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Teak

Vol. 3, Issue 1, April - June 2022

INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY, BENGALURU

Indian council of Forestry Research and Education

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

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INDIAN COUNCIL OF FORESTRY RESEARCH AND EDUCATION

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

VISION

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

MISSION

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

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- A new wood preservative which is comparable to CCA.
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- Developed improved germplasm of many forest tree species.
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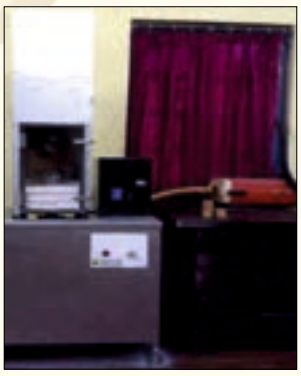
High performing and disease resistant clone of *Melia* sp.

CYCUS v. 1.0

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

Wood Welding

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



Wood Welding Machine

Indian Council of Forestry Research and Education

New Initiatives

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

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

Heat storage based modified Solar Kiln

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

Head based storage Solar Kiln

Xylarium

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

Xylarium- Collection of Authentic wood samples

Tree hollowness detection technique based on ultrasonic waves

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

Measurement of hollowness in a tree using ultrasonic detector

Agroforestry models

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

Poplar based agroforestry model with wheat

Innovative Bamboo Bottles

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

Bamboo bottles

For further details please contact :
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भूपेन्द्र यादव
BHUPENDER YADAV

FOREWORD

Teak (*Tectona grandis*) is the most sought-after species in India for house construction and furniture making. Teakwood forms the bench mark for the grading and price of other wood species and traditionally, consumers in India have an exclusive preference for this wood. Teak is native to India, Myanmar, Laos, and Northern Thailand and there are nearly 8.9 million hectares of teak-bearing forests in India. It is ideally suited to grow as a plantation crop and also as agroforestry species by small holding farmers and is the most preferred species as a bund planting crop by the farmers in India.

India is a timber deficient country and on an average India has imported around 1 million Cubic Metres of teak wood annually during 2015 to 2019. The domestic harvest of teak is insignificant 50 thousand Cubic Metres. There are wood based industries looking for sustainable supply of teakwood for furniture manufacture and export and private investors are keen to develop large scale teak plantation.

There is an imminent need to make concerted efforts at every level in mission mode to improve research, cultivation, harvesting, and marketing of teak. It is the apt time to initiate the process of augmenting teakwood in India so that by 2047, on the 100th year of Independence, the country is self-sufficient in teakwood production. In this current issue of 'Wood is Good: Grow more, Use more' a popular quarterly magazine published from Institute of Wood Science and Technology (IWST), the focus is on various aspects related to Teakwood. The articles cover a wide variety of information related to teak and the steps that should be taken to popularise and expand the cultivation of teakwood.

With best wishes.

Date: 06.09.2022

(Bhupender Yadav)

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Director
Institute of Wood Science and Technology
Bengaluru

Preface

Teak (*Tectona grandis*) is one of the most popular and prominent timber species of India. Teakwood is known across the globe for its remarkable physical and mechanical properties and does not need an elaborative introduction. Its aesthetic and structural qualities are unparalleled, and its utility ranges from its use in carving, veneers, furniture and diversified uses like ship building. Hence, teak enjoys a worldwide reputation as one of the best quality timbers. With the booming economy and rapid urbanization, the demand for its use is increasing rapidly in India as well as the global market.

Teak is indigenous to India and is distributed in very large areas of natural teak bearing forests (8.90 million ha) and teak plantations (1.5 million ha). India alone accounts for 43% of global area covered under teak. Paradoxically, India alone is importing three quarters (74 per cent) of the total global trade volume of teak from more than 50 countries. Considering its popularity and demand, presently, teak is being extensively grown only for export purposes in some of the African and South American countries, which are not the areas in which teak has been found naturally.

In India, the teakwood produced from the natural resources has failed to fulfill the demand for teakwood. Significant decline in teak timber production in India could be attributed to strict implementation of forest conservation policies like blanket ban on green felling of trees, and timber transit rules implemented by some of the governments of the states where teak in abundant. Rigid regulations controlling the felling of teak trees and transit of timber discouraged the farmers to grow teak as agroforestry species that ultimately forced India to rely upon the import of teak from other countries.

Considering the present state of affairs with respect to augmenting teak production in India, Institute of Wood Science and Technology (IWST), Bangalore organized a two day national seminar on "Augmenting Teak Timber in India: Way Forward" by inviting representatives from state forest departments of teak growing states, industry representatives, scientists and academicians. The objective of the seminar was to come up with clear road map to augment teak production as India steps towards Atmanirbhar Bharat in terms of teak production by 2047. From the discussions held during the seminar it is learnt that, although some of the state forest departments are doing their bit to promote teak cultivation, states have not given adequate attention to this issue. State forest departments do not have a holistic plan to make India a self-reliant country in terms of teak production.

In a way, teak had its share of glory and agony in equal proportions. Now, the time has arrived to regain the lost glory of Indian teakwood both in the national and international market. As envisaged by the Hon'ble Prime minister of India, we are entering into the Amrit Kaal and we should try our best to achieve self-sufficiency in teakwood production by 2047 and reduce the massive import of teak wood in the short term. Time is now ripe to rethink about popularizing teak cultivation in India and also associated factors that need immediate attention to encourage teakwood farming. Teak being an indigenous tree, we are endowed with high genetic diversity of teak and it offers an ideal platform for identifying superior genotypes. Therefore, breeding strategies in genetic improvement of teak need greater focus, especially in terms of short rotation teak; and enhancing the options and opportunities for successful implementation of clonal forestry across the country, especially for the promotion of agroforestry and farm forestry plantations. State Forest Development Corporations have been granted forestlands for commercial plantations to meet the demands of the industries. They undertook plantation of *Eucalyptus, Acacia auriculiformis* and such other species suitable for paper and pulp industries. These plantations are competing with agroforestry plantations raised in small landholdings by local farmers in the supply of wood to industries, creating hardships and discouragement for farmers to undertake agroforestry. These forestlands leased to forest development corporations offer great opportunity for undertaking clonal teak forestry on lines of Latin American countries, especially Brazil. Further, to keep our genetic diversity intact, we can promote seed based plantation in our natural teak bearing forest areas.

To make India "Atmanirbhar Bharat" (self-reliant India) in terms of teak production and to realize the dream of our Hon'ble Prime Minister, we need to promote teak cultivation in India on a Mission mode. In this endeavor, there is an urgent need to constitute a "Teak Task Force" (TTF) at the Government of India level that gets down to the nitty gritty of several aspects and becomes the fulcrum of the teak revolution in India. The TTF can act as a guiding force to all the state forest departments to make India self-reliant in terms of teak production by the end of 2047. Further, India should not only be sufficient in teak production to fulfil the demands and aspirations of every citizen seeking this valuable wood, but should also be able to mightily contribute to fulfilling global demand.

(Dr. M. P. Singh, IFS)
Director

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CONTENT

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IWST activities during April–June, 2022

Training for IFS officers on Advances in Wood Production and Utilization

Institute organized, MoEF&CC sponsored one week compulsory training (through physical mode) for IFS officers on "Advances in Wood Production and Utilization". A total of 14 IFS officers nominated by MoEF&CC from different states attended the training from 18-22 April 2022. The training was broadly classified into five sessions viz. Industrial wood production, wood technology, wood sector scenario, wood products design & innovation and wood production. The course curriculum included field trip to BIESSE India, Bangalore, Chennapatna Craft Park, Hunsur Plywood Works Ltd. and Karnataka Soaps and Detergents Limited, Mysore. The officers also visited IWST laboratories, xylarium, wood museum and wood working centre to get an understanding of the research activities being carried out at the institute. Eminent wood based industry representatives, researchers and experts in the field of design of wooden building technology addressed the participants.

World Earth Day

World Earth Day was celebrated on 22nd April 2022 as part of Azadi Ka Amrit Mahotsav. Dr. V. K. Bahuguna, IFS (Retd), Ex DG, ICFRE, Former Principal Secretary & Agriculture Production Commissioner, Govt. of Tripura addressed the scientists of IWST and also IFS officers attending the compulsory training course on Advances in wood production and utilization. He delivered a talk on Relevance of Earth Day: Wood is irreplaceable. In his address, he highlighted about the importance of wood for the survival of man and entire biosphere. He reiterated that wood is the most ecofriendly material and its use needs to be promoted for effective climate change mitigation. He opined that to meet the growing demand for wood, it is pertinent to boost the production of wood through agroforestry systems and government should bring appropriate policy changes to promote agroforestry in the country. He also urged scientists and forest officers to work hard for the production and promotion of wood in the country. Planting of sandalwood saplings in the campus was organized on this occasion. Officers, Scientists, Staff and Students Participated in the Event.

Short term training on Sandalwood and management of its Health

IWST, Bangalore organized a Three days training programme on " Sandalwood farming & management of its health" from 27th to 29th April 2022 at IWST on physical mode. A total of 56 participants from various states participated in the training program. The technical session covered aspects like Sandalwood seed and nursery techniques like processing of sandal wood fruits and seed quality testing, growing sandalwood in different agro-forest systems, heartwood estimation in standing trees, management of diseases in sandalwood nursery & plantations, identification of sandalwood decay, damages caused by insects, products derived from sandalwood, economics, trade, protection, policy and schemes of State Forest Department, and good silvicultural practices and subject expects working on sandalwood farming explained them to the participants. A hands-on session at the IWST nursery to learn about seed handlings and nursery practices and visit to sandalwood plantation, entomology & pathology lab was also arranged.

Dr. B.R. Ambedkar Jayanthi

IWST Bangalore celebrated 131st Birth anniversary of Bharath Ratna Dr. B. R. Ambedkar on 26 April 2022. Sri M. Nanjundaswamy, IPS, Additional Director General of Police, Home Guard & Civil Defence, Govt. of Karnataka and Dr. Basavaraj Itnal, BE, M Tech, presided over the function. Sri. V.S.Shetteppanavar, IFS, IWST and Dr. M.P. Singh, IFS, Director, IWST also addressed the gathering. As a token of appreciation for higher education, students of IWST SC/ST employees were felicitated on the occasion. Officers/staff and students participated in the program.

Anti-Terrorism Day

Anti-Terrorism Day is observed in the interest of the nation to discourage the youth from terrorism, violence and highlight the sufferings of common people and show how detrimental it is to our Nation. IWST, Bangalore observed Anti-Terrorism Day on 20 May 2022. All officers, scientists, staff/employees took the Anti-Terrorism pledge.

Webinar on Identification, analysis and adultrants of sandalwood and its oil

As part of Azadi Ka Amrit Mahotsav, a webinar on "Identification, analysis and adulterants of sandalwood and its oil" was organized on 12th May 2022 for officials of forest departments, industries, sandalwood growers from different states, researchers, students & faculty from forestry colleges and universities. Dr. M.P. Singh, IFS, Director IWST in his inaugural address, mentioned that it is our duty to promote sandalwood cultivation throughout the country for the benefit of farmers and other stakeholders. The webinar covered aspects related to Electric Resistance Tomography: A novel technology in estimation of heartwood in sandalwood trees, identification of hardwoods through anatomical approach, wood structure of Santalum album (Indian sandalwood), differentiation of adulterants from the Indian sandalwood through wood anatomical technique, testing and quality control of sandalwood oil, process of sandalwood oil extraction, different quality parameters, chemical parameters of different synthetic oil etc. The topic of Sandalwood oil, trade, current market and future prospects' was covered by Dr. Chidanand R&D, Head from Karnataka Soap and Detergent Limited (KSDL), Bengaluru.'

International Biodiversity Day

As part of Azadi Ka Amrit Mahotsav, IWST in collaboration with Indian Academy of Wood Science (IAWS) celebrated International Biological Diversity Day on 22nd May 2022. Dr. R. Sundararaj, Scientist G and Head, Forest Protection Division delivered a lecture on Insect diversity. He highlighted the importance of insects and his research contributions in the field of forest entomology. Further, Dr. S.R. Shukla, Scientist G and Head, Wood Properties and Uses Division delivered a talk on trees and timber diversity across the globe including India. Dr. K.S. Rao, President, Indian Academy of Wood Science, addressed the gathering about the importance of biodiversity for human existence. Dr. S.S. Chauhan, Director, IPIRTI and Dr. R. V. Rao, Scientist (Retd. IWST) highlighted on diversity of wood in the country and work done by ICFRE in this regard. Dr. M.P. Singh, Director, IWST in his concluding remarks urged wood scientists to work on lesser known timber species and encouraged them to work on sustainable use of wood material considering the vast diversity of wood available in India.

