Bharatdev, Dhooma, Keolari/ Kanhiwada, Narsinghpur, Sonora, and Gandhigram. These are managed and operated by the local bamboo artisans thereby boosting reviving their occupation and strengthening their socio-economic status. MPSBM endeavors to transform CFC, Baihar into a State of Art CFC & training centre. This will further augment the development of bamboo based art and craft and associated opportunities by providing exposure to advanced technology and skill sets.

Moreover, for enhancing and diversifying the skills and competencies of traditional bamboo artisans, training activities and workshops are frequently organized in collaboration with reputed institutes including the Bamboo and Cane Development Institute (BCDI), Agartala, M.P. Council of Science & Technology (MPCST), and National Institute of Design (NID), Ahemdabad. From 2013-14 to 2020-21, a total of 2017 beneficiaries have been upskilled in multifarious Hotel accessories, Utility items, Lifestyle accessory products, Basketry, Bamboo Joinery, Bamboo Tents,

Jewellery, and Furniture. The training programmes are usually executed in three phases:

- The Orientation phase wherein 3 days training is provided by local master trainers in bamboo clusters,
- The Design phase wherein specialized training of selected artisans from the previous phase is provided by trainers from the aforementioned institutes,
- And the last phase where the final production training is provided to the trainees.

A similar 30 days training programme for skill upgradation of local bamboo artisans is being organized in collaboration with Bamboo and Cane Development Institute (BCDI), Agartala commencing in August, 2021, the applications for which have been invited through the official website of MPSBM. This programme shall aid the beneficiaries in refining their skills related to making bamboo jewellery, furniture, Utility and handicrafts items.

In addition to this, for identification of those genetically superior and commercially important species of bamboo that can be promoted for plantation in M.P, 12 Bamboo setums have been established across the 11 agroclimatic zones. Around

27 species of bamboo are being studied regarding their survival, growth, and productivity with respect to the agroclimatic conditions in the state. Further, 92 Demonstration plots have been set up to exhibit best bamboo management and harvesting practices to farmers with monetary incentive of Rs 3,00,000 per demo plot, thereby encouraging more farmers to take up bamboo farming.

To provide access to wider markets, MPSBM has taken a slew of steps including promotion of bamboo based products through various platforms like Domestic Exhibitions, Fairs, Rural haats, Bamboo Bazaars, as well as online portals like ebamboobazar.org and mianzi.in. The former is the web application of MPSBM that facilitates the exchange of information and transactions between various stakeholders like growers, traders, artisans, depots, manufacturers, professionals, CFCs, and nurseries. mianzi.in is an online bamboo products selling website supported by MPSBM that provides the artisans from CFC Sonora, Satna with a platform to sell the products designed and manufactured by them. This helps them to effectively utilise and benefit from various skill development trainings as well as the manufacturing infrastructure available through the CFC.

To further bolster the market linkages and achieve economies of scale, 6 Bamboo FPOs (Farmer Producer Organizations) are being constituted by NAFED (National Agricultural Cooperative Marketing Federation of India Ltd.) across the state, in collaboration with the National Bamboo Mission. A cooperative model for Bamboo Harvesting and sale in Alirajpur district of M.P. was initiated as a pilot project in 2016 under the guidance of MPSBM. It emerged to be a successful unit deploying scientific bamboo harvesting practices on local farmers' land and selling the same through auctions. By 2020, it made a total income of Rs 38,00,000 from the sale of bamboo sourced from 463 local farmers, since its commencement. This is a brilliant example of how farmers can benefit from such organizations in terms of increased opportunities and better bargaining power.

Consistent efforts in this direction are bound to boost the socio-economic status of the state in a sustainable manner by accelerating employment opportunities in the sector and attaining self-reliance.

Efforts of ICFRE and its Institutes in research and extension of bamboo development through Bamboo Technical Support Group (BTSG) of National Bamboo Mission

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Introduction

Government of India is promoting bamboo outside forest through schemes such as National Bamboo Mission (NBM) by involving farmers, artisans, public and other stakeholders. NBM is a sub scheme of National Mission on Sustainable Agriculture (NMSA) under the umbrella scheme Krishonnati Yojana implemented by Ministry of Agriculture and Farmer's Welfare, Government of India. The objective of the NBM is to promote holistic growth of bamboo sector by adopting cluster based strategy and to increase the area under bamboo cultivation and marketing. National level agencies Bamboo Technical Support Groups (BTSG) are set up to provide necessary technical support to the NBM on various technical issues in different zones of the country. Indian Council of Forestry Research and Education (ICFRE) Dehradun is also recognized as one of the BTSG.

BTSG under ICFRE has been extending technical support to the NBM and implementing NBM's program since 2007-08. It has taken various measures such propagation and multiplication of superior bamboo clumps, maintaining germplasm of superior clumps and multiplying its stock, developing tissue culture protocols for bamboo, raising tissue culture plants, nurseries, setting of primary processing units for trainings, skill up-gradation and technology development, material transfer to users and implementing the bamboo based research programs through its institutes and centers under support from NBM. This article gives an insight of the activities taken up by BTSG under ICFRE with the active involvement of ICFRE institutes and its scientists.

Propagation and cultivation of bamboo

To meet the ever increasing demands of quality planting material, there is a need to improve the productivity of bamboo plantations and large scale plantations with high yielding species and clones need to be raised. The unavailability of genuine, quality planting stock of bamboo species is a major drawback for large scale plantations. In line of this, BTSG-ICFRE has established Hi-tech, big and small bamboo research nurseries in the main campus and field stations of ICFRE institutes (Fig.1 & 2). The details of the bamboo research nurseries set up by BTSG-ICFRE are given in Table 1. These nurseries are producing more than 3.50 Lakhs quality planting material of important bamboo species such as *Dendrocalamus strictus, D. hamiltonii, D. stocksii, D. brandisii, D. somdevai, D. longispathus, Bambusa bambos, B. vulgaris, B. tulda, B. nutans, B. balcooa, B. polymorpha, B. mizorameana,* hill bamboo species etc. on annual basis through vegetative propagation, tissue culture and seeds, which are made available to the bamboo state missions, state forest departments, farmers, industries and other stakeholders as and when required.

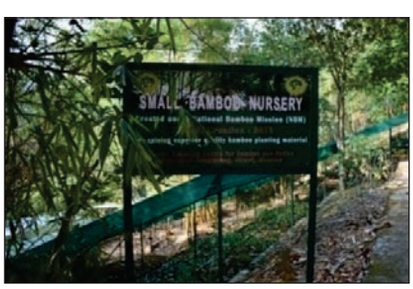

Fig. 1: Small Bamboo Nursery at FRC-BR, Aizawl

Fig. 2: Hi Tech Bamboo Nursery at IFGTB

Table 1: Bamboo research nurseries set up by BTSG-ICFRE

Sl. No	Institute	Nursery type	Major Bamboo species
1	Forest Research Institute (FRI) Dehradun	High tech and Small at FRI campus	*B. bambos, B. polymorpha, B. vulgaris, D. strictus, Arundinecea falcata, Phyllostachys Aurea*
		Small at Khirsu Field Station	*Drepanostachyum falcatum, Thamnocalamus spathiflorus, Yushania anceps, Himalyacalamus falconeri*
2	Institute of Forest Genetics and Tree Breeding (IFGTB) Coimbatore	High tech and Small at campus	*B. balcooa, B. tulda, B. nutans, D. asper, D. strictus, B. bambos*
3	Rain Forest Research Institute (RFRI) Jorhat	High tech and Small at campus	*B. balcooa, B. tulda, B. nutans*
4	Forest Research Centre for Bamboo & Rattan (FRC-BR)Aizwal	Small at Aizwal centre	*D. longispathus, B. mizorameana, B. tulda, B. polymorpha, D. asper, D. hamiltonii*
5	Forest Research Center for Livelihood Extension (FRC-LE) Agartala	Small at Agartala centre	*B. polymorpha, B. tulda, D. hamiltoni D. longispathus, Melocanna baccifera*
6	Institute of Wood Science and Technology (IWST) Bengaluru	Small at Main Campus	*B. bambos, B. tulda, D. stocksii, D. parvifolia*
7	Institute of Forest Productivity (IFP) Ranchi	Big at Mandar Field station, Jharkhand and Small at Main campus	*B. bambos, B. polymorpha, B. balcooa, B. nutans, D. strictus, D. hamiltonii, D. longispathus, Phyllostachys nigra*
8	Tropical Forest Research Institute (TFRI) Jabalpur	Small at Main campus	*B. bambos, B. balcooa, B. nutans, B. tulda, B. vulgaris, D. strictus,*
9	Himalayan Forest Research Institute (HFRI) Shimla	Small at Nalagarh Field station, Himachal Pradesh	*D. strictus*

BTSG under ICFRE has also been focusing to enhance the production capacity of planting material through tissue culture technology. Under NBM supported activities to ICFRE, tissue culture laboratories for bamboo were established at FRI Dehradun, TFRI Jabalpur, RFRI Jorhat, IFP Ranchi, IFGTB Coimbatore and IWST Bengaluru. Important bamboo species has been undertaken for mass multiplication through tissue culture (Fig. 3 & 4). These laboratories are producing tissue culture planting stock of plantation grown species like *Dendrocalamus giganteus, Thyrostachys oliveri, B. vulgaris, B. tulda, B. nutans, B. balcoa and Guadua angustifolia* along with some ornamental species like *B. wamin* and *B. vulgaris var. variegata* and nursery is being utilized for hardening and macro proliferation the tissue cultured propagules to increase the number. A guideline for Accreditation of Bamboo Nurseries, Tissue Culture Laboratories and Certification of Quality Planting Material 2019 was also developed by ICFRE and NBM, which is also available on the website of NBM.

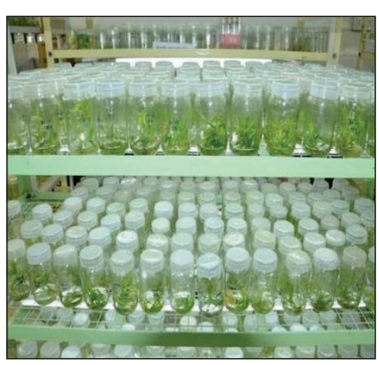

Fig. 3: Mass multiplication through tissue culture

Fig. 4: Tissue Culture plantlets for hardening

The quality planting material of commercially important bamboos species produced through tissue culture propagation and other vegetative/seeds source are being used to raise plantation in farmer fields, KVKs and other community lands for demonstration purposes. This demo plantation can be used for showcasing, training, education and research purposes. Under this activity, demo bamboo plantation of 53 ha had been raised in KVKs,

field stations and farmer's field in 2019-20 and 2020-21 (Fig. 5). The details of the plantation raised are given in Table 2.

Table 2: Detail of demo bamboo plantation by ICFRE institutes

Sl. No.	Institute	Location	Plantation Area (ha)
1	HFRI Shimla	Village Padli, Forest Division: Solan, Himachal Pradesh	2
2	FRI Dehradun	KVKs of Dhakrani & Kashipur (Uttarkhand), Sonipat	2
3	IFP Ranchi	Mandar Research Station, Ranchi, KVK Ranchi, Latehar	13
4	TFRI Jabalpur	Satna, Jabalpur, Katni, Damoh	10
5	RFRI Jorhat	Golaghat, Bokakhat	4
6	IWST Bengaluru	Chikkaballapur, Dodballapur	2
7	IFGTB Coimbatore	Erode, Coimbatore, Tiruppur	20

Fig. 5: Demo bamboo plantation at Tamil Nadu and Jharkhand

Promotion of bamboo treatment, processing and product development

Farmers and people of marginalized section involved in bamboo based livelihood get less return due to lack of mechanization and non-utilization of modern tools and technologies. Therefore, the bamboo processing units are being set up at ICFRE institutes with modern and advanced tools and techniques for value addition of bamboo and bamboo based products. BTSG-ICFRE has established Bamboo Common Facility Centre (CFC) at FRI Dehradun for capacity building, trainings and to carry out the research activities. Another unit of CFC is also being established at IFP, Ranchi. At IFP, Ranchi, incense sticks making unit and bamboo treatment plant is also being set up. Being a lesser known food product bamboo shoot processing has potential to be developed as an innovative and promising enterprise. A bamboo shoot processing unit is being set up at RFRI Jorhat to impart training and demonstration on shoot processing along with production of different value-added products of bamboo shoot. Bamboo handicraft sector is another predominant sector in the Indian handicrafts and there are millions of people who depend on bamboo for part or all their income. A bamboo handicraft and jewellery making unit is being established at Forest Research Centre for Bamboo & Rattan, Aizawl, Mizoram to facilitate diversified use of bamboo handicraft product development and processing.

Research and development on bamboo

Keeping in view the importance of the improved planting material propagation of improved bamboo clumps was undertaken by ICFRE institutes (FRI Dehradun, IFP Ranchi, TFRI Jabalpur, RFRI Jorhat and IWST Bengaluru) on ten priority species viz. *D. strictus, D. hamiltonii, D. stocksii, D. brandisii, D. somdevai, B. bambos, B. vulgaris, B. tulda, B. nutans and B. balcooa.* In this study the evaluation trials of selected bamboo species established in past under various project were revisited across different locations in the country and evaluated with a set of selection parameters. Promising superior clumps were identified through multi-trait evaluation. The rhizomes/offsets of the superior clumps were collected for further multiplication and for establishment of rhizome banks in different regions/states. This study has resulted in identification of 357 superior clumps of ten selected bamboo species across in ICFRE institutes. Out of these selected 357 clumps, 196 clumps were shortlisted based on their previous record of flowering and

further screening. These selected clumps have potential for achieving higher genetic of at least 20%. They are being multiplied to produce multiple copies for transferring to various agencies for mass multiplication and to create germplasm bank of these clumps (Fig. 6). Presently the clumps are being made available to all state forest departments and state bamboo missions through license agreement with a right of their multiplication for next five years (Fig. 7). So far, the superior clumps have been provided to State Bamboo Missions of Madhya Pradesh, Uttarakhand, Telangana, Gujarat, State Forest Department of Bihar and other stakeholders.

Study on development of value chain for bamboos for mass multiplication, popularization in farmer's field and industrial linkages in Central India is also being carried out by Tropical Forest Research Institute, Jabalpur. This study is working towards developing technological package for raising bamboo species in farmers' fields, mass multiplication of planting material of superior clumps, clonal fidelity testing and development of market linkages with wood-based industries in Central India in a multipartite model of association among research institute, farmers and industries. Institute is providing technical knowhow, where plantation is carried out in farmer's fields and industries is linked to utilize the produce.

With increasing demand and cost of pulpwood, new alternatives to produce rayon grade dissolving pulp are being investigated. Bamboo fibres possess many excellent properties when used as textile materials such as high tenacity, excellent thermal conductivity, and resistance to bacteria, high water and perspiration adsorption. A study on assessment of Indian bamboo species for dissolving grade pulp is being carried out by Forest Research Institute Dehradun, wherein bamboo species is being assessed for their potential of dissolving grade pulp production at a level of qualitative and quantitative parameters.

Fig. 6: Nursery established for bamboo propagation

Fig 7: Transfer of quality planting material

Skill development and awareness campaign

Trainings, workshops, exposure visits, demonstrations, and capacity building exercises are needed for farmers, entrepreneurs, forest departments and the artisans on a large scale to improve abilities and skill sets of trainees, develop expertise in specific areas through skill up-gradation and enhancing competence for employability. ICFRE institutes regularly organizing training and capacity building programmes on bamboo. Since 2007-08, total 64 trainings on nursery management and bamboo value addition technologies were organized through BTSG-ICFRE under NBM. Through these programmes, trainings are imparted to farmers, artisans, staff of forest departments on propagation techniques of bamboos in detail with hands-on practice for clonal propagation, raising seedlings, mass multiplication of bamboos through tissue culture, bamboo based skills to make decorative items, handicrafts, furniture, jeweleries, shoot processing and other miscellaneous items (Fig. 8 & 9). Table 3 gives insight of training courses imparted by ICFRE institute to enhance the bamboo based skills.

Fig. 8: Training programme on bamboo product development

Fig. 9: Training programme on bamboo shoot processing

Table 3: Tentative training courses on bamboo

S.No.	Bamboo based training course	Beneficiaries / Trainee
1	Bamboo selection and mass multiplication	Farmer, Staff of Forest Departments, Entrepreneur, Public in community owned forest
2	Bamboo plantation & management	Farmer, Staff of Forest Departments, Entrepreneur
3	Bamboo Nursery management	Farmer, Staff of Forest Departments, Entrepreneur
4	Bamboo based composite board	Artisans, researchers, Entrepreneur, Carpenter
5	Bamboo hut/house making	Engineer, Architecture, Businessman
6	Bamboo furniture making	Artisans, Entrepreneur, Carpenter
7	Bamboo handicrafts, jewellery	Artisans, Entrepreneur, SHGs, NGOs
8	Bamboo incense stick making	Artisans, Entrepreneur, SHGs, NGOs
9	Bamboo shoot processing	Entrepreneur, SHGs, NGOs, food industry
10	Preservation and fire-retardant	Preservation industry, Artisans, Entrepreneur
11	Bamboo charcoal /Briquetting	Farmers, Entrepreneur
12	Bamboo floor tiles	Engineer, Architecture, Businessman, Entrepreneur,

As awareness campaign, radio talks on 'Bans ki Kheti' were arranged from AIR Najibabad. Video documentaries on "Nirgal: Hill Bamboos" developed by HFRI Shimla and the *"D. stocksii"* by IWST Bengaluru have been made as multimedia aids (Fig. 10 & 11) to generate awareness. Bamboo craft mela were organized at Manali, Himachal Pradesh and FRI Dehradun. National conference and seminars on bamboo related sectors were also organized by ICFRE institutes.

Fig. 10 & 11 Video documentaries on "Hill Bamboos" and "D. stockii"

Conclusion

BTSG-ICFRE has been continuously carrying out bamboo related activities through its Institutes, centers and field stations with support from NBM. The major activities by BTSG-ICFRE has been on skill up gradation, research and development for producing quality planting material, propagation protocols, bamboo composites, establishment of bamboo processing centers, developing audio-visual programmes, exposure visits to artisans, and conducting theme-based seminar/workshops on bamboo across the country. BTSG-ICFRE also aims to focus on new products development such as rayon grade pulp, bamboo shoot, incense stick, jewelry, handicraft, bamboo tiles, bamboo lumbers etc. and their value addition. It also emphasizes the strengthening of networking linkages with all stakeholders for growth of the bamboo sector.

Acknowledgement

BTSG-ICFRE is thankful to NBM for rendering financial support to execute bamboo related activities in ICFRE institutes. We acknowledge the sincere efforts and hard work of all the scientists of ICFRE for implementing this programme. Photographs used in this article have been obtained from institutes for which they are acknowledged. Sincere gratitude is expressed to Directors of ICFRE institutes for encouraging their scientists to carry out activities of BTSG-ICFRE. The authors are thankful to Sh. A. S. Rawat, DG, ICFRE and Sh. S.D. Sharma, DDG (Research), ICFRE for their guidance, supervision and support in implementing the mandate of NBM through BTSG-ICFRE.

वन विभाग, म.प्र. शासन

MADHYA PRADESH STATE BAMBOO MISSION (MPSBM)

&

MADHYA PRADESH BAMBOO AND BAMBOO CRAFT DEVELOPMENT BOARD

Resource Augmentation & Livelihood Activities

1. Propagation and Cultivation
   - Bamboo Nursery both in public and private sector
   - High Density Bamboo Plantation on Govt./Panchayat/ community land including waste lands.
   - Block plantation/boundary plantation on farmers field.
2. Promotion of bamboo treatment and preservation.
3. Product Development and Processing.
4. Promotion and Development of Infrastructure for Bamboo Market.
5. Skill Development and awareness campaign.
6. Research & Development.

Plant Bamboo For Tomorrow

MP STATE BAMBOO MISSION

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The Midas touch: *crafting bamboo to build sustainable livelihoods*

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A socially active group of young interdisciplinary professionals from the biodiversity rich region of Sindhudurg district in Maharashtra was captivated by the promise of the potential of Bamboo as a sustainable resource for economic development of rural India, as introduced to them by the then Union Cabinet Minister of Environment, Mr Suresh Prabhu. One of these professionals, an engineer by training, Mr Sanjeev Karpe, decided to commit himself to transform this promise into reality and established the Konkan Bamboo and Cane Development Centre (KONBAC) in 2004.

KONBAC is a Section 25 not-for-profit company, facilitated by the International Network for Bamboo and Rattan (INBAR) through the Centre for Indian Bamboo Resource and Technology (CIBART). As one of INBAR's Action Research Sites (ARS), KONBAC focused its activities on the development of Bamboo as a key resource for catalysing an inclusive green economy.

Dendrocalamus stocksii, a graceful mid-sized non-thorny bamboo species with loosely spaced solid erect culms ranging from 30-50mm diameter, known locally as 'Managa bamboo' traditionally grew on farm and homestead boundaries in the district. But it was grown primarily as a crop for domestic consumption and not as a cash crop for the market. The first task for KONBAC, therefore, was to change the mindset of the local farmers to perceive Bamboo as a cash crop, similar to traditional horticultural crops like mango and cashew.

Sindhudurg district, at the southern tip of the state of Maharashtra is buffeted by a 121-kilometer-long coastline on the western border and the mighty Sahyadri range on the east. Land is mostly hilly, farm holdings, marginal or small and agriculture primarily rainfed. Bamboo, then, with its wondrous qualities like the capacity to establish well in marginal situations ensuring the first harvest from the 4th year after plantation with its ability for regrowth after harvesting, its short gestation period coupled with low annual labour and input requirements, truly lives up to its identity as 'green gold'. Besides, Bamboo plantations do not require existing natural vegetation to be totally removed like for those of mango or cashew. This makes it even more important to increase the Bamboo cover in a biodiversity rich and eco-sensitive region like Sindhudurg.

KONBAC started an extensive program of outreach to raise awareness of the potential of Bamboo as a viable cash crop for the market. It provided hands-on training to farmers in the scientific processes of propagation, cultivation and harvesting. This led to a greater number of farmers planting Bamboo as a cash crop and today over 10000 farmers are growing Bamboo on over 5500 hectares in Sindhudurg district. Improved package of practices taught by KONBAC and the traditional practice of organic agriculture followed by farmers also fetches them a higher price for the raw Bamboo pole sold at the farm gate. But these achievements were only the first step towards realizing KONBACs goal to position Bamboo as the pro-poor credible alternative to timber replacing wood in all its forms, thus creating a positive environmental impact and generating sustainable livelihood opportunities for those at the bottom of the pyramid. One of the key strategies pursued by KONBAC towards this end was to provide the rural poor and small land holders an opportunity to participate in and benefit from the US$100+ billion wood products market by building their capacity to grow, harvest and process Bamboo.

The bamboo furniture unit

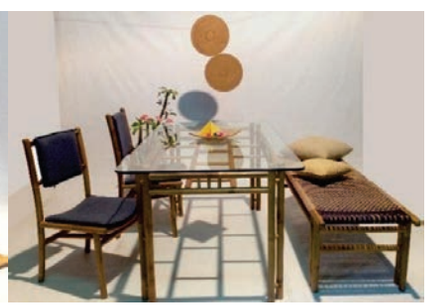
In the first phase, KONBAC tapped the skills of rural youth by

training them to make furniture from round bamboo poles. Select models of furniture were designed, prototyped and test-marketed in Goa and Mumbai, the major commercial markets of the region. The feedback received from the market as well as the on-the-spot orders received, created the need for establishing a production unit for furniture making. In this phase, KONBAC tried to encourage the trained artisans to set up their own furniture unit enterprises, committing to provide technical and marketing support, as well as assistance for accessing a bank loan. However, entrepreneurship is not a culture in this region and the youth, drawn primarily from marginalized communities, were reluctant to take the risk of investing in a product that was new to the local market.

KONBAC then established its own unit at Kudal and followed through on marketing with a set of strategic sales in the region giving round-pole bamboo furniture good visibility. Key clients targeted included the prestigious Shilpagram project of the local municipal council, the Jungle Resort by the district Forest Department, the most famous restaurant in the district, a leading restaurant in Goa, a local restaurant in the area of operation and well-known persons such as ministers, judges and government officials. This led to increased acceptability of bamboo furniture.

The furniture unit uses bamboo poles treated in a pressure-vacuum treatment plant for protection against termites and borers, which helps extend the life of the furniture to more than 50 years. Furniture is designed for home, office and the tourism industry by expert designers. Trained artisans are given the treated Bamboo in a kit form to make the needed components as per designs. The increased lifespan and contemporary designs have also changed the perception of bamboo furniture among consumers and producers.

Niche tourism markets have accepted the Bamboo furniture produced by KONBAC and the increase in demand has been steady. KONBAC's Bamboo furniture fetches a better price than furniture products from regular commercial enterprises because of its superior quality and finishing. Buyers accept the higher prices because of the high quality and superior finishing of the products. The strategic location of Sindhudurg to Goa, which is an international tourist destination, has contributed significantly to expanding the market for bamboo furniture. Smart pricing policies adopted ensure that the artisans get the best remuneration possible for their work. But KONBAC has also consciously strategized to ensure that its work also creates



employment opportunities at the village level, especially for the traditional Bamboo women artisans. The components needed for making furniture, such as bamboo nails, bamboo splits and round bamboo sticks that form essential inputs for furniture making are produced at the household level by the women. Women workers supply this material to KONBAC through regular part-time work. They also do the primary assembly for some designs, and the furniture is brought back to the KONBAC Bamboo Furniture Unit for final assembly and finishing.

Native KONBAC Bamboo Products Pvt. Ltd. (NATIVE KONBAC)

The success of the first phase and the contemporary market scenario for Bamboo led KONBAC to partner with INBAR to set up a professionally managed for-profit institution, Native KONBAC Bamboo Products Pvt. Ltd, to capture the national and international market for Bamboo products. Incorporated under the Company's Act 1956 in 2009, GoI, Native KONBAC is an inclusive social enterprise with a mandate to promote sustainable livelihoods through one of the world's most eco- friendly materials, Bamboo, opening up alternative avenues for capital investment. This move ensures sustainability of the enterprise, by moving away from a project-based to a social enterprise model providing sustainable livelihoods to thousands of families at the bottom of the pyramid and impacting the triple bottom line of people, planet, and profit. Native KONBAC has established itself as one of the strongest players in bamboo furniture and construction production, securing prestigious projects with the tourism industry, from the government as well as private sector.

Eknath Gavandi, Lata Malwankar and Mahadev Kambli are part of this journey of KONBAC. Eknath says when Mr. Karpe asked him to join the KONBAC Furniture Unit in 2009, he was a carpenter working with wood. He had only known of Bamboo poles being used for scaffolding and ladders. "Bamboo", says Eknath, "is a very tough medium to work in. But I persevered and made my first product, a chair. Mr. Karpe was so impressed, he increased my salary from 4500 to 6500! Bamboo is such a fascinating material. No Bamboo is like the other; Bamboo teaches you something new every day. That is the reason I continue to work with Bamboo and have not reverted to wood".

Mahadev had completed a course in book-binding before he joined KONBAC in 2004. "I had to learn from scratch', Mahadev says "but I enjoy working with Bamboo. Earlier we had no idea that Bamboo could be used to make such beautiful products. I make furniture and craft items and really enjoy working on crafting these innovative products".

Lata, a master craftswoman and a mother of two now, joined KONBAC in 2005. "Older women from our community traditionally made items from Bamboo" she says. "But we young girls had a very negative perception of working with Bamboo and though we had learnt the basic skills, we refused to work on it. In 2004, Mr. Karpe visited our locality to procure some raw material and motivated a few of us to join KONBAC's skill building program. I can't even put my feelings in words… the joy, the appreciation and fame this work has brought me is incredible. Today, I exhort the younger generation to take up this vocation. In fact, I feel bamboo craft should be taught as a vocational subject in schools".

Looking ahead

Over the last sixteen years, KONBAC has empowered thousands of youth like Eknath, Mahadev and Lata, not only in Sindhudurg district but across the country and beyond, to build sustainable livelihoods. It has proactively reached out to the underserved segments like youth, women and farmers building their capacity to participate in and benefit from the growing Bamboo sector. KONBAC has simultaneously worked to overcome the key challenges that plagued the Bamboo sector like the availability of the right quality of raw material (Bamboo), consistent quality of its treatment, the designer's knowledge of the characteristics of Bamboo, availability of the artisans to work on producing quality products and last but not the least, the mindset of people at large, of Bamboo being poor man's timber.

The quality and design of the products developed by KONBAC incubated enterprises like Native KONBAC has also benefited from this work and built its identity as a provider of high-quality aesthetic products. Previously, popular perception of Bamboo used to be that as 'poor man's timber'. Availability of high quality and contemporary furniture in the market by the likes of Native Konbac succeeded in creating a demand for Bamboo, the woody grass, as a preferred credible alternative material for manufacturing furniture, lifestyle and interior accessories and construction. This has led to Bamboo being positioned as an aspirational and high-value brand, a preferred material for the environmentally conscious community and consumers who seek novelty, in effect a 'rich man's choice.

'KONBAC has also built a self-sustaining institutional ecosystem with a fully developed facility for designing, prototyping and producing marketable Bamboo products for domestic and international markets. KONBAC has succeeded in establishing linkages between poor Bamboo producers and larger high-value markets ensuring benefits to stakeholders across the Bamboo sector value chain; farmers, entrepreneurs, artisans etc. This model has gained wide recognition and is being replicated across the country and world. The expansive and intensive work put in to achieve this growth has also led to areas of expertise within the organization and spurred innovation.

KONBAC has developed an entire product line of furniture, craft and pre-fabricated structural components for construction thereby creating a holistic ecosystem for supply of high-quality Bamboo products across the country and abroad. KONBAC has developed a blueprint to transfer and disseminate its replicable model to new locations across the country to support the mainstreaming of Bamboo as a key raw material for a green economy to generate sustainable livelihoods. It looks forward to partnerships with like-minded institutions across the civil-society, public and private sector to co-achieve this goal. Such partnerships will generate new business opportunities, motivate investment among producers, define clear rules for both purchasers and sellers and encourage institutions to incubate enterprises. KONBAC envisions the growth of a dynamic domestic Bamboo industry that catalysis an inclusive green economy not only in the country, but also globally.

Engineering applications of bamboo as a key sustainable material

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Bamboo is a light weight, biodegradable, sustainable and renewable material and is the Gift of God to mankind. Bamboo is a wonder material which offers a great scope for innovation in its engineering application/ utilization. General Public is to be informed beyond a normal perception of basket, Hut, agarbathi with Bamboo.

Oxygeneration and health

Bamboo produces 35% more oxygen than other plants, the need of the hour in this pandemic, as well it sequesters CO_2 many times saving us from pollution. Researchers have to work on replacing Lithium Zeolite as sieve material with Bamboo carbon fibre composite molecular sieve in Oxygen concentrators with Electrical swing adsorption. Air purifiers and Ionizers are other areas to look at seriously with bamboo activated Charcoal for neutralizing Indoor positive disease Ions. We need to encourage setting up Bamboo TUNNELS in all Institutions and colleges so that anybody can go there and fill up their lungs with oxygen since these tunnels can boost Oxygen to even 30% in the surrounding air from a normal level of 19%. Municipal authorities have to consider the capability of Bamboo as a major resource to set up Oxy Parks. Bamboo Activated Charcoal (BAC) is well known for controlling odor and toxins in indoors, in kitchens bathrooms and like. It is interesting to know that the Surface area of BAC goes upto 1200 Square meters per gram or in other words one teaspoon of BAC has an area of one football ground. This great quality of BAC is to be understood by all researchers. Nano Bamboo Charcoal as a belly good band for women after Caesarean section and other medical applications. Needless to mention the good health benefits of Bamboo shoots for BP and Sugar control and several other diseases.

Mechanical Engineers to please note the Ethanol production capabilities of Bamboo for a clean fuel for a clean air that outperforms sugar cane and Corn. Our Union government is looking at a 15 billion Rupees Economy boost with Bamboo ethanol. BMW uses Bamboo in Steerings. Bamboo composite washers are being preferred over metal washers. Bamboo boards are again a preference for floorboards in automotives for weight reduction. Rural transport can effectively use bamboo structural frames in Solar powered medium load carriers/ rickshaws. Even Airbus is researching on the long fibres of bamboo floor Aircraft. Power Gasifiers using bamboo as a bio feedstock under pyrolysis is another major area for a standalone power generation in the Rural Areas, not to depend on the grid in remote places. Bamboo composites are highly potential for carbon fibre, steel replacements, Plastic replacements and Central Air conditioning Ductings replacing Galvanized steel.

Electrical Engineers Need to look at Bamboo Anode graphite capabilities for quick charging advantage in lithium-ion batteries insulation properties thin panel designs. Energy saving Innovations with weight reductions, composites application. Odour Control / management is another major area for application.

Rural Development

BLA Bamboo leaf ash helps in improving the compressive strength when mixed upto 10% in cement by volume

BRCC Bamboo reinforced cement concrete application in pillars, beams, slabs for small and medium spaces like 1/2 BHK. Other applications include some structures in Temples, Rural Drains, Rural Roads with Bamboo grids as load distributors, small water tanks. You can target a cost savings upto 30% and reduced temperature in BRCC/grid applications. See pictures attached from IPIRTI, IIT Kharagpur and real time buildings at Vinukonda AP. Small vegetable storage Bins for villages with BAC wet Pads on principle of evaporative

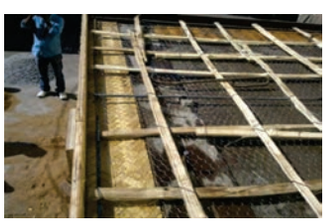
cooling to save their vegetables from getting spoilt, for few days. The list is longer and a great scope exists for INNOVATIONS with Bamboo. We need to take the help of foresters and other Professionals to bring awareness and benefits of Bamboo to Public. Engineering fraternity and Researchers are requested to work on PILOTS/startups to build an awareness of the successes that Bamboo can make for sustainability and GDP of our country

Fig. 1: Chemically treated bamboo reinforced bar used in column

Fig. 2: A model 2-BHK bamboo reinforced concrete hous constructed in school premise near IIT in 2014 (Sponsoring agency BMTPC)

Fig. 3: Security service room at Hostels of IIT Kharagpur in 2015

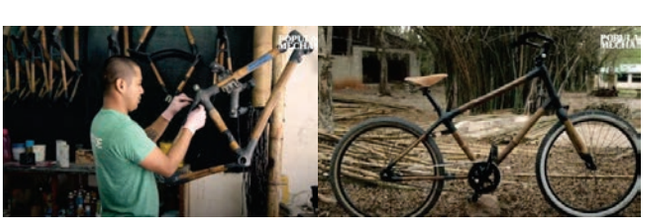
Fig. 4: Plate in the house mentioning STEEL free construction



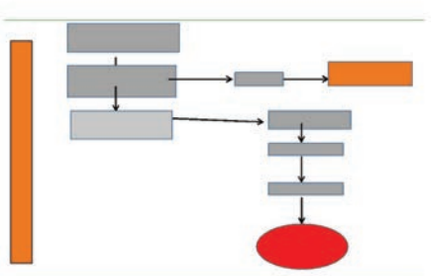
Construction at IPIRTI, Bangalore with Bamboo reinforcement

Bamboo reinforced beam at Vinukonda, Andhra Pradesh

1st floor construction with bamboo reinforcement at Mehaboobnagar, Telangana



Bamboo bicycle



Bamboo Sector : *Kerala scenario in the Indian context*

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Indian Scenario

It is a matter of concern that India, which has the second largest bamboo resources in the world, is practically nowhere in the picture in export of bamboo products. Whereas India has a huge domestic market, India's import and export of bamboo and its products, as shown below, suggests that the bamboo sector presents immense opportunity for growth of export from India, while also reducing imports through a very well-planned strategy for the development of bamboo sector in the country and its efficient execution. With 136 species and 23 genera spread over 16 million hectares of bamboo-bearing forests according to the India State of Forest Reports – ISFR - data by Forest Survey of India (FSI 2019) (50% of the reported bamboo resources in Asia and 30% of the reported bamboo resources in the world), India has the world's second largest bamboo resources, next only to China; despite all these, the country's share in the global bamboo trade is abysmally low. Realizing the situation and its future potential, Government of India (GoI) took initiatives for the development of bamboo sector in late 1990s, first by the constitution of the National Mission on Bamboo Applications (NMBA) and later in 2006, the National Bamboo Mission (NBM). Since 2011, FSI has been assessing forest bamboo resources and the results are reported in the ISFRs. The latest activity of the GoI, through amending the Indian Forest Act 2017 by omitting bamboo from the definition of 'tree' so as to benefit millions of people growing bamboo in private or homestead land, the effect of the same in the agro-forestry sector is under observation.