India Wood Exhibition 2-6 June 2022

IWST, Bangalore participated in India Wood Exhibition 2022 organized by M/s. Nurnberg Messe India Pvt. Ltd at Bangalore International Exhibition Centre, Bangalore from 2-6 June 2022. An exhibition stall was put up by IWST to showcase research activities of the institute and technologies developed. Posters, handouts, artifacts, and models related to thermal modification of wood, chemical modification of wood, transparent wood, wood polymer composite, bamboo lumber, cross laminated timber, use of alternative species for handicrafts, palmyra palm, technical services, short term training courses etc. were displayed at the exhibition. Posters related to courses conducted at Advance Woodworking Training Centre were displayed and few models prepared by outgoing students upon completion of various course were presented. Quality sandalwood saplings and technical publication related to research activities were put up for sale. Many wood working units, pan India, were interested in employing our

students qualified at the Advance Woodworking Training Centre. Also, advanced technologies developed by the institute especially wood polymer composites, transparent wood and potential building materials that are gaining great importance across the globe for multi-storied wooden structures like Cross Laminated Timber (CLT), Glue Laminated Timber (GLT), Laminated Veneer Lumber (LVL) and bamboo lumber were well received by wood industry representatives, architects, interior designers who are interested in adopting these techniques and taking it forward to the market. The enquiries and response to our trainings, services rendered, publications etc. was overwhelming.

Yoga Day 21 June 2022

As part of International Yoga Day and Azadi Ka Amruth Mahostav celebration, IWST, Bangalore conducted Yoga class under the guidance of Yoga instructor Mr. Ravi from Saral Yoga Vedike on 21 June 2022. Officers/ Staff/ Students & visiting RFO trainees of Tamil Nadu Forest Academy Coimbatore participated in the program.

Webinar on Application of IT tools in forestry

As part of Azadi Ka Amrit Mahotsav, a webinar on "Application of IT Tools in Forestry" was organized on 23 June 2022. In his opening remark, Dr. M.P. Singh, IFS, Director, IWST highlighted about developing mobile applications, Wood Certification System and IT based solution in the future perspective. The technical session touched upon overview of IT Application in Forestry Sector, Information Technology trends, e-protection system for high value trees, Multilingual Mobile Application for enhancing Agroforestry and IT Implementation in Karnataka Forest Department. In particular, details were given on e-Parihara application, e-Sasykshetra, e-Evaluation Application, e-Filling and transit permission system, Integrated Forest produce tracking System, Aranya Swattu Nirvahana Vyavaste, Aranya Kaamagari, e-Timber, e-Prahari (Patrol Management System), Stipulation Monitoring System for FC cases, Sawmill Management System (Sakala), Forest Offence Case Management System, Transfer & Counseling Management System, Data Security and Hosting Server. Technical bridge between urbanization and forestry together with frame work and prerequisites for IT enhancement in sustainable forest management was emphasize.

Webinar on Fodder species for different agro-climatic zones of Karnataka

A webinar on "Fodder species for different agro-climatic zones of Karnataka" was organized on 29th June 2022 as part of Azadi Ka Amrit Mahotsav celebration. In his opening remarks Mr. V.S. Shettepanavar, IFS, Group Coordinator (R), IWST, spoke about current scenario of fodder availability in India and need for region wise package of practices to mitigate the pressure of grazing on natural forests. The webinar emphasized on fodder tree and grass species for different agro-climatic zones of Karnataka with specific reference to the experiments conducted at three location in Karnataka. It deliberated upon selection of species, nutritive value, role of fodder species in livestock management and species suited for fringe area so as to mitigate the pressure on natural forest for grazing.

Regional Research Conference-2022 on 'Forestry Research in Southern States of India with Special Focus on Agroforestry Issues'

The ICFRE Regional Research Conference 2022 was organised by the Institute of Wood Science and Technology (IWST), Bengaluru on the topic "Forestry Research in Southern States of India with a special focus on Agroforestry issues" on June 10th, 2022. It was co-organised by the Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore, by virtual participation. The inaugural session was presided over by the Chief Patron, Shri. A. S. Rawat, IFS, Director General, ICFRE, Dehradun, along with Shri. R. K. Dogra, IFS, DDG-Research of ICFRE and PCCFs from the states of Karnataka, Tamil Nadu, Kerala, Andhra Pradesh, Goa, and Andaman & Nicobar, who expressed their views as guests of honour. Senior IFS officers representing the forest departments of various southern states, researchers and academicians from institutes and forestry colleges; and representatives from various wood-based industries participated in the conference. They all shared their views and discussed the research needs of the southern states, especially related to Agroforestry issues, and this deliberation facilitated IWST and other ICFRE institutes in orienting their research activities to solve these issues.

INAUGURAL SESSION:

To begin with, **Dr. M. P. Singh, IFS, Director, IWST** welcomed the PCCFs of all the southern states and their representatives. He explained that the demand for wood products in India is ever increasing, with more than 10% growth, because of which a large quantity of timber and even wood products are being imported. Hence, there is a need to augment the raw materials for the industries in order to make quality wood products. Agroforestry has immense scope for increasing wood production for this purpose. India already has an Agroforestry policy, and there is a need to enhance production through the proper choice of species. He concluded with an anticipatory note that this conference would provide a platform to collectively understand and discuss these issues between researchers and stakeholders.

Dr. C. Kunhikannan, Director, IFGTB also welcomed all the participants, foresters, farmers, industrialists, and researchers. He mentioned briefly the history of initiating the RRCs and how research conducted on the research needs outlined during the previous RRCs has resulted in the release of many useful varieties of tree species for various purposes. He expressed his hopes that, in a similar manner, the outcome of this RRC will also pave the way for extended research in Agroforestry which will be useful for industrial partners as well.

Shri. A. S. Rawat IFS, Director General, ICFRE presided over the inaugural session as the chief guest and addressed the gathering virtually. He welcomed all the participants of RRC-2022 and mentioned that RRCs have become regularized now and are the backbone for new project formulation in ICFRE. He stated that this year's annual budget gave emphasises on Agroforestry and hence, ICFRE institutes should work hard to promote agroforestry in the country. Agroforestry needs to be redefined in certain pockets of the country and some proper structure is needed at local levels for its promotion. The outcome of research in the form of improved tree species can be assimilated by the SFDs by way of providing superior clones or varieties to the farmers for planting. He appealed to SFDs to provide land for ICFRE institutes to conduct their trials and also to maintain germplasm.

He highlighted the need for ICFRE institutes to work with the SFDs in other aspects also to improve the livelihoods of local people, especially on NTFPs (value addition, on-destructive harvesting, and genetic improvement). He opined that more research on natural forest and ecosystem restoration in close association with SFDs is required. Finally, he suggested that wood balance studies can also be taken up by ICFRE institutes, and the preliminary findings of on-going AICRPs may be disseminated to stakeholders after a year, so that they can also incorporate those findings into their guidelines related to plantations and other activities. He ended with a note inviting the states to put forward other issues also for conducting research in the forthcoming years.

Shri. R. K. Dogra, IFS, DDG-Research, ICFRE, addressed the gathering from IWST, and welcomed all the participants. He highlighted that ICFRE has been at the forefront of providing scientific solutions to critical issues in forestry, including certain global concerns. The Council has prioritised research areas and developed the National Forestry Research Plan 2030, which provides a road map of how ICFRE will help achieve national goals and international commitments of the nation. Further, he also opined that the national priorities emanate from National Forestry Policy, focusing on the rights and interests of forest dependent communities, especially for their livelihood, the challenges of climate change, biodiversity conservation, and ecological security, and achieving them through sustainable management of forests, with a special focus on increasing tree cover through Agroforestry. He concluded that the RRC is a formal platform to share the research problems confronted by various stakeholders like forest departments, educational institutions, farmers, industries, and NGOs, and urged that informal discussions should also ensue after the RRC to continue achieving the goals and share updated research outcomes.

Shri. Rajiv Ranjan, IFS, PCCF (Development), Karnataka Forest Department addressed the participants from IWST, and emphasized the importance of the theme of RRC-2022. He mentioned the increase in forest cover in Karnataka is due to Trees outside Forests (ToFs) which are largely because of Agroforestry. The history of Agroforestry in Karnataka began by providing incentives to farmers for up to three years under the KAPY programme, for growing trees on agricultural land.

He informed that farmers are concerned about the economic returns Agarwood, Red Sanders and Sandalwood after planting. Since they are unaware of the Package of Practices (PoPs), and where and how to sell their produce, they are unable to realise returns after planting. So, there is a need work on economics of Agroforestry systems as short-term, mid-term and long-term returns. For this purpose, wholesome integrated farming of trees needs to be practised with grasses, agricultural and horticultural species. To promote ToF he suggested that private areas, waste lands under panchayats etc. should be considered for planting trees, and field officers can take up such activities as extension programmes.

During his virtual inaugural remarks, **Shri. Ajay Kumar Naik, IFS, PCCF, Andhra Pradesh Forest Department,** emphasised Agroforestry as an important component of ToFs. He opined that farmers and the general public will come forward to increase tree cover if we show them the way, and this will happen only if the farmers benefit from short term economic returns and long-term benefits. ToFs are required for carbon sequestration as well, since natural forests are not sufficient for the purpose. He emphasised that the major constraint was the production of quality planting material (QPM), and this could be resolved by research organisations guiding the research wings of forest departments in establishing the QPM.

Shri Keshav Kumar IFS, CCF (Research), Goa Forest Department addressed the gathering by online mode on behalf of PCCF of Goa and mentioned that, in Goa 400km2 area is already under green cover and very little area is available for Agroforestry, due to huge land use competition, especially for tourism.The major land use practices existing in Goa are: Coconut and Arecanut planting in farm bunds, Eucalyptus and Casuarina plantations in community lands, Cajanus cajan agricultural practice in coastal areas, Cashew and Rubber plantations. Wood based industries (WBI) are importing their raw materials, and improved utilisation of timbers in existing plantations is needed. Since Agroforestry has to compete with land used for tourism, suitable species and techniques for plantations need to be identified, and also lower productivity teak plantations may be converted to better Agro-forestry models. He ended with an emphasis on the ongoing issues in forest demarcation in Goa, wherein the fear of inclusion in forest areas is a major constraint in establishing commercial tree plantations in private areas.

Mr. Subrath Mohapatra, IFS, PCCF (Research) representing PCCF (HoFF) of Tamil Nadu addressed the participants virtually and congratulated the organisers for selecting an apt topic for discussion, since the benefits of Agroforestry are multiple. He emphasised the importance of addressing climate change vulnerabilities, agricultural sustainability, wood production, and meeting people's needs in general. Farmers are concerned about the economic returns only, and hence species for Agroforestry should be selected accordingly. Financing from banks is also necessary for farmers to encourage tree planting in farm lands. He ended with a note that marketing and utilisation of Agroforestry products should also be addressed, beyond PoPs for Agroforestry.

Shri. Bennichan Thomas IFS, PCCF (HoFF), Kerala Forest Department, during his online address, mentioned the recent initiation of a new Agro-forestry programme, 'Vriksha Samridhi Yojana' in the state by the Chief Minister. In Kerala, the activities of social forestry and Agroforestry are totally carried out by panchayats, taking care of species selection, plant raising, and fund management. Though free supply of seedlings was done during 1980-85, their survival could not be monitored, and therefore the Grampanchayats are now encouraged to carry out tree planting. Also, 40% of the earnings from the sale of forest produce are diverted back to conduct research, and funding is being provided to various research institutes, including IFGTB, IWST, KFRI, KAU etc. He concluded by mentioning the plan of the Kerala Forest Department to develop Agroforestry models for sandal in collaboration with the support of IWST.

Shri. P. Subramanyam IFS, PCCF, Andaman & Nicobar addressed the gathering virtually and complimented the organisers for this initiative. Recalling his association with ICFRE at TFRI, Jabalpur, he highlighted the need for suggestions of research problems by the stakeholders, upon which the researchers can work and give proper solutions. He made a brief presentation on Agroforestry, research lines needed, and their requirements from ICFRE. He elaborated that the scope of Agro-forestry should go beyond the traditional deliverables of ToFs, carbon stocking, and wood availability to also cover benefits such as climate change resilience, livelihoods, more per acre, tourism, etc. He also suggested that Agroforestry should cater to the other forest-produce also as stated in Sec. 2(4) of IFA, and trees taken up for Agroforestry should include all species covered in Sec. 2(7) of IFA. Generally, when agricultural land is converted to tree cover, the output decreases exponentially. Ultimately, land is a limited resource and agricultural land serves many other purposes, so there is a need to overcome this issue by making multiple uses of the land.

Technical Session: Augmenting Wood Production and Productivity Enhancement Through Agroforestry – Initiations And Issues

The session began with a presentation by Shri. V. S. Shettappanavar IFS, Group Co-ordinator (Research), IWST on the overview of the research work done at IWST, Bengaluru.

Shri. S. D. Pathak IFS, APCCF (Research & Utilization), Karnataka Forest Department presented about the Forest Tissue Culture lab at Doresanipalya, Bengaluru through online mode. They have pioneered in productivity enhancement using E. *camaldulensis, Acacias,* E. *heterophylla* etc. and have moved to raising E. camaldulensis hybrids from ITC. The main focus of the Forest Tissue Culture laboratory is the large scale production of B. tulda for agarbatthi sticks, and increasing the productivity of Agroforestry species. Also, they are already working towards productivity enhancement for Bamboo, Casuarina and Teak.

Shri. G. S. Yadav IFS, APCCF (Social Forestry), Karnataka Forest Department presented on the status and implementation of AGROFORESTRY in Karnataka. He mentioned the major species which are in demand for Agroforestry in Karnataka (Teak, Rosewood, Sandal, Bijasal, Mahogany, Red sanders, Jamun, Jackfruit, Mango, Neem, Bamboo etc.). He described the various schemes to encourage Agroforestry in Karnataka. He listed the major species planted under Agroforestry during the past 3 years (Silver oak, Acacia, Pongamia, Melia, Sandalwood, Teak, Mahogany, Bamboo, Mulberry, Neem, Jamun etc.) and the species exempted by the Government of Karnataka for felling and transit to encourage Agroforestry activities on private lands, and other achievements & initiations of Karnataka FD. Listing the various species that are in demand for planting in Agroforestry, he requested participants to comment on the spacing specified for those trees. He also informed that a new Sandalwood policy with relaxations is under consideration by the government of Karnataka to facilitate and encourage sandalwood cultivation. However, challenges in sandalwood tree protection still exist. He emphasised the need for establishing more wood-based industries, which are lacking owing to difficulties in obtaining licenses for saw mill industries, due to which most of the timber goes out of the state.

Shri. Ajay Kumar Naik IFS, PCCF (Research and IT), Andhra Pradesh Forest Department made an online presentation on various research activities carried out by the research wing of APFD i.e., the State Silviculturist Divisions in Tirupati and Rajahmundry.

The Tirupati center caters to the needs of the Rayalaseema and Nellore districts of Andhra Pradesh, focusing on Red Sanders, other hardwood species and biofertilisers. The Rajahmundry center caters to the needs of coastal districts of Andhra Pradesh, and focus on Casuarina, Teak and Seed technology (seed processing, testing, and propagation). He pointed out various facilities available at BIOTRIM, Tirupati (Tissue culture lab, Microbiology lab, Propagation units etc.), and also informed that the Centre is approved by National Biodiversity Authority for upgrading as Indian Institute of Red Sands and Biodiversity of Eastern Ghats.

Shri. Keshav Kumar IFS, CCF (Research), Goa Forest Department virtually presented the perspectives of Goa on augmenting wood production and strategies for productivity enhancement through Agro-forestry. He listed the various Agroforestry initiatives of Goa FD, and detailed the following major issues in wood production through Agroforestry: suitable species for Agroforestry in Goa, improving utilisation of timber from existing plantations, motivating people to take up exclusive timber plantations considering competing needs of land, and the issue of Private (Deemed) Forests. He also suggested that meetings with industries and farmers are needed to encourage farmers to take up plantations. Low productive teak plantations may be converted to better Agroforestry models. He also requested conducting research on improving the utilisation of timber from cashew plantations, which is otherwise used as fuelwood. Dr. M. P. Singh IFS, Director IWST offered to share data about related work done at IWST and asked to support a research project on it.

Dr. S. S. Chauhan, Director, IPIRTI, Bengaluru made a presentation about AGROFORESTRY for Wood Panel Products. He explained the various wood composites and their wood resources (natural forest, plantations, Agroforestry etc.). The general perception of short-rotation agro-forestry wood resources is that they are more variable, with high moisture content, poor wood properties, poor stability, non-durable and small girth logs. Agroforestry has now become the backbone of wood-based industries, especially wood panel products, since almost 70-80% of plywood and panel products are from Agroforestry. He then explained the whole concept of Agroforestry for composite wood because stable, uniform, and consistent quality material can be produced using the engineering method, taking advantage of different materials (e.g., mix and match of Poplar and Eucalyptus plywood in North India). Smaller trees are also utilised and every part (twigs, branches etc.) can be utilized for composite wood. He also mentioned that augmenting quality wood with higher productivity of suitable species for specific industries would be of immense importance for the growth of the wood-based industries, and promoting use of wood obtained from sustainably managed Agroforestry would play a significant role in mitigating climate change and ensuring sustainable living. For industries to thrive, the supply should be consistent, and more research is needed on the wood quality parameters.

Dr. Ramakrishna Hegde, Professor and Head, Department of Silviculture and Agroforestry, College of Forestry, Ponnampet, made a virtual presentation on augmenting wood production through Agro-forestry. He explained the various research trials/activities carried out by the College of Foresty related to Agroforestry in different species such as Teak, Casuarina, Melia, Mahogany, Gmelina and also industrially important bamboo species. He pointed out that whenever Agroforestry trials are taken up, different aspects need to be considered for the model to be more robust, dynamic, and replicable. It must take care of several considerations, including tree crop interactions, and also the ecosystem services that can be derived from the Agroforestry models. Wood production should increase in agricultural land without adversely affecting food production, and proper models need to be designed for this.

Shri. Ambrish Kumar IAS, Isha Foundation-Cauvery Calling Campaign made a presentation on the conceptualisation and execution of the Cauvery Calling Campaign in collaboration with the Government of Karnataka. Seedlings were initially produced through the project Green Hand. The saplings were raised naturally at Cuddalore, TN and later planted in Karnataka and Tamil Nadu in the Cauvery River Basin. Over 1 crore saplings were planted under KAPY in monsoons of 2020 and 2021, and 15 permanent team members in the 9 districts are executing the programme at ground level. He then explained the role of Mara Mitras in the Cauvery Calling Campaign, who are IT-enabled extension workers using the Cauvery Coogu mobile app.

Shri. Deepak Srivastava, IFS, APCCF, Mission Director, Green Tamil Nadu Mission presented data on the geographic area, forest cover in Tamil Nadu, and explained the viable options of Agroforestry for wood and food security under the Green Tamil Nadu Mission. Agroforestry is prioritised in this mission for sustainable management, land degradation neutrality, and ecosystem restoration, with the goal of improving livelihoods, biodiversity, and productivity. They have selected 16 tree species for developing appropriate agro-silvi-pastoral models in 7 agro-climatic zones of Tamil Nadu as climate smart agriculture. They have also adopted a consortium of industrial-Agroforestry by establishing state and district level green committees, for developing marketing linkages and providing direct benefits to farmers. He detailed the advantages and disadvantages of the multifunctional Agroforestry developed by FCRI, Mettupalayam.

Shri. Nishant Verma, IKEA Hitech City, Hyderabad delivered a virtual presentation about IKEA and the challenges in the supply chain. He mentioned that IKEA sources wood from approximately 50 countries around the world. More than 98% of the wood used for IKEA products was FSC certified or recycled in 2020. Also, IKEA home furnishing suppliers sourced approximately 19 million m^3 of round wood equivalent for home furnishing products and packaging, out of which approximately 12% of their total wood consumption was recycled. He also pointed out the challenges of the industry, such as, illegal deforestation, adverse impact on the environment and climate, wood traceability issues in the supply chain, etc. He further explained the challenges in the supply chain (fragmented small farmers, lack of focus on responsible wood sourcing, enough demand in the domestic market with no global compliance) with respect to different stakeholders like farmers, wood processing industry, board/furniture factories, retailers, and customers. He suggested posing certain questions before farmers invest in Agroforestry or any other venture, such as, what they want to achieve, to whom and why they want to supply, and what long term benefit they are looking for. Dr. M. P. Singh IFS, Director, IWST emphasized that the major wood supply in India at present and in the future will be from Agroforestry. In such a scenario, stressing the need for FSC certification may not be appropriate as the wood does not come from the forest. Instead, the ideal way for IKEA would be to dispense with FSC in India, and efforts towards developing our own indigenous electronic and digital timber tracking and chain of custody certification are the need of the hour for certifying Indian woods.

Shri. Subrat Mohapatra IFS, PCCF (Research and Education), Tamil Nadu Forest Department explained the challenges of Agroforestry in Tamil Nadu state during his virtual presentation. He mentioned the lack of back and forward linkages, research support like seeds and clonal material, value added products and their disposal, market accessibility, uniform price or assured price in a market etc. for developing markets for Agroforestry products. Also, he mentioned lack of familiarity with technologies, lack of awareness of successful examples, competition between trees, crops & animals, lack of financial assistance, lack of apparent profit potential, lack of exposure to demonstration sites, lack of training and capacity building on development and implementation of the Agroforestry model, and also provided suggestions to overcome those. He explained about tree cultivation on private land (TCPL), its objectives, implementation, and case studies in different ranges.

Dr. R. Yasodha, Group Co-ordinator (Research) & Scientist-G, IFGTB presented an overview of the research work done at IFGTB through online mode. She briefed about the species improvement programmes for different end uses of various species. She mentioned that seven clones of Casuarina and Eucalyptus are IPR protected, and 26,500 ha of Casuarina hybrid clones and 9,200 ha of Eucalyptus clones have been planted, and the licence for commercial multiplication is also granted after collection of licence fee.

Ms. R. Keerthi IFS, Conservator of Forests (Social Forestry), Kozhikode made a virtual presentation on various social forestry initiatives in Kerala. She explained about the Haritha Keralam programme developed during 2009-10, and other schemes/ programmes brought under this scheme. She also listed the new programmes like Vidyavanam, Nagarvam, coastal planting, river bank stabilisation, forestry club, Vanmitra awards, incentivisation of sacred groves and mangroves for increasing area under ToFs. She explained the enabling factors that facilitate the growth of Agroforestry, the priority interventions that could result in the improvement of Agroforestry, the benefits of Agroforestry and the major factors hindering its growth.

Dr. K. N. Murthy IFS (Retd.), Treelands, Bangalore mentioned that push factors alone are not enough to increase green cover. He explained the role of

Agroforestry and the reasons for its adoption, especially with respect to pull factors like the economic returns to farmers. He mentioned that there has already been a revolution in wood technology in the last two decades and most of the industrial needs are being met through Agroforestry. The engineered wood meets most of the requirements as they have been extensively using fast growing and short rotation species. Yet, there is a mismatch between the production and consumption of agri-wood and long hauls are added unnecessarily to the cost of raw material. He also stressed that Agroforestry is the main source of wood supply now and in the future, and that mere altruism will not work, and that Agroforestry has to be fully commercialised. For this, the restriction on Agroforestry and related wood-based industries has to be removed, and encouraged for efficient marketing arrangements for agri-wood. To achieve this, industries need to be proactive and support Agro-forestry, and importing wood is not an ideal alternative. The monopoly of industries in purchasing agri-wood is detrimental to the farmers as the rate fixed is meagre.

Shri. Dharmendra Kumar Daukia, Green Panel, Chennai during his presentation, raised certain pertinent issues that need to be addressed to have a better perspective on augmenting the wood supply, both in terms of quality and quantity, from Agroforestry. He stressed that the overall wood based paper industry "plants" more trees than it needs, and is self sufficient in terms of planting and availability of the raw material, which is much more than its requirements.

Shri. Arunanshu Das, Sharon/Century Ply, Chennai delivered a virtual presentation on behalf of Shri. Sujit Dey. He mentioned that the daily requirement of raw materials for the plywood industry is 3500 metric tons. Earlier, the raw material was supplied from tropical forests, but they have been getting material from their own plantations and Agroforestry for the past 5 years. The majority of the raw material usage consists of 25% from Melia dubia and 75% from Eucalyptus plantations. There is more demand, but the raw material supply from markets is very small. He pointed out that the quality of raw materials is lagging behind, and there is a gap between production and the availability of raw materials.

Shri. Ashish Mishra, Greenlam Industries Limited, Chennai introduced the vision and initiatives of his organisation, and mentioned their diversification plans and ventures in various parts of the country, especially in Andhra Pradesh and Tamil Nadu. Some of the initiatives undertaken by them include dedicated structures and resources in place for wood research and development at corporate level. Greenlam is committed to long-term investment and a grassroots approach, with a focus on QPM, clonal forestry, and rural extension programs. He ended with an emphasis that Greenlam is keen to explore long term R & D Collaboration / Tie-Up with ICFRE and other research institutions for research on farm and Agroforestry based clonal research.

Dr. H. B. Raghu, Associate Professor, Department of Forestry and Environmental Science, GKVK, UAS, Bengaluru mentioned that time has essentially come to identify different tree species for short, medium, and long term rotations with different purposes. He urged that marketing links are a major issue and the drive behind the identification of suitable species has to be supported by market demand. Therefore, the link between farmers and the wood industry is of great importance, and this needs to be immediately addressed. He also mentioned that there is a need for developing benchmarks for each model, so that the farmer is convinced before planting in his field. Along with timber tree species, he listed several fruit-producing trees that are also to be encouraged as food, and wood can be a strong combination that would help in doubling the farmer's income. He emphasised that this value chain of diversified products would not only help with species diversity but also encourage increased economic activity.