According to INBAR (2019a), India's presence in international bamboo trade in 2018 is as follows:

Import Country	Amount (x 1000 USD)
China	29,623
Vietnam	1,863
EU	1,187
Malaysia	321
Singapore	197
Myanmar	176
Japan	169
USA	98
Indonesia	80
Philippines	22
Total	**33,801**

Imported Items	Amount (x 1000 USD)
Bamboo raw materials	28,683
Bamboo pulp	1,255
Bamboo basketwork	848
Bamboo flooring	799
Rattan raw materials	547
Bamboo mats/screens	519
Bamboo ply-board	460
Bamboo & rattan furniture	146
Bamboo charcoal	115
Bamboo shoots	114
Rattan basketwork	109
Bamboo plaits & materials	104
Rattan mats/screens	58
Rattan plaits and materials	26
Bamboo and rattan seats	15
Bamboo paper-based articles	2
India Total	**33,801**
Export Country	
Singapore	135

Import and export of bamboo and bamboo products

(Million USD)

Year	Import	Export
2008-09	9.53	0.39
2009-10	9.15	0.92
2010-11	13.98	0.75
2011-12	23.99	1.75
2012-13	23.93	1.86
2013-14	25.35	1.60
2014-15	30.61	2.22
2015-16	32.81	2.26
2016-17	36.19	1.00
2017-18	33.21	1.46
2018-19	34.85	1.72

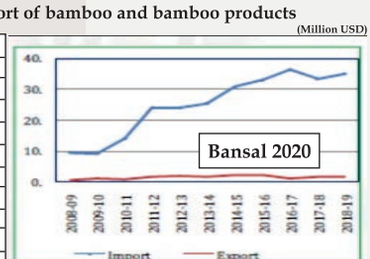


Figure 4: Export-IMport value of bamboo products - India

Utilization of bamboo for various products, as analysed by Tewari (1992) revealed the following emerging picture on the major uses of bamboo:

Sl. No.	Use	Consumption (%)
1	Paper Pulp	35.0
2	Housing	20.0
3	Non-residential	5.0
4	Rural uses	20.0
5	Fuel	8.5
6	Packing, including baskets	5.0
7	Transport	1.5
8	Furniture	1.0
9	Other wood industries	1.0
10	Others, including ladders, scaffoldings, etc.	3.0

The average productivity of bamboo in a Taiwan Plantation is reported to be 20-30 MT per ha per annum while the highest yield obtained in India is only 5 MT per ha in Assam! As far as availability of Bamboo is concerned, the total growing stock of bamboo in the country is reported to be around 80.4 million MT of which only 13.5 million MT is harvested annually; a mere 16.8 % (Malavika (2019). North-East region is one of the most bamboo rich regions in the country, as is evident from the table given below:

Parameters	In the country, as a whole	In the North-East
No. of Genera	22	16
No. of Species	136	89
Total Estimated Stock	90 Million Tones	N/A
Total Area under Bamboo	9.86 Million Ha.	3.10 Million Ha.

The Bamboo found in North East is mainly non-clump forming; making it amenable to easily harvesting. Bamboo shoots are considered a delicacy in the North-East. Bamboo is also used extensively in the neighbouring countries like Bangladesh, Myanmar, which explains the smuggling of bamboo to these regions, while the illegality of the exercise itself can be explained by the restrictions imposed by the laws and rules. Some of the commercially important bamboo species of India, as identified by the various bamboo working agencies are given in Table 1.

In the wake of reducing timber supplies, several environment and people-friendly technologies have been developed in the country for manufacturing innovative products from bamboo. These products include: wood-substitutes - bamboo mat board (BMB), bamboo mat veneer composite (BMVC), Laminated Bamboo lumber or bamboo laminates, bamboo strand lumber, bamboo compressed wood, housing-construction products - bamboo mat corrugated sheets (BMCS) for roofing, bamboo corrugated ridge cap (BMRC), etc. Indian Plywood Research and Training Institute (IPIRTI), a premier research and training institute under the MoEF & CC, has been on the forefront in developing bamboo composites and transferring the technology from lab to the industry. IPIRTI technologies for bamboo mat board, bamboo mat veneer composites, bamboo mat corrugated roofing sheets, bamboo mat ridge cap, which have been commercialized in India and are becoming popular among consumers. Other organizations involved in the development/ demonstration of similar products include RV-TIFAC, and IWST, Bangalore. Bamboo composites have lower emissions compared to similar products of steel and plastics in carbon emission audit studies underway at IPIRTI as a part of Life Cycle Analysis (LCA). BMCS requires lower net energy in production compared to aluminium and galvanized iron roofing sheets, and it has an edge over other competitive roofing material with respect to energy efficiency, green-house effect, storage of carbon, and impact on environment.

The development of the bamboo sector in India has immense potential in addressing the ecological, food, fibre, shelter, energy, and livelihood security of the national, regional, and state concerns while contributing towards the achievement of India's climate change related commitments. Malavika (2019) examined in detail, the viability of bamboo sector as an option for sustainable livelihood, determining the scope of Bamboo based industries in India as well as to evaluate the success of existing policies in harnessing this potential and suggesting the optimal Bamboo Policy for the same. Only in recent years, it is being increasingly realised what a valuable resource bamboo is not only for the traditional subsistence economy but even the modern industrial one. The important characteristics

that make bamboo so useful are- its short growth cycle which makes it highly renewable (the commercially important species mature in 4- 5 years); different parts of the plant have different uses and are obtained at different stages of its growth thus rendering the plant useful during its entire life span; bamboo shoots of some species are edible and have high nutritional value; the plant improves the environment in many significant ways including acting as an atmospheric and soil purifier; it is hardy, light and flexible, thus a good substitute for wood. The development of a vibrant bamboo sector calls for a concerted effort towards blending together the traditional and modern technologies on one hand and balancing equity and efficiency considerations on the other. The country will have a big role to play in freeing the bamboo resources from excessive and unproductive regulations and transforming the unorganised subsistence sector into an organised high value one. Bamboo development in India poses a huge challenge and opportunity, only when we appreciate the magnitude of the opportunity can we have call forth the political will to develop this sector rapidly and holistically.

The following Bamboo Products/Technologies/Testing Standards are available with the country:

Sl. No.	Product/Technology/Testing	Standard
1	National Building Code of India: Part 6 Structural Designs Section 3B. Bamboo	SP (Part 6/Section 3B:2016)
2	Bamboo mat board	IS 13598:1994 BMB for General Purposes
3	Bamboo mat veneer composite	IS 14588:1999 BMVC for General Purposes
4	Bamboo mat corrugated sheet and bamboo mat ridge cap	IS 15476: 2004 (Reaffirmed 2009)
5	Bamboo jute composite corrugated/semi corrugated sheets	IS 15972: 2012
6	Bamboo jute composite panel door shutter	IS 16073: 2013
7	Phenol Bonded Bamboo Jute composite hollow door shutter	IS 16096:2013
8	Bamboo for tent poles	IS 7344: 1974, Reaffirmed 2015
9	Bamboo for Chicks (Fine)	IS 8295 (Part 1): 1976 Fine
10	Bamboo for Chicks (Coarse)	IS 8295 (Part 2): 1976 Coarse
11	Bamboo supports for camouflaging equipment	IS 10145: 1982
12	Methods of test for split bamboo	IS 8242: 1976
13	Methods of test for round bamboo	IS 6874: 2008, (Reaffirmed 2019)
14	Code of practice for structural design using bamboo	IS 15912: 2018 (First Revision)
15	Preservation of bamboo and cane for non-structural purposes: Code of practice	IS 1902: 2006
16	Preservation of bamboo for structural purposes	IS 9096: 2006

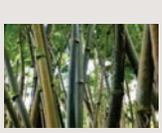
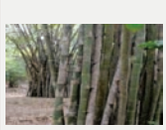
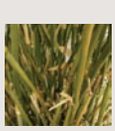
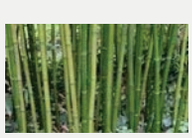
Table1. Commercially Important Bamboo Species identified by INBAR, NMBA & NBM

Sl. No.	Species Name	Distribution	Main uses
1	*Bambusa balcooa*	North East India, West Bengal, Bihar, Jharkhand and Uttaranchal	House construction, scaffolding and ladders
2	*Bambusa bambos (Thorny Bamboo)*	Throughout India. Common in Central and South India.	Pulp and paper, thatching and roofing; panel products and handicrafts
3	*Bambusa cacharensis*	In the Brahmaputra and Barak Valley of Assam; West Bengal; Arunachal Pradesh, Dehra Dun, Manipur, etc.	Housing and construction
4	*Bambusa nutans*	North East, Orissa and Bengal	House construction, basketry and craft
5	*Bambusa pallida*	North East India	Basketry and mats
6	*Bambusa polymorpha*	Arunachal Pradesh, Meghalaya and Tripura	Woven handicrafts, house construction; paper pulp; shoots
7	*Bambusa tulda*	North East and West Bengal.	Basketry and woven mats. Indian timber bamboo
8	*Bambusa vulgaris*	Central and North East India	Paper-pulp, decorative items and handicrafts
9	*Dendrocalamus asper*	South-East/Tropical Asia;	Poles, building material, structural timber for heavy

	Syn. Gigantochloa asper (Sweet Bamboo)	introduced in other tropical countries, including Ghana, Benin, DR Congo, Kenya and Madagascar.	construction such as for houses and bridges; Furniture, boards, musical instruments, household utensils, crafts, outriggers of fishing boats and for paper making; the upper internodes are used as containers and cooking pots; and for shoots
10	*Dendrocalamus brandisii*	Called Burma bamboo in Manipur. Introduced in Coorg (Karnataka).	House construction and basketry, and handicrafts (Preferred spp. for cultivation due to large size, straight culms, and being thorn-less)
11	*Dendrocalamus giganteus*	North East, West Bengal and Bihar.	Construction purposes and boat masts
12	*Dendrocalamus hamiltonii*	North East and Himachal Pradesh	Edible shoot, for roofing and construction purposes.
13	*Dendrocalamus strictus*	Widely distributed all over India/ most common bamboo in India.	Building material and for making furniture, mats, basketry and implements
14	*Gigantochola apus*	Native to Burma (Myanmar) and southern Thailand. Indonesia & Malaysia	Handicrafts, musical instruments, and furniture industry; Poles as building material to construct roofing, scaffolding, bridges, walls, fences, etc., fine strips for weaving hats, baskets, etc.
15	*Melocanna bambusoides* Syn. *M. baccifera* (Muli bamboo)	North Eastern India	Paper pulp, house construction, woven products
16	*Ochlandra travancorica* (Reed)	Southern Western Ghats, India.	Basketry, mat-making and decorative handicrafts
17	*Oxytenanthera stocksii*	Confined and endemic to southern peninsular India	Construction purposes, furniture, ladders and supports
18	*Schizostachyum dullooa*	North East India	Making baskets, mats and small boxes
19	Thyrostachys oliveri	Introduced in Tripura	Fishing rods, javelins, pole vault poles. Shoots are edible.

Kerala scenario

In Kerala, 28 species of bamboos are found to occur. Total bamboo growing area is reported to be around 11,100 Km2 in the Kerala forests and the total dry stock is estimated to be around 26,30,500 Tones. Annual availability is calculated to be 2, 19,200 Tones. The main species found in Kerala are *Bambusa bambos, Ochlandra travancorica,* and *Dendrocalamus strictus*. Kerala has large number of types (around 11) of thin walled bamboos called 'reeds' (*Ochlandra genera*) which are used mainly for weaving purposes by the traditional artisans. Exotic varieties like *Dendrocalamus giganteus* and *Dendrocalamus brandisii* are cultivated by farmers in areas like Waynad District. Earlier, bamboos from the Kerala forests are being supplied mainly to the pulp and rayon units under concessional rates. Reed bamboos are supplied to the artisans through the Kerala State Bamboo Corporation. A unique feature of the Kerala bamboo scene is that 67.3 % of the extracted bamboo comes from home gardens rather than from the forests. *Ochalandra travancorica* (reed) is the species of bamboo found abundantly in the forests of Kerala and is the main species used for mat making by the traditional bamboo working artisan community of Kerala. The estimated numbers of culms available from the homesteads of Kerala is 13.61 million with a total weight of 0.331 million tons. The major species available in homesteads and the number and weight of culms available per year are as given below:

Species	***Bambusa bambos***	***Bambusa vulgaris***	***Dendrocalamus strictus***	***Thyrsostachys oliveri***	***Ochalandra travancorica***	***Pseudoxytenanthera stocksii*** **Syn.** ***Dendrocalamus stocksii***	
Details							***Total***
No. of culms & % Weight (Tones)	13003843 (95.50) 326736	303835 (2.23) 3767	16000 (0.11) 3767	98440 (0.72) 486	188434 (1.38) 262	8360 (0.06) 46	13618912 (100) 331702

Kerala Forest Research Institute (KFRI) offers the centre of research, training and extension activities for the bamboo sector of the state. Dhamodaran et al. (2020) gave an overview of the some of the recent R & D efforts in the bamboo technology sector in **Kerala. Kerala State Bamboo Mission** (KSBM) was constituted under Department of Industries & Commerce and functioning at Kerala Bureau of Industrial Promotion (K-bip) as a state agency of the National Bamboo Mission (NBM) with the broad aim for marshalling the scattered bamboo resources of the state by adopting a focused approach to revitalize the state bamboo sector by promoting value addition, enhancing income generation and alleviating poverty through the necessary interventions. From 2009 onwards till 2019, KSBM used to organize Annual Bamboo Fests at Cochin, Kerala which use to be a great tourist assemblage and Business Meet and product selling point on bamboo themes and products. Training of Trainers in product improvement and quality enhancement in the fields of weaving, jewellery & handicrafts making, Training workshops to bamboo artisans of micro enterprises and SHG's in furniture design and making are some other recent activities undertaken by KSBM. The Mission also keeps an updated identified list of expert artisan trainers for bamboo products in Kerala. KSBM takes care the more than 500 private and cooperative society level nano – to - micro scale stand- alone bamboo enterprises existing in Kerala. The GoI agency, the MSME Development Institute in Kerala is also joining their hands for the development of the bamboo sector in the state.

Kerala State Bamboo Corporation (KSBC) Ltd., a government of Kerala undertaking, is established in 1971 at Angamaly in the Ernakulum District (Cochin) of Kerala with a mission to support and uplift the bamboo working community in Kerala; owns a bamboo ply board manufacturing factory and another bamboo flooring tile manufacturing unit, with several decentralized and low level mechanized and manual bamboo sliver manufacturing and mat weaving centers and associated bamboo depots with a pan state presence, is the major public-sector bamboo player in Kerala.

The main activity of the Corporation is collection of good quality reeds from Government forests and distributing these reeds to the registered mat weavers throughout the State of Kerala on credit basis and procuring woven mats made of these reeds at reasonable prices for making the bamboo ply boards at the factory; thus providing employment and regular means of livelihood to the traditional bamboo weaver/artisan communities of the society. Bamboo mats woven from reeds is very popular in the state and is traditionally used in agricultural activities, for sun-drying raw green paddy and other food grains. Bamboo-ply boards, the resin bonded bamboo mat boards are popular substitute for wood/plywood-based applications.

With a capital base of about Rs.700 lakhs, KSBC is serving almost a total of one lakh number of traditional bamboo workers including about 1500 reed cutters, about 38, 000 mat weavers, and about 30,000 other traditional workers engaged in making baskets and the remaining artisans in the handicrafts sector. About 80% of these marginalized traditional bamboo artisans/workers belong to socially and economically backward classes; majority are women. The mat weavers are given training in mechanical production of bamboo slivers and weaving bamboo mats of particular specifications required for the manufacture of the resin bonded bamboo ply boards at its factory. The Corporation is authorized by the Government to collect 29,000 MT reeds per annum from the forests. It has 12 reed collection centres, 87 depots for distributing reeds to the weavers, and 15 reed distribution centres to supply reeds to the traditional workers. The centres are in different parts of the state. Sale of the products, mainly bamboo mats and bamboo ply boards are to different dealers/customers in the Government/Private sector. Bamboo-ply sales in Kerala are through about 100 dealers in the state. The product is of superior quality, wood/plywood substitute, marine grade boards in sizes 5'x3', 6'x3', 6'x4', and 8'x4', in thickness 3mm, 4mm, 6mm, 9mm and 12 mm. The boards are termite resistant, water resistant and heat resistant. Product has been exported to Kenya & Maldives and the Middle East. Food Corporation of India (FCI) and Central/State Warehousing Corporations use these mats for dunnage purpose. Sugar mills use mats for covering temporary shelters during sugar seasons.

Major products of KSBC consist of bamboo-ply boards (Resin Bonded Bamboo mat boards with or without veneer in between) of various thickness and bamboo flooring tiles (treated). Other products include minor quantities of bamboo curtain blinds, utilities and handicrafts, furniture, etc. and they are in the developmental plan for the manufacture of flattened/crushed bamboo boards. Now 21,500 square feet (1998 Sq. meter) of Bamboo-ply, on 4 mm basis is reported to be produced daily on an average, in normal conditions of working. The installed capacity of the bamboo flooring tile factory is reported to be around 1, 44,000 Sq. meters of bamboo flooring tiles per annum. The Tiles are produced mainly in the size of 0.96metres x 0.096 meters and thickness of 15mm and 18 mm. In order to utilize full capacity of the factory, in order to ensure the prompt supply of bamboo mats which is not available in the open market, Corporation has taken initiatives for starting up Community Weaving Centers in various parts of the state with a low-level mechanization. At Present Corporation is having 13 mechanized community mat weaving centers and the work of establishing another set of 2 centers are in pipeline.

Using the bamboo waste from the flooring tile factory, ranging from 50 to 70%, by products such as tooth picks, window curtain blinds and incense sticks are being manufactured at its Feeder Units/ Primary Processing Units. The Corporation now is capable of undertaking bamboo constructions (huts, houses, kiosks & buildings) and bamboo interiors. They also used to offer services such as Trainings, Demonstrations, Study Tours, Awareness-making, Meetings, Workshops, Bamboo CFCs, Publications, Bamboo Planting for Riverside Protection, etc. A 'Bamboo Innovation Centre' is also established at the Corporation by the Kerala State Bamboo Mission (KSBM) for providing an opportunity for producers in the state to be familiarized with technology interventions and processes. A Digital Bamboo Information System including details about Propagation, Tools and Equipments, and Treatment of Bamboo has been developed in the Centre in addition to a Product Manual and Catalogue. An Android App has also been developed to access the information system. The Corporation is at present undertaking programmes for the establishment of High Density Bamboo Plantations, Treatment and Seasoning Plants, Livelihood Business Incubators, Waste utilization in Bamboo Primary Processing Units, Bamboo Furniture Marketing Units, Incense Stick Making Units, Common Facility Centers (CFCs), Corrugated Sheet Manufacturing Unit, Bamboo Depots and Godowns, Bamboo Bazaars, and Bamboo Processing Units for Value Addition, etc. for the bamboo sector development of the State with a budget of around Rs. 2541 lakhs.








URAVU IndigenousScience & Technology Study Centre - A non-profit bamboo-based developmental Non-Governmental Organi sation established in 1996 at Wayanadu, Kerala that strives for rural empowerment through sustainable solutions is the major NGO player and motherhouse of the bamboo craft sector of Kerala. This NGO supports more than 100 rural artisans from about 17 SHGs with women majority through a CFC established for the purpose of training, demonstrations, design interventions, value-addition, and for forward and backward marketing linkages. Several agencies like UNIDO, NABARD, KVIC, Bamboo Mission, MSME, etc. have partnered with Uravu in disseminating the knowledge by organizing training programs and workshops and were able to develop more than 500 designed products, more than 1000 lives impacted and planting more than 12000 bamboos per year.

Uravu's major contribution lies in mainstreaming bamboo-based economic activities in Kerala. It has tremendously helped to improve the social status of bamboo artisans by removing caste-based perceptions in the occupation. Uravu hosts Kerala's only bamboo art gallery and strives to establish the potential of bamboo as a strong medium of expression and creativity. With more than 600 designed bamboo products during the journey, from crafts and curios to lights, decor, lifestyle, and utility items, the product range of Uravu is diverse and unique. All these products testify to bamboo's potential in promoting a more sustainable way of living.

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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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Bamboo Lumber : *a potential substitute to solid wood for various applications*

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Introduction

Bamboo is one of the ecofriendly materials which can be potentially utilized in modern green buildings due to its high fast renewability, productivity and superior strength properties. Due to its several benefits such as outstanding performance in load bearing applications, ecological aids, ease of availability, bamboo has gained a lot of interest to be utilised as a replacement for wood in various applications. Studies indicated that the strength properties of bamboo are at par or even higher as compared to commonly used structural timber species, making it as a potential material for wood substitution. However, certain drawbacks such as susceptibility to attack by biodegrading agencies, hollow, tapered and irregular culm shapes etc. which can obstruct its use in load bearing components where uniformity, endurance and adoptability are the major factors in widespread load bearing utilizations.

The modern technological interventions allow to transform the bamboo into various engineered composite materials like Laminated Bamboo Lumber (LBL) and Bamboo Strand Lumber (BSL). The composite materials increase the possibilities of utilization of bamboo in various applications. Engineered bamboo composite is a relatively new concept that involves bonding bamboo material in various forms (e.g., strips, strands or mats) with a structural grade adhesive to form rectangular boards, similar to lumber. These bamboo composites provide several advantages such as uniform cross section, better mechanical properties, improved durability, dimensional stability and fire resistance which subsequently helps in improving its longevity as a sustainable structural material in various applications as a potential alternative for commercially used timber species. The composites can be manufactured into various sizes and shapes depending upon the availability of processing equipments and the requirements of desired applications.

Methodology for making bamboo lumber

For the fabrication of LBL and BSL, the bamboo culms are converted and processed with the help of various bamboo processing machines as per the steps given below:

1 **Cross cutting:** The bamboo culms are cross cut into sections having length of about 4 feet.

2 **External knot removal:** The knots and irregular protrusions present at the node portions of the bamboo are removed with the help of external knot removing machine.

3 **Strip formation:** The round green bamboo culms are passed through multiple strip making machine to get bamboo strips with uniform width of one inch.

4 **Internal knot removal:** The internal knots in strips are removed with the help of internal knot removing machine.

5 **Removal of skin:** The strips are then passed through a two-side bamboo planer in order to remove the outer waxy-silica layered skin, simultaneously removing the inner soft layer to get planned strips.

6 **Hydrothermal treatment:** The bamboo strips are boiled in water. Simultaneously, the preservatives such as borax-boric acid was added in the water. The treatment is done in order to remove starch present in the bamboo and as well as to improve resistance against bio deteriorating agents.

7 **Planning of strips:** The strips are then passed through two-sided bamboo planing machine to remove the outer green waxy layer along with inner soft fibrous tissue. The process is carried out to obtained bamboo strips of uniform thickness.

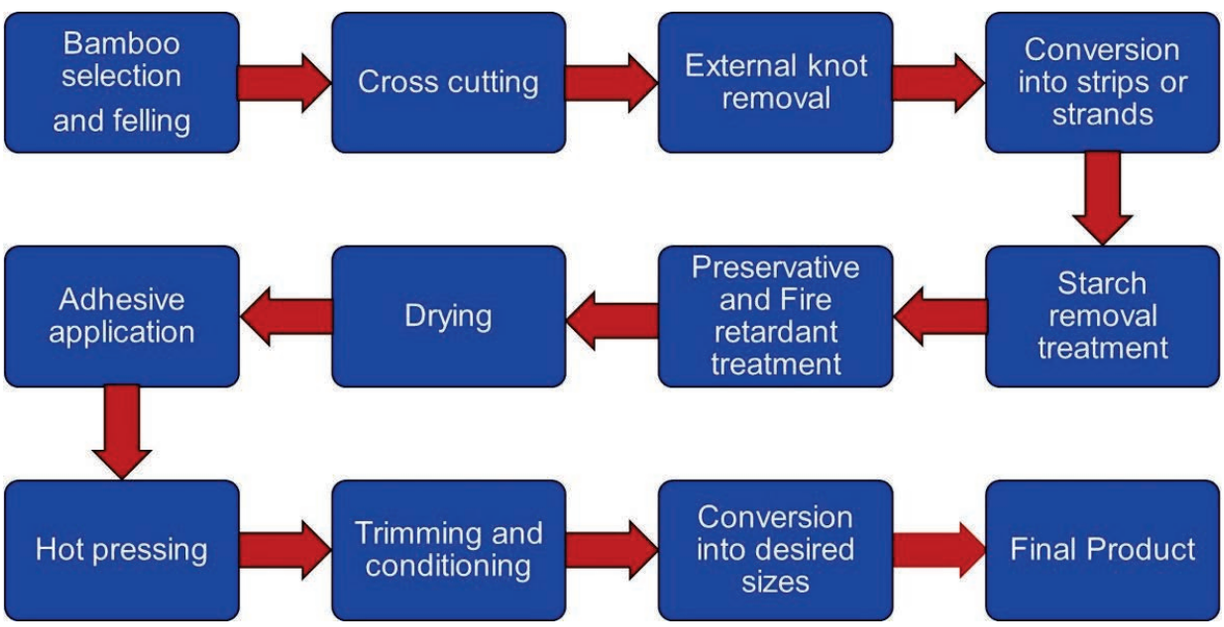
8 **Crushing of bamboo:** For obtaining the bamboo strands for preparation of BSL, the bamboo strips are passed through sets of rollers mounted on a bamboo crushing machine to disintegrate the fibre bundles present in bamboo.

9 **Drying:** Bamboo strips are dried in shed to reduce the moisture content of bamboo to 8-10% and to improve the chances of adhesive absorption.

10 **Adhesive application:** For fabrication of LBL, thermosetting adhesive was applied on the bamboo strips. For the production of BSL, crushed bamboo strands are dipped in the diluted adhesive. The resin coated bamboo strips and strands are further air dried to remove excess amount of water.

11 **Assembly and pressing:** For LBL, air-dried adhesive-coated strips were assembled in between layers of uncoated strips. The assembly was then placed in a preheated press and hydraulic pressure is applied simultaneously from horizontal as well as vertical direction. For fabrication of BSL, the adhesive coated and dried strands are weighed and prerequisite quantity is assembled in a hot press to achieve desired density.

12 **Trimming and conditioning:** The prepared LBL and BSL, composites are trimmed to remove the uneven edges and ends. Further, the panels are allowed to attain equilibrium moisture content.



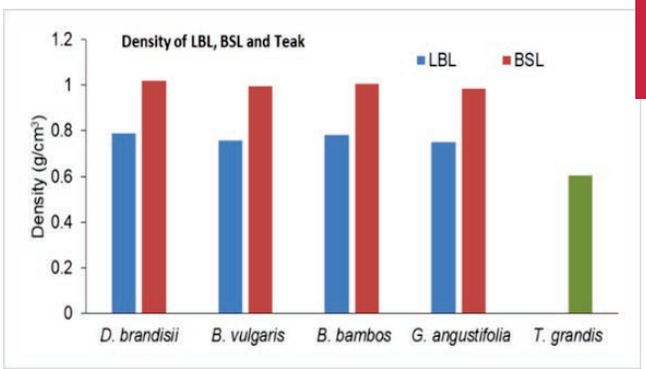
Flow chart of fabrication process of LBL and BSL

LBL and BSL made from different bamboo species

Physical properties

Density

The density of BSL is found to be significantly higher as compared to LBL. The higher density observed in BSL can be attributed to the fabrication method adopted during production of the bamboo boards. The adhesive soaked fibre bundles subjected to high temperature and pressure causes compression of cell walls of parenchymatous tissues and vascular bundles leading to greater compaction, reduced porosity and improved density values.



Volumetric swelling

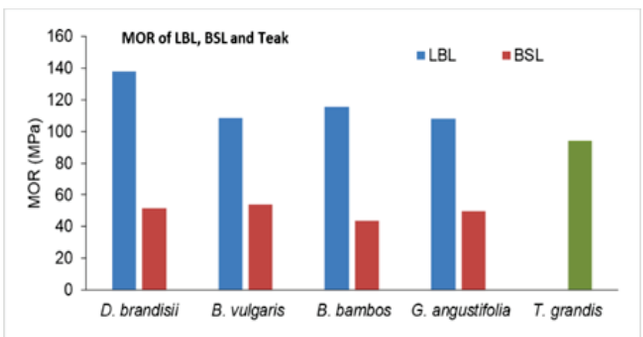
The water absorption and volumetric swelling for LBL and BSL are given in the following table. The BSL composites showed higher water absorption and volumetric swelling as compared to LBL composites.

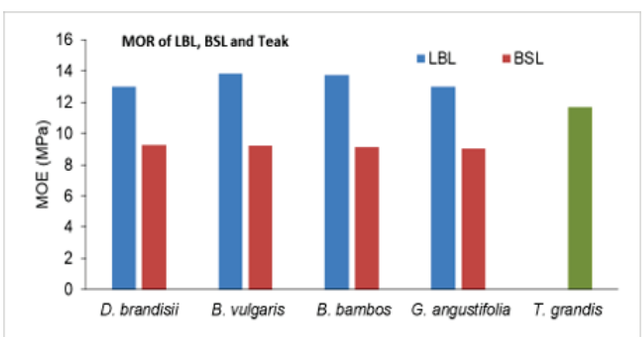
Species	Volumetric swelling (%)	
	LBL	BSL
D. brandisii	10.46	17.04
B. vulgaris	11.18	16.44
B. bambos	11.68	18.72
G. angustifolia	13.12	19.33
Tectona grandis	8.4	

Mechanical properties

Bending strength

The modulus of rupture (MOR) and modulus of elasticity (MOE) of the LBL and BSL prepared from *D. brandisii, B. vulgaris, B. bambos* and *G. angustifolia* along with MOR and MOE of *Tectona grandis* (teak) wood are given in following figures.

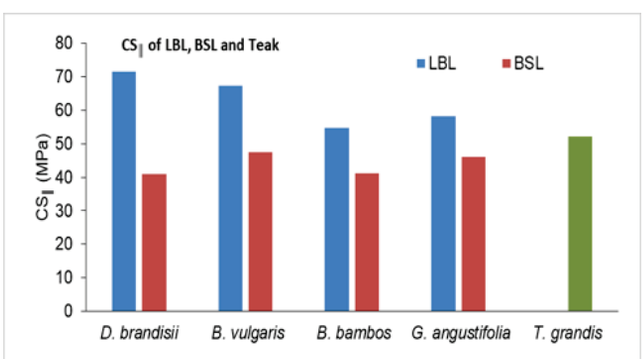




The LBL showed significantly higher MOR and MOE as compared to BSL. The higher bending strength of LBL is attributed to the unidirectional arrangement of fibres which is undisturbed during the fabrication. During the production the BSL, bamboo fibres are subjected to mechanical separation when passed through sets of rollers, leading to lower flexural strength and stiffness. The LBL maintains the inherent characteristics of longitudinally aligned fibres embedded in lignin matrix present in bamboo during the fabrication leading to higher mechanical properties as compared to BSL.

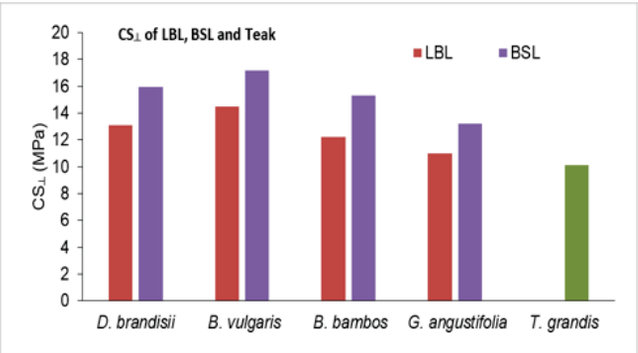
Compressive strength parallel to grain (Csll)

The LBL showed significantly higher values of compressive strength parallel to grain as compared to BSL. During fabrication of LBL, unidirectional fibres are compressed at high pressure resulting into a denser material with improved mechanical properties. However, in BSL, the fibres bundles get disrupted during crushing process resulting into lower compressive strength parallel to grain.



Compressive strength perpendicular to grain

The BSL shows higher compressive strength perpendicular to grain as compared to LBL for all the species as bamboo strands are compressed at high pressure during fabrication resulting into higher density. Thus, BSL may provide higher resistance to the compressive forces acting perpendicular to surfaces.



Durability against fungi and termites

The bamboo is highly susceptible to attack by biodegrading agencies such as fungi, termites and borers. It is classified under non-durable class (III). The bamboo composites can be prepared with preservative strips, which can increase the durability of the products by providing resistance against bio-degrading agencies. The study is carried out to assess the durability of LBL and BSL prepared from preservative treated and untreated strips.

Decay resistance

LBL and BSL were classified into various categories as per average weight loss percentages of white rot and brown rot fungi species. The decay resistance of both LBL and BSL is significantly improved compared to the composite specimens prepared from untreated bamboo. The durability classification given in table showed that the resistance of LBL significantly improved from moderately resistant class (II) to highly durable class (I). The BSL specimen shows better decay resistance as compared to specimens of untreated LBL.