Dr. K. T. Parthiban, Dean, Forest College and Research Institute, TNAU, Mettupalyam made a virtual presentation on 'A Value Chain on Industrial Agroforestry Status and Development in TN'. He explained the status and development of the value chain for industrial Agroforestry in Tamil Nadu. He briefed about the wood requirements in India, by giving the details of wood demand and supply pattern in Tamil Nadu. He explained in detail the constraints and challenges of industrial Agroforestry and provided the solutions through technological interventions. He highlighted timber based Agroforestry systems, including high value models, pulpwood Agroforestry models, plywood Agroforestry models, matchwood Agroforestry models, dendrofuel Agroforestry models, and NTFP production Agroforestry models.

Dr. T. K. Kunhamu, Professor and Associate Director of Research, Head, Dept. of Silviculture & Agroforestry, College of Forestry, Kerala Agricultural University discussed in detail the status of Agroforestry in Kerala and associated issues. Agroforestry per se cannot be extensively practised in Kerala, as land availability is an issue. While discussing the timber scenario of Kerala, he mentioned the various species used and that 35% of wood supply in Kerala is from homestead gardens, while it is merely 1.6% from forests. The homestead gardens are, in a way, the epitome of sustainability, as they are closely associated with the home owner. It is a multi-storey combination of trees and crops, sometimes in association with domestic animals, and is the principal source of fuel wood for rural households.

Dr. Raju L. Chavan, Professor, College of Forestry, Sirsi, Karnataka, during his virtual presentation, detailed various AGROFORESTRY models and technologies developed by UAS-Dharward Center in the Northern Transition zone, in their AICRP on Agroforestry.

After several deliberations and discussions on the research priorities pertaining to AGROFORESTRY for the southern states, Dr. A. N. Arun Kumar, Scientist G & Head, SFM Division, IWST concluded the meeting with a formal vote of thanks.

CRAFTING SKILLS FOR THE NEW AGE WOOD

Association of Indian Panel Board (AIPM) along with illustrious organisations such as IPIRTI, IWST, FFSC are working hand in hand to train & promote skilled and unskilled carpenters / trainees to understand & handle the optimum usage of the New age wood(Medium density Fibreboards).

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Teak Production - Global and Regional Perspectives

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Introduction

Teak has a unique blend of elements to produce an exceptional timber quality: medium density, stability, high resistance to biological agents and appealing aesthetical features. The exquisite furniture crafted by the colonial craftsmen way back in the 18th century adorns London's Hyde Park to Kew even today. Teak has been the traditionally preferred timber for the construction of high performance vessels, furniture, beams, flooring, plywood, decorative face veneer, solid fixtures, handicrafts, laminated panels and boards. The teak timber quality depends on its geographical origin and ranges from straight yellow tight grain to dark wavy brown coarse grain.

Distribution of teak

Natural teak forests cover an area of approximately 29 million hectares, nearly half of which is grown in Myanmar. Over the years, the natural teak area has declined substantially due to over exploitation (legal and illegal), shifting cultivation, population pressure, agricultural expansion, and grazing. Further, targeted removal of the best quality teak trees (creaming) from the natural populations has resulted in the genetic depletion of residual stands. The decrease in availability of natural teak logs coupled with increasing market demand has facilitated teak plantations outside their natural habitats. Teak is now increasingly planted in about 70 countries throughout Africa, Latin America, Asia, and Oceania (Table 1). Planted teak forests, according to various estimates, cover between 4.35 and 6.89 million ha, of which approximately 85% are in Asia, 10% in Africa, and 5% in tropical America. For most of these countries, albeit being an introduced species, teak represents a good opportunity to produce quality timber and is a major asset for the forestry economy, attracting large investments from the private sector.

Table 1: Changes in area of planted teak by region during 1970 - 2000

Continent/ Region	Plantations (m ha)		
	1970	1995	2000
Africa	0.099	0.109	0.469
Asia	1.185	2.108	3.598
Caribbean	0.010	0.008	0.015
Central America	0.002	0.023	0.132
Oceania	0.002	0.003	0.008
South America	0.001	0.003	0.122
Total	**1.299**	**2.254**	**5.346**

(Source: Keogh (1979); Pandey and Brown (2000); Kollert and Cherubini (2012)

Global teak imports (average 2005–2014) total 1.07 million m^3/yr, valued at $487 million USD/yr. India, followed by China, imports more than two thirds of global teak (Figure 2a-b). Thus, the global teak market is governed by trends in the Asian market, which holds more than 90% of the world's teak resources. Since 2000, the global trade in teak logs of the major importing countries (India and China) has more than doubled in terms of volume and more than quadrupled in terms of value. Among the different teak-growing countries, Myanmar remains the dominant supplier of teakwood to the global market even though the teak supplier base has broadened manifold outside the traditional natural forests in Asia. The non-traditional areas in Ghana, Tanzania, Ecuador, Costa Rica, Panama, Colombia, and Brazil have continuously expanded their trade volumes since 2000, reaching a peak in recent years, a trend likely to continue in the future. However, the lack of uniform grading rules, standards, and consistency in measure-ments and quality assessment for teak logs results in widespread uncertainty and confusion around teak trade and investments.

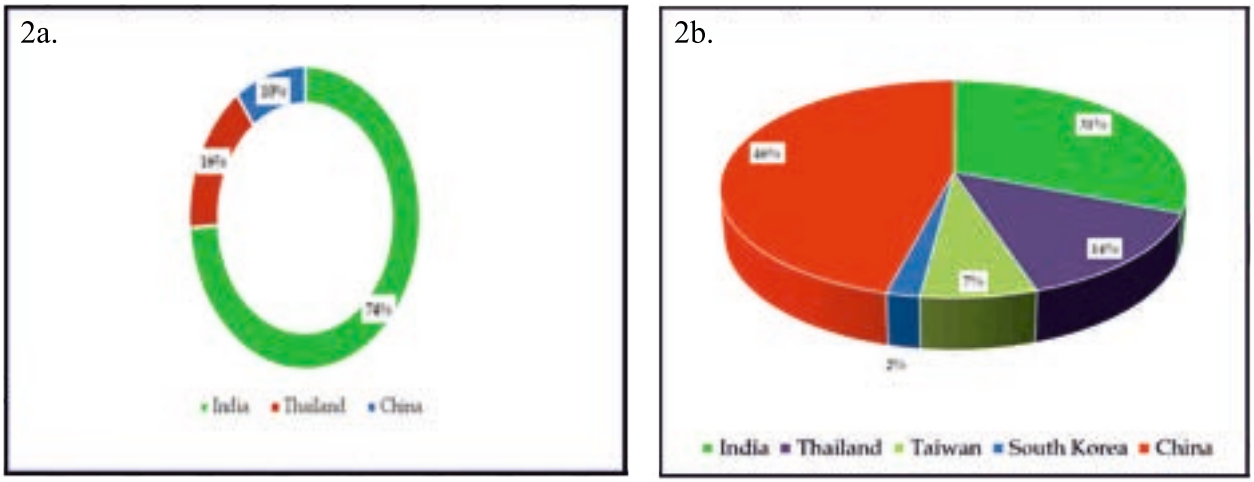
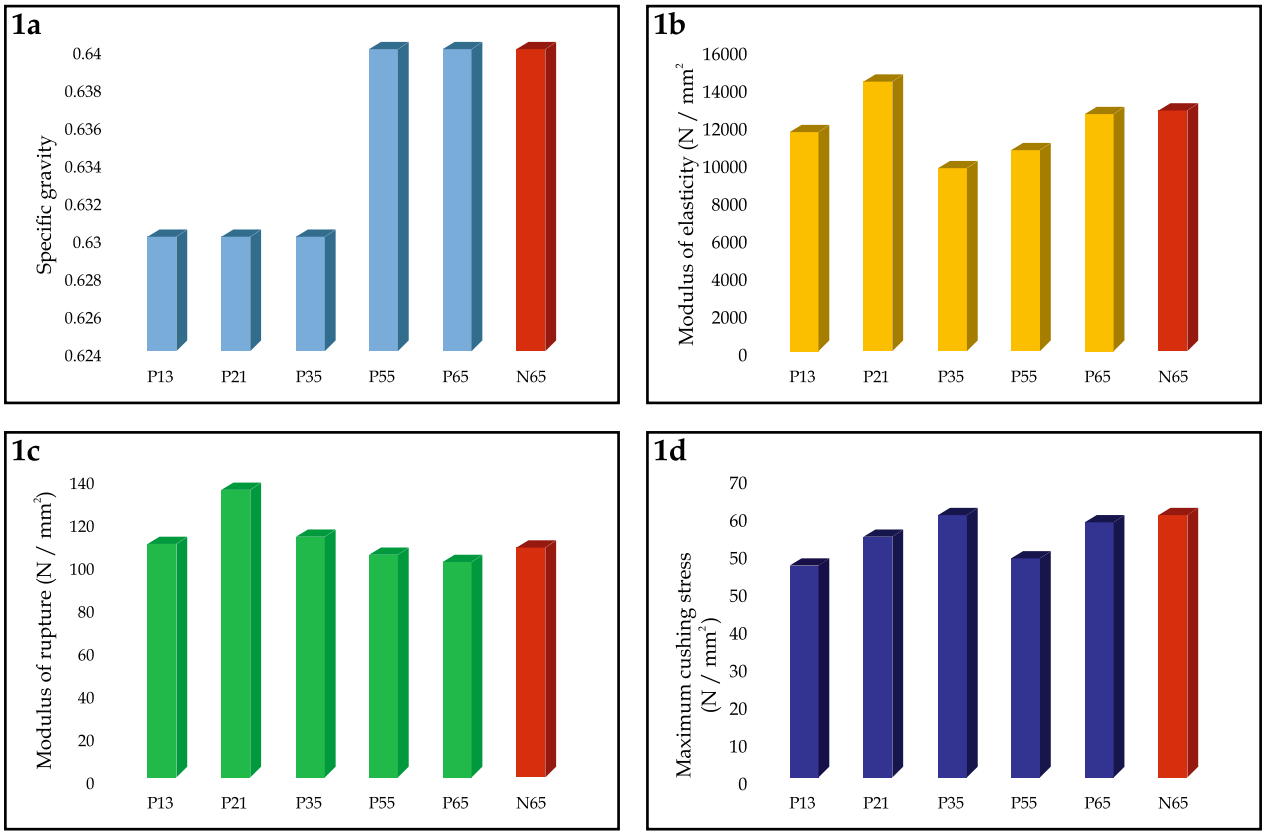


Figure 2a. Global teak wood imports (Avg. for 2005 – 2014 is 1.07 million m^3/year; a. round wood imports 2b. sawn wood (Kollert and Cherubini, 2012).

As per the International standard classification (ASTM, 1981), teak wood belongs to the highly resistant class of timber (durability class I). The synergetic effect of a large number of factors enables the requisite protection from wood decaying organisms, dimensional stability, and hydrophobicity. The intrinsic properties of teak wood that distinguish it from other timbers are attributed to the presence of active extractive elements encrusted on the cell wall. These extractive elements in the heartwood vary from 10–19.8% and are poisonous to wood-degrading microbes, invading termites, and help repel water (Yamamoto et al., 1998; Thulasidas and Bhat, 2007). These extractive contents increase with the age of the



Figures 1a – 1d. Strength property variation among different age groups of planted teak in comparison to natural teak from Nilambur, India (P13 – Plantation of age 13 yrs; P21 – Plantation of age 21 yrs; P35 – Plantation of age 35 yrs; P55 – Plantation of age 55 yrs; P65 – Plantation of age 65 yrs; N65 – Natural teak of 65 yrs; Source: Bhat et al., 2001).

teak plant and act independently or in combination to provide exceptional dimensional stability and durability to teak wood (Bhat et al., 2005; Sumthong et al., 2008; Moya et al., 2010). However, there are studies that refute such notions. For example, studies by Bhat (1998) show that the modulus of rupture and Young's modulus of juvenile wood phase in phenotypically superior fast-grown teak trees were lower by 20-21% than the slow-grown ones, but the maximum crushing stress did not differ significantly between them. Enough evidence also exists to establish that short-rotation plantation-grown teak need not always be inferior to natural teak in terms of density, strength, and shrinkage (Bhat, 1999, Thulasidas and Bhat, 2012). Bhat et al. (2001) demonstrated that teak can achieve optimum strength properties by 21 years of age, implying that concerns about juvenile wood in logs from short-rotation plantations may be unfounded (Figures 1 a-d).