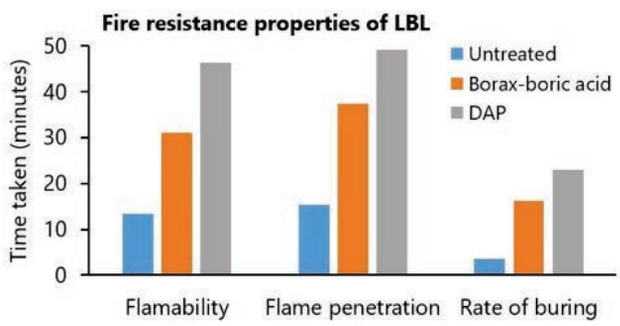
Treatment	LBL		BSL	
	Decay Resistance Class			
	White Rot	Brown Rot	White Rot	Brown Rot
Untreated	III	II	I	I
Treated	I	I	I	I

Termite resistance

The LBL showed significantly improved resistance against termites when the stripes of bamboo are treated with preservatives. The BSL prepared with untreated and treated strands showed no evidence of degradation symptoms such as termite holes, tunnels or evidence of wood damages due to termite attack on visual inspection after exposure.

Fire resistance properties

The fire resistance properties (flammability, flame penetration and rate of burning) of LBL treated with 5% borax-boric acid and 10% di-ammonium phosphates (DAP) were tested. The results showed that treatment had a significant effect on the fire properties of LBL. The borax-boric acid treated strips improved the fire resistance of LBL but failed to meet the minimum recommended times. Whereas the DAP treated LBL passes the minimum requirements mentioned in standards for all three tests.



Value added products

The bamboo composite can be efficiently processed with the standard wood working machines and tools. Suitability of bamboo composites for making various prototypes is found practically promising and can be utilized for large scale production of various products. Few prototypes fabricated from the bamboo lumbers are shown below.

Side Table

Centre Table

Window Frame

Flooring Tile

Conclusion

The engineered bamboo composites such as LBL and BSL are produced successfully using locally available bamboo species converted to strips or crushed form and compressed after applying required amount of adhesive. The physical and mechanical properties of the LBL and BSL composites were found to be at par or even better than the commonly used high quality timber species such as Tectona grandis (Teak). The physical and mechanical properties as well as resistance against natural degrading agencies and fire hazards can be improved as per the desired application of the final product. The bamboo composites can therefore serve as a strong, durable, cost effective and ecofriendly alternatives to traditionally used timber species, which may help in reducing the pressure on precious forest and plantation resources of the country.

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Black bamboo Shyama for production of premium furniture

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Bamboo was termed as poor men's timber though this perception has changed lately and now it is being considered as a most sustainable alternative to wood which can match steel and plastic in strength and elasticity. Bamboos are tall perennial woody grass, distributed between 46° N to 47° S latitude. Its woody stem is round timber like structure with lumen or hollow in the centre pith and shiny but very thin bark. There are more than 1600 species which contributes in livelihood of more than 1 billion people. During last decades of 20th century more than 1500 uses of bamboo were highlighted which is increasing further with novel uses. Bamboos are being used in sectors like construction and housing, paper and boards, wood and furniture, food, energy, fibre and handicrafts. Worldwide market for bamboo product was estimated to US $ 69 billion in 2018 and bamboo furniture contributes 12 % of it. Bamboo and rattan sector of India is estimated around Rs. 30 billion, in which rattan has a lion's share and most products are being consumed in domestic sector and India is now a net importer of bamboo. Bamboo furniture is a big market where round as well as flat strips are being used. Presently in India, bamboo furniture is manufactured in cottage industry sector with traditional designs and low quantity production. Though there is a traditional domestic market, globally Indian bamboo furniture are uncompetitive as compared to Chinese, Vietnamese, Indonesian and Italian products. This sector needs premium products, process improvement, contemporary designs, appropriate testing and adoption of standard operational protocols, joineries and better finishing for global as well as mainstream domestic market. India has more than 135 bamboo species but only few species like *Bambusa tulda, B. nutans, B. polymorpha, B. chcharensis, Dendrocalamus asper, D. brandisii, D. giganteus D. longispathus, D. sikimiensis, D strictus, D. stocksii, Gigantochloa attrovoilaceae, Thyrsostachis oliveri* are suitable for round bamboo furniture, mostly because of good finishing and working ability. State wise demands of bamboo species varies; in Assam preferred bamboo species are; *Bambusa tulda (jaati), B. nutans (Mokal or makla), B. pallida (Bijli) Dendrocalamus sikimiensis (Bhutan bamboo)* and *D. giganteus,* in Tripura it is *B. chcharensis, Bambusa tulda, B. nutans, B. polymorpha, D. giganteus, D. longispathus* and *Thyrsostachis oliveri,* in West Bengal and UP *Bambusa tulda, B. nutans* and *D. strictus,* in Chhatisgarh and MP *B. nutans* and *D. strictus,* in Maharastra and Gujrat *D. strictus* and *D. stocksii.* Round bamboo furniture are being produced either in clusters or by sporadic producers spreaded over places like Barpeta, Guwahati, Silchar, Golaghat, Jagi Road and Jorhat in Assam, Tripura, Manipur, West Bengal, Chhattisgarh, Madhya Pradesh, Uttar Pradesh, Maharashtra, Gujarat and Kerala. There is no big production facility or house involved but there are aggregators in some places. In India, demand of bamboo-based products is not explored fully as compared to wood mostly because of a perception of 'no steady market' for bamboo products like furniture and similar products. This sector is low volume and has a niche demand in handicraft sector, however there is potential for bamboo in broad furniture sector as a low cost and light weight furniture as well as value added and aesthetically designed premium products.

Round bamboo furniture has certain issues and challenges like; crack in bamboo furniture in dry area, variable Culm thickness, susceptibility to insects and pest, storage of raw material and joinery etc. Bamboo furniture is bulky and hence it is costly to transport from northeast to rest part of India. Most of the skilled persons of bamboo furniture are in northeast India and regular carpenter in other part of country lack those specific skills. Bamboo in natural condition has a very nice outer skin of green, yellow colour which turns light pale after drying. Challenges in manufacturing round bamboo furniture can be mitigated by right technology and approach which is already available. Attractive outer skin colour of bamboo can be retained by developing appropriate technique. One such practice has been standardised in a species of black

bamboo which is also suitable to produce premium furniture of natural dark brown to chocolate brown colour. There are two species of bamboo whose stems are black or purplish black in colour; *Gingantochloa attrovoilaceae* Widjaja syn *Bambusa lako Widjaja* is a tropical clumped bamboo with height more than 20 m and basal diameter 8 – 13 cm and *Phyllostachis nigra* (Loddiges ex Lindley) *Munro* is a temperate monopodial bamboo 4 – 8 m tall, 5 cm or more in diameter. Later is small so mostly used in ornamental garden. Former is called as Java black or Timor black bamboo and mostly prevalent under cultivation in Java Island of Indonesia and Timor Island. *Gingantochloa attrovoilaceae* is widely grow in west and central Java and introduced to several parts of the world. In India, it was introduced from Java to Botanical Survey of India, Kolkata 130 years ago. This big sized bamboo is commonly used in construction, furniture, decorative products, premium bamboo fence and musical instruments. In India, it is introduced and is being used for ornamental garden in mostly tropical part of India. Usually, this species prefers frost free environment though one cultivar is thriving well in sub-tropical condition of Dehradun.

Black bamboo was introduced from several places to Forest Research Institute, Dehradun. The most recent introduction was around 2000 without any known history. The black bamboo growing in FRI, Dehradun is tall and culm length reaches 17 - 22 m, diameter at middle of fifth internodes is also 8 - 12 cm and 1.5 - 3.0 cm wall thickness in cultivated clumps and also frost hardy (Fig. 1). The culms are green in first year with intact golden culm sheath, in second year stem colour starts changing from green to purplish brown to black, in third year stem colour changes to purplish black to dark black, fourth year onwards stem colour changes to black with little olive spots most likely due to lichens. These bamboo plants growing in FRI Dehradun might have origin from Timor Island which is described as larger and relatively stronger than Java black. In FRI Dehradun, minimum temperature goes around zero degree Celsius, despite that the black bamboo is growing well and adapted in this climatic condition. We have cloned the adapted clumps through offset and rhizomes and planted in field. The growth was encouraging and we found that thick shoots emerged in second year which were ready for harvesting in end of fourth year. This vigorously growing and cold adapted cultivated variety of black bamboo is named as 'Shyama'. The erect and straight culm of Shyama emerging from the clump indicates its strength and suitable for uses other than ornamental plant. Colour of matured stem of Shyama bamboo is beautiful black and brown, so it was obvious that if colour was retained then there is a potential for this black bamboo in premium segment. To explore this potential, first its uses were visualised and primarily it was appeared to be fit for furnishing products

Fig. 1 Clump of fully grown Shyama cultivar of *Gigentochloa attrovoilaceae* growing in compound of tissue culture laboratory of Forest Research Institute, Dehradun.

because of its aesthetics. Initially, small products and artefacts were developed (Fig. 2) after the standardised practices. During 2009 to 2018, characters of Shyama cultivated variety were evaluated for desirability in furniture. These all points observed are being summarised as follows:

1 **Workability:** Working with tools like saws and chisel are easy and finished products is of good quality.

2 **Retaining its colour:** Most of the coloured bamboo loose original colour after few months. We have tried with *Bambusa tulda* (green), *Bambusa straita* (yellow) and black bamboo Shyama. The Shyama has beautiful colour so experiments were laid to retain its colour for long period. This bamboo was studied for colour retention in 2009 -10, the colour of this bamboo little faded after one year of drying but retained faded brown for 2 years. Further treatments and polishes were given this bamboo for colour retention as well as durability of culms in dry and moist conditions. The results were amazing,

Fig. 2B Curtain rings and rod developed from culms of the Shyama

Fig. 3A Trials for colour retention, joinery and structural stability

Fig. 3B manufacturing of bamboo frame for table.

Fig. 4 Bamboo furniture, bed and dining table with stool made from the Shyama bamboo at Scientist Hostel, Forest Research Institute, Dehradun.

Table is being tested for weight.

Real time weight testing of first sofa made from Shyama

Fig. 5 Small table and stools developed from the Shyama bamboo

some treatments and polishes were not only retained the colour but also enhances its aesthetic appeal even after five years (Fig. 3).

It is medium to thin-walled bamboo. So basically, it was not considered strong enough to be used in furniture-by-furniture makers. Also, it has bigger lumen or hollow apparently there was problem of joining by nails and screw, most likely to split.

Present technology of joining of bamboo is difficult as nailing between bamboo to bamboo is difficult due to its longitudinal fibre. We have a developed a technique of bamboo joining by hybrid between bamboo and wood, where we used a baton of wood inside hollow stem, so nails and screw can easily be used for joining. This made structure stable and durable.

Here we developed a frame-based hybrid method so that a regular carpenter can use bamboo for making furniture from Shyama bamboo. Wooden frame provides extra strength and ease of work so that bamboo can be nailed and joined easily. Sofa and beds were developed from this bamboo (Fig. 4).

Wall thickness of culm was standardised and it was found that ratio between wall thickness to culm thickness should not be less than 0.12. The culms were subjected to crude tests like human weight in the middle and it was found that basal portion of culms (180 cm) easily withstand weight of 65 kg person, this was encouraging hence culms of Shyama was initially used for stools and table (Fig. 5).

This bamboo was not tested for preservation. Like all bamboo this may also be liable to disease, insects and pest. Though we have not used chemical preservation but we have soaked bamboo in water pond for 15 days. This method reduces cellulose and hemi cellulose from bamboo and bamboo are less likely to be attacked by insect.

Development of product is an ongoing practice and process can be improved with feed backs and other inputs. Over the years we have standardised packages of practices to make furniture from the Shyama bamboo which is durable. Work at FRI is going on improvement of designs and finishing. Now we are using mostly bamboo dovels instead of nails. Since technology has been developed and a lot of good feed backs are coming, we are ready to provide training and consultancies for all aspects like; growing of this species to manufacturing furniture and artefacts from beautiful black bamboo 'Shyama'.

Fig. 2A Artefacts like cups, tumblers and decorative items developed from black bamboo Shyama

Acknowledgment: I am grateful to Sri. Arun Singh Rawat, Director General ICFRE for his continuous support and encouragement. Also, I thank my team to help in developing and designing the products.

Bamboo based bio-composite material developed at IPIRTI

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Introduction

India is the second most populated country in the world. With only about 1% of the world's forests, India supports 15% of world's human population and 16% of cattle population. The increasing needs of growing population and environmental awareness have put severe restrictions on management of forest resources. This has resulted in shortage of wood required in housing, transport and other sectors. Several non--wood alternatives like metal and plastics also have serious limitations on account of non-sustainability, high-energy requirements and non-biodegradability. In this situation, there is an emphasis on development of sustainable and environment friendly wood alternates. Bamboo, a fast-growing giant grass, found in abundance in India and several other countries in tropics as well in subtropical and temperate regions except Europe, is emerging as a highly potential natural and renewable material to fill the void. India has the second largest resource of bamboo both in terms of diversity and distribution (about 13% of the forests or app. 10 million ha.). India accounts for around 135 of about 1250 species of bamboo found in the world. Of this only 30 species are commercially important. Apart from being available in natural forests bamboo is also raised as plantations, both pure and as under planting, and also in homesteads. Bamboo is also suitable for restoration of degraded forest and other wastelands as well as of abandoned shifting cultivated areas. Bamboo is an important cultural feature in many parts of India and has played an important part in daily lives of people in India. Bamboo craft is one of the oldest cottage industries primarily due to versatility, strength, lightness, easy workability of bamboo with simple hand tools. Bamboo has been put to use for various applications ranging from construction to household utilities and have more than 1000 documented uses including an important industrial use in paper and pulp manufacture. Due to plethora of essential uses, it has been aptly described as "poor man's timber", "green gold", "friend of people", "the cradle to coffin timber", "Green Gasoline", etc.

Relevance of bamboo-based panels

In the 1980s, guided by dwindling wood supplies in the tropics, interest on bamboo as an alternate material intensified resulting in its emergence as potentially the most important non-wood renewable material to replace wood in construction and other uses. The realization that bamboo produces woody bio-mass faster than many fast growing timber and that some of its physical and mechanical properties are even superior to wood available from fast growing plantation species like Eucalyptus, Poplar, Acacia, has evoked keen interest in bamboo growing countries and elsewhere on theoretical and applied research on bamboo based products to replace wood in housing, furniture, packaging, transport sectors, etc. Some earlier studies have revealed that bamboo in panel form is best suited to substitute wood and therefore development/refinement of cost-effective technologies to produce bamboo-based panels has been identified as an extremely important area of research. The environmental and socio-economic implication of bamboo-based panel industries also favours their promotion on priority.

Classification of bamboo-based panels

Bamboo based panels can be broadly classified into three groups.

Bamboo Mat Composites

1] Bamboo Mat Board
2] Bamboo Mat Veneer Composites
3] Bamboo Mat Corrugated Sheet

4] Bamboo Mat Moulded Trays

Strip Based Bio -Composites

1] Bamboo Curtain Board
2] Bamboo Strip Board (or) Bamboo Plywood
3] Laminated Floorboard
4] Parallel Glulam
5] Parallel Cured Gluccam
6] Bamboo Net Board (or) Bamboo Block Board
7] Bamboo "Zephyr" Board (or) Bamboo "Semi fibre" Board
8] Bamboo Moulded Shuttle
9] Bamboo Picking Stick

In addition to above, technologies are available based on bamboo strips such as Agarbathi sticks

1 Tooth pick
2 Ice cream sticks
3 Match splints

Technologies developed at IPIRTI

The versatility of bamboo for wide range of applications has made it a very important raw material and extensive research has been carried out at IPIRTI on the development of many such products from different bamboo species. The Institute has played a key role in promotion and commercialization of these products. A brief description of some of the developed technologies are given in the following section.

Bamboo Mat Board (BMB)

BMB is essentially a layered composite comprising several layers of woven bamboo mats having excellent internal bond strength, and are resistant to decay, insects and termite attack. They have physical and mechanical properties at par with waterproof plywood and are fire resistant. Their mechanical properties depend upon the material used for making mats, i.e. bamboo slivers, the weaving pattern and the adhesive used for bonding. BMB meet all the requirements prescribed in the relevant Indian specifications and have in fact much higher cross sectional shear strength compared to plywood.

Bamboo Mat Veneer Composite (BMVC)

In BMVC, wood veneers are placed in between the layers of bamboo mats. The properties of BMVC depend upon the mechanical properties of wood veneers that are placed in between bamboo mat layers, in addition to the properties of the bamboo mats and the adhesives used in bonding. The properties are comparable to that of structural plywood. Hence for all practical purposes BMVC can be used in a similar way to plywood for structural applications. BMVC are more economical in higher thickness as compared to BMB.

Bamboo mat moulded products

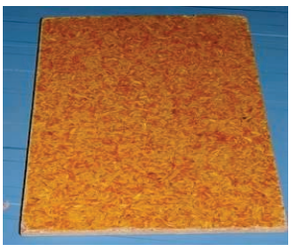
Considering the flexibility of bamboo mats due to *"Herring-Bone"* weave pattern, a process was developed to produce moulded products in rectangular or round shaped such as trays which can be subsequently finished with coating materials to enhance the appearance and acceptability by the consumers. The moulded products were found to be highly durable and leak proof which can be conveniently used for various applications like the ones based on metals, plastics, etc. The technology for the manufacturing of bamboo mat tray has been transferred to two units.

Bamboo mat corrugated sheets

The Institute developed a complete package for BMCS including the design of moulds. The technology has already been transferred to industries and the product already seen a commercial success.

Bamboo mat overlaid particle board

Particle board are characterized by poor mechanical properties as compared to plywood and also known to have coarse surface. In order to improve



Bamboo Raw Board

Bamboo Mat Overlaid Particle Board

the properties and surface, processes have been developed for overlaying wood/rice husk particle boards with bamboo mats. The overlaying is found to improve physical & mechanical properties of the boards as well as the appearance. The bamboo mat overlaid particle boards may be suitable even for semi structural applications. The results obtained from bamboo mat overlaid wood particle board in comparison with the data on wood particle boards indicated that water absorption and swelling properties of bamboo mat overlaid wood particle board improved considerably enhancing the durability of such panels even under adverse climatic conditions.

Bamboo wood

Development of appropriate technologies for the manufacture of both horizontal and vertical laminates using synthetic resin like urea formaldehyde, melamine urea formaldehyde and phenol formaldehyde resins have been developed. Machinery for exerting side pressure for making laminates has also been designed and developed by the Institute. These laminates exhibit properties superior to plantation timbers and are suitable for applications such as furniture, other household component and flooring.

Bamboo strand lumber

Technology has been developed to make Bamboo Strand Lumber from bamboo strands which poseshigh strength, stiffness and rigidity. is These panels are characterized by resistance to deformation, abrasion and weathering. Its bending strength properties are superior to wood panel and therefore application potential, particularly as platform boards, vehicle platforms, transport floorings, etc., are suggested.

Establishment of Bamboo Processing Unit

IPIRTI has been progressively engaged in setting up bamboo processing centres and common facility centres for primary processing of bamboo. So far, the institute has established eleven CFCs in various parts of India.

JAN'S

KONBAC
Community First

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Bamboo - *material for construction of contemporary structures*

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Scope of bamboo as material of construction

Bamboo has a long and well-established tradition of being used as a construction material throughout the tropical and sub-tropical regions of the world. The high tensile strength of Bamboo and its capacity to withstand up to 3656 kg/cm2 of pressure make it an ideal material to be used in the construction industry. The positive strength-weight ratio of bamboo also supports its use as a highly resilient material against forces created by high velocity winds and earthquakes. Bamboo can be worked upon by simple tools and machines and if properly treated components made by bamboo can have a reasonable life of 30 to 50 years. Besides, unlike iron and steel Bamboo does not rust in damp tropical climate.

Besides, Bamboo is the most environment friendly plant on this planet, being one of the highest carbon sequesters amongst all the floral species. Bamboo also requires lower emissions intensive processes to create components for the construction industry. Bamboo requires 1/3rd of energy compared to timber, 1/8th of energy compared to cement and 1/50th of energy for processing equivalent mild steel. At the end of a bamboo component's life cycle, it can be recycled, repurposed, or burned to produce heat or electricity. Thus, compared to other materials, bamboo products can have a low or even negative eco-cost over the course of their lifecycle. Last but not the least, Bamboo is a perennial 'renewable' agro-forestry resource. It grows fast, matures within a few years and re-grows after harvesting without the need for replanting. A 60-hectare bamboo plantation would yield enough material to build 1000 bamboo houses annually whereas it would require 500 hectares of forest cover if the houses were to use timber instead. With a 10-30% annual increase in biomass versus 2 to 5% for trees, bamboo creates greater yields of raw material for use. It can be harvested within 3- 5 years versus 10-20 years for most softwood. Bamboo generates an annual crop with one clump of Bamboo yielding 200 poles within three to five years. Though Bamboo is also known as poor man's timber, research and development undertaken by the Bamboo sector over the past few decades has established and adequately demonstrated that Bamboo could be a viable substitute of wood and other traditional material, like steel and cement, for the housing and building, construction and other infrastructure sectors.

The findings of the International Resource Panel (IRP) synthesis report, (Hertwich, van der Voet, & Tukker, 2010) a global assessment of final consumption categories and product groups that have the highest environmental impacts across their life cycle, show that housing and building construction falls in the top three high impact categories. The building and construction sector accounts for 39% of global energy-related CO_2 emissions and construction and demolition waste accounts for upto 40% of all municipal solid waste with a significant part of it ending up in landfills in most countries. The most effective strategy to reduce the negative environmental impacts caused by the building and construction industry would be for it to use Bamboo as a raw material.

These qualities of Bamboo are critical to the contemporary policy discourse on 'circular economy' that involves designing products, services and supply chains which are regenerative: that is, which are based on renewable energy and resources, do not generate waste and keep products and materials in use for as long as possible. Bamboo can become the cornerstone of the circular economy and presents the opportunity to leap-frog to an inclusive green economy.

Present status of bamboo in the construction sector

Understanding bamboo as a material-

Non-renewable natural raw materials like steel, wood, iron etc have a

legacy of over a century or two as preferred raw material in the construction industry. Huge investments in research and development have been made globally to mould these raw materials to the requirements of the construction industry while the construction industry has also innovated to optimally harness the strength of these materials. Policy has also played a crucial role in this exercise.

As practice on the field has highlighted, the specific technical properties of Bamboo, as different from traditional raw material like wood and steel, have to be taken into consideration to optimally harness Bamboo as a universally applicable construction material. The key dimensions to be considered are structural strength and durability, jointing & bolting, elasticity, flammability, design and codification of bamboo.

ISO standard for bamboo construction

Recognising the unique properties of Bamboo that lend itself to the construction sector, the International Organization for Standardization (ISO) recently published a new standard on structural design with bamboo poles, ISO 22156:2021 that applies to the design of bamboo structures whose primary load bearing structure is made of round bamboo. This second edition cancels and replaces the first edition (ISO 22156:2004), which has been technically revised. This document was prepared by the Technical Committee ISO/TC 165 and INBAR's Bamboo Construction Task Force supported ISO to develop this standard. This standard provides a means of structural design for one- and two-storey building structures for residential, small commercial or institutional and light industrial use, using full-culm round bamboo poles as the primary vertical and horizontal structural load resisting systems. This standard addresses connection design, light cement bamboo frame shear panel design, and issues of durability, means of achieving design and performance goals in these areas. This International Standard permits an allowable load-bearing capacity design and/or allowable stress design approach for the design of bamboo structures. This International Standard additionally recognises design approaches based on partial safety factor design and/or load and resistance factor design methods, previous established experience, or documented 'design by testing' approaches.

Showcasing contemporary bamboo structures

Konkan Bamboo and Cane Development Centre (KONBAC)

Bamboo has been traditionally used in the rural Konkan region for construction of roofs, farm structures and scaffolding. In 2004, realising the critical role of Bamboo in catalysing a circular economy, KONBAC decided to start work on developing a high-value Bamboo supply chain. The first step was to start working with farmers in Sindhudurg District of Maharashtra to grow Bamboo species that had commercial value. KONBAC partnered with INBAR (International Network for Bamboo and Rattan) for technical support to impart training on selection of high-quality planting material and scientific cultivation techniques to the farmers.

The crop was ready for harvesting from year 2008 onwards and an entire ecosystem was created to derive high value from this produce. It covered sustainable harvesting, age grading, proper treatment for longevity, aesthetic design and development of structures. KONBAC conducted extensive research and development on using Bamboo for construction of residential and commercial structures for over a decade to create aesthetic and durable Bamboo structures.

Organo community centre

In 2015, KONBAC along with Navira and Fountain Head Design (FHD) Group achieved a landmark by constructing the largest Bamboo structure in India. India's first self-sustainable collective farming rurban community. The structure covering 10,750 sq ft with a maximum span of 82 feet and weighing 61,000 kgs is located at Aziz Nagar, Hyderabad. Organo embraces the best of nature's elements integrating 7 strands of sustainability (food, water, air, earth, energy, shelter and people) thereby making it the first and one of its own kind project in the world. FHD used a low impact design approach to reinvent their Community Hall into a version of a

village 'Chaupal' with the objective of giving the structure an Indian touch and bringing back the good old days. Situated adjacent to the community's Club House, the Community Hall is used as a multi-purpose community space. The project executed by KONBAC, required extensive research and went through many iterations. This Bamboo structure was built within 100 days using 50mm and 80mm dia bamboo. A total of 4.9 kms length of Bamboo was used to build this magnificent structure which is 3 times larger than the previous Bamboo structures in India. Tata Trusts provided KONBAC financial support that enabled it to invest time and resources to construct this structure, the largest bamboo structure in India.

Jans bamboo products pvt. Ltd. (JANS)

JANS was established in 2016 to mainstream Bamboo in the building and construction sector by bringing together the resources, right mindset, sector design capability, better management skills and technical manpower to scale the achievements made in the construction sector by KONBAC.

JANS has constructed large, beautiful and contemporary structures that are considered value-for-money propositions by its clients, ranging from Government Institutions, Private Builders, Hospitality Industry to name a few. Despite India being a late starter in the field of Bamboo construction, especially compared to South-East Asian countries such as Indonesia, China, Colombia, Vietnam, etc. JANS has been able to spread its wings internationally too. It has built one of the most intricate and beautiful structures for the international high-end brand Waldorf Astoria in Maldives using Indian bamboo, artisans and technique.

Floating dining pods @ Resort at Maldives for Waldrof Astoria

Hilton Hotels & Resorts is one of the biggest hotel brands in the world with more than 5,800 properties spread across 114 countries. Waldorf Astoria, the luxury resort brand of Hilton, one amongst its 20 brands, opened its 1st resort in Maldives, a luxury family resort consisting of 122 villas on 1st July 2019. The floating dining pods, built by JANS, christened "Terra" is one of the 7 specialty restaurants at this island resort and located on the highest point on the island.

The concept sketch was given by the architectural firm "Stickman Tribe" and JANS was commissioned to design and build this beautiful bamboo structure. This signature venue has been sectioned into a series of platforms with vast island views, a cat-walk entrance and semi- private dining cocoons. The cocoons made up of bamboo are hidden in dense bamboo forests and are layered for optimizing views for the guest.

A full-scale mock-up, with Bamboo taking up the structural load too, was set up on the site. This was appreciated by the Client, the Architect and the Operator Hilton and the entire design was unanimously approved. In fact, the other areas such as walk-way trellis, hand railings for support etc. which were earlier planned in Stainless Steel were eliminated and it was decided to build the entire structure in bamboo.

JANS managed the entire eco-system, procured the high-quality bamboo from the farmers in India, age graded it, treated it using vacuum pressure treatment conforming to IS- 9096:2006, straightened the bamboo poles using heat treatment, carried out the bending of bamboo poles, bunched the different poles and prefabricated all the components at Kudal, Maharashtra. These components were then shipped to Maldives and were assembled on-site using Indian master artisans. This strategy of splitting the work in two processes, refabrication and installation saved a lot of time and the construction was completed in a record time of 2.5 months. This structure has been recognised by the CNN travel magazine as one of the top 16th waterfront restaurants in the world to visit. Such recognition helps establish the strength of Indian Bamboo Construction with respect to aesthetics, quality and competitiveness.

BambooPecker
in bamboo beyond imagination

Bamboo Construction:

Bamboo can be utilized as a building material for scaffolding, bridges, houses and buildings. Bamboo, like wood, is a natural composite material with a high strength-to-weight ratio useful for structures. Bamboopecker having a trained team to Bamboo construction

Bamboo Furniture

Bamboo has been used to make various kinds of furniture for centuries now. Sustainable, strong, and highly durable, bamboo furniture is becoming an integral part of everyday life.

Bamboopecker is very well known brand in the Bamboo furniture sector across India because of the high quality craftsmanship and finish

Bamboo Training/Workshops

Bbamboopecker used to conduct training and workshops for Government Organisations and individuals. This is a part of our other activities to make sure that trained professionals are available for the bamboo sector and for our own expansion plan.

B2B Bamboo raw material and products

The bamboo sector is not in an organized form in India. Lack of linkage issues with farmers to industry. Bambooepcker realized the importance of raw material, so we have our own network and system for procurement and our own treatment facility. Apart from our users we also sell treated or untreated bamboo poles. And we recently started the production of Bamboo powder for industrial applications

Art Installations

Bamboopecker also closely working with Designers, senior artists for designer products to art installations. Our experienced craftsmen are known for the quality finishing and understanding of the concept.

Photo Courtesy : Design By Shanthamani Muddiah and executed by Bamboopecker team

Cane/Rattan Furniture

Rattan is a fibrous climbing vine that is woven together to make furniture. Outdoor rattan furniture can last for generations. Bamboopecker traditional craftsman team only for rattan furniture and its crafts. Our team is capable to make furniture from out of a stamp size photo as a reference.

Bamboopecker Lifestyle Crafts Pvt Ltd

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Wood is Good, Bamboo too

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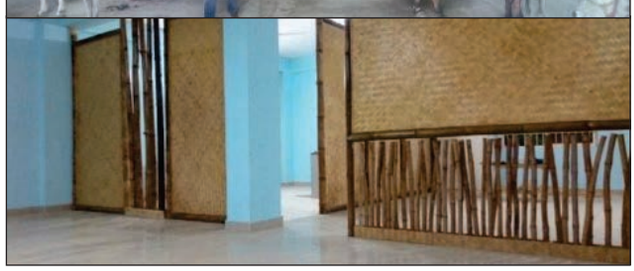
Wood has been used for centuries as a common material in furniture. Similarly, bamboo has also a long-

and well-established tradition for being used as a furniture material throughout the tropical and sub-tropical regions of the world. With the rising global concern, bamboo is a critical resource as it is very efficient in sequestering carbon and helps in reduction of Green House gas emissions.

Bamboopecker entered the field and proved that there is a possibility and potential of bamboo sector for a wide range of applications from furniture to construction by using bamboo. A mass production and distribution is possible in India but still basic sectoral infrastructure need to be upgraded to make it possible and viable. With such a large domestic market, India has the potential to become one of the largest producers of Bamboo furniture in the world. Boost in the domestic production will automatically results in looking at markets outside India.

In the modern context when forest cover is fast depleting and availability of wood is increasingly becoming scarce, the research and development undertaken in past few decades have established and amply demonstrated that bamboo could be a viable substitute of wood and several other traditional materials for furniture sector and several infrastructures works. Its use through except Canada, Europe, Antarctica and Western Asia where bamboo is not found as a native plant species. Most, however, occur at low to medium elevations in the tropics, growing wild, cultivated or naturalized in a great variety of habitats. In India, cane furniture and most bamboo products fall in the un-organised sector and 95% of Bamboo and cane sector industries production remains in the hands of rural craftsman especially tribes. Bamboopecker entered in this sector with a vision to create rural employment by making this unorganised sector in an organised way

Industrial processing has shown a high potential for production of furniture and components which are cost-effective and can be successfully utilized in furniture. Main characteristic features, which make bamboo as a potential building material, are its high tensile strength and very good weight to strength ratio. It can withstand up to 3656 kg/cm^2 of pressure. It can be easily worked upon by simple tools and machines. The strength-weight ratio of bamboo also supports its use as a highly resilient material against forces created by high velocity winds and earthquakes. Above all bamboo is renewable raw material resource from Agro forestry and if properly treated and industrially processed, Components made by Bamboo can have a reasonable life of minimum 30 to 40 years. Though natural durability of bamboo varies according to species and the types of treatments, varied applications in furniture have established bamboo as an environment-friendly, energy-efficient and cost-effective furniture material.



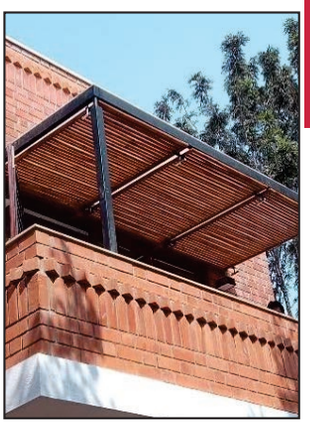
Bamboo and cane industry is an Agro based industry performing its activities from long ago. Bamboo is one of the most versatile plants and perhaps the fastest growing plant with some varieties growing at the rate of 5 cm per hour or 1.5 meters a day. Heights of 250 feet were not unusual for prehistoric bamboo varieties. Bamboo grows in different climates – it can be found on all the continents

Therefore, non-availability of statistics, demands on that the debatable nature of figures are not available on record. Unfortunately, in India, no comprehensive and serious study of bamboo and cane furniture sector has been undertaken till today. Using estimated consumption pattern of wood itself as the base, the size of India's wooden furniture market as on 2018 is to the tune of U.S $20650 million and expecting to the 13 to 14 % per growth every year.

It is estimated that up to one billion people rely on bamboo in one form or another. Throughout the sub-tropics and the tropics, rural populations live in bamboo houses, build their agricultural infrastructure and tools from bamboo and sleep on bamboo mats. Bridges and boats which allow rice farmers to tend to their paddies are made of bamboo.

The allure of the Asian aesthetic, particularly in using bamboo materials to endow products an essence of simplicity, has created a continuously growing market in the recent years. Environment conscious buyers have considered the durability and renewability and aesthetic of the bamboo being a natural and eco-friendly alternative to more traditional wood choices.

Bamboopecker Lifestyle Crafts Pvt. Ltd. is a company incorporated on 2nd February 2009 with a



Registered Office in Thiruvananthapuram, Kerala and having corporate office, manufacturing setup and showroom in Garden city Bangalore, Karnataka. We are the Start-up Social Enterprise with an Aim of manufacturing customized Bamboo and rattan Furniture and Lifestyle Crafts as an eco-friendly substitute to synthetic materials. All our products are made with chemically treated bamboo so that our crafts are not only pleasing to the eye but also durable and bug free.

Bamboopecker group having two production facilities and one showroom in St marks Road, Bangalore. We Bamboopecker Lifestyle Crafts wanted to revive the dying art of bamboo craft making and showcase the artisan's abundant talent to the appreciative buyer with quality products. The encouragement from the Bamboo lovers will not only make them economically independent and but also keeping the nature green.

From 2014 onwards, Bamboopecker expanded its activity from furniture to bamboo construction, art installations, Training for artisans and construction training and industrial processing of bamboo material for B2B requirements.

Bamboo as a substitute for solid wood in wood-based and wood-handicraft industries

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The soaring prices of raw materials for wood-based industries, the future sustainability of natural reservoirs and threat to the environment have forced to use natural redeemable materials for the development and fabrication of wood-based products. However, bamboo is the alternate source and substitute for wood. Similar to wood, bamboo is a green building material which is environmentally friendly and in line with sustainable development strategies. Bamboo is a fast growing, non-woody and highly renewable resource with great development value. It is one of the fastest-growing non-woody plant on an Earth, with reported growth rates of 100 cm (39 in) in 24 hrs. It is estimated 20 million tons of annual production worldwide. It is extremely resilient and durable as a fibre and has served a foundation structure. It can be used for many purposes such as building construction, furniture, panel products, handicraft etc. Over the last 3 decades, bamboo has evolved from being a raw material for basic goods into a material base of an increasingly diversified array of products. It has been recognized as a potentially important source of cultural and environmental services. The bamboo industry plays a significant role in the economy and society development worldwide.

India ranks second in terms of species, area, volume and output of bamboo. It has 136 bamboo species throughout the country. In recent years, in order to alleviate the high demand for timber resources in India, the bamboo industry rapidly. With natural bamboo as raw material, a series of new products, such as bamboo mat plywood, bamboo-woven plywood, and laminated bamboo lumber (LBL) have been developed by using advanced and reconstituted technology and are gradually achieving a high level of industrialization. As an ecological material with good mechanical properties, natural elegance and low price, its application in architecture has been existed since ancient times like wood.

Nowadays, in India several governments, non-government organizations (NGO) and industries offering bamboo plantation materials to promote the bamboo plantation. The main aim of this activity is to pay the attention of every individual from farmer to the wood-based industries towards bamboo utilization. Many bamboo industries have been set up and producing the bamboo products at commercial scale to fulfil the demand of society. Moreover, educational organizations also have a scope to identify the importance of bamboo utilization and develop the different bamboo products which can help to the nation's economy and society. In fact, some of educational and research institutes in country are working on bamboo utilization and developing the different bamboo-based products.

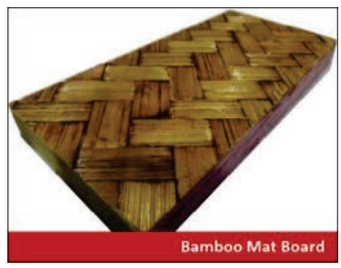
Treatment of bamboo

Bamboo treatment is an important aspect to increase the life span of bamboo products. The treatment can be done for interior and exterior purposes. Generally, chemicals like borax and boric acid with different concentartions apply on bamboo cane to expand the life span of bamboo.

Suitability of bamboo for various products

Bamboo is the promising and eco-friendly alternative material for wood-based and wood-handicraft industries.

Bamboo mat board is a plywood-like wooden board made from layers of woven bamboo mats that have been coated with glue and then pressed firmly together. Bamboo mat board has similar properties to plywood and can be used for panelling, housing, doors, furniture and household


Bamboo Mat Board

utensils. It is more flexible than plywood and can be used for stressed skin panels and wall bracings for which plywood is not suitable. It is also very suitable as concrete formwork.

Bamboo veneer is becoming very popular nowadays in the market as bamboo is an eco-friendly material rather than hardwood. It has very natural colour and is suitable for several modern design, such as hotel, museum.

Bamboo Veneer

Bamboo plywood is made of fine layers of bamboo strips laying in parallel order. The strips are kiln dried, sanded smooth and then laminated edge to edge to create a single-ply panel. These panels are then laminated again to each other to create a multi-ply bamboo plywood with free formaldehyde emission. The multi layers are cross-laminated and heat pressed together to provide stability and to prevent warping. Bamboo plywood have been widely used in building applications, such as flooring, ceiling, walls, windows, doors, fences, housing roofs, trusses and rafters.

Plywood Bamboo

Bamboo Blockboard is made up of a core of bamboo strips. These strips may be up to about 25mm wide. The strips are placed edge to edge and sandwiched between veneers of bamboo. The sandwich is then glued under high pressure.

Bamboo Blockboard

Bamboo handicrafts is one among the oldest crafts better-known to man. The craft from bamboo cane is full time employment of thousands of individuals in India. These are some bamboo handicrafts prepared by students of Forest College and Research Institute, Hyderabad. With such varieties of products which can be developed from bamboo. Bamboo can be the best substitute for solid wood which can help in discouraging timber import and mitigate the scenario of timber shortage for wood-based and wood-handicraft industries.

Bamboo jewellery - *the neglected Gems*

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Introduction

Bamboos are versatile, arborescent, perennial and non-wood forest trees with tremendous eco-sociological and commercial importance. It is a fast-growing world's greatest natural and renewable resources gaining approximately 75 to 400 mm per day. Bamboo is a vernacular term for the members of subfamily Bambusoideae of the family Poaceae, the grasses. The bamboo can be sub-divided into 1450 species. In total, about 18 million ha of bamboo are distributed in world ecosystems in Asia, Africa and America It has been in use in diverse ways since more than 500 years. Bamboos are widely used for making furniture, handicrafts, and jewelry. In India about 10 million hectare forest land is covered by bamboo. Tripura is one of the major bamboo producing states in India. According to "Traditional Bamboo Craft of Tripura: 2 species of bamboo were used for jewellery preparation such as *Bambusa tulda* and *Bambusa vulgaris*. Bamboo jewelry designs are colorful celebrations of nature, art, and science. The intricate designs made by the artisans of Assam are a rendition of their skills, developed in the past two decades. The technique of splicing, polishing and weaving is painstaking and smaller the piece, the more difficult it is to make. The warm yellow sheen of bamboo makes it a perfect choice as an accent to precious jewelry. Its ability to retain dyes expands its variety in colors. Bamboo adds natural elegance to jewelry crafted in gold especially when combined with pearls or diamonds. Bamboo handicrafts are mostly made in West Bengal, Assam and Tripura. Bamboo jewelry is hand-crafted by talented artisans using sterling silver, fine braided wire. They have multicolor blending to give a picture of three-dimensional contours to take various attractive forms and realistic shading. These are especially enameled on the reverse with counter enameling which minimizes tarnishing, strengthens pieces, and enhances appearance; this practice is uncommon in bamboo's price range. Assam in the North East of India has a lot to offer in bamboo, having rich reserves. The products have been sought after and are exported to UAE, Singapore, Malaysia, Japan, Europe, USA and Thailand. Bamboo is also used by the Akas tribe, for making bangles and earrings. The North East Indian state of Arunachal Pradesh is famous for its trible jewelry made of bamboo.

Wear bamboo-plant bamboo

John Hardy has always been a brand with an intriguing story. Started in Bali in 1975, the brand creates handcrafted jewelry made by artisans who pay tribute to the beauty of life in Bali. So it makes perfect sense that the Indonesian-based company would opt for sustainability and giving back to the land that has inspired it. As such, John Hardy has vowed to plant a bamboo seedling (and sometimes multiple seedlings) every time it sells a piece of jewelry in the coveted Bamboo collection. The "Wear Bamboo, Plant Bamboo," initiative was begun by the brand 10 years ago. The one millionth seedlings were planted on the grounds of the John Hardy design studio and workshops by CEO Robert Hanson and creative director Hollie Bonneville Barden. Through the program, the seedlings are given to local families for planting -- not just for sustainability but also because the plant helps purify air and water. Locals are also given cultivation training. The number of seedlings planted with the purchase of a particular piece of Bamboo Collection jewelry varies according to the price of the piece.

Bamboo species used for Jewellery

1 *Bambusa tulda* Roxb.- [common name - Mirtinga (Tripura)]

2 *Bambusa balcooa* Roxb.- [common name - Barak (Tamil), Bhaluka-banh/ Bholuka-banh, (Assamese)], Balku bans (Bengali)].

3 *Bambusa bambos* (L.) Voss – [common name- Hebbidiru (Kannada) Kanta bans (Odisha)]

4 *Bambusa jaintiana* R.B. Majumdar – [common name- Tetua (Tripura), Kyathaungtu-thaiktu (Burmese)]

5 *Bambussa nutans Wall.* ex Munro [common name- Bidhuli (Assam), Kali (Beng.), Makla (Tripura)]

6 *Bambusa polymorpha* Munro [common name- Mokal-banh (Assam)]

7 *Dendrocalamus longispathus* (Kurz) Kurz – [common name- Rupai (Tripura)]

Baansuli Jewels

While working on the bamboo products, Ms Saloni and the team (Gujarat) realized that bamboo posed a major challenge. Bamboo is a natural material made of organic elements and attracts excessive moisture to warp the product or allow moulds to grow, resulting in a shorter life. Saloni came up with the idea of treating the bamboo with alum, making it resilient from moisture and bacteria. And that's how BANSULI was borne. Through this process, Bansuli turned its weakness into its strengths as a majority of bamboo jewellery dealers neglect this crucial step which assures long-lasting quality and finesses visibility in the products.

Maintenance

Bamboo jewellery needs to be handled with care, as they cannot adhere to usual wear and tear that metal jewellery can cope with.

Marketing

Ethnic bamboo jewelleries are available online in E-commerce platform such as amazon.in, pinterest.com, utsavpedia.com. indiamart.com, bamboojewelry.com, craftsandlooms.com and many others. UNICEF Market Bamboo Jewellery Collection helps UNICEF to save and protect the world's most vulnerable children. The bamboo market is characterized by intense competition with the presence of several international and local players across different parts of the world. The consumer awareness towards the use of sustainable products concerning environmental protection is growing over the years. Focused approach on product innovation, infrastructure development and strengthening of supply chain will boost the bamboo market.

Prospects and challenges

Bamboo is a neglected gem and has enormous potential. Bamboo craft is the major source of developing rural economy of the state. Bamboo market size values USD 72.10 billion in 2018 and forecasted market size was USD 98.30 billion by 2025. This industry has a great export potential as well because greater acceptance of eco-products processed in ecological parameters is encouraging in world trade. Pricing policy, transportation, consumption of bamboo in all sectors needs to be solved with the policy maker. Technical research is needed to develop eco-friendly preservatives and scientific management of clump for higher productivity. New range of product line could be developed considering traditional knowledge for contemporary market maintaining quality of the products.

Lack of awareness and literacy are the quite a few challenges in this sector especially in remote villages of Northeast India. Skill enhancement initiative for the under privileged, empowering artisans across the country to earn a decent livelihood by making jewellery out of bamboo is very much required.

Way forward

Bamboo has blooming future. Technologies guidance and encouragement should reach people in the remote areas. Different bamboo research institutes should starts courses to give proper training on bamboo handicrafts including bamboo jewellery. Apart from generating awareness about bamboo, one has to ensure that artisans of the craft receive proper wage and support.

Bamboo leafy jewellery set

Bamboo earrings

Modern Bangles

Necklace

Bamboo preservation: *Traditional and modern techniques*

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Introduction

Bamboo has age-old connections with the basic needs of the people in several regions of the world. It is a common thing in rural India and in every household to have its own bamboo clumps for the daily need and its supply. Bamboo has made its way in everyday uses as building material, as agricultural implements, in paper and pulp industry, and in various utilization sectors. In the Indian Forest (Amendment) Act, 2017, bamboo was removed from the definition of tree. This change in legislation reduced the constraints faced by farmers initially. Thus, bamboos grown in non-forest areas can be harvested and transported without difficulties. This creates a scope for the popularization in usage of bamboo for various usage particularly in rural areas. Since the bamboo is very susceptible to decay, the preservation is essentially required for the promotion of its usage. There are various methods of treatment of bamboo and wood for preservation and drying. This article discusses about the various aspect of preservations treatment of bamboo.

Natural durability

Bamboo is underutilized in most of the sector due to its low durability. Bamboo has high starch and water content and that makes it more susceptible to staining fungi and the powder-post beetles. Liese (1980) reported that harvesting pattern also affects the durability of bamboo. Durability depends on the species and climatic conditions of the place. Systematic data on the natural durability of bamboo underground condition and in exposed condition is very limited and unorganized. Graveyard tests were conducted on Indian bamboo species and it was found that some species of bamboo have average life of less than two years in untreated condition. Bambusa balcooa and Bambusa tulda had an average self-life of 32 months and 41 months respectively (Purushotham et al. 1954). Thus, according to the durability classification, bamboo falls in class III (non-durable category) with little variation among different species (Kumar et al. 1994).

Drying and protection

Green bamboos may contain 100-150% moisture content, depending on the species, area of growth and felling season. Bamboo also possesses hygroscopic materials in parenchyma and therefore, takes longer time to dry compared to wood of same density. Bamboo is mainly air dried, which takes 6-12 weeks, depending on initial moisture content and wall thickness. Excessive and non-uniform shrinkage is a common problem in immature culms of bamboo and thus mature culms are recommended. Kiln drying is not recommended for round bamboo since they tend to crack and collapse under temperature.

Insects and defoliators, bamboo stem beetles, weevil borers and sap-sucking beetles tends to attack green bamboo readily. This can be controlled by spraying with 0.2% fenitrothion. Bamboo is affected mostly during the storage. Prophylactic oil treatment is another traditional method of protecting bamboo in rural parts of India. Bamboo stacks of more than four months of felling, affects the yield and quality of pulp. Prophylactic treatment, involving sodium pentachloro phenate, has given positive results in saving stored bamboo (Kumar et al., 1994). However, pest management

Fig. 1: Stacked bamboo for seasoning

strategy using minimal application of pesticide is preferred. BBA (Borax-Boric Acid) treatment at regular intervals followed by stacking of bamboo on concrete levels reduces chances of infection in bamboo. Soaking of bamboo under water is another method of protection of bamboo followed in South Asian countries mainly in Thailand, Indonesia and Myanmar.

Chemical protection ensures longer life for bamboos. Bamboos are treated using chemicals by steeping, sap displacement, diffusion process, pressure treatment methods, Boucherie process, and modified Boucherie process. Steeping treatment or Butt-End Method is one of the easiest and less expensive methods of treatment that gives satisfactory results. Thus, there is various methods and varied preservatives for the treatment of bamboo. The treatment and preservatives depend on the purpose (structural and non-structural) for which the bamboo is used. The specifications for the non-structural purposes are given in IS:1902 (2006) and the specifications for the structural purposes are listed in IS:9096 (2006).

Treatment techniques

The treatment techniques can be broadly classified into two groups based on the type of treatment applied on bamboo.

A. Nonchemical method of bamboo protection

Insects and fungus are generally attack the Bamboo in search of food, if starch and sugar content of bamboo are reduced or controlled then it will reduce the chances of any fungal or insect attack. There are numerous traditional practices for this sole purpose:

Bamboo felling at maturity: Bamboo should be felled only when it reaches its rotational age or maturity when the sugar content is low. Sugar content in bamboo varies with age and optimum age for harvesting of bamboo is 3-4 years (Kumar et. al. 1994).

Seasonal felling: It has been found that sugar content in bamboo varies with seasons. It is higher in the spring seasons than winters. Time after monsoon till the arrival of winters i.e., from August to December is ideal for harvesting.

Water soaking: After the harvesting the bamboo is soaked in water and during this process the sap or sugar content of bamboo is leached out. It is a time-consuming process sufficient time for soaking of bamboo is 4 to 12 weeks.

Curing method: It is always suggested to leave freshly cut bamboo culm for 1-2 weeks along with the leaves. During this time, respiration of leaves and tissues cause significant loss of starch.

Oil treatment: This practice is mostly in use in the rural parts of India where oil is smeared all along the surface of the bamboo and dried under sun. This toughens the bamboo surface and is often used as weapon in villages.

Smoke treatment: The smoke treatment of bamboo is in application from ancient times. Bamboo culms are placed over gentle fire and the surface is rotated continuously to avoid burning of bamboo and excessive heating can reduce strength and cause damage to bamboo. The starch present in bamboo got destroyed by toxic agents present in smoke and heat making bamboo resistant to insect and fungi. Smoke treated bamboo turns black giving a nice texture.

B. Chemical method of bamboo protection

Protection using chemicals ensure longer life of the bamboo as compared to the non-chemical methods of protection. Depending on the end use and the condition of bamboo (Green/Dry) the method of treatment is decided. Treatment methods are different for dry and green bamboo both including pressure and non-pressure methods (Chakraborty et al. 2007).

Pressure Methods:

Full cell process: This method provides the maximum retention of the preservative. This treatment method is performed in three stages. First stage involves creating vacuum in order to remove all the excessive air from inside the bamboo, followed by second stage in which preservative is pumped into the bamboo at a pressure of 5-15 bars for some hours so that the cell cavities completely get filled with preservative solution, and finally vacuum is again created for 8-10 minutes after draining out the

preservative solution for removing excessive chemical. This method is used when the high retention in bamboo is required.

Empty cell process: This method obtains high penetration with low retention. In this method the wood is first subjected to high air pressure; after that, the preservative is forced into the cylinder at a rate that air escape from the cylinder to maintain the constant pressure in the tank. When preservative is filled the pressure is increased till the desired penetration is achieved. The final stage involves vacuum to remove excess preservatives.

Modified Boucherie process: This is an advanced version of boucherie process. In this method a pressure of 1.0-1.4 kg/cm^2 is applied and this reduces

Fig. 2: Modified Boucherie setup

the time of treatment significantly. The time of the treatment depends on the length of the bamboo and 30-60 minutes are required to treat bamboo of short length with pressure of 2 kg/cm^2.

Non-pressure methods:

Spraying: This is the simplest method of treating bamboo with preservative. In this method the bamboo is stacked preferably on slopping ground and on polythene sheets. The excessive preservative can be collected and reused. Proper precaution is required while spraying as the chemicals can be hazardous.

Brushing: It is done for small pieces of bamboo. In this method the preservative is applied on the bamboo surface using a normal paint brush. A uniform layer of preservative is formed on the surface after applying 2-3 coats. Type of surface will decide the size and type of the brush to be used.

Dipping: This method is more effecting than brushing and spraying. In this method the small bamboo samples or bamboo products are dipped in preservative solution for a minute or two. The excessive material should be drained properly and reused for the next treatment.

Butt end treatment/steeping: In this method, the freshly cut bamboos are kept vertically in a bucket filled with preservative. The preservative then moves upward through the vessels by capillary action and diffusion. After the bamboo is cut in required length by making base cut and removing the foliage, the bamboo is placed in preservative in an upright position. Treatment should be done for 7-14 days depending upon the size of bamboo. In midway, the bamboo should be inverted for better and thorough treatment. Once treatment is done, bamboo culm is removed and then placed under shade for seasoning. This method can be only done in green or freshly cut bamboos, and time of treatment will depend upon the length of bamboo.

Soaking/diffusion: Bamboo slivers, splits or round bamboos are kept submerged in water borne preservative solution. The preservative moves into bamboo due to concentration gradient. Time for this treatment can be reduced by increasing the concentration of the preservative or puncturing the nodes. In this method, the bundle of bamboo is submerged in the container and then container is closed to reduce the water loss due to evaporation. The submerged bamboo is kept for 15-20 days. After treatment, the preservative solution is drained, and bamboo is stacked for further diffusion and air drying under cover.

Hot and cold process: This method of treatment depends upon the principle that during heating process the air present in bamboo will expand and escape partially and at the time of cooling it will create a vacuum, hence allowing the preservatives to enter the bamboo. Also, heating decreases the viscosity of preservative enabling ease of flow into bamboo. In this method, the bamboo culms are loaded into tank filled with preservative. This tank is heated for 3-4 hours, and then allowed to cool to an

ambient temperature and then, the bamboos are stacked for conditioning.

Sap displacement/Boucherie process: This is a widely used method for the treatment of freshly cut bamboo. Preservative is pushed in the bamboo with the help of gravity from a container placed at some height. The twigs and branches of bamboo to be treated are kept intact. The penetration and absorption depend upon several factors like time of treatment, concentration of preservative solution, age and moisture content of bamboo and some other factors (Chakraborty et al. 2007).

Fig. 3: Treating green bamboo by Boucherie Process

Conclusion

Bamboo has been used by rural people since long time and it is called as poor man timber. But it is highly susceptible to decay which leads to its low durability. Therefore, it is underutilized in most sector. Bamboo preservation is very important to make it more acceptable among people and industries. Depending upon the different requirements, there are various method for its preservation treatment. It is important that the preservative used is of high efficiency and low mammalian toxicity. Effective treatment along with proper drying and usage of preservatives will enhance the life of bamboo products and make it a suitable alternative of wood and increase its utilization.

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Approach for making solid bamboo furniture in India

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Introduction

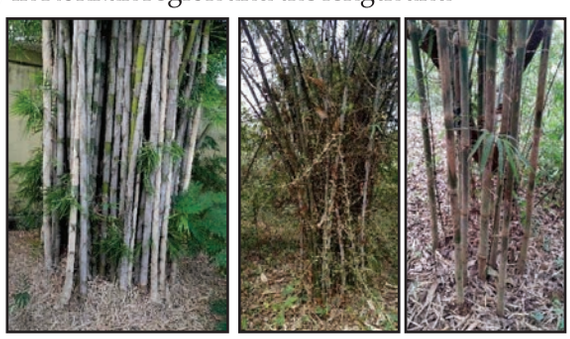
Bamboo is one of the fastest growing plant, whether to call as green gold, giant grass, or woody grass it is one of the amazing raw materials to explore in various ways and means for all kinds of applications. Conversion of bamboo to various sizes of splits and its pliability to weave and construct structure etc. makes this material very special among other natural materials. Similarly, many of the special properties of bamboo helps to create various products for day-to-day life. It is the most sustainable – ecofriendly - renewable natural resource used for various purposes. India has got good tradition in utilization of bamboo as a raw material for various usages especially in basket making. The North-East part of India has demonstrated the utilization pattern of bamboo through many applications with various species and its properties.

Bamboo culture from Nagaland, North-Eastern part of India

When we look at the applications for the modern lifestyle market, furniture is one of the most important products that can be built using bamboo and can replace many materials like wood, steel, and plastic. We can make bamboo furniture in many ways such as using hollow bamboo, bamboo splits, bamboo boards, bamboo timber etc. However, using solid or partially solid type of bamboos for making furniture have a great potential in Indian sub-continent. Here in this article, I am sharing the experience of designing and making bamboo furniture using solid bamboo with various joints and construction methods. The Centre for Bamboo Initiative at National Institute of Design (NID), Bengaluru has been experimenting and demonstrated many such innovations for making furniture for Indian bamboo sector since many years.

Solid Bamboo Species in India

*Dendrocalamus stocksii, Thyrsostachys oliver*i and *Dendrocalamus strictus* are some of the solid bamboo species cultivated in India. I have experimented with all these three species of bamboo for making furniture. However, I have found Dendrocalamus stocksii is very suitable with its physical & strength properties. Mostly in all the above species the bottom portion of the culm is solid and partially solid towards top portion. Sometime entire culm is also being found solid in some regions in these species. Since this is solid and have got dense fiber structure, we can do all kind of machining and tooling like solid wood. Because of its inherent properties as a solid bamboo, it can be bent to form a curve or arc by applying heat and pressure on the poles. This is one of the important properties when we consider it for making furniture. Similarly, since it is solid in nature, joining it with various joints like a timber is also an added advantage. Dendrocalamus stocksii has been cultivated widely in Konkan region and the length and diameter of this varies according to place and climate differences. This is an important fact that need to be kept in mind while planning and designing of furniture.



Solid bamboo Species available in India – *T. oliveri, D. strictus, D. stocksii*

Approaches for design

The process of designing a bamboo furniture starts with some of the key considerations

Bamboo Furniture using solid bamboo and combination with bamboo splits

like, it could be produced or made in an Industrial, semi-industrial or handmade set-up. It should be suitable for available and selected species. It should have a utility and lifestyle value as per the focused market segment. It should be considered for easy transport, knockdown type or foldable etc. The designer also must know about the raw material, how to use it, tools, and technology available which shape up the ideas and detailing of furniture designed. A lot many experiments and explorations need to be worked out while development of concept to perfect the structural and aesthetics of new products. Since there are no proper technical guidelines and many of the details of structural exploration must be developed through trial-and-error methods, which eventually helps to develop a proper guideline for a particular species for product development and manufacturing.

Component Based Design for Easy Production & Assembly

In the process of designing a bamboo furniture, designer also must satisfy the production process, which must be planned at the stage of design itself. This connects the material knowledge and technical understanding with the designer for achieving the final design. If we take the example of children rocker the following are the system level approach in components and assembly. Sometime many new techniques, process, joints, or details are developed in the process of new product development. For example, most of the knockdown joints are developed during the critical stages of product development.

It may be due to the limitation of material or technology or may be a user need. For example, the steel joints used in some of the bamboo furniture and rocking horse came as a solution for a problem appeared in the process of its development. Such explorations can be refined and made to a standard joint or a fixture for making a range of furniture which will help in systemizing the production process.

The Approach for Joinery System

The above examples show a new direction to follow in making furniture from solid bamboo species. One of the important components evolved in this is various joints. Joints like bamboo to bamboo and metal connectors are playing a key role in this approach. To make this approach more practical and viable one need to standardize the raw material and joints. It requires more research and trial and error method to conclude the subject as a systematic method of bamboo furniture construction. Like any other raw material like wood, metal, panel boards etc., bamboo also requires a vocabulary of joints with basic standardization of it. This can change the future scope of Indian bamboo furniture sector and it is very

Component based assembly for rocking horse, designed by Vatsla Batra, NID

Furniture system designed with steel connectors

much possible in near future. The metal joints explored at NID was part of experiments done towards making bamboo furniture construction and assembly easier for the manufacturer and consumer. It also reduces the volume in transportation and reduce the market cost to keep it more affordable. To make this more practical and suitable, the standardization of solid bamboo material need to be taken further. Once this is achieved the standardized joinery system can make a difference in our bamboo furniture making process

Combination of Materials with Solid Bamboo

Combination of Solid bamboo with other bamboo materials like bamboo splits, mat board and bamboo sliver/splits board can increase the potential output much more to satisfy the need of the customer in Indian furniture market. The solid bamboo frames with metal joints can be used for structural parts and the boards can be used for the surface. This combination can create many possibilities to make furniture for residential, office, school etc. for modern market requirement. NID's Centre for Bamboo Initiatives explored many such combinations in furniture innovations.

As a designer I have been experimenting with these possibilities since many years. According to my findings there is a huge potential in India to invest in this sector and can bring a sustainable approach for

Furniture system using solid bamboo with other combinations of materials, Rapangi Khosla

Indian furniture market. These experiments led me to take an approach in standardizing the size/dimension of solid bamboo poles suitable for furniture manufacturing and developing joints and connectors for this. The experiment with simple metal connectors and few bamboo-to-bamboo standard joints can open a wide opportunity for designers and manufacturers to investigate this as a sustainable future for the sector. Through that the sector can provide livelihood opportunity, either directly or indirectly, to many from farming to the consumer market.

Furniture items made out of solid bamboo

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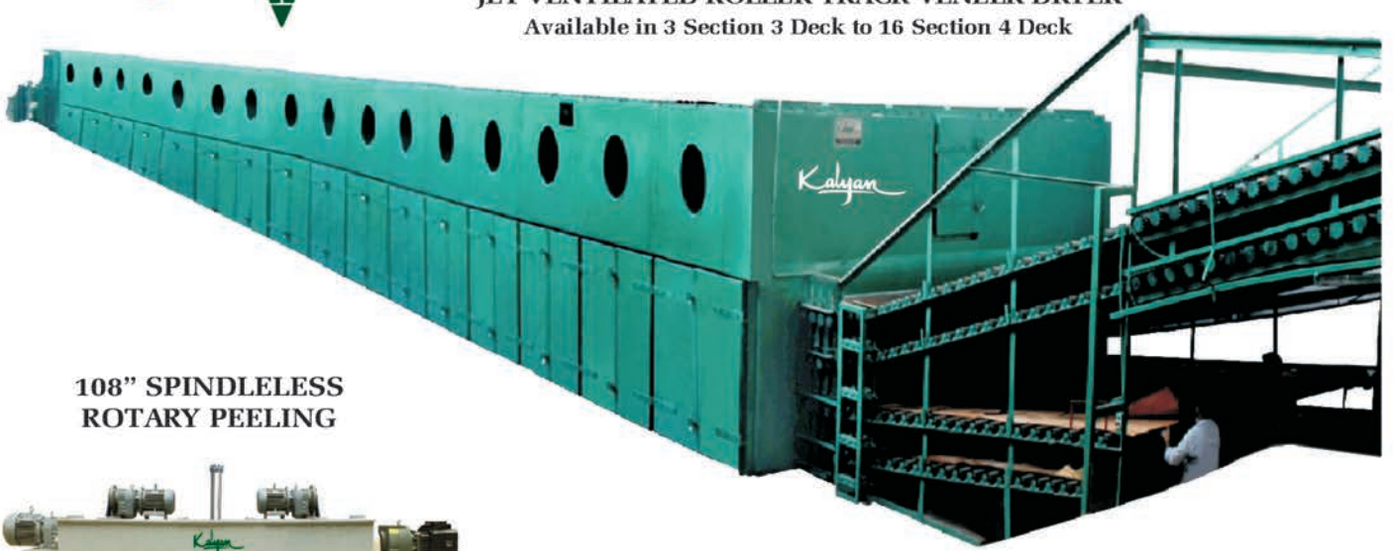

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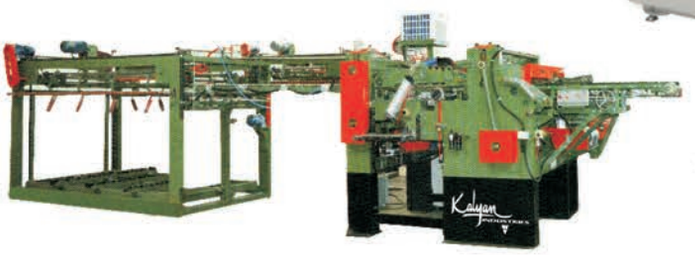

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Microwave processing of bamboo

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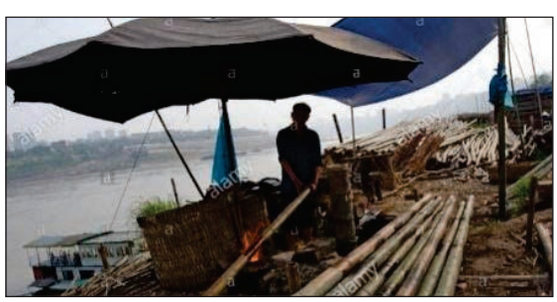
Bamboo often called 'poor man's timber' to 'green gold' is a fast-emerging super material of the 21st century. It is one of the fastest growing and highest yielding renewable natural resources making it a good substitute for wood in mitigating pressure on natural forests. Bamboo belonging to the family of grass; matures in as little as 3 to 5 years which is much faster than natural trees or plantation species. It has an unrivalled capacity to sequester carbon and has immense economic potential. It is being used from bamboo flooring, bamboo home and outdoor furniture, bamboo weaving products, handicrafts, bamboo charcoal personal care, healthcare products and affordable and super-premium eco-homes to bamboo bicycles, bamboo beer, bamboo shoots, bamboo tea and luxury bamboo items like sunglasses, shoes, bags and more it has found usage in almost every walk to life. India has the largest area and the second-largest reserve of bamboo in the world. This super material indeed has tremendous potential to transform the country's rural economy and contribute to sustainable development efforts.

Challenges: The uncontrolled drying and the crooked bamboo

Seasoning of bamboo is an essential prerequisite for maintaining the appearance and strength of bamboo products and structure. Unseasoned bamboos are highly susceptible to insects and fungal attack, decay and mechanical degradation. Seasoning of bamboo still stays an enigma.

Traditionally bamboo is dried either under direct sunlight or is air-dried under shade. They are also baked over an open fire to sterilize the green bamboo to obtain the benefit of slight formation of wood tar creosote and to reduce its surface moisture to provide primary protection against fungal discolouration and decay in storage (IS 1141:1993). All these methods somehow lack the option of controllability of factors that regulate the speed of drying rate and may hamper the bamboo in the process of drying by causing splitting, cracking or leave a burned appearance at the surface.

Another challenge that is present most of the time with bamboo is its crookedness or deviation in its straightness of pole. Most of the Indian bamboo species exhibit some degree of crookedness which hampers their efficient utilization. The crooked bamboo pieces are straightened by localized heat treatment followed by pressure treatment. With heat, bamboo tends to become a little soft which helps in straightening. At the same time, during product development, bamboo also needs to be converted into a curved shape for many products like furniture and handicraft. Same heat treatment is used for this purpose. The procedure of heat treatment changes the colour of bamboo due to charring at the surface which may affect their aesthetic values.



Bamboo being preserved via fire treatment

Bamboo straightening by baking over an open fire

Crookedness of bamboo

Microwave Heating: A solution

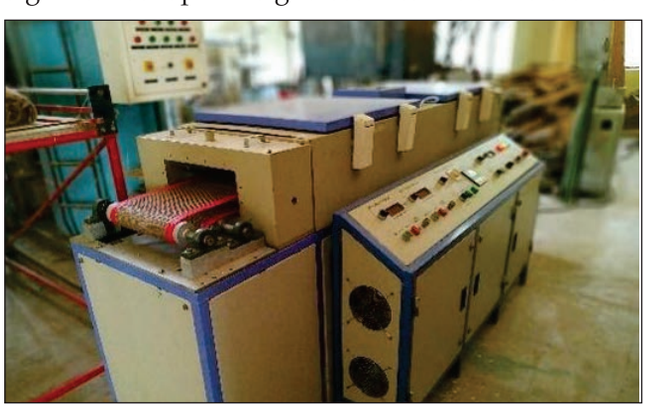
Microwave heating, which is an application of dielectric heating can induce volumetric heating in substances containing polar molecules. In this process of heating, molecular rotation occurs in materials containing polar molecules having an electrical dipole moment, with the consequence that they will align themselves in an electromagnetic field. If the field is oscillating, as it is in an electromagnetic wave or a rapidly oscillating electric field, these molecules rotate continuously by aligning with it. This is called dipole rotation, or dipolar polarization. As the field alternates, the molecules reverse their direction. Rotating molecules push, pull, and collide with other molecules (through electrical forces), distributing the energy to adjacent molecules and atoms in the material which increases the temperature of the material. Microwaves have wavelengths approximately in the range of 30 cm (frequency = 1 GHz) to 1 mm (300 GHz).