Establishment and management of teak plantation

Successful teak plantation should encompass careful planning and execution of different components as shown in Fig. 3

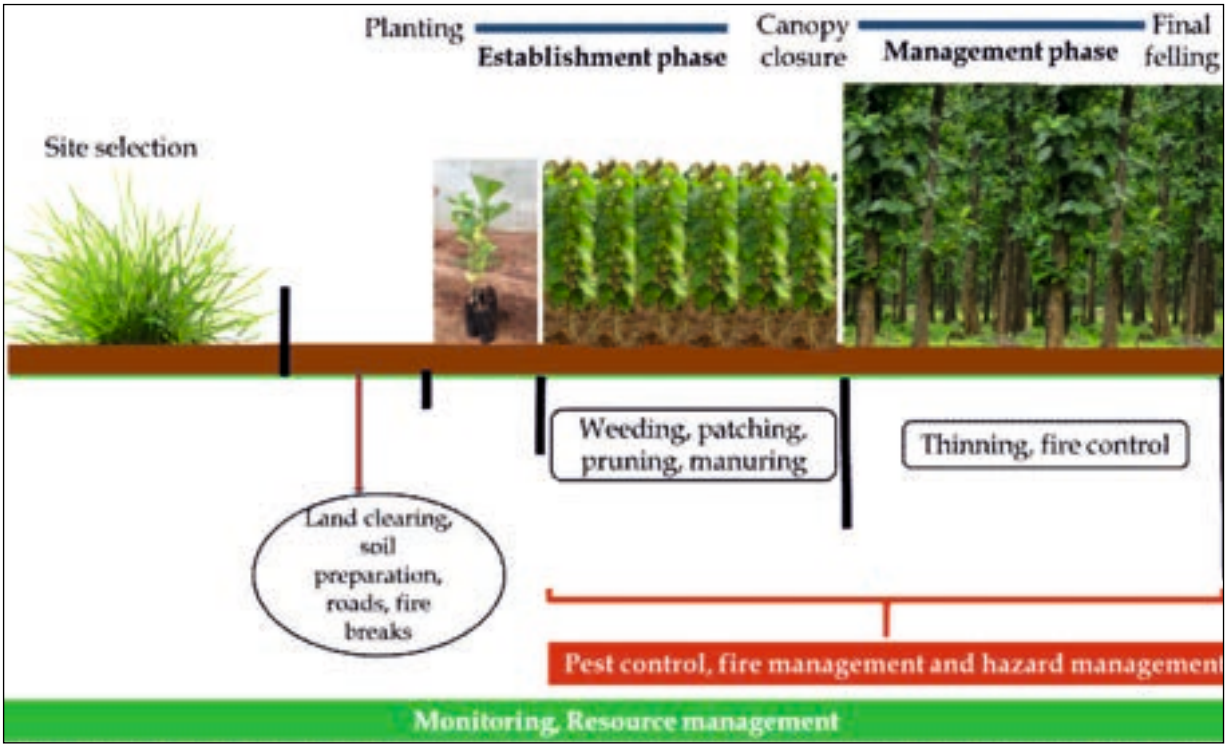


Fig. 3 Stages and activities in Teak Plantation

Teak is naturally distributed in the tropical humid climate and mixed with various species such as *Afzelia, Dalbergia, Diospyros, Irvingia, Xylia, Lagerstroemia, and Pterocarpus*. Outside the natural ecological habitats, the first critical activity for a successful teak plantation would be determining the suitability of the site to raise the plantation. Failure to assess the proper site conditions would lead to poor growth and failure of the plantation. A set of both abiotic and biotic factors influence teak growth & development (Table 2). Teak prefers a humid tropical climate with a mean annual rainfall of 1200–3000 mm and mean annual temperatures of 22–26°C. Edaphic factors assume prominence under frost free tropical climates and should be given priority while selecting sites for teak plantations due to teak's specific soil and topographic requirements. Teak grows well on porous, well-drained, loam to sandy loam soils and requires a soil pH of between 6.5 and 7.5 (Troup, 1921; Tanaka et al. 1998; Kaosa-ard, 1989). Apart from these factors, a number of chemical constituents in soil such as calcium, phosphorus, potassium, magnesium, and nitrogen also play important roles in regulating teak growth.

The quality of the planting material accounts for 40–50% of plantation productivity. Shifting to a customised production system based on the concept of Target Planting Material (TPM), which specifies the production of Quality Planting Materials (QPMs) that meet the requirements of the target site conditions, would ensure maximum productivity at selected sites. The initial spacing in the teak plantation determines the future standing stock and post planting operations. Slash burning to clear the land of debris is being abandoned, and now a days chemical or mechanised cleaning methods are used.

Table 2: Optimum and limiting site conditions for teak plantations

Site factor	Optimum conditions	Limiting Conditions	References
Latitude	Tropics	Cold subtropical and tempretute	Pandey and Brown, 2000
Altitude	0-900 m AMSL	> 900 m AMSL	Kaosa-ard 1998
Temperature	22 - 26°C	Freezing colder months <13°C	Webb et al, 1984: Pandey and Brown 2000
Mean Max. temperature of hottest month	25 - 32°C		Webb et al. 1984
Mean min. temperature of coldest month	18 - 24°C		
Precipitation	1250 - 3000 mm per annum	<1200 or >4000 mm per Annum	Balagopalan and Rugmini, 2006
Seasonality	dry season for 3 - 5 months	Very Long (> months) and short (<3 months)	Alvarado,2013
Slope	< 25%	Hign windy slopes	Alvarado, 2013
Topography	Flat or undulated	Abrupt, depressions susceptible to flooding, stoniness	Alvarado, 2013
Soil origin	Alluvial, basaltic, limestone, sandtone, quartizite, shale	Cohesive high clay, sans, smectitic clays	Balagopalan and Rugmini, 2006
Soil orders		Oxisols, Verticols, Ultisols	Jerej et al. 2015: Kollert and Cherubini, 2012; alvarado, 2012a
Depth	90 cm - 2m	Depth < 90 cm with hardpans, plintite, stininess and chemical restrictions	Alvarado, 2013
Water holding capacity	Good	Bad	Alarado, 2013
Compaction	Non compacted surface or sub surface layers	Very compact layers	Alavardo, 2013
Drainage	water stagnation	Good drainage with no rainage	Poor or excessive Alvarado, 2013
Aeration	High	Poor	Balagopalan and Rugmini, 2006

Timely implementation of establishment and management activities is crucial for developing successful plantations. In rainfed areas with no supplementary irrigation, untimely planting has been found to lower survival rates, reduce growth, and sometimes total loss. Delay in planting and planting during non-appropriate seasons are common causes of plantation failures. Post planting operations comprise specific activities such as weeding, singling, casualty replacement, and pest control that generally aim at creating an optimum condition for teak growth. During the management phase, thinning and pruning activities

are conducted with much broader objectives to reduce tree competition for volume growth and ensure the best trees reach the final felling. However, the opportune implementation of post planting operations would drastically reduce the final yield from teak plantations.

Emerging opportunities for teak

Globally, approximately 1.5 billion ha of deforested or degraded land would be available for restoration, in which teak could be used to restore them to productive uses and provide dependent communities with a secure income. Besides, its restoration potential, teak would be a viable climate change mitigation option in the tropics. Emissions of carbon dioxide, the most potent greenhouse gas, threaten life on earth in an omnipotent manner. Storing atmospheric carbon in terrestrial sinks is increasingly being realised as one of the viable options to mitigate the ill effects of climate change. Options include reversing forest losses and restoring the landscape for increased carbon absorption or sequestration. Achieving the Bonn Challenge alone would sequester 47 $GtCO_2e$ (at an approximate rate of 1 $GtCO_2e$ per year), generating US $5 billion in annual net benefits and reducing the current "emissions reduction gap" by between 11% and 17%. To convert such estimations to reality, species with relatively higher productivity, a longer-life cycle, and stem density with options for a longer rotation period would be the most effective. Teak satisfies all these criteria along with producing sustainable wood. It can be considered as one of the climate friendly alternatives, substituting several energy intensive materials such as steel, concrete, aluminium and plastic (Sandeep, 2021; Sandeep and Yasodha, 2021).

The rising global demand for teak wood, especially in major client countries like India and China, ensures an assured market for any rises in production and supply. However, the forest product certification and legality issues influencing plantation-grown teak should be sorted out to ensure smooth trade across international borders. The legislation enacted by North America (Lacey Act) and Europe (European Union Timber Regulations -EUTR) timber markets are pointers to future timber market laws. Technological improvements along with good artisanal manufacturing procedures in major teak importing countries offer an ideal condition to absorb further surges in teak wood production in the future.

With its high adaptability, wood quality, potential to replace energy intensive materials, unique ability to fetch premium prices in the timber markets and global information and support networks, teak has the potential to become a pioneering species in meeting global restoration goals in a tangible time frame and an economically viable manner. However, an enabling environment and a shift in approaches from governments are quite essential for teak based restoration efforts to reach the levels necessary to achieve global impacts.

Conclusions

The unique blend of wood quality, durability, and appealing aesthetical features makes teak a premium timber in the global market. Teak has a geographically separated and environmentally diverse range of natural distribution spanning India, Myanmar, Thailand, and Lao PDR. The wide natural distribution, ease of raising plantations and high market price make it a preferred and potential hardwood species for large scale plantations in the tropics. Teak has been introduced outside its native distribution area for centuries, and in some of these areas it has even naturalised over the years. In recent years, the natural teak area has declined substantially in all major native teak growing countries, and the market depends highly on planted teak to meet the demand. Though there exists a notion of higher wood quality in natural and long rotation plantations, enough evidence also exists to establish that short rotation plantation-grown teak need not always be inferior to the former in density, strength, or shrinkage. With its high adaptability, exceptional wood quality, and premium prices, teak could also be considered a potential species in Forest Landscape Restoration (FLR) efforts in the tropics. With community based landscape planning, inter-sectorial cooperation, and a shift in government policies towards an enabling environment, raising teak plantations could ease the global pressures on restoration and provide livelihood options to the dependent communities.

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Trade of Teak wood : An Indian Perspecetive

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Introduction

Teak is one of the most valuable timbers all over the world. The physical and aesthetic properties of teak make it a very valuable timber species, and it is widely used to produce indoor and outdoor furniture, housing materials, crafts, ships and many other products (Midgley et al. 2015). For this reason, teak enjoys a worldwide reputation as a quality timber, especially in the global market.

India is a developing country with a booming economy and rapid urbanisation. Rising living standards are urging people's choices towards wooden artistic work to lead their comfortable lives, for which teak demand in the domestic market is at its peak, as teak is one of the best timbers. India relied heavily on teak imports to meet rising demand. But, as the Indian government is putting its steps towards Atmanirbhar Bharat Abhiyan (Self-reliance India), where one of the priorities is scaling up sourcing of raw materials in the country and gradually reducing import requirements for wood-based industry. To achieve this, it is very important to have the knowledge on international trade trend of wood especially teak, being the premier wood. Though the literature collection suffered with updated data and presents status of teak, in this paper we attempted to throw the light over, teak distribution, its demand in domestic market and its international trade trends.

Distribution of teak at global level

Natural Teak

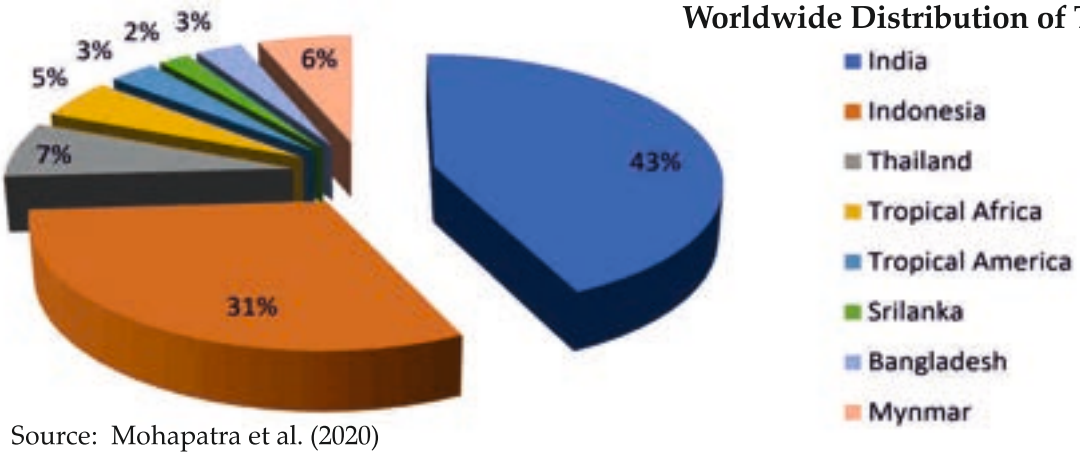
Teak grows naturally in South and Southeast Asian countries such as Myanmar, India, Lao PDR, and Thailand. However, natural teak forest area has declined substantially in all native teak growing countries, mainly due to overexploitation (legal and illegal), agricultural expansion, shifting cultivation, population pressure, and grazing. (Michael Kleine, 2017). All these factors, coupled with the imbalance between demand and supply, led to the pathway for the planted teak.

Planted Teak

The high demand for teak timber and its ease of establishment have made it one of the most important tree species for planting in the tropics, even outside of its natural distribution area (Keogh, 1996). Realizing the potential for global timber demand, the private sector poured money into the establishment of planted teak in Africa, Asia, and Latin America.