The use of microwaves in seasoning offers several advantages over conventional sun/shade drying, or baking over an open fire, apart from the seasoning benefits some of the exclusive advantages of microwave drying are;

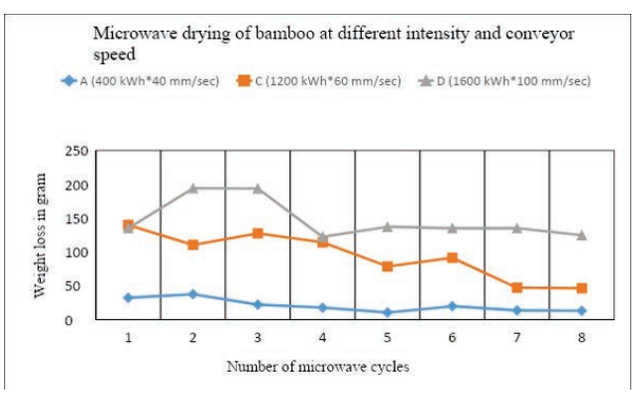
- Refractory woods, timbers and bamboo of large dimensions can be dried easily.
- The speed of heating is fast because heat is generated throughout the material and it is possible to achieve a high rate of heating.
- Because of uniform heating, drying stresses are small or non-existent so that checking hardly develops.
- Since the microwave drying process is free from gases, chemicals and other health-hazardous substances, it is cleaner than other contemporary alternatives.
- Uniformity in drying can be achieved in a re-drying process as wet areas get preferentially heated, thus levelling the moisture content throughout the material.
- Rapid on-off control of heating apparatus; i.e. no warm up time
- Drying can take place in an atmosphere of 100% water vapour.

In the case of bamboo, primary research on bamboo seasoning done with the help of microwave was reported first by Prasad and Pandey (2012). They achieved good results by rapid drying of Dandrocalamus stocksii using a conveyor belt microwave dryer. According to their observation, the drying rate increased rapidly with an increase in microwave input power. Also, the time of drying in microwave reduced from several days in kiln drying to a couple of hours in Microwave drying. Lv et al. (2018) applied Vacuum-assisted microwave drying (VMD) technology to dry round bamboo. According to their studies, VMD reduced the moisture content of bamboo to 10% in just 150 minutes. The resulting dried bamboo showed good appearance and mechanical performance. Further, Lv et al. (2019) observed that the drying rate of round bamboo increased with drying temperature, microwave power and vacuum level. Resultant, the surface colour changed to yellow from the green after drying.

Similarly, based on some preliminary experiments conducted by us here at IWST, Bangalore we have found that rapid weight loss due to reduced moisture levels can be achieved by microwave drying of Bamboo. This experiment was conducted on three different microwave intensities (400, 1200, 1600 kWh) and with different speeds of the conveyor belt (40, 60, 100 mm/sec) respectively and has given significant drop in weight loss in terms of moisture.



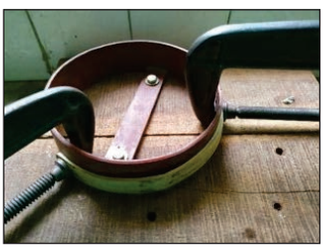
Microwave conveyor belt dryer used for drying experiments



Microwave is not only helpful in the seasoning of bamboo but it has also shown some promising results in bending of bamboo strips. In the initial experiment conducted, bamboo samples were converted into strips and those strips were exposed to microwaves for different intervals in a domestic microwave chamber of 900 Wh power level, immediately after microwave exposure strips were put on a customised circular frame for bending for different time intervals and curved bamboo strips were obtained. The curvature was directly dependent on the intensity of the microwave and time on the bending frame. The bamboo strips were able to achieve a curvature up to the resemblance of the alphabet 'U' which can come in handy in many bamboo-based product designing and fabrication.

Bamboo strips dipped in water

Bamboo strip on frame after Microwave treatment



Close up of bamboo strip on frame after Microwave treatment

Resultant curved bamboo strips

Conclusion

Bamboo is an important resource due to its varied degree of applications but its processing still requires some research to smoothen the processing of its products. Conventionally available methods of seasoning are unreliable and uncontrollable when it comes to temperature and moisture regulation, whereas microwave heating not only gives control over these factors but also facilitates rapid drying of bamboo with the least seasoning defects. Studies have shown microwave heating is advantageous over conventional methods of seasoning and also aids in the modification and processing of bamboo. Microwave heating applications in term of bamboo processing is still in its nascent stage and requires more standardisation and research especially in terms of India. A very little literature is available for the application of microwaves in bamboo processing and it requires to be explored more.

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Traditional uses of bamboos by Karbi Tribe of Assam

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Introduction

Traditional Knowledge System (TKS) refers to the knowledge inherent by local/indigenous communities through their relationship with the nature and its different components. Communities staying in vicinity to forest are directly or indirectly are dependent on its resources. Bamboo is a precious endowment of nature and life line of the people in North East India strongly interwoven with the everyday life and culture of the region. The local crafts range from tools for hunting, fishing, farming, furniture, toys, baskets, utensils to traditional housings. The crafting pattern ranges from the traditional head gear or Japi of Assam to being the pride to a peculiar Khasi umbrella of Meghalaya, the bamboo flowers of the Manipuris using both aesthetics and functionality, to the beautiful bamboo crafted hats of Mizoram and the special purpose basket Khopi of the Angamis of Nagaland district. These show the versatility of bamboo as a craft specific material in the entire region.

Karbi tribe is one of the important ethnic groups of Assam with a very rich and unique traditional culture. Bamboo plays an important role in socio cultural life and the most commonly utilized bamboo species of the region are *Bambusa balcooa, B. tulda, B.pallida, Dendrocalamus hamiltonii, Schizostachyum dulloa,* and *S. polymorphum.* The traditional uses of bamboo by the Karbi tribes are illustrated in this article.

Karbi hill houses

Karbi Anglong hill district of Assam is seismically active region and considered as resistant to earthquake and also heat proof. Bamboo is the major frame work material of traditional houses in tribal people of this region. The cheap and easy availability has made bamboo a popular building material among the tribe. In the rural household almost all the parts of houses viz., Post, ceiling, roof, beams, walls are made of different bamboos such as *Bambusa balcooa, B. tulda, B.pallida, Dendrocalamus hamiltonii, Schizostachyum dulloa,and S. polymorphum.* Tender bamboo stems are good for ropes in binding. The skeleton of the houses is mostly finished by *Dendrocalamus hamiltonii, B. tulda* and *B. balcooa* and the walls woven from bamboo are plastered with mud mortar. In all the areas bamboo is used as fencing which protected their houses and crop fields (Fig. 1)

Craftsmanship

A craft or trade is a pastime or a profession that requires particular skills and knowledge of skilled work. Crafts are the great part of any tribal's life. Karbis of Northeast India have inherited a rich treasure of knowledge on art and crafts which are reflected in their material culture such as pottery, baskets and storage container for food items, clothes & valuables, traditional ornaments, toys, mats, musical instruments, hats, weaving tools, agricultural equipments, sieves, winnowing trays, fans, granary, fishing gears, splits bamboo broom etc. Their survival in the remotest areas of hilly terrains, the "necessity" might have compelled them to utilize the resources available in their immediate environments. It is a natural offshoot of the dense forests and the variety of trees and bamboos available to artisans since the ancient times. There is a popular proverb prevalent among the people read as "Karbi aso ke jintak cheripdongse pirthe kevang lapen jintak cherip pondongse chomarong kedam" which also means a Karbi is born with jintak or bamboo split in his hand and leaves the world holding jinta. These crafts which are often decorated with unique designs attributed to the needs of day to day life. The primary occupation of the Karbi tribe is agriculture and majority practice jhum cultivation on hill slopes. In this traditional method of cultivation bamboos are used as hoes. The crop fields are often a considerable distance away, hence they carry boiled rice with bamboo shoot vegetable and others with them in baskets

specially made for this purpose. Bamboo baskets of Karbi tribe come in various shapes and provide for various purposes (Fig. 2).

Traditional fish gears

Karbi people studied the behavior of different fishes and also developed various types of fishing implements to catch them with a lot of fish gears. A variety of fish gears are used during the fishing festival of Okhi-Pru (Fig. 3). Bannas made of D. hamiltonii is installed to place the Soklet in its front for giving a way to fishes into the fish gears. Another assortment of bamboo fish trap and storing containers Tokprok, Ok-keap-apot, Ingtong, Ing-krung are used customarily by the rural inhabitant.

Traditional handlooms

Every tribal community practices its own age-old traditional weaving of textile. Folk costume is the identity marker of a community that represents their culture and brings up an image of the tribe. Weaving is a skill and livelihood occupation inherited from their forefathers and passed down generations among women. Karbi tribe is also known for their rich and unique culture, especially their hold over beautiful textiles. Since they were people who have been deeply influenced by nature and its beauty, definitely this influence is seen manifested in their attires and other varied textiles. The Karbi traditional loom is the back strap simple tension movable loom known as "Therang".

Conclusion

The Karbi Anglong hill district of Assam possesses immense resource of bamboo and wide spread distribution of craft skills. There is a great possibility of taking the traditional practices towards craft based industrial oriented mass production system. For getting GI registration of the products as it protect the identity of the community, different steps have required and might be the challenges. The affluence of tradition and distinction of artisanship is well reflected through the bamboo crafts of Karbi people.

Fig. 1. Ethnic Houses of Karbi tribe roofing and Entrance of a house

Fig. 2 Bamboo made carrying baskets of Karbi tribe

Fig. 3 Fish gears use by Karbi tribe

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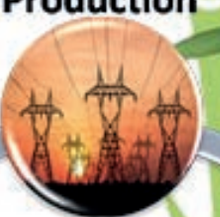

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Bamboo handicrafts in Northeast India

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North eastern region of India, comprising of eight states viz. Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura is a home of large number of tribes and sub-tribes who have been associated with craft tradition from time immemorial. Traditional bamboo craft provides livelihood to the tribal and other socially and economically backward classes of the entire region. The abundance of natural raw materials for handicrafts such as bamboo, cane, timber, silk, clay, natural fibre, etc. provide advantages for most creative expression through the craftsmanship. The handicrafts in the north eastern region include mainly bamboo works, bamboo and cane works, reed mats, terracotta art, brassware, pottery, weaving, carpet making, etc. which are eco-friendly and hence, there is always a considerable demand for these products in the global market. Without any major initial investment, bamboo handicraft sector provides direct and indirect economic benefit through employment generation to the artisans and has a great potential to upgrade the region's economy.

Diversity and uses of bamboo in North East States

North eastern region of India has great diversity of bamboo resources. India is home to about 136 species from 23 genera, of which 99 species grow in abundance in the north eastern region of the country. It is also reported that 39% of the country's growing stock and 35% of the bamboo growing areas is found in this region. (ISFR, 2019). Here, people are using bamboos for diverse purposes such as house construction, scaffolding, furniture, agricultural tools, basketry, handicrafts, fencing, edible shoots, pulp and paper, agarbatti sticks, fishing trap, musical instruments etc. Apart from these common uses, various applications such as alternative to rapidly depleting wood resources, many expensive constructions and furnishing materials, charcoal making, jewellery, value added products, etc. have been adopted in recent years. Of late, bamboo is also being used as a reinforcement to replace mild steel bars in light concrete structures.

Bamboo species used for handicrafts

Despite the species diversity of bamboo in the north eastern region of the country, only a few species are used by the artisans. This is because, all species are not suitable for making handicrafts as the strength and other properties of bamboo vary from species to species. Bamboos like *Bambusa balcooa , B. tulda, B. bambos, B. nutans, Dendrocalamus giganteus, etc. are used for construction purposes, whereas B. polymorpha, B. jaintiana, B. pallida, B. tulda, D. hamiltonii, D. hookeri, M. baccifera* are used mainly for making baskets, containers, tool handles, agricultural tools, agarbatti sticks, toys and many more items. *Bambusa multiplex, B. nana, D. strictus*, etc. are used for making fishing rod. Bamboo species used by the artisans of eight states of the region are mentioned in Table -I

Tools used by the artisans

The commonly used tools by the bamboo artisans of north east states are Hacksaw, Hammer, Dao, Knife, Electric heater, Varnish sprayer, Wrench, Sand paper, Blowlamp etc. (Pattanaik et. al, 2003). The shape and size of some tools used by the craft persons for operations like cutting, splitting, slivering, sizing and finishing of bamboo may vary from state to state in the region. As these traditional tools do not help in making quality products so, there is a need to introduce modern tools to maintain the quality and uniformity of the products. It is reported that a total of 109 different types of tools have been innovated by Industrial Design Centre (IDC) at IIT-Bombay, through Development Commissioner-Handicrafts (D.C.H). Apart from these tools, there is a need to apply Small Technologies in bamboo handicraft sector of north eastern region which include non-powered machines, jigs and fixtures, treatments, colouring methods and finishes for best products (Rao, 2004).

Table – 1 : Bamboo species used as raw material in Handicrafts in North East States

State	Name of bamboo species Scientific name	Local name
Arunachal Pradesh	*Bambusa pallida, B. tulda, Chimonobambusa callosa, Dendrocalamus hamiltonaii, D.sikkimensis, Phyllostachys mannii, Schizostachym arunachalensis, S.fuchsianum, S.helferi, S.pergracile, S.polymorphum, S.seshagiriana*	Eso, Ejo, Tao, Eni, Egi, Tabo, Tachur, Toak, Tappin, Madang,Tador, Tabum.
Assam	*Bambusa balcooa , B. pallida, B. tulda, B nutans, D. giganteus, D. hamiltonii, Melocanna baccifera*	Bholuka, Bijuli, Jati, Mokal, Gadhoi, Kako, Muli.
Manipur	*Bambusa balcooa , B. nana, B. tulda, B nutans, D. giganteus, D. longifimbriatus, M. baccifera &* 4 other unidentified sp.	Leewa, Khokwa, Saneibi Ootang, Maribob, Unan, Moubi, 4 unidentified sp viz. Ching saneibi, Kaha, Ngarik, Ngatha.
Meghalaya	*Bambusa balcooa, B. bambos, B. cacharensis, B. jaintiana, B. pallida, B. tulda, D. hookeri, D. hamiltonii, M. baccifera, S. helferi, Phyllostachys mannii, B. polymorpha, D. longispathus,*	Wahiong, Wahkanteh, Ba, U shken, Skhein, Wati, Siej iong, Wanoke, Watrai, Tuma, Shken
Mizoram	*Bambusa bambos, B. mizoramiana, B. tulda, D. hamiltonii, D. longispathus, M. baccifera, Schyzostachyum dullooa*	Rawbling, Talan, Rawthing, Pbulrua, Rawnal, Mautak, Rawtblaw
Nagaland	*Bambusa balcooa, B. tulda, B. pallida, D. hamiltonii, M. baccifera*	Otu, Warak (Ao), Longmi (Ao), Tsero (Lotha), Vupa (Angami), Turiah (Angami)
Tripura	*Bambusa balcooa, B pallida B tulda, B cacharensois B polymorpha B vulgaris D. hamiltonii, D. strictus, D. longispathus, M. baccifera S. dullooa, Thyrsostachys olivery*	Barak, Makhla, Mirtinga, Bom, Paura, Bari, Pencha, Lathi, Rupai, Muli, Dolu, Kanakaich
Sikkim	*Dendrocalamus hamiltonii, M. baccifera*	Choya bans, Tama (Nepali)

Handicrafts of North East States

Wide variety of bamboo made handicrafts of the north east states are tabulated as below (Table -2).

Table – 2 : Bamboo Handicrafts of North East States

State	Name of some common bamboo handicrafts
Arunachal Pradesh	Bamboo houses, bridges, smoking pipes, hats, trays, knives, baskets, ornaments, barrels, carved bamboo mugs, storage pouches, fishing traps, jewellery, gift items, etc.
Assam	Bamboo houses, Japi, baskets, mats, trays, hats, agricultural implements, toys and dolls, mugs for rice beer, hukkas, musical instruments, Jakoi, Khaloi, Jhuluki, chalani, kula, dukula, khoralu, doon and dhol, moorha, fishing rod, hand fan, etc.
Manipur	Bamboo houses, fencing, baskets, furniture, trays, mats, flower vases, fishing traps, etc.
Meghalaya	Different types of baskets (pig basket, fruit basket, khoh, shang), Khasi fish trap, rain shield and headgear, winnowing fan, comb, water pipe, bamboo mat, stools, flute, etc.
Mizoram	Bamboo house, different types of baskets, utensils, hats, handcrafted furniture and flower vases, musical instruments, etc.
Nagaland	Bamboo house, Agricultural implements, bow and arrow, baskets, beds, blinds, boats, bottles, brushes, cooking utensils, fishing rods, furniture, food basket, hookah -pipe, joss –sticks, kites, toys, tool handles, fences, walking sticks, etc.
Tripura	Bamboo house, baskets, table mats, other mat products, lamp shades floor mats, room dividers, rhizome artefacts, bags, moorahs, fruit-baskets, decorated wall panels, furniture, agarbatti sticks, jewellery, flower vase, various gift items, etc.
Sikkim	Basket, bamboo bed, utensils, musical instrument, flower vase, lamp holder, hair band, decorative items, etc.

UNIQUE BAMBOO HANDICRAFTS OF NORTH EAST STATES OF INDIA

a) Hats, Baskets and containers of Arunachal Pradesh

b) Traditional Bullock cart and Phulam Japi of Assam

c) Baskets and other bamboo handicrafts of Manipur

Bamboo handicraft industries in North East States

Bamboo handicraft industries of north eastern region are found in many places of the states namely Assam, Meghalaya, Manipur and Tripura. In Assam, bamboo-based handicraft industries are more prevalent in lower Assam. The products range from bamboo mats to highly decorative item like Japi. The artisans of Dima Hasao district of Assam use M. baccifera from natural forest for mat making whereas the artisans of Nalbari and Barpeta districts use homestead grown bamboos for making decorative items. The other marketable product Murrha is extensively found in Nagaon, Goalpara and Karbi-Anglong districts of Assam. According to the Department of Industries and Commerce, Assam, there are 480 units undertaking cane and bamboo works in 26 districts of Assam with an investment of Rs. 371.34 lakhs, employing 2212 people. Tripura bamboo and cane handicrafts are considered to be among the best in the country for their exquisite design, wide range of products and artistic appeal. These industries are mostly at Kailashahar, Dharmanagar, Khowai, Sadar, Sooamura and Belonia besides Agartala town. In Manipur, the products are not only aesthetic in look but are also highly functional in nature. The artisans belonging to the districts of Imphal East, Kakching, Chandel,

Ukhrul, Senapati, and Tamenglang are associated with bamboo handicraft industries. Likewise, in Meghalaya bamboo crafts is a crucial part of the daily lifestyle of the people. Meghalaya is known for its various art and crafts. The famous 'Khasi' tribe weave mats and different baskets out of bamboo. Another tribe 'Jaintia' of Meghalaya is involved in making bamboo fishing traps. Markets like Police bazaar, Bara bazaar and Laitumkhrah in the capital city of Shillong are a few places where one can buy the innumerable bamboo handicraft items that the state produces.

Economy and market of bamboo handicrafts

Bamboo based handicraft sector contributes a lot to the north east Indian economy. It was reported that the bamboo craft sector generated about 250 million days of work by employing mainly women from the rural and tribal area, generating income of Rs. 15 billion a year (Borah et. al, 2008).

The world bamboo market is currently worth US$ 8 billion/year, and traditional markets cover handicrafts, blinds, chopsticks and traditional bamboo furniture, which count for 95 % of the market as on date. New market products include modern/laminated furniture, flooring and panels covering the remaining 5% of the bamboo sector (Bhandari, 2018). India exports bamboo items worth Rs. 289 million. Most important export items are mats and screens followed by furniture and flooring products (Kosemund, 2020). The size of the bamboo market in Northeast region is estimated to be Rs. 62.5 billion. It is estimated that of the total incense stick (agarbatti) market of Rs. 1100 crore, the size of the organized market is about 40% of the total market (Sarma, 2014). Some of traditional bamboo products from Tripura have found substantial markets throughout the country. The marketing of these products can be greatly enhanced if information relating to source, functions and interesting features of each item are provided along with the product. Regarding furniture, it is reported that global market for eco-friendly furniture which was worth $36 billion (Rs. 2,70,000 crore) in 2020 is expected to be worth $ 68.82 billion (Rs.4,48,650 crore) in 2027 (Bordoloi, 2021).

Conclusion

The region is yet to attain its full potential in the bamboo handicraft sector and the reason for this may be attributed to the lack of value addition in bamboo products, lack of training facilities, absence of organized marketing network, lack of minimum support price for the produce etc. A concerted effort, if made by the Government and executed can open up a new vista for bamboo handicraft sector in north eastern region which in turn will give a huge fillip to the economy of the region.

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5) Ministry of Environment, Forest & Climate Change, Govt. of India
6) National Bamboo Mission, Ministry of Agriculture & Farmers Welfare, Govt. of India
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- Super Heavy Duty Both Side Calibrating Machine
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A success story in bamboo sector

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Radhakishorenagar, Tripura 799008
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India being one of the largest producers of bamboo gave him a ready raw material and he was keen on monetizing the same. Thus, he implemented the idea and Mutha Industries Pvt Ltd. (MIPL) set up a state of the art unit wherein they manufacture Bamboowood – an eco-friendly substitute to hardwood at Agartala, Tripura. They are the pioneers in this field.

MIPL is a Mumbai based company, and market their products under the brand name of "Epitome Bamboowood". Their industry has truly adopted the principals of "MAKE IN INDIA" as it has set up its first manufacturing unit spread across 10 acres in Bamboo Park at Agartala, India. Epitome provides innovative solutions and market- oriented products based on a natural and renewable material - Bamboo.

MIPL has created employment opportunities for more than 200 people directly and 500 people indirectly in the industrially backward state of Tripura. It has been successful in creating a ready market for the bamboo growing farmers of Tripura. This unit is in perfect sync with the government's policy of ACT EAST and Atmanirbhar Bharat.

They are the first company in India to do maximum value addition to bamboo and are working towards the revival of the poor man's timber to the timber of the 21st century, by offering this green gold (bamboo) to India as an eco-friendly construction material. Also, the leadership of our Hon'ble Prime Minister Shri Narendra Modi has always inspired the team of MIPL. The Prime Minister has always instilled a sense of belongingness and patriotism to our great country.

In one of his Independence Day speech, he did the same and infused great confidence within the team of MIPL when he said, "I request our young entrepreneurs not to compromise on two fronts, manufacture goods without any defect in quality that is Zero Defect and without any adverse impact on the environment that is Zero Effect!" Mutha Industries acted quickly and have adopted these principals right from day one that is manufacture best quality products without any defects and they are proud to say the quality of their product is at par with the best quality available globally. Also, MIPL manufacturing unit is such that, it does not make any adverse effect on environment and hence zero effect. They have a biomass boiler and the ash that's left behind by the boiler is provided as manure to the bamboo growers.

"We are the first company in the North East to be awarded with ZED Certificate" says Neeraj Mutha. ZED is a rating agency of Govt. of India, Ministry of Small & Medium Enterprises in coordination with Quality Council of India.

Epitome - Bamboowood is a stunning invention, offers the sheen, durability and luxurious finish of hardwood - but without the ecological damage. Its beauty and finish lend a resplendent aura of opulence to any residence, commercial space or recreational arena.

Epitome - Bamboowood offers flooring for the interiors, decking for the outdoors, wall cladding for the rich feel on walls of conference rooms or auditoriums etc., doors, door frames and stunning custom-made furniture for homes, offices and institutions. Our range of shades, textures and sheens are specially designed for an international feel that's perfect for all weather conditions, says Neeraj Mutha MD of MIPL.

Epitome Bamboowood is a compelling substitute to hard wood and engineered wood; having plant, process and products certified on world parameters such as ISO 9001, EMS14001 and OHSAS18001.

Being eco-friendly, Epitome Bamboowood Products have been included in the GRIHA catalogue (The national rating system of sustainable habitats).

Epitome Bamboowood Products have received Performance Appraisal Certificate from Building Material Technology and Promotional Council (BMTPC), a body of the Ministry of Housing and Urban Poverty Alleviation, Govt. of India.

Some advantages of bamboowood products are:

- It is made in India
- It is completely eco-friendly, as it is made from bamboo

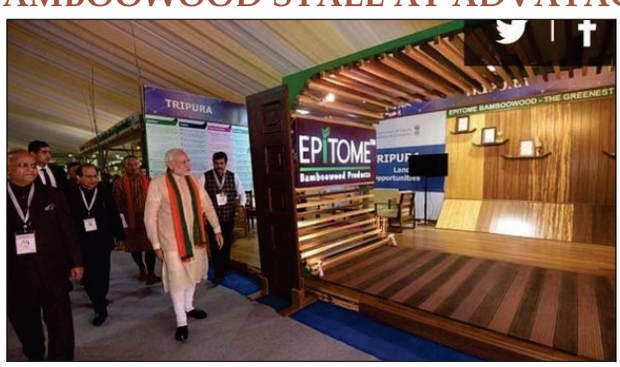
- Bamboowood products also help to improve the indoor air quality, which creates a healthy environment to live in
- Bamboowood when installed acts as an insulator. That it keeps the surroundings cool during summer and warm during winter. This helps to save power consumption.
- During the process of making bamboowood products, bamboo is treated to remove the sugar and starch content in it, which happens to be the main components why termites or bore attack any form of wood. Hence bamboowood products are termite resistance.
- Bamboowood products are extremely durable and long lasting.

MIPL, one of the most successful industry in bamboowood is proud to have completed over 500+ projects where it has supplied and installed bamboowood products. It has been able to showcase and gain appreciation with some of the most successful architects across the world that include, HCP – Ahmedabad, Pininfirnia – Italy, Nuru Karim – Mumbai, SHIFT Architects – Delhi. MIPL has been privileged to use bamboowood products in many prestigious projects in India that include:

Guwahati Airport, Guwahati Samrat Ashoka Centre, Patna Godrej Bhawan, Mumbai Patna High Court, Patna

It is a matter of pride for India to have a successful local company reaching such great heights in the bamboo sector. A true success story in this sector that believes, "saving the Earth does not mean sacrificing style". Hence giving a choice to leave behind a cleaner legacy for the coming generations - in style, by using Epitome Bamboowood Products.

HON'BLE PRIME MINSTER SHRI NARENDRA MODI VISITNG EPITOME BAMBOOWOOD STALL AT ADVATAGE ASSAM



MIPL'S state of the art unit at Agartala

Projects where epitome bamboowood has been used

Godrej Bhawan, Mumbai

Samrat Ashoka Convention Centre, Patna

Large scale cultivation and industrial application of bamboo resource

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Introduction

Bamboos are giant, woody, tree-like grasses that are a wonderful gift from nature. They have a long history as an exceptionally versatile and widely used resource in nearly every aspect of daily life and linked with mankind ever since the beginning of civilization. Its plethora of essential uses has led to the use of terms such as the **"poor man's multi-purpose timber"**, the **"cradle to coffin companion of man"**, the **"green gold"**. It supports many major industries such as housing, construction, handicrafts and furniture making, fishing, banana cultivation, food production, animal husbandry & poultry and musical instruments. It is a prominent renewable resource that yields considerable biomass over short rotations. Bamboo is very effective in preventing soil erosion by binding to the earth against raging floods and the shocks-of earth-quakes.

Description of *Bambusa balcooa*

There are many species of bamboo suitable for cultivation, among which *Bambusa balcooa* is one of the cultivable species suitable for energy plantation. *Bambusa balcooa* (Roxb.) also known as *Arundarbor balcooa* (Roxb.) *Kuntze* and *Dendrocalamus balcooa Voig* belonging to the family Bambusoideae, stands as an important multi-purpose bamboo species of the Indian subcontinent. *Bambusa balcooa* is a fast growing, thorn-less, thick-walled, clump-forming bamboo with an underground sympodial rhizome system. The green culm height varies from 15-25 m. Diameter of culm varies from 8 to 15 cm (at breast height). And thickness from 2.7-3.2 cm at breast part, 1.2-2.0 cm at mid part, and 0.3-0.7 cm at upper part of the culm. The internode length is 20 to 46 cm. The leaves are comparatively bigger than many other Bambusa species. Its tender shoots are eaten by local indigenous people in Meghalaya, Assam and Tripura. The leaves are used as emergency fodder during floods. In Manipur, the species is used in making bamboo bows by indigenous people. Various food preparations like pickles are also made by natives. This bamboo species is mostly used for making ladders, scaffolding and for house construction, agriculture implements, and baskets and bridges. **Beema Bamboo** is a superior clone, selected for high Biomass yielding out of *Bambusa balcooa.* It is the product of continuous Research for over 15 years by Dr. N. Barathi, the Director, GrowMore Biotech ltd, Hosur. This clone is thornless, sterile, fast growing and a superior Bamboo and it will be growing in the field for more than hundred years without replanting i.e. No flowering & death. Beema bamboo is a Tissue culture plant of Indian origin.

Advantages of Beema bamboo

- Cultivation requires less cultural operation and hence the labor requirement is less
- Its biomass has higher energy value (4000 kcal/kg)
- It does not require replanting for several decades – over 100 years
- It keeps on growing as long as the water and nutrients are provided
- It can grow even in a degraded soil
- It is relatively free from pest and diseases
- It has got higher bulk density and lower ash
- It is a source of bio renewable energy to replace coal and other energy sources
- It has no sulphur content as against coal.

Industrial application of Beema bamboo

Major industrial application of Beema bamboo at present is for generation of electricity, Bio-CNG, Bio-Ethanol and Coal substitution apart from conventional use for paper pulp, construction, furniture, etc.

Energy plantation – scope of bio power crop

Energy plantation means growing selected species of trees and shrubs which are harvestable in a comparably shorter time and are specifically meant for fuel. The fuel wood may be used either directly in wood burning stoves and boilers or processed into ethanol or producer gas. The energy plantations provide almost inexhaustible renewable sources (with total time constant of 1-5 years only for each cycle) of energy which are essentially local and independent of unreliable and finite sources of fuel. The energy potential of "**Fast growing grass – Bamboo"** remains untapped due to lack of awareness of its potential. Bamboo is highly cultivable and responds very well to agriculture management practices, whereas today, the bamboo is available mostly in the wild or grown with no care.

The national average yield of Bamboo is less than 1 ton/acres/year in India and less than 3 tons/acre in China, while cultivated Bamboo in farmland is between 5– 8 tons/acre/year. The Recent development in breeding, tissue culture and agronomy of bamboo has led to the development of precision farming which yields from 40 to 60 tons biomass per acre every year. When Bamboo is grown as Energy Plantation, it is harvestable continuously every year, which provides biomass under closed intervals as compared to many other tree species. Because of the very low yield of Bamboo in the wild, so far Bamboo is never considered as an energy crop though it is the fastest growing plant on earth. Introduction of high yielding clones and best agronomical practices developed specifically for Energy Plantation by "GROWMORE BIOTECH LTD" in Hosur, Tamil Nadu, India has led to the status of Energy Plantation. The dry matter production of "Beema" Bamboo under optimum condition reaches 40 to 50 tons per acre. The total carbon accumulation every year, after 5 years of growth is from 18 tons to 23 tons per acre, which is equivalent to carbon dioxide of 70 tons to 88 tons per acre respectively.

Cultivation of bamboo as energy plantation under hi-density

Bamboo is planted under close spacing and harvested from 2½ years when it is grown as an irrigated crop, with drip irrigation and fertigation. The plantation is established with fast growing thick wall Bamboo species with no thorns and, with higher cellulose content. The Bamboo is harvested annually as immature bamboo and utilized as raw material for energy generation.

Availability of planting stock

Certified planting material is essential for the establishment of bamboo plantation. Vegetatively propagated planting stocks are available at KFRI-Peechi, Thrissur; Kerala; SFRI, Chessa, Arunachal Pradesh; DFO, Arunachal FD; FRI, Dehradun; State Silviculturist, Assam; DFO, Kokrajhar, Assam; BCKV-West Bengal; BEEDS-Tamil Nadu; GBPUA&T- Uttrakhand; NBDA-Nagaland; TBM-Tripura. Tissue cultured planting stocks can be collected from Growmore Biotech, Hosur, Tamil Nadu; Hindustan Newsprint Limited- Jagi Road, Assam; KFRI, Peechi, Thrissur; RFRI, Jorhat, Assam.

Intensive cultivation

Beema bamboo can be cultivated at 1000 plants per acre similar to sugarcane cultivation with spacing of 3m between rows and 1.2 m between plants. The best suited irrigation is by drip along with a fertigation system to supply required fertilizer to the plants. The general requirement of fertilizer is 160:40:200 N:P:K per acre/year. The ultimate requirement of fertilizer and water would be decided based on the site condition, soil condition and water quality and rainfall pattern of the particular place. The recommended cultivation practice for Beema bamboo is "Precision farming" which involves application of required nutrients and water at the appropriate time and at the appropriate zone as per the requirement of the plant.

Plantation output

Under high density plantation with appropriate irrigation and fertilizer application, the harvest of the

Beema bamboo starts after 2 ½ years (30 months). By then the bamboo culm would have grown to a thickness of 7.5cm at the bottom and 3.5cm at the top with a height of 4.5-6m, and each culm weighing 6-10 kg dry weight. Under ideal conditions each plant has 6 poles, amounting to 7 kg of dry biomass weight at 10 – 12 % moisture for each pole. Therefore, one acre under ideal conditions would produce 7 kg x 6 poles/plant x 1000 plants for a total of 42 tonnes/ acre.

Benefit to the company

Energy from bamboo biomass would reduce not only the cost of energy feedstock but also reduces carbon footprint. Utilization of bamboo biomass would make the process more sustainable with less environmental impact and earning carbon credit. Cultivation of bamboo provides ample opportunity for the local community and provide scope for utilization of company's CSR fund towards greening as well as generation of raw material.

Benefit to the farmers

Today farmers are facing difficulties in continuing agriculture in many parts of the country due to several reasons such as increase in cost of labour, non-availability of labour, perishable nature of the agriculture commodity, variation in the price, lack of assured and direct marketing of the product produced, reduction in availability & quality of water and migration of the landlords from village to the nearest towns and cities leading absentee landlordism and lack of personal supervision in agrifarming. Cultivation of bamboo as energy plantation is the best solution to address all the above problems apart from good assured return to the farmers as compared to the present crops. Cultivation of bamboo will certainly ensure a return of 70,000 to 80,000 rupees per acres/year, which is more lucrative than many other agricultural crops being cultivated. In fact, the average return per acres in farming is less than Rs. 10,000/- per annum with many problems and uncertainty in the realizable income.

Electricity production

In India, energy demand is expected to grow in line with industrial growth, but may not be the energy production, leaving a gap which provides opportunity for energy projects. With the electricity supply being erratic, captive power production shall be the answer for the industries that require uninterrupted power supply. Among the several options available for captive power production, biomass based power plants are the most environment friendly. Biomass is an important source of energy in tropical countries. Properly managed biomass energy plantations can be sustainable, environmentally advantageous, economically sound and generate substantial local employment. Beema bamboo is a clone of bamboo selected out of the open pollinated population of *Bambusa balcooa* found in North Eastern India followed by multiplication by Tissue Culture. This new high yielding clone of bamboo – BEEMA BAMBOO developed is thorn less, fast growing, thick walled, sterile and responsive to field management practice.