As per the study conducted by the Mohapatra et al. (2020), it is coated that, all over the world the India (43%) contributed maximum in term of planted teak area followed by Indonesia (31%), Thailand(7%), Mynmar (6%), Tropical Africa (5%), Tropical America (3%), Bangladesh (3%), and Sri Lanka (2%)

Worldwide Distribution of Teak plantation



Source: Mohapatra et al. (2020)

Teak distribution in India:

India is one of the natural habitats of the teak, confined to the Peninsula region below 24°N latitude, and it extends southwards through the states of Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu, Karnataka and Kerala. Considering the importance and to meet the growing demand for domestic teak, commercial cultivation has been taken up during the 1960s in India, and it is planted on a large scale every year, and the majority of the planted teak is managed in rain-fed conditions (Palanisamy and Hegde, 2009). In total, India is considered as one of the richest genetic resources of teak, with large areas of natural teak bearing forests (8.9 million ha), plantations (1.5 million ha), clonal seed orchards (1000 ha) and seed production areas (5000 ha), and it is planted on a large scale every year. (Teaknet 2010).

Scenario of Teak market in India:

The domestic demand for teak wood is sustained by a boom in construction of residential housing, particularly for doors and windows, and wooden furniture manufacturing (ITTO, 2010). In India, the emerging concept of standard lifestyle, interior designing, and architecture has given the sense of an indispensable concept for the furniture industry. Due to its excellent timber-fitting properties, teak has occupied a prominent position and is the most preferred species in the Indian furniture market. The richest 20% of the Indian population consumes 47% of the total teak fabricated round block wooden furniture production for interior design (MSME, 2020-21). But as per the analysis conducted by Kant and Nautiyal (2021) only an insignificant amount of about 50000 m^3 is harvested annually from domestic sources, which contributes a small portion to meeting the domestic demand, where the remaining demand and supply gap would be met by import. However, the export of round and sawn teak has been negligible.

Table 2. Export and Import of teak wood from India between 2011-12 to 2020-21:

Year	Export Data		Import Data	
	Quantity (CUM)	Value (Rs. in Lakhs)	Quantity (CUM)	Value (Rs. in Lakhs)
2011-12	8820	7293	1685800	361983
2012-13	10300	9300	1650320	437757
2013-14	30950	9980	1473560	456404
2014-15	6980	12808	1557330	444633
2015-16	4900	9382	1152850	334794
2016-17	2910	5185	1043040	305635
2017-18	2000	1501	1153610	315122
2018-19	1000	983	1211710	317037
2019-20	890	1069	1182130	310732
2020-21	660	918	965870	254769

Teak exports increased from 2011-12 to 2013-14, but have been steadily decreasing since then due to rising domestic demand for teak (Table 1). If India does not take action to reduce rising demand, it will be unable to export teak in the near future.

The pressing demand in India has been met largely by plantation teak from Central and South America. India's import preference is for round or squared logs, rather than sawn wood, which takes advantage of India's modern infrastructure of ports, low costs of processing, and attractively low tariffs for round and squared logs (Midgley et al., 2015).

India imported a significant quantity of teak from the international market. In the reported period of 2011–12 to 2020–21, teak imports have followed intermittent rise and fall trends. This is mainly due to fluctuations in the international market and also subjected to modi fications in the internal domestic conservation policies of respective nations involved in the international teak trade. In the last six years of the reported period, there has been a decreasing trend in teak imports with a slight variation. This is due to the implementation of a log export ban on 1st April 2014 in Myanmar, which is one of the world's leading teak suppliers, coupled with a pandemic situation in the last two years.

Being the dominant importer of teak, India fulfils their requirement from more than hundred countries. Among them the list of top ten countries are provided in table 2 and the proportion contribution from each of those countries is depicted in Figure 2.

Table 4. Top 10 countries from which India imported Teak Wood during 2020-2021:

Country	Value (USD Million)
Benin	13.73
Brazil	8.31
United Rep. of Tanzania	6.87
Myanmar	4.87
Ghana	1.98
Singapore	1.49
Cote dIvoire	1.4
South Sudan	1.08
UAE	1.04
Mexico	0.74

Source: https://connect2india.com

Pie chart showing top ten countries from where India imports Teak wood.

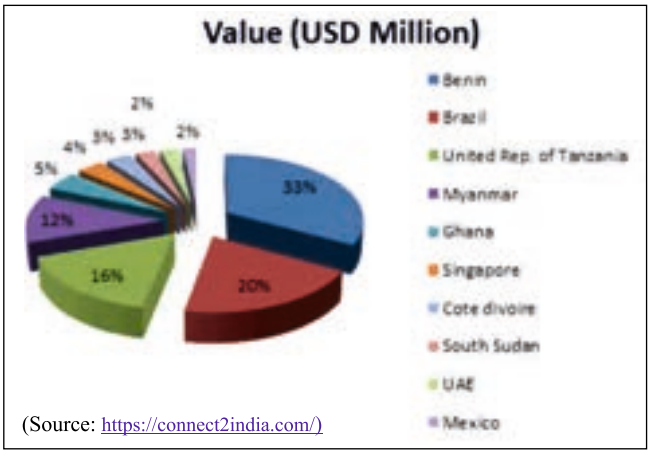
Why India is dominant importer of Teak:

Between 2005 and 2014, the global annual trade of teak round wood was more than 1 million m^3 on average; the imports were valued at US $ 487 million a year, which is about 3% of the value of the global timber trade (US $ 15.5 billion). In the global teak trade, the importing role is significantly shared by three countries, namely India, importing three quarters (74 per cent) of the total trade volume from more than 100 countries, followed by Thailand (16 per cent of the total from about 15 countries) and China (10 per cent of the total from about 65 countries).

In India, a significant decline in timber production could be observed after the implementation of stricter forest conservation policies. It has affected the availability of teak too. This situation urged the finding of an alternative where the concept of planted teak served as a boom. Though various government and private players are investing in teak plantations, as teak has a long duration like 80 years in Madhya Pradesh, 50 to 60 years in Kerala and 40 years in Maharashtra (Teaknet 2010), the demand is far higher than all the additional supply. Ultimately, to meet the rising demand, India resorted to the import of teak.

Conclusion:

Though India is one of the natural habitats of teak



(Source: https://connect2india.com/)

wood, we heavily relied upon the import of teak and emerged as the world's dominant importer. However, there is scope to change this current trend by meeting the domestic teak demand through the intervention of biotechnological tools. Most of the teak in India requires a long rotation period to transform into quality timber, but through clonal forestry and hybridization, the rotational period can be reduced by retaining the timber quality trait in it. In order to substitute the import of teak from other countries, there is an urgent need to promote agro-forestry in the country and also there is a need to improve the productivity of teak wood, which would help us to be more competitive in the international market.

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INDIAN PLYWOOD INDUSTRIES RESEARCH & TRAINING INSTITUTE (IPIRTI)

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

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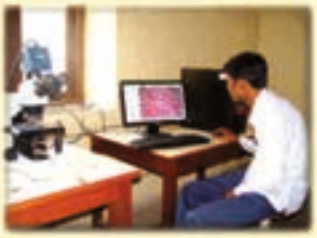
- Raw material analysis of chemicals used in resins
- Identification/classification of timbers/binders used in panels
- Retention of preservative chemicals in treated wood/plywood
- Fungal/borer/termite resistance of wood/wood-based products
- Specialized testing such as thermal conductivity, acoustic properties, weathering studies, emission of formaldehyde in panels etc.



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Rise of Commercial Teak Plantations in Latin America for Indian Consumers

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International Trade Centre data reveals that China and India have been, the top two importers of tropical hardwoods and logs for almost two decades now. At the same time, experts feel demand is expected to grow at a far higher rate in India than China in the next two decades as the middle class continues to expand in India consistently.

Timber production from Indian forests have been sliding consistently over the years, primarily due to increasing emphasis on conservation of forests and biodiversity. Though various government and private players are investing in teak plantations, the fact that teak has long rotation periods and demand is far higher than all the additional supply that plantations can generate, means imports will continue to remain high, making imports a round-the-year profitable proposition.

Teak wood is one of the multipurpose timbers, native to Asia and it is cultivated in abundance in India, Burma, Laos, and Thailand. Due to many valuable properties such as durability, strength, decay resistance, high oil content, resistance against fungus and aesthetic value, teak wood has been widely used for construction, furniture, ship decking and boat floors. Owing to wide variety of usage and great demand in the international market, its cultivation is being promoted in other tropical countries including Latin America (LatAm).

Teak is the only species of fine dark wood being planted widely in tropical countries."As the international market will face mainly a supply of white woods, a dark wood like Teak will have little competition" (Pandey 1997). This analysis along with the suitability of soil and weather conditions for growth of teak wood in Latin America were the underlying bases for the European funds to invest in teak plantations in the region. This is coupled with incentives from government to grow teak, helped in widespread growth of teak farms during late nineties in this region. Further, price trends were favorable during this period (1990s) and there was a prediction of decrease in teak supply from natural forests of Asia and Africa which motivated the investors and LatAm farmers to grow teak.

Foreign companies with expertise to plant, manage and commercialize teak began to invest in LatAm by establishing their own operations and through establishing contracts with local plantation and forest management companies. From this plantation business both overseas organizations and local farmers get benefits; foreign companies invested in plantations get land tax exemption and income tax exemption from sales of plantation proceeds, on the other hand, local farmers get incentives from plantation promotional schemes sponsored by the governments.

Government incentives

There are several government schemes in most of the countries in LatAm to tap the foreign investment which creates direct and indirect employment, generates carbon credit and boosts economy of country with abundant potential for agroforestry. It will take more than this article to deep dive in all the incentive schemes of the region, so here we discuss two major programs of Costa Rica and Guatemala.

Costa Rica: FONAFIFO

Costa Rica promotes afforestation activities in a big way by running "National Payment for Ecosystem Services" program through National Investment Fund for Forest Financing (FONAFIFO). This is a public entity founded in 1996 that dedicates its efforts to finance small and medium producers of forestry goods and services, through the management and administration of resources of national and international origin. FONAFIFO seeks to support the development of the forestry sector in Costa Rica through the direct execution of projects, channeling of economic incentives, establishment of public-private partnerships and management of international cooperation agreements in forestry matters.

FONAFIFO focuses its operation on 3 strategic lines defined from the financing, sustainability and institutional management of the forestry sector, which is reflected in its executions on biological corridors, basins,

private lands in protected wildlife areas, indigenous territories, among others. In addition, in compliance with domestic carbon market regulations, the institution provides Costa Rican compensation units to organizations interested in offsetting their carbon footprint. This scheme finances the planters with credits at priority interest rates and flexible guarantees of mortgage, collateral or trust bonds and the payments are set in accordance with the cash flow of the project.The objectives of the program are as given below.

- Strengthen organizational capacities for the administration and design of environmental financing mechanisms.
- Increase sources of resources for financing environmental services.
- Maintain the provision of environmental services through permanent financing in areas of priority interest.
- Support forest productive activity by strengthening the capacities of those who provide environmental services.

Guatemala: PROBOSQUE

PROBOSQUE is a "Payment for Ecosystem Services" program through which the State of Guatemala grants economic incentives to forest land owners who wish to reforest or manage existing natural forests. The Government encourages the management and protection of natural forests, as well as the establishment of plantations forestry, with prioritized species according to the requirements of each regionalforest of the country. The Forestry Incentives Program of Guatemala started in 1997 and was named as PINFOR. After completing 20 years, it was renamed as PROBOSQUE in the year 2017. The objectives of the program are given below.

- Promotes the creation of centers of high productivity regional forestry production, to boost the supply of competitive forest products, reduce deforestation, and generate environmental services and employment in rural areas.
- Encourages investment for the establishment and management of forest plantations, the sustained management of natural forests and forestry for environmental purposes, which makes Guatemala the leader in the production of environmental goods and services in the region.

The incentive is paid out depends on species and final usage. Below is the incentive structure for Teak plantation:

- Establishment cost of $1,032 per ha. in the 1st year.
- Maintenance cost of $392 per ha. in the 2nd year
- Maintenance cost of $326 per ha. in the 3rd year
- Maintenance cost of $261 per ha. in the 4th year
- Maintenance cost of $248 per ha. in the 5th year
- Maintenance cost of $131 per ha. in the 6th year

Country wise Plantation data in LatAm

LatAm countries grow teak primarily for the export purpose. Teak is primarily exported to India which consumes which consumes about 90% of the teak wood exports of the world. Thus, Indian economy drives the volume and prices of teak wood across regions. The estimated area under Teak plantation in LatAm countries is given in Table.1.

Table 1. Estimated area under Teak plantation in LatAm countries

Country	Teak (Hectares)*
Brazil	70,000
Ecuador	45,000
Panama	40,000
Mexico	35,000
Costa Rica	28,000
Colombia	25,000
Guatemala	25,000
Nicaragaua	17,000
Others	15,000
Total	**300,000**

*Data estimated by secondary research and more than a decade long presence in LatAm

The Table 1. Illustrates the approximate hectarage of teak wood available in Central and South America. Brazil, Ecuador, and Panama are the countries with the maximum presence of teak wood plantations. In this region several American, European, and Mexican funds have invested heavily in the farms as well as facilities for sustainable extraction, value addition and export to Asia. Some noteworthy names are Floresteca/TRC (45,000ha in Brazil), Santa Genoveva (18,000ha in Mexico), Tripan (14,000ha in Guatemala), GKM (8,000ha

in Panama), Novel Teak (6,000ha in Costa Rica and Nicaragua), Proteak (Mexico), Ecoforest (Panama), Sustainable Timber (Panama), Tropibosques (>2,500ha in Ecuador), Reybanpac (>2,000ha in Ecuador), Grupo Siembra (Ecuador), Tekia (4,000ha in Colombia) & PanAmerica (2,000 ha in Costa Rica) and Forestal Rio Grande (1,800ha in Costa Rica).

Almost all these plantations were established and being managed by private entities where we will throw some light on one of them to explain the model. In the Central American country of Guatemala, there are teak assets of around 14,000 Ha. which belongs to the US based Forestry Investment Advisors – Global Forest Partners (GFP). These plantations are said to be the second largest private teak plantation in the world after Teak Resource Company (TRC) also known as Floresteca in Brazil.

Teak plantations managed by Tripan in Guatemala

Tripan Guatemala S.A. is the forestry operator in charge of the administration of these plantations, managing matters related to the acquisition of farms, establishment of plantations, management, and marketing of forest products. These plantations have certifications for endorsing environmentally responsible, socially beneficial, and economically viable forest management.

Export of wood from the region to India is about 50,000 containers which is about 65% of the total teak import of India; rest are from Africa. Brazil, Ecuador, and Panama account for almost 50% of teak wood export to India on account of large teak plantations managed by corporations which necessarily must extract a part of their farms unlike individual owners of Costa Rica or Guatemala who do not extract if prices or weather is unfavorable.

During the last decade and half there has been various economic and political crisis leading to low imports affecting the harvest in Latin America – Great recession of 2009, crash in oil prices in 2014, demonetization of INR, COVID-19 and shipping line crisis leading to skyrocketing freights to name a few.

Commercial expectation at Origin

The movement of "commercial teak plantations" which started in 90s in Latin & South America flourished very well for 2 decades. The plantation owners and farmers bought/leased land to plant teak wood owing to high influx of overseas funds, government support and absence of better alternatives. Initial 3 years of teak management is highly cost intensive and the first commercial thinning is done at 11 years which takes a toll on the investors and the farmers and that is where Government support in the region made a huge difference in motivating and sustaining them.

All stakeholders were positive of this investment model to be beneficial for sustainable development as everyone believed that the demand would rise which will increase the prices over the years. Decrease in supply from natural forests will spike increase demand from plantations. Price of timber and lumber from plantations could rise steadily in the future (Keogh 1997b).

However, there was a steep decline of INR against USD over the last decade and half which coincided with other economic hazards as mentioned above. It has declined from 1USD = INR 51 to INR 80 in last 10 years. This 45% decline has been a defining factor behind the stagnancy of teak wood price in origin thus making the investors uncertain and lose confidence in the model. Many are thus opting for planting wood with shorter gestation cycles like Gmelina.

Quantum of Teak import in India

India is completely dependent on its imports for fulfilling the "timber" requirement for its growing and expanding market. Pine wood has been by far the biggest player when it comes to the share of Indian

timber imports with almost 35.4 million Cbm a year, followed by hardwoods at 18.5 million Cbm and then Teak with approximately 13.2 million (all date as per the manifest filing of calendar year 2021). The supply of hardwoods has been on a decline since last decade starting from Malaysia which has been historically the biggest partner of India when it comes to the volume of the timber imports. On top of it, Africa has started slowing down too with EU and US restrictions on incessant cutting of their forests. Pine can only play a specific role when it comes to consumption pattern and uses in India and hence it is only Teak which has slowly started filling the space which is consistently being created because of the decreasing supply of hardwoods from all over the world. Quantum of total Teak import in India during 2021 is given in Table 2.

Table 2: Quantum of total Teak import in India during 2021 as per the manifest data filed in major ports.

Origins	Volume/Cbm	Containers
ECUADOR	276686	15371
GHANA	215413	11967
BRAZIL	170263	9459
PANAMA	165592	9200
COSTA RICA	107127	5951
BENIN	106177	5899
COLOMBIA	78392	4355
TOGO	33398	1855
TANZANIA	32299	1794
GUATEMALA	27027	1501
MEXICO	17235	958
NICARAGUA	14937	830
NIGERIA	14473	804
IVORY COST	14146	786
SUDAN	10219	568
CAMEROON	9959	553
LIBERIA	9672	537
EL SALVADOR	5713	317
VENEZUELA	2771	154
MALAYSIA	2562	142
HONDURAS	2532	141
MYANMAR	2013	112
PAPUA NEW GUINEA	1585	88
CHINA	907	50
Others	579	32
Grand Total	**1321676**	**73426**

The Teak consumption in India is consistently growing as the only viable substitute for the hardwoods. What Vietnam and China import in a year is what India imports in every three weeks. EU, US, and Oceania do not even move the needle. In effect, 90 percent of the plantation teak is marketed in India. The above table with approximately 13.2 million cubic meters yearly shows the monumental size of Indian Teak market and the game becomes even more interesting when we put a conservative price of $350/Cbm here making it almost half a billion USD import market on a yearly basis.

Conclusion

India is known for best quality Teak across the globe. However, the State Forest Departments are busy with conservation the forests and their by ignored the commercial production of Timber. At 75th year of Independence, State Forest Departments need to do an introspection considering the immense opportunity sitting right in front of us which is begging for the attention to make a plan of action with clear timely deliverables to help India participate in this hugely appealing trade flow uniquely based only on domestic demand.

References :

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Small Holder Teak Agroforestry Plantations : Scope and Prospects in India

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Introduction

Establishing an Agro Forestry System (AFS) is a strategy that can meet sustainability equirements & increase the annual income of the farming community. The ability to combine annual and perennial crops with a tree component is crucial to the success of AFSs. Thus, the economic benefits would continue from the first year of setting up the system. AFS is attractive to smallholders as it can be adopted without a large capital investment in the initial years. In addition to these benefits, the other recognised benefits of AFS are fibre and food production, nutrient cycling, soil conservation, biodiversity restoration and carbon sequestration.

Teak is one of the species most studied and grown in the world. The global area of teak plantations is a minimum of 4.3 million ha, of which 83% is in Asia, with India, Indonesia, and Myanmar having the largest areas. Plantation ownership is dominated by governments in Asia, Africa, and the Caribbean and by corporations in Central and South America. According to the International Federation for System Research (IFSR) (2021), the growing stock of teak occupies the top second position, occupying 4.37 per cent of the total growing stock of the country. Unfortunately, it does not find any place in the growing stock of Trees Outside Forests (ToF).

India's preference for teak, along with rapid urbanisation, proportionately enhances its demand. Therefore, teak plantations have been successfully established in India and elsewhere since 1850. For many years, traditional teak stands in India have been disappearing. Thus, there is a major risk of losing their high diversity of genetic and wood traits. The logging ban in natural teak forests in India, Laos, and Thailand, along with the increasing gap between demand and supply of teak, provides opportunities for smallholder production.

Farmers and private growers also prefer teak. To increase teak cultivation under TOF, State forest departments are incentivising farmers. Forest departments (eg. Kerala, Tamil Nadu) target 1 lakh seedlings per annum for farmlands/homesteads. Hence, the demand for quality planting stock is steadily increasing.

The rotation age of teak in India is the largest globally, almost twice that of other countries. Long rotation age deters extensive cultivation of the species. In many exotic locations, teak is grown on relatively short rotations, with MAI (Mean Annual Increment) at harvest (15-25 years of age) ranging between 10 and 15 m^3/ha/yr (Cañadas et al., 2018). Such a volume increment has been achieved mainly with the use of clonal material. Despite holding the largest area under teak populations, India imports teak from South American and African countries, where several million hectares have been established as short rotation plantations. These teak timber exporting countries source the stock from international provenance trials laid by DANIDA, where ~ 50% of the seed collections were from India. In India, efforts are under way to reduce the rotation age with minimal compromise on quality as in other countries.

Small holder teak plantations denote those farmers managing 0.5–3.0 ha of land with an average of 1.0 ha, favouring teak with annual crops, and livestock. These teak plantings occupy 19% of the area in Africa and Asia, and 31% and 34%, respectively, in Central and South America (Kollert & Cherubini 2012). These plantations show great promise because of their successful cultivation in 65 countries outside their natural distributions. The major indicators of success are genetically superior seeds, high yielding clones, suitable plantation sites, and appropriate silvicultural practices.

Teak timber exporting countries source the stock from international provenance trials laid by DANIDA, where~50% of the seed collections were from India. In India, efforts are under way to reduce the rotation age with minimal compromise on quality as in other countries.

A 5 year-old bund plantation of teak in a farmer's field; Ht 10.2 m, GBH -52 cm

About 0.92 million ha of teak is in small holdings (Kollert and Cherubini, 2012). This concept emanated from Java, Indonesia, during the 1960s, specifically for teak, and later was adopted as a novel agroforestry model. Smallholder and short rotation teak plantations were initiated in Thailand during the 1990s when the farmers were supported to meet their children's education by planting teak in farmlands (Mittelman, 2000). Similarly, home garden grown teak accounted for a significant portion of domestic demand in India and Sri Lanka (Mohan Kumar et al., 1994; Mattsson et al., 2013). By the end of the 20th century (1990-2000), realising the high returns, smallholder planting was vigorously promoted in Thailand, Bangladesh, Sri Lanka, China, Philippines, Lao People's Democratic Republic, Nepal, Vietnam, Nigeria, Zimbabwe, Côte d'Ivoire, Sierra Leone, the United Republic of Tanzania Togo, Costa Rica, Trinidad and Tobago, Panama, El Salvador, Colombia, Guatemala, Venezuela, Ecuador, Fiji and the Solomon Islands (Krishnapillay, 2000). The Australian Centre for International Agricultural Research (ACIAR) supported programmes to improve economic outcomes for smallholders growing teak in the agro-forestry systems of Indonesia (Roshetko et al., 2013), Solomon Islands (Midgley et al., 2015), Lao PDR (Dieters et al., 2014) and Papua New Guinea (https://aciar.gov.au/).

Smallholder teak has a promising future in India as a component of agroforestry. One of the main causes of disinterest among farmers in teak cultivation in India is the exaggerated output projections of a few commercial tree investment programmes by private players, leading to its downfall (Balooni, 2000). Recent studies in India estimate the individual tree volume productivity of block plantations of 21 to 25 year old to be 0.865 cum and farm grown trees at 1.321 cu.m. (Shahapurmath et al., 2016). A twelve year old block plantation showed 0.199 cu.m. whereas a line plantation had 0.242 cu.m. (Shukla and Viswanath, 2014).

The market demand and price of teak timber are determined by key characteristics such as clear bole height, diameter at breast height (DBH), knot and buttress free timber, sapwood to heartwood ratio and heartwood colour, which are addressed in tree improvement programmes. Seedling plantations from genetically improved seed sources have the added advantages of cost effectiveness and high genetic diversity over clonal plantations. However, the performance of clones reveals improved yield. An evaluation of the performance of clones and seedlings in Mexico and Brazil revealed the highest mean annual increment of 32.0 cu.m. per ha (Ugalde, 2013). In Brazil, clonal plantations that are 12 to 13 years old demonstrate height growth of 22.7 m and DBH of 28.5 cm, and substantial standing volumes with 208 to 347 standing trees, depending on the site conditions.

A 5 year-old block plantation of teak in a farmer's field; Ht 12 m, GBH -55 cm

The contributing factors include lack of motivation to adopt tissue culture technology, insufficient field demonstration trials, inadequate data on the performance of clonal planting stock, higher cost of propagules, and estimations on the extent of the area to be cultivated. Clonal production of teak is easible through a public private partnership between government recognised private commercial tissue culture units with larger production capacities and breeders.

The Indian Council of Forestry Research and Education (ICFRE) has developed various Agroforestry models with teak: an Agri silvicultural model involving Teak and Casuarinas with agricultural crops like maize, cotton, turmeric, tomato and chilly, an Agri silvi-horticulture model of teak and coconut with agricultural crops like turmeric, vegetables, maize and cotton. However, the dynamics of AFS are unique and very different from pure plantations. Lack of information on teak's growth characteristics and the wood quality when the species grows on AFS is a major reason for poor adoption.

ICFRE institutes, namely TFRI, Jabalpur, IFGTB, Coimbatore, AFRI, Jodhpur, and IFB, Hyderabad, work on various aspects of teak (on a regional basis), such as pest management, yield modelling, genetic variations /diversity, germplasm assemblage, and genetic transformation. IFGTB is engaged in establishing breeding populations, clonal selections and evaluation and identification of genetic diversity hotspots with particular reference to Tamilnadu, Kerala and Karnataka. IFGTB is developing descriptors for registration of teak clones with the Protection of Plant Varieties and Farmers' Rights Authority (PPVFRA), Government of India, to secure the intellectual property rights.