- Beema Bamboo is the fastest growing plant, which grows 1 to 1½ feet a day.
- Beema Bamboo has high energy values of 4000 kcal/kg with an ash content of 1 %, at a low production cost of 1/4th of the predominant energy source – coal.
- Beema Bamboo stands 1st when it is compared for ash content with commonly available agricultural waste – rice husk (20 % ash content) or coal (10 – 15 % ash content).
- There is no sulphur content in Beema bamboo biomass as compared to coal or furnace oil whereas its energy value is similar to that of coal.

Biomass Power Project of 1 MW (1 MW/hour or 7200 MW hours/year) can continuously produce electricity for a several years with 200 acres80 hectare of Beema Bamboo energy plantation cultivated

under "High-Density Plantation" as per the precision farming methodology developed by Growmore Biotech Ltd, Hosur, Tamil Nadu, India.

Process of biopower generation

The power is generated out of biomass by two major paths

1. Complete combustion

The combustion process involves complete burning of biomass to generate steam under pressure which is converted into mechanical energy by steam turbine and ultimately into power by alternator connected to a steam turbine. 1 ton of biomass generates 1 MWH power and the end residue is ash.

2. Partial combustion/pyrolysis:

This Biomass is made to generate combustible gas known as producer gas/syngas by a thermo chemical conversion carried out through the process of oxidation and reduction with limited air supply. The residue of the pyrolysis process is activated charcoal known as Biochar. 1 ton of biomass is required to produce 1MW of exportable power which also produces charcoal to an extent of 70-100 kg/ MWH of biomass. An added advantage of gasification of bamboo is that 10 % of the biomass would also be available as a by-product in the form of high grade charcoal and generate energy (activated charcoal). Biomass gasification technology can not only generate power, but also create employment in rural areas. Biomass based distributed power generation has got huge potential to electrify the non-electrified villages.

Electricity from bamboo

The Beema Bamboo generates green electricity by pyrolysis from the biomass generated out of bamboo based energy plantation as an alternative green energy source to meet the growing energy needs. Char coal is produced as byproduct, thereby it is highly efficient and cost effective.

Product

- 1MW POWER (7000 MW hours annually) from 200 acres of energy plantation.
- 1200 tons of activated charcoal annually, sold as Biochar, an efficient soil amendment.
- 7000 REC (Renewable Energy Certificate) every year

Presently, biomass is collected from agriculture fields, from a vast area of over 10,000 acres to feed 1MW biomass power projects. The Beema bamboo based energy plantation provides required biomass just from 200 acres, with the following characters.

- Biomass with 4,000 kcal/kg.
- Biomass yield of 40-50 tons per acre/year
- Biomass with low ash content of 1% by weight

This is a major break-through for biomass based power projects in tropical countries. As the country is facing a shortage of agricultural labour, Beema bamboo is the best crop as it requires less labour.

Process: High biomass producing Beema bamboo is planted as energy plantation to supply the biomass. This biomass is made to generates a combustible gas known as "producer gas" by a thermo-chemical conversion carried out through the process of oxidation and reduction with limited air supply. The residue of the pyrolysis process is activated charcoal known as Biochar.

Uniqueness

- Low cost of Biomass (Rs 1,500/ton) from captive own energy plantation
- Self-sustaining Renewable energy at low cost (Rs.2.50 / kWh).
- Carbon Negative Technology – Conversion of biomass into producer gas and biochar for the generation green electricity
- The capital subsidy is available for renewable energy generation
- The term loan is available from the Banks.

One village one MW

The project of generating 1 MW can be easily established in each village, in an area of 200 acres of plantation and 2 acres of power project. The power generated in the rural village can be connected to the grid to supply power to cities and towns. The revenue generated from the electricity in the cities and towns would go to the rural villages instead of getting diverted to coal mines abroad as dollars. India could be self-sufficient in green power / renewable energy through this approach and at the

same time we create job opportunities and wealth generation in rural India. India with 6.5 lakhs villages can generate 1.0lakh MW even if we consider 15 % of the villages undertaking this project in next 10 years which is 40% of power requirement for India and will create job opportunities and wealth generation.

Beema bamboo cultivation for power generation in tribal area

In India has excellent network of power connections connecting many cities, towns and villages. Still there are many tribal settlements in deep forests with no accessibility for power. Due to prohibitory cost of drawing electrical lines to remote tribal settlements, power is not made available. Biomass based distributed power generation system at lower capacity of 10kW- 50kW would provide power to tribal villages, raw material for power generation could be produced locally.

Power generation in sugar Industry

In India, sugar mills operate for 6 months in a year. During the off season, due to the non-availability of the raw material (bagasse), mills are unable to generate power. Some of the mills use coal as a fuel material to produce power, which is not only costly but also polluting. The imported coal could easily be substituted with biomass from BEEMA BAMBOO at a cost of less than Rs. 4000/ton if the Bamboo is cultivated by the farmer similar to sugarcane. The raw material cost of biomass for the off season could further be brought down to Rs. 1500 /ton if the sugar mills can grow the BEEMA BAMBOO in their own land for the biomass purpose. This opens up opportunity for the sugar mills to operate throughout the year, double the income not only to the farmers as well as to the sugar factories.

BIO-CNG from Beema bamboo

CNG is less polluting to the environment than other popular fuels such as Petrol and Diesel. At present CNG is mostly delivered through pipes which are running for several thousand kilometres. Bamboo is convertible into biogas which can be processed into Bio-CNG and Bio-CNG is a renewable fuel that is identical in composition and better in purity than fossil CNG. Bio-CNG from Bamboo generates income for

the rural population and serves as an import substitute. Every 350 acres of cultivated bamboo can feed one gas bunk on the road side which does not need pipe lining for a long distance. Bamboo based Bio-CNG can be produced locally throughout India adjoining the highways. Agro Gas, a subsidiary of Primove Engineering Pvt. Ltd., Pune has tested Bamboo and established a model of Bio-CNG plant in Pune and functioning for the past 3 years. The technology was developed by Mr. Santhosh Gondlekar after several years of continuous research and hard work. This It is the first Bio-CNG gas production and gas dispensing station in India.

Conversion of bamboo biomass into CNG

All parts of Bamboo are collected from specifically grown in "Energy Plantation " are collected and fermented with the right combination of microorganisms and bio-digested for 24 to 36 hours. The process generates biogas and biomass slurry. Bamboo biomass of 8 kg would produce 1 kg of CNG gas and 4 kg. of dry undigested biomass having Lignin as a major component. The gas is scrubbed and cleaned from carbon-dioxide, carbon monoxide and sulphur compounds. The processed biogas is compressed into bio-CNG and filled in dispensable gas cylinders. The undigested Lignin mass is converted into briquettes/pellets as by-products. 8 kg of bamboo biomass will produce 1 kg of "gas" and 4 kg of briquettes/pellets in the process.

Why bamboo for Bio-CNG?

With strong emphasis on clean energy, Fossil Compressed Natural Gas sales are increasing @ 6% every year and reached a level of 2155 TMT. The CNG is partially available in India and the balance is imported.

Bamboo in ethanol production

Ethanol is a form of fuel derived from the complex carbohydrate in plants. For decades, scientists have been trying many potential plants as fuel. Many of the plants happen to be in the food chain such as sugarcane, sugar beet, maize; sorghum etc., several years of research had led to the successful development of bamboo cellulose to ethanol in Japan, UK, China, Taiwan etc. Scientific research for the last one decade at Growmore Biotech Ltd, India in the area of Biotechnology and Agronomy led to the development of Beema Bamboo and high density energy plantation as a means to produce highest quantity of cellulosic biomass on a sustainable basis at affordable cost as raw material for ethanol production in India. Today's ethanol demand is met by sugarcane which yields only 500 litre of annual ethanol production. With this, India is not able to meet even 5% requirement of ethanol blending in the current consumption of fuel. The annual market requirement of ethanol is 4.6 billion lit in India for 20 % blending in fuel. The Beema bamboo under precision farming along with appropriate agri inputs provides cellulosic ethanol yield of 10,000-12,000 lit per acre per year. The big challenge to increase ethanol production to meet 20 % of blending can be met easily by cellulosic ethanol from Beema bamboo in 3 – 5 years time.

Cultivation of Beema bamboo as an energy plantation for Bio-ethanol production

- Doesn't harm the environment
- Increase the oxygen while reducing the CO2 5 times faster than any other tree
- Harvested every year, from 3rd years onwards
- Planted once harvested for centuries
- Biomass, at a cost attractive for Bio-ethanol production
- Higher income from farm cultivation - Increases the renewable energy
- Cost effectiveness and eco-friendly option for ethanol production

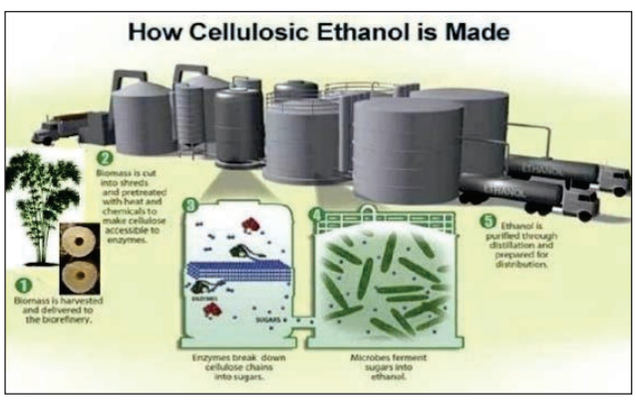
Project on Bio ethanol from bamboo plantation

Minimum viable capacity: 60,000 ltrs./day, 18 million ltrs./year

Area required: 2000 acre of bamboo cultivation & 25 acres of Factory site

Conversion of bamboo biomass into ethanol

All parts of Bamboo are collected from specifically grown in "Energy Plantation" are pre-processed, followed by enzyme treatment and fermentation.



The process gets completed in a week's time, which results in ethanol, water, undigested biomass and lignin. By the process of distillation, the ethanol is separated and the undigested biomass along with Lignin is compressed and made free from water, which is used as feed stock for steam generation, utilized for co-generation of electricity. Bamboo biomass of 4 kg would produce 1 kg or 1.2 litre of Ethanol

Why ethanol?

Ethanol is less polluting fuel and an import substitute for crude oil. The present Govt. has fixed the target of blending Ethanol for fuel at a rate of 22.5 % for petrol and 15 % for diesel.

Why bamboo for ethanol?

The present source of Ethanol is from Sugarcane, which is yielding only 500 litre from a acre of sugarcane while cultivated bamboo similar to that of sugarcane would result in 10,000 litres of Ethanol. Bamboo has 65 to 75 % digestible cellulose and is suitable for bio-ethanol production. At present, the

CHARACTERS	BAGASSE	BEEMA BAMBOO	COAL
Total Moisture	45 – 55 %	10 – 12 %	2.8 – 16.3 %
Ash content	2 – 5 %	0.4 to 1.0 %	9.7 – 20.2 %
Volatile Matter	40.87 %	80 to 83 %	24.20 %
Fixed carbon	4.0 – 6.4 %	5 to 6 %	44.9 – 78.2 %
Total sulphur	0.05 – 0.06 %	0.05 to 0.06 %	0.7 – 4.0 %
Carbon	22.12 – 35.20 %	48 to 52 %	67.90 %
Net Calorific value	2100 – 2400 kcal/kg	3600 kcal/kg	3600 kcal/kg
Gross Calorific value	1700 – 2000 kcal/kg	4050 kcal/kg	4000 kcal/kg
Bulk Density	79 – 110 kg/m^3	400 kg/m3	800-929 kg/m^3
Ash deformation temp	1200 – 1250° C	1200 – 1250° C	+1400° C
Ash fusion temp	1300 – 1350° C	1300 – 1350° C	+1400° C
Nature of resource	Renewable	Renewable	Non-Renewable
Renewable Energy Cert.	Available	Available	Non available
Level of Sulphur	Low	Low	High
Cost of Material	Rs. 3,000	Rs. 4,000	Rs. 5,000

Ethanol blending has reached a level of 5 %, which is mainly met by the sugarcane. There is not much scope available to increase the Ethanol availability to meet the huge target fixed by the Govt. Bamboo is the best alternative available in hand, especially for a tropical country like India.

Replacing coal with bamboo

The Biomass from bamboo can easily replace coal since Beema bamboo has average calorific value of 4,000 kcal/kg. with 1% ash content as against coal which has 4,000 to 4,500 kcal/kg with an ash content of 12 to 20%. In other words, 1 to 1.2 ton of Beema bamboo biomass can effectively replace one ton of coal. The landed cost of coal being more than Rs.4,500/-, this can be economically replaced by 1.25 tons of green bamboo or 1 ton of dry bamboo which would cost Rs.4,000/- per ton. Most of the boilers used for sugarcane bagasse are also suitable for using chips of Beema bamboo with less alteration. In fact, the quality of Beema bamboo biomass is much superior than sugarcane bagasse which is evident from the following table. Hence, coal can be replaced with thorn-less Beema Bamboo which produces the highest biomass. The Beema Bamboo can be cultivated under captive farming or contract farming with farmers to substitute coal feedstock during off season in Sugar Industry for the power generation.

Conversion of bamboo biomass into charcoal

Pyrolysis is the thermal decomposition of biomass in an oxygen free environment at a temperature between 400°C to 900°C. The process results in release of syngas and a residue of charcoal. The charcoal found is known as bio-char and it is a stable carbon with a property of high adsorption of chemicals.

Why bamboo for charcoal?

Bamboo has 40 to 50 % carbon in the biomass from culm, branches, rhizome, roots and leaves. Bamboo is the fastest growing plant and improved clones like Beema bamboo generate over 40 tons of dry biomass / acre / year under appropriately cultivated conditions. The charcoal produced out of bamboo due to the high level of potash results in best quality charcoal in terms of surface area. The experiments at IISc., Bangalore on Beema bamboo have confirmed the higher quality of Bamboo charcoal having a surface area of 900 to 950 sq. m/gm. Bamboo is harvestable on an annual basis, in a sustainable way which additionally generates 30% more oxygen than other trees.

Activated charcoal from bamboo

Bamboo is convertible into charcoal in a specially designed kiln and depending on the temperature of the kiln, the quality of Bamboo charcoal gets altered. Regular charcoal has a surface area of 50 to 100 sq. m/gm while charcoal from Beema bamboo has 900 to 950 sq. m/gm

Conclusions

B. balcooa is considered to be the best raw material for structural usage and pulping. However, Beema bamboo, a superior clone selected from *Bambusa balcooa* has calorific value of 4000 kcal energy and low

ash content between 0.4 % and 1 % and is highly suitable for combustion and gasification systems of power generation. As per the precision farming methodology developed by Growmore Biotech Ltd, Hosur, Tamil Nadu, 1 kg of Beema bamboo biomass will produce 1 unit (1 kWh) of electricity. The Biomass Power Project of 1MW (1 MW/hour or 7200 MW hours/year) can continuously produce electricity for several years with 200 acres of Beema Bamboo energy plantation cultivated under High-Density Plantation. In addition, it has 68 % cellulose and hemi-cellulose, highly suitable for bio ethanol production. 4 kg of biomass is sufficient to produce 1 litre of ethanol. This easily meets the big challenge to increase ethanol production to achieve 20 % of blending cellulosic ethanol at the National level. Beema bamboo also has 48 – 50 % carbon content on dry basis in the biomass, by which 30 – 35 % of charcoal can be recovered and used as a substitute to coal. Apart from that, it is important for Bio-CNG production. Bamboo biomass of 8 kg would produce 1 kg of CNG gas. Thus, Beema Bamboo could be an import substitute for fossil fuel based energy.

Short term trainings @IWST

Sl No.	Name of Course	Course Director Particulars	Apr 2021	May 2021	Jun 2021	Jul 2021	Aug 2021	Sep 2021	Oct 2021	Nov 2021	Dec 2121	Jan 2022	Feb 2022	Mar 2022
1	Bamboo Tissue Culture	Ms. Tresa Hamalton SFM Division Ph: 080-22190137		24 -28										
2	Sandalwood: Farming and Management of its Health	Dr. R. Sundararaj FP Division Ph: 080-22190154			02-04									07-09
3	Bamboo: Propagation and Management	Dr. T. N. Manohara SFM Division Ph: 080-22190156					24 -26							
4	Wood Protection	Dr. K.K. Pandey WP Division Ph: 080-22190175						13-17						
5	Sandalwood: Establishment and Maintenance of Healthy Nurseries and Plantations	Dr. R. Sundararaj FP Division Ph: 080-22190154						20-24						
6	Extraction and Quality Assessment of Sandalwood and other Essential Oils	Dr. Rakesh Kumar & Dr. S.S. Bisht WPU Division Ph: 080-22190191, 080-22190193							05-07				22-24	
7	Bamboo: Propagation, Management and Value Addition	Dr. M.V. Durai SFM Division Ph 080-22190159							18-22					
8	Wood Modification	Dr. S.R. Shukla WPU Division Ph: 080-22190171							25-29					
9	Field Identification of Important Timbers	Dr. M. Sujatha WPU Division Ph: 080-22190173								08-12				
10	Wood Balance Study	Dr. Ritesh Tailor Extension Division Ph: 080-22190199								25-26				
11	Insect Pest Management	Dr. A. Muthukumar FP Division Ph: 080-22190153									07-08			
12	Sandalwood: Seed handling, Nursery and Plantation Technology	Dr. B.N. Diwaka & Dr. N. Ravi SFM Division Ph: 080-22190119, 080-22190155									13- 17		07- 11	
13	Sandalwood : Tissue Culture Techniques	Ms. Tresa Hamalton SFM Division Ph: 080-22190137										11-13		
14	Plant Molecular Biology Techniques	Ms. Tresa Hamalton SFM Division Ph: 080-22190137										17-21		

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Method of grading and trade of bamboos for high economic returns

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Introduction

Bamboo associates with socio-economic, culture of the Indian society since many centuries. It plays an important role in rural economy and international trade. The size of the domestic bamboo economy is about 2000 crores. A recent estimate places the bamboo market at about US$ 12 billion and market was expected to double by 2015. Recently, the government of India has regarded bamboo as an easily manageable export item that provides high yields, has lots of uses and has the potential to provide employment for millions. Bamboo can replace the projected import of timber to the tune of Rs 300,000 million by 2025, if proper encouragement is given to bamboo cultivation and its use. The total demand of various bamboo consuming sectors in India is estimated at 26.9 million tonnes with estimated supply of only 13.47 million tonnes. The demand for housing purposes, road construction, bamboo grids and miscellaneous industry will rise. Since the quality of bamboo varies with species to species, all culms cannot be used for the same purposes. Hence, some sort of grading or classification is required before to put in use.

Factors affecting quality of bamboo

The quality and strength of bamboo culms are depending upon various factors such as species, age, climate, time and method of harvesting, management and post -harvest treatments. Some of the major factors (Trujillo, 2016) are given in the Table 1 below:

Table 1 Factors affecting strength of bamboos

Sl No	Factor	Effect on bamboo strength
1	Species	Different species have different strength properties.
2	Maturity	The optimum maturity for strength varies from species to species, but typically is around 3 to 6 years. It is thought that this increase in strength results from the continuous thickening of the walls of both the fibre and parenchyma cells during the life of the culm. However, not all mechanical properties are affected by age to the same extent.
3	Position along the culm	Strength (in N/mm2) increases with height as does density.
4	Node or internode	Mechanical properties vary from node to internode, this is a consequence of the change in the direction of the fibres at the node.
5	Position within the wall	There is a greater density of fibres towards the outer part of a bamboo wall, than to the inner.
6	Density	There seems to be a correlation between density of a culm or a species and its strength.
7	Load duration	Similar to timber, under the presence of a long-lasting load, bamboo seems weaker than when subjected to a short-term load.
8	Geometric deviations	Taper and warp (bow) reduce the resistance (in kN) of a member in compression.
9	Splitting	Splitting can seriously reduce the resistance (in kN) of a member in bending, shear and compression.

Grading and its kinds

The grading of bamboo should be viewed as part of a marketing strategy, designed to ensure that buyers get the quality of bamboo culm apt for their needs and bamboo sellers receive an optimal price for their product, i.e., it creates an environment where both sellers and buyers mutually benefitted. Grading of bamboo is sorting out bamboo culms on the basis of important characteristics, viz., diameter and length of culm, taper of culm, straightness of culm, inter nodal length, wall thickness, density and strength, and durability and seasoning. One of these or, sometimes, combination of 2 or 3 characteristics form the basis of grading of bamboos. The culms, generally, sorted out species-wise.

Generally, grading is two kinds viz., (a) Machine strength grading and (b) Visual grading. Normally, the former is not followed in any national or international building code for bamboo. Although visual grading of timber is a very old practice, bamboo builders use some form of visual grading. A formalisation of these visual grading practices has been incorporated into the few existing codes and standards for bamboo throughout the world. For visual bamboo grading, some culm features like fissures, warp or distortion (<0.33%), rot, insect damage, taper (<1%), density, rate of growth and maturity (4-6 years old) are considered. In generally, rot and insect damage are not allowed during grading (Trujillo, 2016).

Grading principles

In India, a separate section, 3B has been incorporated for bamboo grading in the Part- 6 of Structural Design of National Building Code (NBC) for its structural use. The NBC provides different safe working stresses standards for 16 bamboo species. However, one cannot solely rely on diameter and strength property-based grades for make use of bamboos. Between September 2018 and August 2019, the INBAR in collaboration with ISO/TC165 had been approved two new international standards, viz., (a). ISO 19624:2018 for grading bamboo poles and (b). ISO 22157:2019 to test their physical and mechanical properties of bamboo grading for bamboo structures. The ISO 19624:2018 standards are developed based on three kinds of properties such as (a) conditional properties, (b) dimensional properties and (c) geometrical properties. Recently, the ISO has published a new standard on structural design with bamboo poles in June, 2021.

Conditional properties

Conditional properties include moisture content, age at time of harvesting, insect and/or fungal damage, and defects such as fissures and longitudinal indentation. According to the grading rules, if the pieces have some indication of insect or fungal damage, it shall be rejected, even if, its meet other grading rules. Enforcement of age as criteria at the point of grading is difficult as it is more readily controlled at the plantation only, not in the natural forest. Matured bamboo of at least 4 years of age shall be used. Bamboo tends to split longitudinally. The width, depth, length and position of these cracks or splits may affect load-bearing capacity of an element. Fissures are cracks that are clearly visible on the surface of the culm, originating on the surface of the culm and developing towards the interior. In India, it is refereed as 'collapse'. Splitting can be minimised if the drying is undertaken in a controlled manner.

Moisture content

With decrease of moisture content (M) the strength of bamboo increases exponentially and bamboo has an intersection point (fibre saturation point) at around 25% moisture content depending upon the species. Matured culms shall be seasoned to about 20% moisture content before use. Air seasoning of split or half-round bamboo does not pose much problem but care has to be taken to prevent fungal discolouration and decay. However, rapid drying in open sun can control decay due to fungal and insect attack. Seasoning in round form presents considerable problem for several of Indian species of bamboo as regards mechanical degrade due to drying defects. There is general observation that thin-walled immature bamboos get invariably deformed in cross-section during seasoning and thick-walled immature bamboo collapses. Thick mature bamboo tends to crack on the surface, with the cracks originating at the nodes and at the decayed points. Moderately thick immature and thin and moderately thick mature bamboos season with much less degrade. Accelerated air seasoning method gives good results, in which the puncturing in nodal diaphragm (septa) enable the hot air passes through from one end to other end of resulting bamboo culm.

Dimensional requirements

Culm diameter

External diameter of bamboo culm is most important dimensional property, because 10% increase in external diameter will result more than 24% increase in the flexural capacity. For estimating it, average of the two orthogonal readings taken at the top and the two orthogonal readings taken at the bottom of a piece would be considered. Diameter

measurements can be done by means of a ruler, tape or, preferably, a Vernier calliper.

Wall thickness

Wall thickness may have a relatively small effect on flexural capacity and stiffness. When directly measured, wall thickness is typically measured at the middle of the internode region, and away from a node. In wall thickness measured in 3 ways viz., average of 4 measurements taken around the circumference of the culm at angular spacing of 90° at both ends of the piece, average of four measurements taken around the circumference of the culm at angular spacing of 90° at the narrowest end of the piece and smallest measurement taken at the narrowest end of the piece. Preferably minimum wall thickness of 8 mm shall be used for load bearing members.

Other dimensional properties

Although less critical to structural design, it may be deemed necessary as part of a grading process to control for internode length. Nodes play a role in the prevention of propagation of splits and buckling, and therefore, specimens with very long internode lengths maybe considered undesirable for certain species and/or applications. When directly measured, internode length can be controlled during grading either by measuring average of all internode lengths along piece or average of internode lengths readings measured at the top and bottom of the piece. The mechanical properties and dimensions of bamboo vary along the culm. The minimum length of culms shall be preferably 6 m for facilitating close fittings at joints, etc.

Geometrical requirements

Dimensional properties include external taper, internal taper, out of straightness and ovality or eccentricity, are typically directly measured from the specimen. Geometrical properties are obtained from making measurements to the specimen and making calculations. The geometrical properties may lead to strength reducing. External taper, or simply taper, is the variation in diameter along the length of a piece. The ISO 22156 and India's NBC limit external taper to 1:170 (0.58%), whereas Colombia's NSR10 limits external taper to 1%. Internal taper is the variation to the internal diameter along the length. The taper shall not be more than 5.8 mm per metre length (or 0.58 percent) of bamboo in any grade of bamboo. Out-of-straightness may be defined as a measure of variation of the culm from a straight condition; reported as the ratio of transverse variation to culm length. The NSR-10 and NBC 2005 advocated limit of out-of-straightness is L/300 and L/80, respectively. The maximum curvature shall not be more than 75 mm in a length of 6 m of any grade of bamboo. Ovality, defined as the ratio between the smallest external diameter and largest external diameter reading measured at one end of a specimen, should also be considered during grading. One of the above characteristics or sometimes combination of 2 or 3 characteristics form the basis of grading. The culms shall be segregated species-wise. For grading of bamboo culms, common defects such as bamboo bore (ghoon-hole), crookedness, discolouration, collapse, end splitting, surface cracking, and wrinkled and deformed surface are considered.

Durability

The natural durability of bamboo is low and varies between 12 to 36 months depending on the species and climatic conditions. In tropical countries, the biodeterioration is very severe. Bamboos are generally destroyed in about one to two years' time when used in the open and in contact with ground while a service life of 2-5 years can be expected from bamboo when used under cover and out of contact with ground. The mechanical strength of bamboo deteriorates rapidly with onset of fungal decay. For making bamboo durable, suitable treatment shall be given. The durability of bamboo can be enhanced with preservative treatment. However, bamboos are difficult to treat by normal preservation methods in dry condition and therefore treatment is best carried out in green condition in accordance with good practice. The Boucherie process of preservative treatment, water borne preservative, is generally applied to end surface of green bamboo through a suitable chamber and forced through the bamboo by hydrostatic or other pressure.

Methods of bamboo grading

The "culm selection system" silviculture system is adopted for bamboo harvesting in India. Feeling starts from 1st October every year and continues up

to end of June. The annual coupe is divided into convenient sectors depending upon the accessibility and harvesting takes place in one direction. All dead, dry and crooked culms, lops and tops and also high cuts are extracted and converted into 1.5 - 2.0m long billets and are made into bundles of 20 pieces each and are stacked. Mature green bamboo is cut and converted into 6-8 m lengths and are stacked separately. Based on basal diameter, bamboo culms are graded into 5 classes viz., as super class (≥18 cm), special class (15 to 18 cm), first class (12 to 15 cm), second class (9 to 12 cm) and third class (≤9 cm). The India's National Building Code -2005 (Table 2), Colombia's NSR-10, Bangladesh National Building Code-2020 (Table 3) and INBAR's new bamboo grading standards-2021 are currently available grading rules for bamboos.

Un-classified bamboo

Classified marihal bamboo in air seasoning

Table 2 Classification of bamboo based on mean outer diameter and strength properties

Groups	Grade	Diameter (mm)
On the basis of mean outer diameter (Clause 4.4.2.1)		
A & B	Special	> 70, ≤ 100
	I	> 50, ≤ 70
	II	> 30, ≤ 50
	III	≤ 30
C	I	> 80, ≤ 100
	II	> 60, ≤ 80
	III	≤ 60
On the basis of strength properties (Clause 4.1.1)		
Group	MoR (N/mm^2)	MoE (kN/mm^2)
A	> 70	> 9
B	> 50, ≤ 70	> 6, ≤ 9
C	> 30, ≤ 50	> 3, ≤ 6

Table 3 Classification of bamboo species for structural applications

Sl No.	Species	Extreme Fibre Stress in Bending N/mm^2	Modulus of Elasticity $\times 10^3$ N/mm^2	Allowable Compressive Stress N/m^2
	GROUP A			
1	*Barnbusa glancescens*	20.7	3.28	15.4
2	*Dendrocalamus strictus*	18.4	2.66	10.3
3	*Oxytenanthera abyssinicia*	20.9	3.31	13.3
	GROUP B			
4	*Bambusa balcooa*	16.05	1.62	13.3
5	*B. pallida*	13.8	2.87	15.4
6	*B. nutans*	13.2	1.47	13.0
7	*B. tulda*	13.3	1.77	11.6
8	*B. auriculata*	16.3	3.34	10.5
9	*B. burmanica*	14.9	2.45	11.4
10	*Cephalostachyum pergracile*	13.2	2.48	10.5
11	*Melocanna baccifera*	13.3	2.53	15.4
12	*Thyrsotachys oliveri*	15.5	2.16	13.4
	GROUP C			
13	*Bambusa bambos*	14.6	1.32	10.1
14	*B. polymorpha*	9.15	1.71	8.97

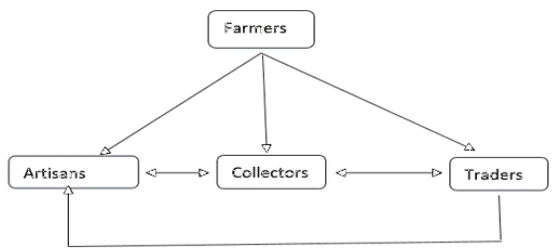
Bamboo trade

Bamboo is mainly traded in form of raw materials, bamboo charcoal, housing, pulp, paper and cloth, bamboo panels and floorings, weaving products and crafts, furniture, fuels, edible bamboo shoots, etc. In general, two types of marketing viz., (a) Direct purchase and (b) Through middleman are observed in bamboo marketing. In direct purchase, traditional bamboo communities are used to buy directly from bamboo growers, private growers and state forest department for livelihood. In second case, the bamboo users purchase bamboo from middleman/ agents who procure bamboo in bulk from the collectors. As the bamboo community is directly involved in purchase of raw bamboo and selling the bamboo products, marketing is not a problem. However, in 2nd case, there are certain marketing obstacles. The small quantities from each collector depress the price received from the middleman and prevent the collector from receiving a larger portion of total income generated from bamboo and services provided by the middleman. Due to a lack of information on current market and price, the collectors cannot be effective in negotiating price for a higher product. Besides, information is needed on future supply and demand of the product, processed product development, and future price projections, which is needed to transform the current selling into a marketing system. According to nature of market, bamboo products are categorized into three groups viz., (1). Bamboo products for export market- charcoal, chopsticks/flower sticks, hats, bamboo culms, bamboo shoot, bamboo parquet, bamboo split, bamboo slice, fishing rods, (2). Bamboo products for domestic market- bamboo curtain, bamboo chair, bamboo rulers, sieves, bamboo round trays, baskets and bamboo culms and (3). bamboo products for souvenir market- bamboo bag, bamboo mat, bamboo mat, tissue box, bamboo tray, flower basket, stationary holder, lamp shade, bamboo strip hat, photo frame and wallet.

Bamboo marketing channels

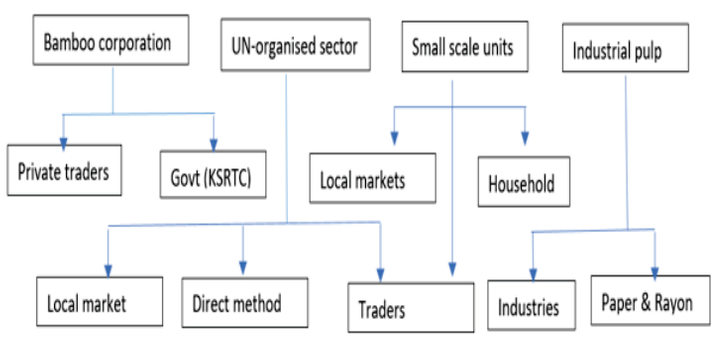
A marketing channel refers to the people, organizations, and activities necessary to transfer the ownership of goods from the point of production to the point of consumption. It is the way products get to the end-user, the consumer; and is also known as a distribution channel.

In bamboo marketing, five kinds of people, viz., collector/producers, middleman / broker, manufacturer, trader, customer are involved. The collectors are the farmers or villagers, who resided around the forest, collected bamboo culm and/or bamboo shoot from the forest and bamboo growers. Then they sold some collected/produced culms and or bamboo shoots to the manufactures/factory owners for manufacturing / processing. The remaining is sold to the traders, who brought them to the markets and sold to the customers. According to study, about 22% of collected culms are kept for home consumption and rest 78% sold to the middlemen and the brokers in Thailand.



General marketing channels of bamboo

The handicraft items are being mostly sold through Government sponsored Emporia, private traders and trade fairs in Kerala. There is no mechanism to sell these products outside the state or abroad. Industries under modern sector have their own marketing mechanism for selling their products. The marketing channels are given below:



In Maharashtra and North Karnataka, the following four common marketing channels are operating:

Channel-I: Producer - Contractor - Retailer - Consumer

Channel-II: Producer - Village trader - Retailer - Consumer

Channel-III: Producer - Commission Agent/Wholesaler - Retailer - Consumer

Channel-IV: Producer - Processer - Retailer – Consumer

Among marketing channels, the channel-IV is more effective than channels I, II and III because marketing efficiency, producer's share in consumer's rupee and net price received by producer was reported higher and this channel also incurred less marketing cost. Similarly highest marketing cost is reported in channel-I; less producer's share in consumer's price is found in Channel-III and also less marketing efficiency is seen in channel-II.

Constraints in marketing of bamboo products

There are certain issues are reported in marketing of bamboo products such as handicraft, shoot and bamboo charcoal. The severe fluctuation in daily marketing price, lack of marketing information system, no guarantee of the bamboo crafts, lack of Government policy, lack of institutionalization, strong competition between the craftsmen, and farmers do not want to take large amount of money for investing in bamboo enterprise are problems in bamboo handicraft marketing. Only a few shipping lines under-take the transportation of bamboo charcoal as it is considered as dangerous materials, high freight charge, quality and timely delivery of the exported items, frequent delay in obtaining necessary clearance from the government departments, and unsystematic and unsustainable cut of young bamboo are listed as major constraints on market expansion.

Conclusion

Currently, bamboo grading system is use in a few countries including India. The INBAR has been developed international standards for bamboo grading in 2021, but it is yet come in force. The grading of bamboo may help not only to improve quality of materials but also enhance consumer confidence and high returns to the growers. Thus, it gives win-win opportunities to growers and consumers.

Further Reading

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Bamboo for environment, bamboo for economy - *The Uravu Story*

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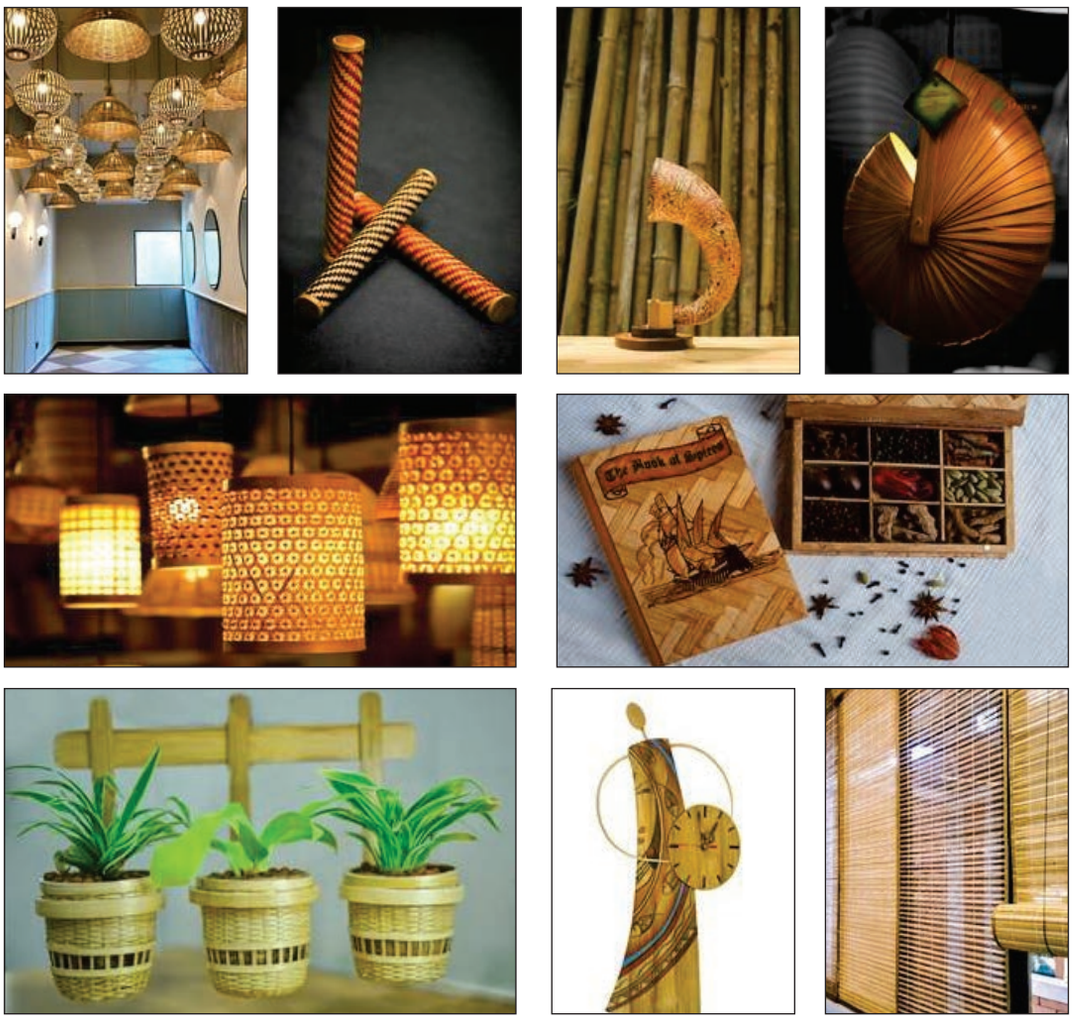
Uravu Indigenous Science and Technology Study Centre commonly known as Uravu located in Thrikaipetta village of Wayanad District, Kerala is a unique organization with inimitable history. Established in

1996, URAVU -a not for profit, non-governmental organization - works with people, governments and businesses to facilitate initiatives with the prime motive of sustainable development and implements focused end-to-end programs in the bamboo sector.

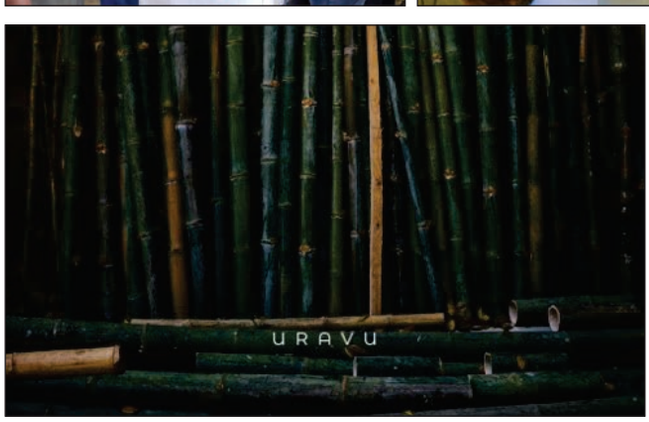
Over the years Uravu has evolved as a knowledge centre and a one stop point for bamboo solutions. Today Uravu has interventions across 6 different verticals of bamboo namely Bamboo Nursery and Plantations, Bamboo Products and Blinds based Livelihood Support Program, Trainings and Workshops, Bamboo Constructions and Sustainable Architecture, Bamboo Depot, Advocacy and Consultancy. Being one of the pioneer organisations in the bamboo sector of Kerala, Uravu aims to develop a wholistic model that could address the major issues related to the bamboo value chain from availability of quality and diverse planting materials and treated, quality raw material for production units to R&D, marketing and awareness creation.

Bamboo Nursery and Plantation activities is one of the defining features of Uravu's model. The nursery primarily strives to aid with eco-restoration programmes and to ensure the availability of raw materials for bamboo-based production units. With more than 55 bamboo species commercially available, the Uravu nursery is the largest in South India in terms of species variety. Bamboo being a viable agriculture crop that could provide guaranteed income with minimum risk and maintenance, Uravu is highly committed for the promotion of bamboo plantations both for its environmental and economic reasons. Apart from supplying saplings, Uravu also takes up plantation and plantation management programs on a contract basis.

Bamboo lifestyle products-based Livelihood Support Program is arguably the flagship program where Uravu has made long strides over the last 24 years. Uravu has trained and established many Self-Help Groups that make primarily bamboo lifestyle products. 100+ artisans- 90% women depend on this Bamboo based ecosystem as their primary source of livelihood. The Livelihood Support Program is aimed at providing handholding support and forward backward linkages including marketing for the production units. The SHGs are equipped to create a wide range of bamboo products ranging from lampshades, corporate gifting, office stationery items, interior, wall decor, bamboo blinds etc.



Trainings and Workshops is another major area of activity of Uravu. Curated, customised as well as standard training programs are organised aimed at addressing the needs of different stakeholders that include government and development agencies, artisans, students, tourists, bamboo lovers etc. Uravu has been associating with several institutions like UNIDO, UNDP, NABARD, KVIC, Bamboo Mission etc. to organise and facilitate these training programs.

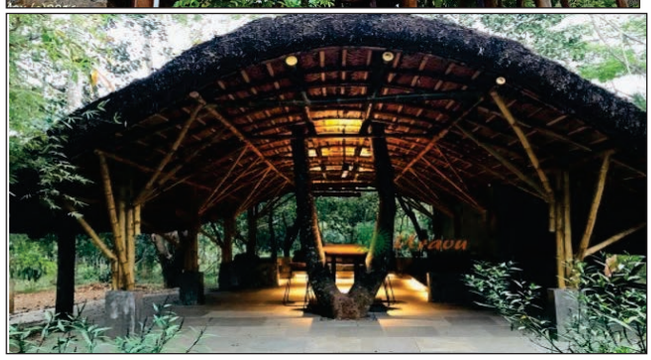


A crucial aspect of Uravu's intervention is the **Bamboo Depot** that aims to address the critical issue of lack of quality raw material supply. This is a fundamental concern for the development of the bamboo industry. Though bamboo is widely available, finding the right kind of bamboo to suit the specific requirements is still an uphill task given the lack of focussed bamboo plantations. Uravu through its raw material yard, procures different varieties of bamboo poles from sources across the nation and make it available under one roof there by providing treated, segregated and high-quality raw material for artisans and industries alike. CCB treated and boric borax treated bamboos are made available at this facility.

Bamboo interiors & bamboo construction focusing on sustainable architecture & green buildings is a key area with vast possibilities to innovate. The sustainability quotient of bamboo combined with its aesthetic brilliance and material properties that could even rival steel, makes it an ideal choice considering the essentiality of a shift to planet friendly structures. Through the Bamboo construction and Green Architecture wing, Uravu aims to be the chief proponents of this idea of buildings and dwellings that could bring down our carbon footprint drastically.

Advocacy and Consultancy is central to the entire operations at Uravu. The institution has been providing consultancy support to various projects and agencies across the nation with its immense experience of bamboo and grass root development. Advocacy efforts go hand in hand with almost the entire activities of Uravu with the prime focus of introducing bamboo into the mainstream psyche as the plant species most suited to facilitate sustainable development. The relevance of bamboo plantations in climate change mitigation, soil stabilisation and improvement of microclimate are the most discussed topics alongside positioning bamboo the green gold as the best alternative for plastic, wood and steel. Uravu works in close connection with schools and colleges spreading the slogan 'Bamboo for Environment, Bamboo for Economy'.

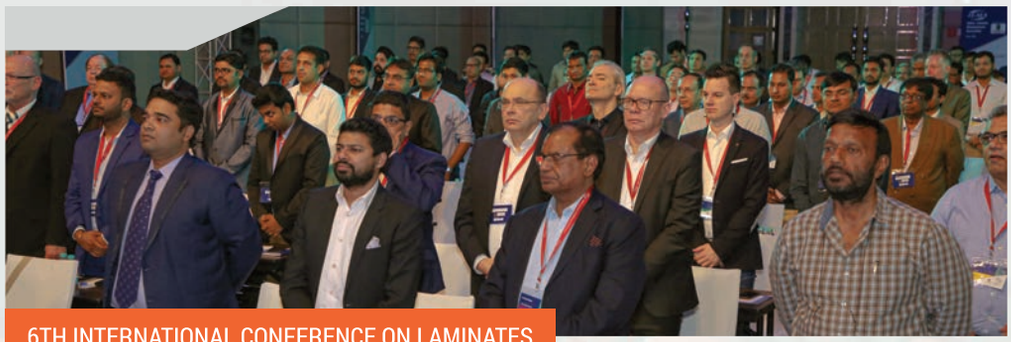
Uravu's major contribution lies in mainstreaming bamboo based economic activities in Kerala. It has helped tremendously to improve the social status of bamboo artisans by removing caste-based perceptions in the occupation. Their per day income levels have risen from Rs. 20-30 in 1990s to Rs. 175-1000 now. From 8 families in 1996, more than 100 families depend on bamboo-based actives as their primary income source in Thrikaipetta village alone today, transforming the whole village economy. Today Uravu is in its journey forward with a larger vision to create a truly sustainable and scalable development model, that would hold the planet and people together, using bamboo, the green gold.



www.ilma.org.in

INDIAN LAMINATE MANUFACTURERS ASSOCIATION

ILMA



6TH INTERNATIONAL CONFERENCE ON LAMINATES

Strength of Unity

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

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

Key Achievements

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

Upcoming Events

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

FOR REGISTRATION

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REACH OUT TO US AT

INDIAN LAMINATE MANUFACTURERS ASSOCIATION
Regd. Office:
301, ILMA, Shubham Complex, Nr. Vastrapur Lake, Opp. Sanjeevani Hospital, Vastrapur, Ahmedabad, Gujarat, INDIA 380015.

Glimpses of bamboo folklore in India

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The ancient civilisations thrived and gradually prospered near river banks and dense forests because of the copious availability of water and food. Therefore, in the religious history of our civilisation, water and forests are worshipped. While the civilisation flourished, so also did religion and philosophy. From our ancient literature, it is evident that most of these religious and cultural activities were discussed profoundly and expounded in these dense forests and resulted in developing genuine worship and respect for trees as they were the essential components of these dense forests. For eons, they revered trees, and bamboo is one of them.

Bamboo is one of the fast-growing and multipurpose species closely associated with humans from time immemorial satisfying, a multitude of human needs, especially in the East and Southeast Asian region. Bamboo is the name of those plants belonging to the family of grasses (Gramineae). It is estimated worldwide that there are around 1300 species covering 25 million hectares. They are generally rapidly growing, large, and sort of tree-like with a woody stem. The stems that emerge from the underground rootstock can reach up to a height of 40 m. having characteristic joint marks known as nodes which are closed by a strong diaphragm. Considered to be a good luck charm bamboo symbolises consistency, integrity by many people and commands dignity and beauty by painters.

It is a belief in many Asian cultures that humanity has emerged from a bamboo stem seemingly good enough to accept the reverence for bamboo. Way back 5000 BC in *Rig Veda*, Bamboo was mentioned as – "Bestow upon us a hundred bamboo clumps". Therefore, bamboos are known for imparting loyalty, integrity, and purity in the matter of emotional and spiritual life of people. In Northeast India, bamboos are considered as *Kalpavriksha* (a tree that fulfills wishes as per Indian mythology) as every part of the tree is useful and takes care of most of the daily essentials both at a physical and spiritual level. It was narrated in Ramayan that Bamboo was abundantly found on the banks of the river Yamuna. Lord Rama during *vanavas* (forest exile) crossed the river Yamuna near Prayag to reach Chitrakoota as per sage Bharadwaja's suggestion by using a raft made of wood and bamboo canes. Lord Rama selects a suitable place during their stay at Panchavati and Lakshmana builds a *parna shala* - a straw cottage using bamboo as pillars. In Mahabharata, it is mentioned that the king of Chedi, Uparichara Vasu of the Puru Dynasty used to conduct every year festival of the bamboo pole to worship Lord Indra and prayed for his cities and kingdom expansion. Bamboo poles were erected and were decorated with golden cloth, ornaments, perfumes, and garlands.

Bamboo is sacred to Hindus as Lord Krishna always had a flute in his hand made of bamboo. The Lord Krishna used the flute as a weapon to conquer the devotee's heart and allowed them to gather around him. There is an interesting story about Krishna and Bamboo which portrays the beautiful association of surrender and faith. Once Lord Krishna approaches bamboo and requests that he wishes cutting it. With no other choices given by Krishna, the bamboo surrenders. Lord Krishna cuts the empty bamboo and starts carving holes in it. During that process of sculpting, bamboo sobs in pain but endures it. Ultimately it was chiselled into a beautiful flute which when played by the Lord, the sound enthralled the entire universe. Thus, the flute became a treasured component of the Lord. The subtle message in this story reveals that being completely hollow within and surrendering to God elevates any object as per the divine wishes.

Another interesting association of bamboo is the 'Kaavadi' in the South of India. There is an interesting mythological story about Lord Shiva reposing Sage Agastya to carry two hillocks to South India which was done by the sage using a bamboo pole balancing on his shoulders. After lifting it for a certain distance, the sage felt tired and requested his disciple Idumban to carry it further. The disciple carried it with great difficulty and put them down near Palani to take rest. When Idumbam wanted to restart his journey, he asked the help of a boy standing nearby to lift it. The boy (a disguised form of Lord Muruga/Kartikeya) instigated Idumban

mentioning that the hillocks belong to him and refuses to part with the hillock. This results in a fight between Idumban and the boy leading to Idumban's defeat. Realising the Lord himself is in the disguised form, Idumban profusely apologises for fighting with the Lord. Seeing Idumban's predicament, Lord Muruga/Kartikeya gives a boon informing that whoever visits Muruga temple carrying a Kavadi made of a bamboo pole, the divine would fulfil all their wishes. This Kavadi now symbolically signifies harmoniously living with some of the inevitable essential facts of life like happiness and unhappiness, wealth and poverty, joy and depression, and maintaining a proper balance with optimum poise and leading a fulfilling life. In Tamil Nadu, the practice of carrying Kavadi to the Muruga temple is followed. Even Kanwariyas of Bihar also follows a somewhat similar ritual. They carry a bamboo stick sling and at either end of the sling pots containing Ganges water are tied that is to be poured in the Shiva's temple in their village. The sling is never allowed to touch the ground. This ritual marks the beginning of the monsoon and the end of summer.

In Kurma Purana, it is mentioned that the *'danda'* used by the *Sanyasi* or the sage and the *Yati's* or ascetic person's food bowl should be of bamboo. One of the important rituals during the sacred thread ceremony in Hindus, the boy has to undertake *Bikshatan* or seeking alms. The boy carries a basket weaved from bamboo towards his mother and she fills the basket with rice. In the Northern part of India, while conducting a marriage ceremony, green bamboo and its branches are used as a canopy. It is also a known fact that both cradles and coffins are made from bamboo, and therefore, bamboo is rightfully called a friend from birth to death of an individual. To symbolise a large family, newly married couples in Uttar Pradesh and Bihar slowly walk without falling by placing their feet on bamboo baskets. During the marriage ceremony in the Prabhus of Pune, bamboo baskets are placed on the bride and bridegroom's heads.

A kaavadi made of bamboo used by the devotees of Lord Murugan in Tamil Nadu

Two small pieces of bamboo are kept in the confinement room to prevent any evil spirit influence on the newborn in the Turi tribe of Gujarat. Rajabanshi tribes in West Bengal set aside a place on the northern end of their houses for the household deity. A bamboo pole from *Bambusa vulgaris* is erected there and worshipped. The tribes consider it as a good omen to see the sprouting of bamboo culm while it is a bad omen if one comes across cutting or a cut piece of bamboo culm during an auspicious occasion. *Gudi padwa* is a festival marking the arrival of the new year in Maharashtra. The word *Gudi* means flag or emblem of Lord Brahma while *Padwa* signifies the first day of the moon phase. The *Gudi* or the flag is hoisted using a long-decorated bamboo pole. An inverted vessel is placed and covered on this bamboo pole and displayed in the front of each household signifies the victory of good over evil. The bamboo pole is obtained from *Dendrocalamus strictus.* The Goddess Gauri festival is celebrated a day before Ganesha Chaturthi in Karnataka, *Mora* a form of a plate made out of bamboo slivers is extensively used to clean grains by separating from the chaff and forms an essential tool in every kitchen. As a token of prosperity and respect ladies exchange *morada bagina* (bagina is offering) consisting of cereals and pulses used in everyday cooking and other items such as jaggery, fruits, bangles, mirror, cloth piece, etc. Kurichya is one of the more developed tribes in the Waynad area of Kerala and is known for being excellent bowmen. *Bambusa bambos* culms used in their traditional ceremonies are known as *Kumbham* and *Thulappathu*. During the *Kumbham* festival, Kumbham (water pot) is made out of the bamboo cut at the base and filled with toddy. Thulappathu is an important festival celebrated on the tenth day of Tulam, the Malayalam month facilitating the Kurichya tribe to start hunting using traditional bow and arrow. It is ensured they follow fasting before cutting the bamboos only on full moon days. They

use the strong part of the culm to make the bow.

Northeast India and bamboo are associated closely since time immemorial. Lepcha community in north Sikkim proudly call themselves "the beloved children of mother nature" and their life is intricately associated with bamboos that bamboo is associated with right from birth, marriage, and death. Bamboo is associated with the creation myth of Lepchas. According to the legend of the Lepcha community,

A Morada bagina of bamboo used during Goddess Gauri festival in Karnataka

Bongthings prayed to mother nature for the bamboo collected from a mythical place *Youngmin youngsun*. The nodes of *Dendrocalamus hamiltonii* are believed to signify their clans and are one of the reasons for having several clans in this community. The elders bless the newly married couple saying that 'like bamboo, your family will grow quickly' as bamboo symbolises fertility. When the wife is pregnant, care is taken to prevent the husband from cutting bamboo shoots because this activity is believed to be adversely impacting the baby's birth. Bamboo is associated with the rituals of death. The dead body is carried on a bamboo structure with a bamboo container filled with the holy drink chi. Invariably Bamboos are used in all their ritual ceremonies and Lepchas cannot even comprehend life without bamboo. Bamboo is also an essential part of Karbis a hill tribe of Assam and the following proverb depicts their intricate association – 'A Karbi is born with bamboo in his hand and leaves the world holding bamboo'. Meetei is an ethnic group of Manipur and considers planting bamboo in the courtyard brings prosperity and luck. In Karang, an isolated island in Loktak lake of Manipur, they use in their courtyard a long and tall bamboo pole decorated with a cluster of small branches and leaves indicating that the eligible daughter for the marriage in the family is already engaged to a boy.

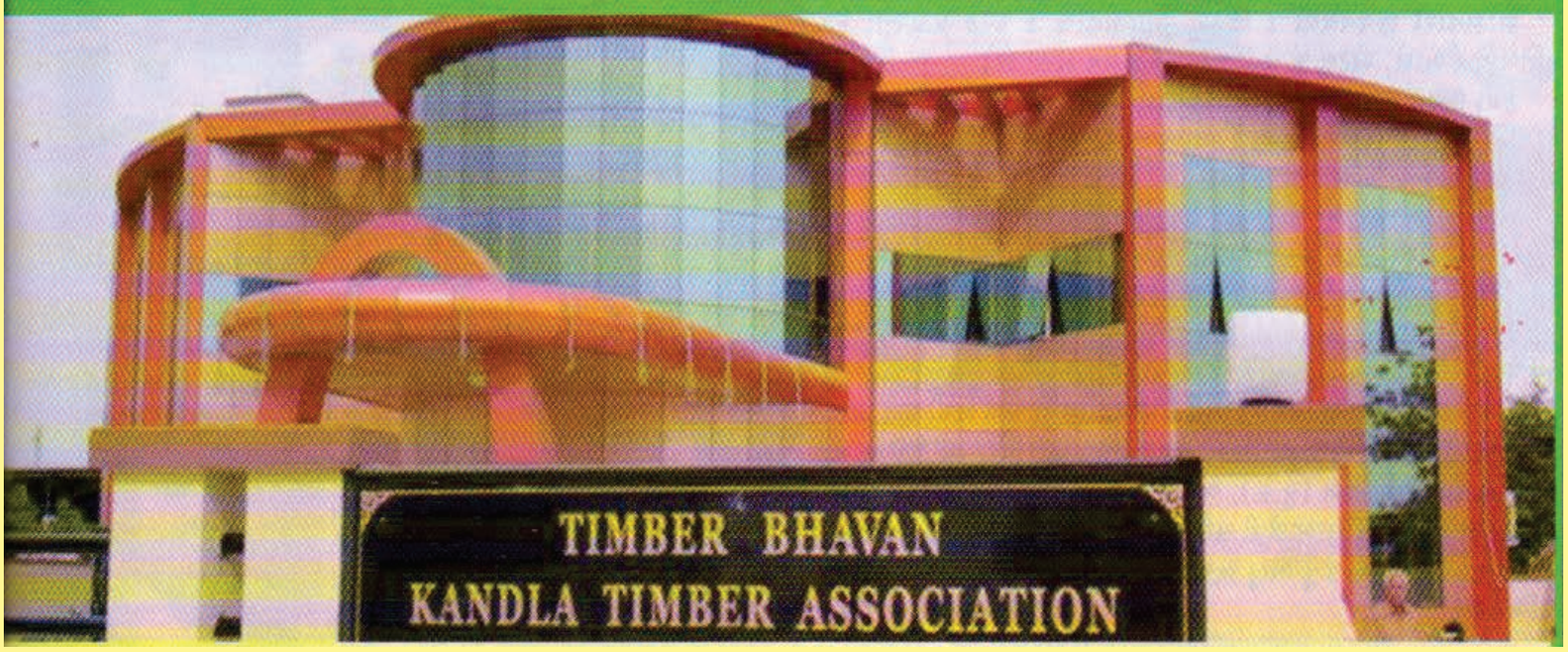
Though Northeast India is popular for bamboo crafts there is also an interesting story depicting the reason why the people of the Ao Naga tribe from Mokokchung district in Nagaland could never learn the method to complete the handicraft items made from bamboo and cane. In the olden days, Changki Changlamba was a most popular magician and had developed expertise in making crafts from bamboo and cane. Once, he restricted himself in a closed room along with tools for crafting bamboo and cane. He informed everyone not to open the door

Phiruk – a ceremonial bamboo basket used in marriages of Meitei community, Manipur

till he comes out on his own. People in the village were concerned and lost patience as he did not come out of the room even after many days. They broke open the door and saw half-done craft works of bamboo and cane. Changlamba scolded and cursed the villagers for being impatient and not heeding to his request. He flew towards the sky and ultimately became a star. Therefore, the villagers still believe they can never complete their crafts and therefore valued less for their craft items.

One of the great masters of the Aikido (Aikido loosely in English means the way of unifying with life energy or as the way of harmonious spirit) aptly exalts bamboo in a single sentence – "the bamboo in its simplicity expresses its usefulness. The man should do the same". There are many more folklores and religious beliefs about bamboo across pan India. However, in this article, a few are recounted. The most positive aspects of these folklores and the reverence for bamboo have enormously culminated in the cultivation, propagation, and conservation of bamboos.

Kandla Timber Association



Association of Timber Importers, Traders, Saw Mill Owners, Plywood & Veneer Manufacturers

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Telefax: 02836-222337, E-mail: kata.gdm@gmail.comi
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Bamboo regeneration within glass bottles: *A boon for bamboo planters*

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Dating back to the 1890's, the feasibility of plant tissue culture was first demonstrated by Haberlandt. When only microbes and animal tissues were being cultured *in vitro* (Latin: within glass) under controlled conditions using artificial media for their survival and growth, the German Botanist- Gottlieb Haberlandt showed that it is possible to culture photosynthetic higher organisms in a similar manner. History says, Henri-Louis Duhamel du Monceau pioneered experiments on wound healing through spontaneous callus formation in elm plants, as early as 1750's. But it took 150 years for Haberlandt to conceptualise 'the totipotent ability of plant cells' and prove that isolated plant cells can be maintained in artificial conditions. Later, many researchers have experimented plant tissue culture for various species, leading to the development of their micropropagation protocols. Today, the use of artificial media and controlled conditions is adopted for macropropagation as well. Nevertheless, micropropagation has proved to be more advantageous than traditional vegetative propagation techniques, and the same is true for bamboos too .

Popularly known as 'the green gold', bamboo is indeed one of the most important renewable resources with a multitude of uses from 'cradle to coffin'. Clustered in Asia, this plant is distributed through the wet evergreen and moist deciduous forests of tropical, sub-tropical and temperate parts of the world, with over 1500 species belonging to 75 genera, of which India houses 148 species in 29 genera. Though it grows naturally and is also being cultivated since time immemorial, bamboo witnesses the same deterioration as other plants. In an attempt to conserve their depleting reserves, the vast bamboo genetic resources were studied, and industrially and economically important species and individuals were selected for propagation and improvement. However, this was impeded by long flowering cycles, lack of seed availability and their short viability when available. Traditional techniques like offset cutting, rhizome splitting, air layering, culm cuttings and culm branch cuttings have helped overcome these issues for bamboo propagation, but they are not without constraints. These methods are season specific, and given the fact that these propagules are often bulky, obtaining planting stock in large numbers is not possible due to difficulty in handling and transport, limited availability and insufficient multiplication rates. This gap can be filled by employing micropropagation, which is one of the most important applications of plant biotechnology that can be used for rapid and large-scale production of true-to-type plants for plantation programmes and germplasm conservation. The application of micropropagation in forestry has a history of about four decades. Protocols of more than 1000 plant species are known throughout the world, but practical use in large scale production is restricted to few dozens, which includes bamboos. The first report on successful tissue culture of bamboo was the culture of embryos of *Dendrocalamus strictus* in 1968. Extensive research on micropropagation of bamboo species has been carried out thereafter using juvenile (zygotic embryo, seed or seedling) and mature clump derived (nodal buds) tissues, and clonally multiplied plants can be produced round the year without the influence of season and other environmental conditions..

Micropropagation stages

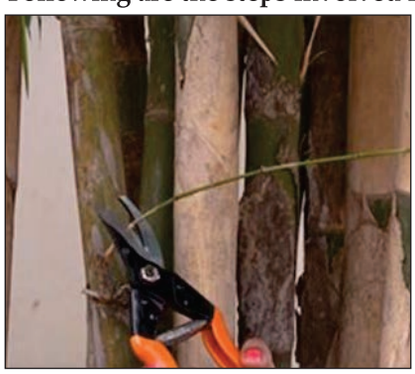
The following three methods are generally followed for in vitro bamboo regeneration.

(I) In vitro seed germination: Surface sterilized seeds are germinated in vitro, and the shoots are further clonally multiplied using micropropagation protocols.

(ii) Regeneration through axillary shoot proliferation: Axillary buds are initiated from surface sterilized nodal segments obtained from mature clumps, and the axillary shoots are multiplied for plantlet production. This is the most commonly used micropropagation technique for clonal propagation.

(iii) Regeneration through somatic embryogenesis: In contrast to germination from zygotic embryos in seeds, somatic embryos are induced from adventitious somatic parts like leaves and internodes obtained from mature clumps, and these are further germinated to raise plantlets. Though this method can produce huge quantities of plants, the synchronised production and germination of somatic embryos is very tricky. It is very laborious and requires continuous monitoring as well.

Following are the steps involved in micropropagation of bamboos through axillary shoot induction



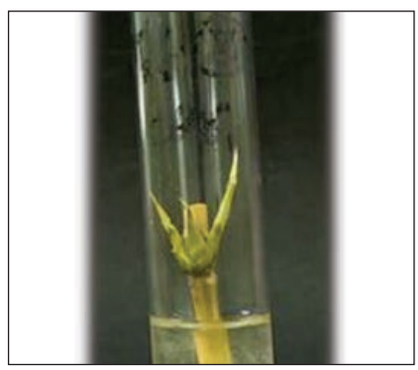
1. Collection of explants from healthy mother culm

2. Trimming of nodal shoot segments

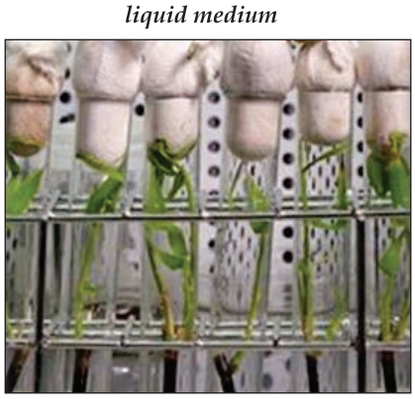
3. Treatment with surface sterilants

4. Inoculation in sterile liquid medium

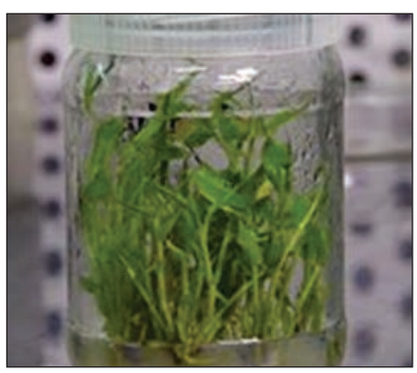
5. Incubation in growth room under controlled conditions



6. Sprouting of axillary buds



7. Excising axillary shoots and placing in fresh sterile medium



8. Incubation in growth room for multiple shoot induction

9. Subculturing to fresh medium for shoot multiplication

10. Transfer of multiplied shoots to rooting medium

11. Incubation in growth room for root induction

12. Treatment of rooted plants with antifungal agent

13. Transfer of rooted plants to root trainers or plastic trays

14.Primary hardening inside polytunnel

15. Transfer of plantlets to polybags containing potting mixture

16. Secondary hardening under shade nets

Factors affecting bamboo micropropagation

The plant growth hormones namely, auxins and cytokinins are routinely used in plant tissue culture and the balance between these hormones plays a crucial role in determining the morphogenic development of explants in culture. When a balance between these two factors promotes callus formation, a high cytokinin to auxin ratio promotes shoot formation and a low cytokinin to auxin ratio results in root formation. Success of any micropropagation protocol depends on the rate of shoot multiplication and frequency of rooting. The major factors which influence *in vitro* propagation are: (i) explant type, (ii) source of explant (seed/seedling/mature plant), (iii) season of explant collection, (iv) nutrient medium and plant growth hormones for shoot initiation, multiplication and root induction, (v) additives, (vi) sub-culturing period, (vii) incubation condition, (viii) *ex vitro* rooting media and auxins, (ix) hardening condition and duration.

At IWST

The journey of bamboo micropropagation is vast. At the Institute of Wood Science and Technology, Bengaluru, research work on bamboos - on propagation, improvement and cultivation, was pursued for the past two decades. With the support of NMBA, NBM, UNDP, ICFRE, World Bank, KFD and DBT, several projects have been carried out on

the development and refinement of protocols for macro and micro propagation, production of quality planting material, establishment of germplasm bank, field evaluation and development of agroforestry models of industrially important bamboo species. Highly efficient micropropagation protocols (axillary mode and/or somatic embryogenesis) have been standardised for various industrially and economically important bamboo species. Field trials of the tissue culture raised bamboo plants have been carried out at Gottipura and Nallal, Bengaluru. Molecular marker-based studies were also carried out to assess the genetic (clonal) fidelity of the micropropagated plants using RAPD and ISSR markers. The institute has transferred technology (tissue culture protocols) to Madhya Pradesh Bamboo mission and Maharashtra Bamboo Development Board. As are in demand by various stakeholders, base culture of different bamboo species was also supplied to various Biotech Companies through MP Bamboo Mission, Maharashtra Bamboo Development Board and Karnataka Forest Department.

IWST now takes credit for developing micropropagation protocols for 15 bamboo species viz., *Bambusa balcooa, B. bambos, B. pallida, B. nutans, B. wamin, B. vulgaris, B. tulda, Dendrocalamus asper, D. brandisii, D. stictus, D. stocksii, D. longispathus, Phyllostachys bambusoides, Guadua angustifolia and Thyrsostachys oliveri.* These techniques are taught to students, farmers and other stakeholders during training programmes offered at the institute. Also, the institute houses a well-equipped plant tissue culture facility which produces and supplies base cultures (tissue culture raised shoots in bottles) of these species, which can be used for further multiplication and plantlet production. Also, rooted plants, after primary and secondary hardening within our mist chambers and shade-nets, are sold for direct planting in the field. The contributions of various researchers including scientists, foresters, research scholars, technical staff, project fellows and dissertation students in developing these techniques are highly appreciated and gratefully acknowledged.

Techno-commercial feasibility of bamboo micropropagation

The demand for tissue cultured bamboo plantlets is growing rapidly. India is advantageous in naturally possessing both essentials for tissue culture, low-cost skilled labour and scientific manpower. Additional factors are the wide range of bamboo diversity in the country and favorable tropical climate. Micropropagation attracted a lot of attention but the translation and transformation of these expectations into commercially viable propagation systems has been affected with several problems that were either technological or related to marketing. At present, limited number of laboratories specialise in the commercial production of bamboos for supplying to the farmers and stakeholders. With the availability of improved varieties as starter cultures, and refined micro propagation protocols, the scope of large-scale production of quality planting material and their marketing can be enhanced.

Future prospects

Bamboo is one of the ideal species that can be utilized in many ways and has a major contribution in the rural economy of India. Due to the exponentially increasing demand for bamboo and its products, cumbersome conventional propagation needs to be supplemented with micro propagation techniques for regular supply of quality planting material. Not only is micropropagation a cloning method, but also has unique advantages like the potential for year-round production of disease and pest free planting material, rapid multiplication of valuable genotypes, expeditious release of improved cultivars, germplasm conservation and facilitating their easy international exchange. Somatic embryogenesis has the potential for very high rates of multiplication and once optimised, is amenable to mechanisation using bioreactors. The improvement of *in vitro* regeneration techniques can also further their use for genetic improvement of bamboo through transgenics and other biotechnological tools. The future goal of bamboo micropropagation is to provide high quality plants in very short time, while overcoming the problems of hybridization, and developing bamboos with added values and improved nutritional and health characteristics.

Bamboo species in Mizoram

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Introduction

Bamboo is traditionally called 'mau' in Mizo language. Mizoram has abundant natural bamboo resources and is also known as the "Bamboo Queen" of the country. About 57% of the geographical area of Mizoram is under bamboo cover found at heights ranging from 400m – 1500m above mean sea level. Bamboo plantation in this hilly state constitutes nearly 14% of the country's total bamboo plantation. Bamboo forests are found mainly along the riverbanks and abandoned jhumland cultivation as a dominant secondary vegetation. Both the clump forming and non-clump forming bamboos are available in most part of Mizoram except in the higher altitudes of the eastern parts of Mizoram. There are twenty species of bamboos in Mizoram of which Melocanna baccifera is the dominant forest resource of the state.

The dominant species Melocanna baccifera called 'Mautak' is a versatile species; it is a spreading species forming no clumps. The culms grow up to 8-10m, they are widely used for construction of Kacha houses, furniture, fencing, weaving and pulping. The shoots are eaten during rainy season in forms a dominant food item. The strength of culms, straightness and lightness combined with hardness, range in size, hollowness, long fibre and easy working qualities make bamboo suitable for multiples purposes uses.

Originally known as a poor man's timber species, bamboo today has gained great importance in the economy and has undoubtedly become one of the most important renewable resources, which is able of producing maximum biomass per unit area and time. Bamboos belong to perennial evergreens in the true grass family Poaceae. They are tall, arborescent woody grasses, belonging to the family Graminae; only a few species being solid, most being hollow and often gregarious in nature. They consist of three distinct morphological parts, viz., the leafy aerial part (the culms) and two underground parts (the rhizome and the roots).

Bamboos in Mizoram

Mizoram it is one of the Seven Sister States in North Eastern India, sharing borders with the states of Tripura, Assam, Manipur and with the neighboring countries of Bangladesh and Burma. Mizoram became the 23rd state of India on 20th February , 1987. The living and lifestyle of Mizo are largely extent dependent on bamboos for its variety and uses and it has much to offer by way of contributing to socio -economic advancement of the state.

The assessment (MIRSAC,2008) indicated that Lunglei had the maximum growing stock of bamboos tonnes, followed by Mamit, Aizawl, Kolasib, Lawngtlai and Serchhip, respectively having 4.164, 4.004, 2,800, 2.661 and 1.720 million metric tonnes of bamboo available in these districts.

Table 1.1 Bamboos in Mizoram

Species	Uses
Bambusa balcooa	Building purposes, agricultural implements and scaffoldings
Bambusa bambos	Floating heavy timber, structural purposes, mat-making, basket works
Bambusa mizorameana	Pandal making, agricultural implements, baskets, heads of men's pipes
Bambusa multiplex	Hedge, ornamental in garden, umbrella handles, fishing rods
Bambusa nutans	Sundry ornamental, rafters, shafts of ekkas
Bambusa tulda	Mats, furniture, scaffolding, hats, wall plates, wall hangers, toys, writing & printing paper, RCC, construction, edible
Bambusa vulgaris	Toys, handicrafts, fencing, ornaments
Bambusa vulgaris var. vittata	Ornamental planting, poles, construction, pulping
Bambusa vulgaris f. waminii	Ornamental purpose
Dendrocalamus asper	Building, water containers, edible
Dendrocalamus giganteus	Building construction, paper pulp, crafting, edible

Dendrocalamus hamiltonii	Construction, baskets, mats, water and milk vessels, fuel, floats, edible
Dendrocalamus latiflorus	Construction, edible.
Dendrocalamus longispathus	Thatching construction, basket making, fuel, posts, mat making, furniture, edible
Dendrocalamus sikkimensis	Containers, churns, edible
Dendrocalamus strictus	Paper, construction purposes, furniture
Melocalamus compactiflorus	Hat and basket making
Melocanna baccifera	Paper, pulp, construction, fencing, edible
Neomicrocalamus mannii	Building
Phyllostachys mannii	Fencing, construction, walking sticks
Schizostachyum dullooa	Ceiling, partition wall, baskets, umbrellas, Mizo looms, kites
Schizostachyum fuchsianum	Basket making, edible
Schizostachyum munroi	Bows and arrows, traps, edible
Schizostachyum pergracile	Shingles, mats, baskets, paper, pulp, tying
Schizostachyum polymorphum	Basket making, fishing, pipe, edible
Sinarundinaria falcata	Arrows, hedges, baskets, fishing rods, pipes, hookas
Sinarundinaria griffithiana	Construction, fencing
Thyrsostachys oliveri	Building purposes, broom, handles, agricultural implements, lance staves, fishing rods

(Source: - Bamboos of Mizoram, Published by E & F Dept. Govt. of Mizoram, Aizawl)

Flowering of Bamboo

As it is being reported that there are two types of flowering in bamboos, viz., gregarious flowering and sporadic flowering. When gregarious flowering occurs, the clumps of an entire species flower, seed, it dies. Although large quantities of seed are produced during gregarious flowering, they are viable only for a short period, sometimes only for a few days or months. Melocanna baccifera is called Mautak in Mizo and the famine that is caused by its flowering is named Mautam.

Bambusa nutans

Bambusa vulgaris

Bambusa multiplex

Bambusa balcooa

Dendrocalamus longispathus

Dendrocalamus hamiltonii

Thyrsostachys oliveri

Schizostachyum Pergracile

Bambusa bambos

Dendrocalamus strictus

Bambusa tulda

Conclusion

As bamboo is known as a poor man timber. It has played an important role in human society since time immemorial and now contributes to the subsistence needs of over a billion people worldwide. It has been traditionally used as fuel, food, for rural housing and shelter, fencing, tools and various other purposes. But today, it is being used as industrial raw material for pulp and paper preparation, construction and engineering materials, panel products, etc. Bamboo, which can be grown easily, is much faster in growth than any known woody species. It is eco-friendly and adaptable to various locality factors, is now becoming the most promising wood substitute.

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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.

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Status of use of bamboo for pulp and paper mills in India

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Introduction

The paper making in India is almost two centuries old with first unit commissioned in 1832 in Serampur, West Bengal. Rags and waste paper were the raw materials used for producing paper in 1867. Commercial production started in 1882 with non-wood fibers. Bamboo pulping process was developed in Forest Research Institute, Dehra Dun during 1922-24 which provided impetus to pulp and paper industry in India CPPRI, 2005).

Paper Mill growth

The growth of paper mills (Table 1) is quite rapid from 1990. One can say that the establishment phase was from 1970 to 1990 and the expansion phase was from 1995 onwards (Kulkarni, 2013). All most all wood based paper mills expanded their capacities of pulp, paper and paperboard by modernizing the machineries and processes in order to meet the stringent pollution standards as well as to meet the growing market demand. However, no new green field integrated pulp and paper mill has come up since the year 2000 because of huge land requirement and Environmental clearance issues.

To start with in 1950, there were 17 paper mills with production capacity of 0.11 million tonnes and the per capita consumption of paper was just 0.9 kgs. Now in 2021, there are more than 750 to 800 mills with estimated 18 million tonnes production and the per capita consumption has gone up to 13 kgs but it is far low compared to the world average of 56.7 kg. As per estimates, out of 750 to 800 pulp and paper mills nearly 30% are closed and rest 70% are continuing the production. The Indian paper mills have not become globally competitive due to many reasons and some of them are - higher production cost, shortage of quality raw material and higher raw material cost.

The present annual turn-over of Indian pulp and paper industry is INR 70,000 Cr. and India's share in world production of paper is about 4%. The annual pulp production (Table 2) from 1970 to 2000 period was about 12.30 million tonnes utilizing 4.56 million tonnes of raw material. The bamboo to wood utilization ratio was 43% (1.99 million tonnes) bamboo and 57% wood (26.61million tonnes).

Table 1. Growth of pulp and paper mills.

Year units	No. of	Production (million tonnes)	Per capita consumption (kgs)
1950	17	0.11	0.9
1970	57	0.75	1.9
1990	325	2.43	3.6
2000	380	4.87	5.5
2006	660	6.80	6.7
2007	667	8.30	8.3
2010	759	10.11	9.3
2021	800	18.00	13.0

However, the present pulp production is 3.2 million tonnes from 11.98 million tonnes of raw material with 11% (1.30 million tonnes) bamboo and 89% (10.68 million tonnes) wood if all mills are functional (Table 3). Owing to closure of 30% mills, the pulp production now stands at 2.58 million tonnes with 2.07% (0.2 million tonnes) bamboo and 97.92% (9.42 million tonnes) wood (Table 3).

Paper industry category

The Indian pulp and paper industry is divided in to 3 sectors based on raw material usage viz.

Wood and Bamboo: Mills using wood and bamboo contribute 25% production which is 4.5 million tonnes of paper and there are 26-28 large integrated paper mills. The annual pulp production is nearly 3.20 million tonnes from 11.98 million tonnes of wood on the peak level when

all mills were functioning (Table 3). Nearly, 8 mills are now sick and are closed and hence, present days wood consumption is approximately 9.62 million tonnes (2.36 million tonnes wood is not consumed out of 11.98 million tonnes) and pulp production is 2.58 million tonnes (0.62 million tonnes pulp is not produced).

Agro-based: There are 168 to 186 mills using agro residues like bagasse, wheat, rice straw etc., which produce 3.06 million tonnes of paper which is 17% of the total production. The agro-based fiber usage has decreased considerably.

Recycled fiber: Mills using waste paper / recycled fiber contribute almost 58% of the country's current production which is 10.44 million tonnes paper and there are 556 to 586 mills in operation. Over the years the recycled fiber usage has increased considerably.

Today, demand for better quality packaging of FMCG products marketed through organized retail, booming e-commerce, rising healthcare spends, over-the-counter medicines and increasing preference for ready-to-eat foods are the key demand drivers for packaging paper / paperboard.

Bamboo for pulp and paper

The total bamboo bearing area of India is estimated to be 15.69 million ha (Tewari, et. al., 2019). States like Assam, Mizoram, Tripura, Nagaland, Manipur, Orissa, Andhra Pradesh, Telangana, Madhya Pradesh, Tamil Nadu, Karnataka, Kerala and Maharashtra are important producers of bamboo. The general consumption pattern of bamboo in India indicates that 8.4% of bamboo is being consumed by pulp and paper industries while, cottage, furniture and implements industries consume 65% bamboo. Earlier, India was leading in the utilization of bamboo for pulp and paper manufacture. More than 70% bamboo was used for paper and paperboard production (Tewari, 1996).

As per the silviculture norms, forest operations are ceased during Monsoon season (May to Sep) for forest regeneration and wildlife breeding. Moreover, during rainy season, flood and heavy rainfall makes the forest inaccessible for bamboo operation. Hence, bamboo procurement is seasonal in nature and sufficient bamboo is to be stocked (buffer stock) for manufacture of pulp and paper during lean season.

It is interesting to note that for promotion of bamboo, Hindustan News Print Limited (HNL), Navgoan had established a Tissue Culture Laboratory in 2006 to propagate bamboo (*Bambusa tulda* (Jati), *Bambusa balcooa* (Bhaluka) and *Bambusa nutans* (Makal) with an installed production capacity of 3.5 lac plants.

Some of the advantages of bamboo is that it is a quick renewable resource. Bamboo is the single fastest growing species of plant on the planet with some species growing more than a meter a day. Bamboo timber can be harvested every year after 4-5 years of its establishment, compared to 5 to 15 years for trees. With 10-30% annual increase in biomass versus 2-5% for trees, bamboo can yield 20 times more timber than trees on the same area. Bamboo can be selectively harvested annually and it regenerates on its own without re-planting.

Paper has been made from bamboo for hundreds of years. The bamboo fiber morphology and length (2 to 3 µ long fiber) are intermediate between wood fiber (0.7 to 1.0 µ short fiber), straw fibers and more or less equal to coniferous soft wood fiber. Bamboo paper is strong and it has wide applications. The bamboo paper's tear is high and the breaking strength and tensile strength are low. Bamboo fiber imparts high mechanical strength.

For production of pulp by Indian paper mills, earlier the raw material furnish was 40% bamboo and 60% wood for a long time. Generally speaking 2.3 to 2.4 tonnes of bamboo is required for production of one tonne of paper as against 4 tonnes of wood. Earlier, the Indian paper industry used bamboo to the extent of 43% (1.99 million tonnes) of the total requirements of cellulosic raw material (Table 2).

Over the years, usage of bamboo reduced considerably to 11% (1.3 million tonnes). Further adding to the problems, most of the bamboo based mills like HNL are closed. Now only 0.2 million (2.07%) of bamboo is being used in the production of pulp, paper and tissue paper (Table 3). *This does not speak well about bamboo usage by paper industry in India.*

Table 2. Earlier (1970 to 2000) bamboo & wood consumption per year by pulp & paper mills

Sl. No.	Company	Raw material requirement (tonne)			
		Pulp (tonne)	Bamboo	Wood	Total
1	ITC Ltd. PSPD, Bhadrachalam	65000	75000	185000	260000
2	Tamil Nadu News Print Ltd.*				
	(50% Bagasse+50% wood)	75000	0	150000	150000
3	Century P & P Ltd. *	60000	100000	140000	240000
4	JK Corp, Raighad (Orissa)	60000	120000	120000	240000
5	JK Corp, Songhad (Gujarat)	40000	100000	60000	160000
6	Orient Paper Mill Ltd.	60000	200000	40000	240000
7	Star Paper Mill Ltd.	60000	150000	90000	240000
8	Mysore Paper Mill *				
	(50% Bagasse+50% wood)	60000	0	125000	125000
9	Sirpur Paper Mill Ltd.	60000	150000	90000	240000
10	BILT Ballarpur/Asthi	40000	120000	40000	160000
11	BILT Sewa	60000	100000	140000	240000
12	BILT Yamunanagar	60000	0	240000	240000
13	BILT Kamalapur	100000	0	400000	400000
14	BILT Chowdwar	40000	100000	60000	160000
15	Seshasai P & B Ltd.*	40000	0	160000	160000
16	Andhra Pradesh Paper Mill Ltd.	60000	180000	60000	240000
17	Circar Paper Mill *	0	0	5000	5000
18	West Coast Paper Mill Ltd.	65000	130000	130000	260000
19	Rama News Prints *	0	0	0	Waste paper
20	HNL Kottayam	40000	70000	90000	160000
21	HNL Naogaon	40000	70000	90000	160000
22	HNL Cachar	40000	70000	90000	160000
23	HNL Nagaland	20000	80000	0	80000
24	Nepa Paper Mill *	40000	80000	80000	160000
25	Yash Paper Mill*	5000	0	16500	16500
26	Delta Paper Mill *	40000	100000	60000	160000
27	Emami Paper Mill *	0	-	-	-
28	Naini*	0	-	-	-
29	Pudumjee*	0	-	-	-
30	Trident*	0	-	-	-
	Total	**1230000 (1.23 mn)**	**1995000 (1.995 mn)**	**2661500 (2.661 mn)**	**4656500 (4.656 mn)**

** Mills using Agro residues and waste paper for Pulp Production apart from Wood and Bamboo. mn=million*

Table 3. Present (2021) Bamboo and Wood consumption per year by Pulp & Paper Mills.

Sl. No.	Company	Raw material requirement (tonne)			
		Pulp(tonne)	Bamboo	Wood	Total
1	ITC Ltd. PSPD, Bhadrachalam	370000	0	1480000	1480000
2	Tamil Nadu News Print Ltd. * (wood pulp =100000 + Bagasse pulp = 170000)	270000	0	400000	400000
3	Century P & P Ltd. *	280000	0	1120000	1120000
4	JK Corp, Raighad, (Orissa)	240000	0	1000000	1000000
5	JK Corp, Songhad (Gujarat)	70000	0	300000	300000
6	Orient Paper Mill Ltd.	100000	100000	300000	400000
7	Star Paper Mill Ltd.*	100000	0	400000	400000
8	Mysore Paper Mill *				

	(50% Wood 50% Bagasse)	60000	0	120000	120000
9	Sirpur Paper Mill Ltd.	110000	0	450000	450000
10	BILT Ballarpur/Asthi	220000	100000	780000	880000
11	BILT Sewa	100000	100000	300000	400000
12	BILT Yamunanagar	100000	0	400000	400000
13	BILT Kamalapuram	100000	0	400000	400000
14	BILT Chowdwar	60000	100000	140000	240000
15	i) Seshasai P & B Ltd.* (400 TPA pulp) ii) SPB Tirunelveli (new acquisition) (72000 TPA paper in 2020-21)	100000	0	400000	400000
16	Andhra Pradesh Paper Mill Ltd.	220000	0	880000	880000
17	Circar Paper Mill *	0	0	5000	5000
18	West Coast Paper Mill Ltd.	280000	0	1120000	1120000
19	Rama News Prints *	0	0	0	Waste paper
20	HNL Kottayam (Kerala Paper products Ltd. Govt. of Kerala)	80000	100000	220000	320000
21	HNL Naogaon	100000	400000	0	400000
22	HNL Cachar	100000	400000	0	400000
23	HNL Nagaland	20000	0	80000	80000
24	Nepa Paper Mill *	40000	0	50000	50000
25	Yash Paper Mill*	5000	0	16500	16500
26	Delta Paper Mill *	80000	0	320000	320000
27	Emami Paper Mill*(Orissa & W. Bengal)	0	-	-	Imported pulp
28	Naini *	0	-	-	"
29	Pudumjee*	0	-	-	"
30	Trident*	0	-	-	"
	Total	**3205000 (3.205 mn)**	**1300000 (1.30 mn)**	**10681500 (10.68 mn)**	**11981500 (11.98 mn)**

** Mills using Agro residues and waste paper for Pulp Production apart from Wood and Bamboo. Some mills use imported pulp also. Red colour - Mills are closed (pulp production and bamboo/wood consumption now not there). mn=million*

Reasons for reduction of bamboo usage

1) Technical process related issues: The negative factor for bamboo is low pulp yield 38 to 40% compared to 42 to 49% pulp yield from wood. Bamboo has high silica content whereas wood has low silica content. High amount of silica creates quality problems in paper as well as problems in lime kiln. The bamboo surface layer is hard and highly cutinized with a waxy coating and is impermeable to water, with reduced moisture the chip dust generation is very high in bamboo. While, the wood absorbs moisture quickly and during chipping of wood the chip dust generation is lower.

2) Loading and transport issues: Per truck, the bamboo quantity is around 6 tonne compared to 10 to 15 tonnes of wood. The transport cost per tonne therefore is higher for bamboo.

3) Bamboo harvest: The harvest of bamboo is cumbersome and requires trained and skilled man power whereas wood harvest is not that cumbersome.

4) Bamboo trade restrictions and other impacts: For a long time there were restrictions for bamboo harvest and its movement. A transit pass was a must as per the Forest Act. There were debates whether bamboo is a tree or a grass.

Gadchiroli district in Maharashtra made history. One of its villages become the country's first to win the right to sell and harvest bamboo as per the Forest Rights Act (FRA) of 2006 (Aparna, 2011). Further bamboo is declared as a grass. In-spite of removal of harvest and Transit rules, the bamboo usage by paper mills and bamboo plantations have not picked up as envisaged.

Paper mill managed bamboo areas were infested with Naxalites and it was going difficult for the paper

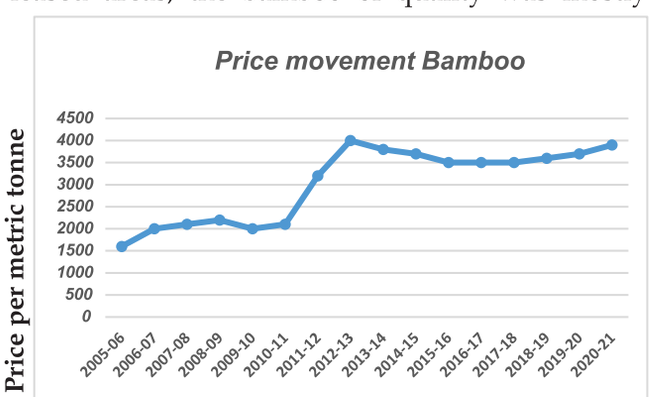
mills as well as the forest departments to manage and extract bamboo from the forest areas. Leasing of bamboo areas by the state to the paper companies was stopped in 1990 by some states. This is one of the major reasons of paper mills coming out of bamboo usage.

5) Environmental impact: The paper industry was blamed for reckless extraction of bamboo from forest areas which they have managed. The growing consciousness for preservation of forests and maintenance of ecological balance and biodiversity during the last few years is impacting the availability of bamboo raw material. Environmentalists are also up in the arms against the paper industry on account of pollution. Due to stoppage of bamboo usage by paper industry, it is stated that the bamboo areas have regenerated well in certain states and is a happy state of affair.

6) Bamboo Price vs wood price: Since 1968 the bamboo areas were leased to paper companies who managed the bamboo areas, harvest and supply. The paper mills paid royalty of Rs. 1200 to 1500/tonne of bamboo to the state. There were disputes between paper mills and the states on royalty issue as the states realized that the bamboo is procured at very low price. On the otherhand the mills claimed that the mill delivered price of bamboo is more than Rs. 4000 per tonne which is higher than the wood price (Aparna, 2011).

The local mill delivered price for bamboo today is Rs. 3900/tonne while, the bamboo procured from faraway places like Assam the mill delivered price is Rs. 7000 to 9000/tonne. However, the average price now is around Rs. 3500/tonne. Compared to bamboo the wood price is lower. This is one of the major reason that the paper industry shifted from bamboo to wood.

7) Supply of industrial cuts: From the bamboo leased areas, the bamboo of quality was mostly



reaching the mill with less amount of industrial cuts (top thin portion of bamboo). However, when leasing of bamboo area to the paper mills was stopped, more material as industrial cuts was coming to paper mills in certain states. The big girth and long bamboo pieces were first supplied for other usages than to the paper industry. This low quality of bamboo (industrial cuts) impacted the quality and cost of production of paper to certain extent.

8) Reduction in bamboo usage: From the Table 4, one can surmise that there is a drastic shift from bamboo to wood i.e. reduction in bamboo usage from 43% to 2% and increase in usage of wood from 57% to 98% or 100%. Majority of the paper mills have completely shifted from bamboo to wood and are vigorously promoting pulp wood tree plantations.

Table 4. Reduction in bamboo usage

Raw material type	Period		
	1977 - 2000	2000 - 2012	2020-21
Bamboo usage by paper mills	43 %	11 %	02.07 %
Wood usage by paper mills	57 %	89 %	97.93 %

9) Industrial plantations: Paper industry over the years nurtured the partnership with farming community for meeting its raw-material demand by promoting agro / farm forestry plantations (Kulkarni 2013). Industry through its R&D units succeeded in developing high yielding, fast growing, disease resistant, short rotation (4 to 5 years) clones of Eucalyptus, Casuarina and Subabul which are planted on large scale by farming community. Nearly 125,000 ha plantations are planted per annum. On cumulative basis, 1200,000 ha plantation exist thus meeting the entire pulp wood requirement of the paper mills through agro / farm forestry plantations. The consumptions of Eucalyptus now in is 50% while, Subabul 26% and the rest 24% from Casuarina, Acacia, Bamboo etc.

Management of pulp wood tree species plantations is easy compared to bamboo plantations. Farmers adopt wood plantations easily. Adoption of bamboo plantations by farmer is little difficult.

Market outlook for pulp and paper

Paper industry is a cyclic industry with high and low price regime of the pulp and paper products. Sometimes there is sluggish movement of paper products and godowns are full with the paper / paper boards stock giving sleepless nights to the marketing and paper godowns personnel's. The paper industry is now coming out of recession. Presently, the market outlook for pulp and paper is not so good. However, there is considerable demand for Tissue paper and Packaging paper / board compared to culture paper. Stringent environment related regulations by EPA are expected to slow down the market growth rate and paper industry is striving very hard to over-come the problems related to pollution .

Way forward

According to related reports, India, Bangladesh, Thailand and China are the world's largest countries of using bamboo for pulp production. From the cost view point, China has found that the unit cost of bamboo pulp is lower than that of wood pulp. Bamboo fiber is required for specialty papers like tissue paper and tetra pack (liquid packaging) due to inherent strength properties imparted by the bamboo fiber.

The annual yield of bamboo is very low i.e.1-2 tonnes/ha and can reach 3-4 tonnes with better management. Until and unless, the productivity of bamboo plantations is improved to more than 10 to 25 tonnes/ha/yr, the bamboo availability on continuous and sustainable basis to the paper mills is a big question mark. The paper industry wish to have a comfortable position in respect of bamboo raw material availability. This can happen if the paper companies promote bamboo plantations in their catchment areas to keep the cost (harvest cost, transport cost) under control. Bamboo harvest is quite cumbersome compared to wood harvest. Developing special machines, logging practices and training people to upgrade the skill is also important.

Unless technology to solve the paper mill effluent problem is evolved along with reduction of silica content in bamboo apart from availability of bamboo at reasonable price, the bamboo usage on large scale by the paper mills may not happen!

In fact, China has embarked on increasing the production capacity of pulping by 5.55 million tonnes including bamboo pulp of 3.95 million tonnes under its National Forestry and Paper Integration Project. The development and layout of bamboo pulp is focused on the southeast coastal areas and southwest area in China. However, the availability of bamboo resource, environmental issues etc., constraints similar to India have slowed down the project.

There is no doubt that bamboo pulp making with technical and market advantages is a huge gold mine which the Indian paper industry once again needs to explore to become globally competitive and reduce import of soft wood fiber.

Acknowledgement

The author wish to thank M/S. Ajay Neoding, Akshat Nagar, Surendra Narkhede, Dr. Seenivasan, R. and Jose, M. P. for providing latest information on raw material usage, pulp production and related matters and Ms. Sampanna for assisting in preparation of the article.

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Thermal processing of bamboo for enhancing properties and improved utilization

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Introduction

Bamboo is world's fastest growing plant. It is light, strong, versatile, environment friendly, self-renewing resource, and highly productive. Bamboo as a traditional building material is being used throughout the world, particularly in tropical and sub-tropical regions in construction in rural areas. However, it also has certain limitations in the context of durability, on account of fungal & insect attacks. Bamboo when used for structural and various other applications need to be treated with toxic preservative chemicals (e.g., CCA, CCB etc.) to prolong its longevity. However, these hazardous chemicals are slowly losing their acceptability due to environmental and health concerns. The bamboo product markets are therefore exploring a eco-friendly method for enhancing service life. Thermal treatment is a non-hazardous method for value addition of bamboo. Thermal modification of bamboo improves certain technological properties including dimensional stability, water uptake and durability. More recently, the interest in heat treatment processes has also been renewed due to the declining production of durable timbers, increasing demand for sustainable building materials, deforestation of especially sub-tropical forests, and increased introduction of governmental restrictive regulations reducing the use of toxic chemicals. Thermal modification of lignocellulosic materials such as wood, bamboo etc. has shown great potential as an alternative to chemical preservative treatments in many lifestyle products such as furniture etc.

Thermal modification of bamboo is a promising and environmentally friendly (chemical free) treatment technique for preserving the bamboo. The process is carried out at high temperatures in a controlled environment such as under a steam blanket (hygrothermal modification), under nitrogen, vacuum or using hot oils. Important parameters of heat treatment process include temperature, duration, atmosphere, species, initial condition etc. Thermal modification of bamboo is entirely different process than seasoning of bamboo. Seasoning or drying of bamboo is a process of bringing down its moisture to level closer to equilibrium moisture content in service (~12±2%). Seasoning is done following controlled schedules to avoid deformations, cracks, and splits. Seasoning also improves fungal resistance and insect attack to some extent. Studies on the effect of heat treatments of different bamboos on various physical, mechanical, chemical and biological properties have been carried for developing the protocol of treatments for producing value-added products.

Thermally modified bamboos have huge market and export potential for many value-added products such as furniture, home accessories, handicraft items etc. This may also encourage other local entrepreneurs to take up value-added products from bamboo and create local employment opportunities. IWST has carried out study on thermal modification of some of the locally grown bamboo species, namely *Bambusa bambos, Dendrocalamus stocksii, Dendrocalamus strictus, Thyrsostachys oliveri* etc.

Thermal modification under partial vacuum

After proper selection of the air-dried culms, defect free sample of each bamboo species were prepared and subjected to thermal modification in a controlled closed chamber (Fig. 1). Bamboo culms were thermally modified at different temperatures in the range of 140-220°C for different durations up to 4 hours under partial vacuum condition. The presence of air or other oxidative medium can accelerate the degradation process of woody components of bamboos during heat treatment; hence the process is usually carried out in a protective partial vacuum.

Thermally modified bamboos showed uniform brownish surface and culm wall color, which darkened with temperature (Fig. 2). Heat

treatment protocols were developed for thermal modification of bamboos under vacuum. Density of heat-treated bamboos did not reduce significantly up to 180ºC. However, heating temperatures >200ºC were found to be detrimental for density depending on bamboo and severity of temperatures. The thermally modified bamboos exhibited reduced EMC (50-60%), water uptake capacity (by 40-60%) and improved dimensional stability (50-55% in wall thickness). Flexural stiffness (MOE) was found to be almost unaffected with increasing treatment temperatures (up to 200°C), maximum reduction of 7-10% was observed in different bamboos at higher temperature. However, flexural strength (MOR) of bamboos reduced by 15-40% with increasing treatment temperatures (up to 220°C) and correlates with weight loss during thermal modification. Thermally modified bamboos have improved decay resistance due to heat treatment. Composite boards such as laminated bamboo lumber (LBL), scrimber bamboo lumber etc. can be produced using strips and crushed thermally modified bamboo (Fig. 3). Thermally modified bamboos can be used for different valued-added applications such as furniture, flooring tiles, bamboo boards and strip-based panel products in structural and non-structural industry sectors.

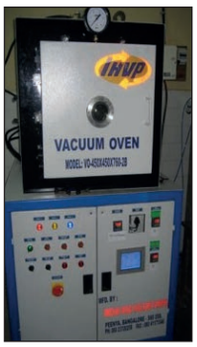

Fig. 1 Vacuum oven used for heat treatment of bamboo in laboratory

Fig. 2 Control and thermally modified bamboos

Fig. 3 Bamboo lumber from thermally modified bamboo

Thermal modification by immersing in hot oil

Thermal modification of bamboo/wood can also be carried out by heating in hot oils (e.g., linseed oil) at 150°C - 220°C by immerging specimens in a reactor containing linseed oil. Use of hot oil facilitates easy heat transfer and provides restricted oxygen environment. Thermal modification of bamboo in vacuum results in mass loss due to partial degradation of some of constituent polymers at high temperature whereas in hot oil treatment, a slight increase in weight is observed due to oil uptake. As observed in vacuum heat treatment, hot linseed oil treatment also induces uniform dark colourations (Fig. 4). Thermally modified bamboo is less hygroscopic and exhibits good dimensional stability. The degree of dimensional stability is determined by calculating the volumetric swelling coefficient and Anti swelling efficiency (ASE). Due to heat treatment of bamboo there is the reduction of volumetric swelling coefficient. ASE increases with heat treatment severity and weight loss. Heat treatment increases dimensional stability which depends upon treatment severity (Fig. 5).

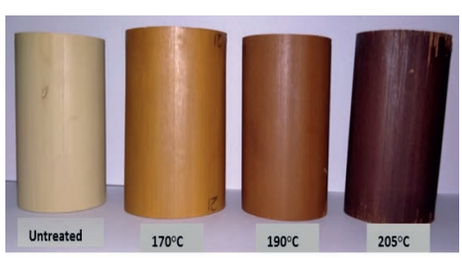

Fig. 4 Effect of hot linseed oil treatment in colour of D. brandissi

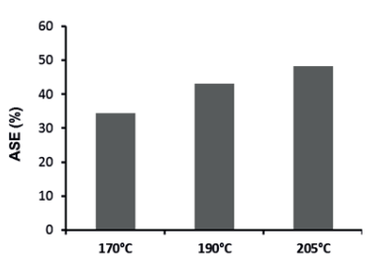

Fig. 5 Anti swelling efficiency of hot oil treated D. stocksii

Summary

Eco-friendly process of thermal modification involves heating of bamboo at high temperatures under inert environment such as partial vacuum or immersion in hot oil. These processes can serve as alternative techniques that eliminate the usages of hazardous chemical preservatives. Through this chemical-free process, decay factors may be eliminated along with improvement in dimensional stability and resistance to water/moisture absorption related problems. Thermally modified bamboos may be used for different valued-added applications such as furniture, flooring tiles, bamboo boards and strip-based panel products in structural and non-structural industry sectors. Heat treated bamboo has a huge market in country with untapped potential due to slowly banning of toxic preservative treated bamboo for environmental reasons. Technical know-how of this domestically sourced, affordable and eco-friendly technique of processing is available with this Institute to produce thermally modified bamboo for different applications.

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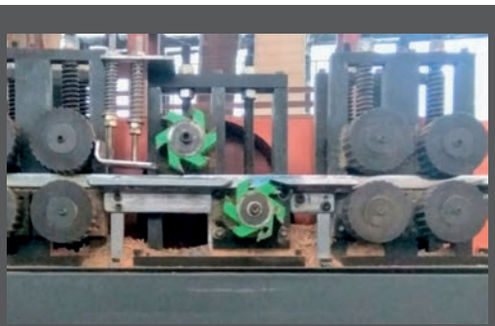


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