All India Coordinated Research Project

The All India Coordinated Research Project on Bio technological Interventions in Tree Improvement-Quality Teak Production: Capitalising on Cloning of the ICFRE is an extension of biotechnology to the field. IFGTB has initiated large scale multiplication of clonal selections from the breeding programme and is supplying tissue culture teak plants to farmers in Tamilnadu, Karnataka, Odisha and Chhattisgarh at a highly competitive price. The project also aims to enrich the teak genetic resources by deploying regionally available material, thereby addressing the issue of shifting germplasm across locations. IFGTB,Coimbatore provided start-up cultures of teak (five clones) to the four participating Institutes, namely TFRI, Jabalpur, IFP, Ranchi, FRI, Dehradun and AFRI Jodhpur. The cultures of the five clones of teak are being multiplied at all the Institutes. The Quality Planting Material (QPM), thus produced, is distributed to smallholder farmers to popularise tissue culture teak in farmlands. Convinced by the fast growth of the plants, farmers have evinced interest in increasing the area under teak. To meet the increasing demand, an MoU has been signed with three commercial tissue culture laboratories to mass-produce teak through TC.

Impediments to the adoption of teak in smallholder plantings

1. Teak is listed as a scheduled timber.
2. Lack of availability of good quality seed /germplasm supply.
3. Low quality timber due to poor silvicultural interventions.
4. Lack of capital to invest in teak.
5. Inability to wait for long periods of time.
6. Access to market information and connections is limited.
7. Poor bargaining position.
8. High transaction costs for traders are passed on to farmers.

Conclusion

Teak tissue culture plantations are commercially practised in Latin America, Thailand and Malaysia. In India, most teak plantations continue to be raised by stumps. Selected and wisely deploy teak clones multiplied through tissue culture combined with intensive practises appears to be the best option for small holder plantings in India.

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AGRO FORESTRY

RURAL EMPLOYMENT

TECHNOLOGY

GROWTH with SUSTAINABILITY

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

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

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

Indian Paper Manufacturers Association

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Utilization of Teak Genetic Resources in India for Higher Productivity and Farm Income.

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Introduction

India is a timber deficient country, importing 40 million cu.m. of wood a year, of which 2.5 million cu.m is teakwood, with an import bill of Rs.7500 crore a year. Teak is the major timber in the households of the country and is known as the "King of timber". India imports teak wood from around 30 countries, and except for Myanmar, the rest do not have natural teak, and the source of planting material is mostly from India. Though India harbors the largest genetic diversity of teak (more than the combined diversity of all other countries where teak occurs naturally), its economic potential has not been exploited. The world's recorded teak plantation is 5.28 million ha, out of which India has 1.50 million ha. The pre-independence era Indian Forest Records show that the British knew the importance of teak not only in making warships but also as a timber in house construction and furniture making. Teak trees were harvested in large quantities from Indian forests for use in railway sleepers, shipbuilding, and other purposes. It is said the best teak wood is found in the castles and palaces of Britain. Dysgenic felling, removal of the best trees from populations in the past, has resulted in a skewed population, not allowing the natural process of evolution. But on a conciliatory note, the British are also credited with initiating the large scale plantations of teak. The first ever teak plantation was established by H. V. Conolly, Collector of Malabar in 1846, which shifted the trend from a purely extraction and regulatory function of forestry to a phase of resource development. Since it was an important wood for the Britishers, research on nursery production of seedlings, stump handling, soil nutrient requirement, spacement trials, wood properties of plantation grown timber, pests and diseases was studied in detail and published as a series of articles in Indian Forest Records during 1930s. Even before the colonial rule, teak was a preferred species for shipbuilding, a thriving business in West Bengal and Kerala. The interest in teak cultivation lost focus gradually post Independence. In India, teak is the preferred species in the construction industry and furniture making. The import of teak wood has doubled from 0.5 million cu. m. to 1.0 million cu. m. between 2009 and 2019 (Pramod Kant and Nautiyal, 2021). The demand for teak is going to increase in the coming years.

Teak in India and SE Asia – Natural range

Teak is native to India, Myanmar, Laos, and Northern Thailand. (White, 1991). It was introduced to other countries in Asia as well as in Africa and Latin America (Keogh,1979). There are nearly 8.9 million ha of teak-bearing forests in India (Tewari, 1992). Presently, 1.5 million ha of teak plantations exist in India. (Subramanian et al., 2000). Though India imports huge quantities of teak, the imported teak does not match the natively grown timber in terms of quality (Somaiya, 2003).

Due to its wider distribution in its natural range, it exhibits great variation. At least five different types of teak have been identified in India based on the type of forests they are growing in, such as very moist, moist, semi-moist, dry and very dry by the field forest officers. Large differences in the level of genetic diversity were observed in natural teak distribution areas. The landmark study by Ole Hansen et al. (2015) encompassing all the natural and landraces of teak revealed that teak in India has the highest amount of genetic diversity. The Eastern Indian population recorded higher diversity than the Western Indian population. It is interesting to note that Eastern India is much drier than humid Western India. Even in the Western population, the moisture regime changes from Kerala to Gujarat. These differences in environmental conditions have resulted in the evolution of populations in different niches. Hence, Teak seed source testing, selection of clones and gene conservation must be based on a much finer scale.

Teak outside natural range

Teak is the most favoured plantation crop in many countries outside its natural range. As per the "State of the World's Forest Genetic Resources" report published by Food and Agriculture Organization (FAO) in 2014, Teak takes the top rank in the list of prioritized species in more than 20 countries. Teak is being cultivated in over 70 countries. As per the "Global Teak Study" report published by International Union of Forest Research

Organization (IUFRO), there are 69,500 ha of teak plantations in Africa and Latin America as in 2010 (Walter and Michael, 2017). Further, The planted teak area has increased greatly in the last decade in Africa (Benin, Ghana, Nigeria, United Republic of Tanzania), Central America (Costa Rica, El Salvador, Guatemala, Nicaragua, Panama), South America (Ecuador, Brazil), and Australia mostly by the investment of private companies. Another recent development is the International Tropical Timber Organization (ITTO) funded project "Enhancing the conservation and sustainable management of teak forests and legal and sustainable wood supply chains in the Greater Mekong Sub-region", consisting of five participating countries, namely Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam for three years starting in 2019.

Reports published by FAO indicated a growing rend in teak plantations outside its natural range (Table 1).

Table 1: Area of planted teak forests by region (in thousand ha) (FAO, 2012)

Continent/Region	1970	1995	2000	2010
Africa	99	109	208	469
Asia	1185	2108	5408	3598
Caribbean	10	8	9	15
Central America	2	23	66	132
Oceania	2	3	7	8
South America	1	3	18	122
World	1300	2254	5716	4346

Most countries target India as a destination for the timber produced. Eleven out of fourteen reporting countries name India as their number one importer, absorbing 70% to 100% of global teak exports, including shipments of plantation logs and sawn timber from Africa and Latin America. In Africa, significant exporters are Benin, Ghana, the United Republic of Tanzania and Togo. In Latin America, Ecuador, El Salvador, Guatemala and Brazil, are important teak exporters. (Table 2)

Table 2: Import of Teak by India in Cu.m (ITTO, 2013)

Country	Quantity Imported
Benin	42,986
Brazil	16,535
Columbia	1,103
Costa Rica	35,844
Ecuador	96,658
El-Salvador	5,488
Ghana	53,422
Guatemala	1,975
Guinea	3,934
Ivory Coast	34,297
Mexico	1,429
Myanmar	75,797
Nigeria	8,814
Panama	42,488
Sudan	13,104
Tanzania	16,345
Togo	11,553
Urugway	2,677

Teak as a planation and agroforestry species

Teak is ideally suited to grow as a plantation crop and also as an agroforestry species by small holding farmers. Teak is the most preferred species as a bund planting crop by farmers in India. But the farmers face constraints in the cultivation and marketing of teak, such as the non-availability of quality planting material and the cumbersome procedural formalities in getting clearance for harvesting and transportation of teak. During the 1980s, teak was promoted for cultivation by many private companies in India with the floating of teak bonds, but these ventures did not succeed because of poor genetic quality of planting material, improper site selection, and poor management practices. These companies started operating in the 1980s and mobilised huge investments from the general public, with the promise of very high, tax-free returns. Aggressively promoted through media campaigns and commission

agents, such schemes are estimated to have mobilised between Rs. 100 billion and Rs. 250 billion, from between 2.7 and 15 million investors. However, the experience with these schemes has not been good and has shaken the confidence of investors in the plantation programme of the country.

Although most people in India would like to use teak timber for house construction and own teak furniture at home, they are not able to afford it. As an alternative, the import of low-cost furniture is steadily increasing, depriving farm workers, wood processing units, carpenters, and artisans of livelihood opportunities. Apart from increasing the tree cover, Teak is the best species to lock carbon. It is reported that the carbon storage potential of a 20 year teak plantation is 120 t/ha Since it is used in the construction of houses and furniture, the carbon gets locked in permanently for centuries. Apart from traditional planting by the forest departments and forest development corporations in India, in the last decade, many private companies and farmers have ventured into teak plantations. All these planting activities require a huge quantity of quality seeds. The scientific advancements made in teak propagation and precision silvicultural practices have resulted in the establishment of clonal plantations of teak harvested under rotation age of 18 to 20 years in many countries outside India. In a study conducted in a 12 year old planation in Brazil, clones recorded 14% superior diameter growth and 40% higher volume per tree than seed plantations. A good performing clone is promoted as "Super Teak" by Sabah based company YSG biotech (Goh and Monteuuis,2006). The species possesses fast juvenile growth and establishes well in good soil and moisture regimes. Successful plantation establishment depends on the quality of planting stock and precision silvicultural practices. All these developments promoted the planting of teak on a large scale in the continents of Africaand Central and South America mostly by investment from private companies. A venture that failed in India in the 1980s has become successful outside India in the last decade.

Teak improvement in India

a) Traditional work

Teak breeding activity started in India as early as 1962, encompassing the selection of plus trees and the establishment of clonal seed orchards (Kedharnath and Matthews, 1962). Over the past half century, around 250 plus trees have been identified and 5000 ha of seed production areas (SPAs) and 1000 ha of clonal seed orchards (CSOs) established in different teak growing states (Katwal, 2003). A national germplasm bank of teak was established at Chandrapur, Maharastra, and an international provenance trial of teak was established at Maredmalli in Andhra Pradesh. The strategies involved in the improvement of teak in India have been reported by Kumarvelu (1993). The seed orchards established with the intention of supplying quality seeds for plantation activities were bogged down by unperceived low seed production (Hedegart, 1976,Nagarajan et al. 1996,). With the passage of time, these resources, which were created with a lot of effort, money, and time have been pushed to oblivion. Even though teak improvement activities in India started along with improvement of pines in Europe and US, the gains realized in pines have yet to be realized in Teak.

b) Clonal technology

Between 1968 and 1972, many Plus trees were identified in almost all teak growing states in India. These plus trees were deployed in clonal seed orchards through a series of activities like the establishment of clonal banks, multiplication gardens and grafting processes. Though plus trees were identified, they were not deployed for the establishment of clonal plantations for two reasons, one, the clonal plantations were not in vogue at that time and secondly, the difficulties involved in multiplication of teak. Unlike Eucalyptus, Casuarina and Melia, teak is not a good coppicer and its rooting percentage is also poor. The multiplication rate through traditional technology is much lower, making it economically nonviable for clonal planation. Hence, in recent years, the process of micropropagation has been integrated into the clonal propagation of teak. The process involves collection of bud sprouts from the Multiplication Garden and proliferation of buds in culture media in the Tissue Culture laboratory. The shoots so multiplied are brought back to the propagation chamber and rooted in root trainer under mist. The rooted plants are transplanted to the polybags and maintained till planting time.The multiplication garden is established by collecting coppice shoots from the selected plus trees and/or by assembling the outstanding progenies of selected trees in the nursery stage by early evaluation. The latter process provides the advantage of selecting a large number of outstanding trees from the seed production areas and creating a genetic base large enough to sustain a long term breeding strategy. The Institute of Forest Genetics and Tree Breeding, Coimbatore, an institute under ICFRE has developed about 60 clones following the above method and is commercially supplying six clones

for large scale planting by farmers and forest departments. These clones have recorded good height growth and DBH at the end of six years.

c) Seed certification and supply of seeds

Certification of forest seeds in India is still in its infancy. A "Scheme for Certification of Forest Reproductive Material in India" was proposed in 1978. The scheme proposed was based on the Organisation for Economic Co-operation and Development (OECD) scheme (Madana Gopal, 1978). Though the scheme was to be implemented in all the states in India, it remained only on paper as the seed orchards were not yet mature enough to produce the seeds at that time. With the passage of time, the scheme was forgotten and the excellent genetic resources that were created with great vision, effort, time and money were pushed to oblivion. With the inclusion of 'Forestry' in the proposed Seed Bill 2019 and already notification of Forestry Crops under the PPVFR Act 2010, the certification assumes greater importance. In recent years, there has been great interest among farm communities in planting teak in their fields. As a result, there is a mushrooming of many private nurseries supplying seedlings of questionable quality. The establishment of plantations costs just the same whether the plantations are established from 'bad seed' or 'good seed', but the difference in returns at the end of the rotation period is substantial. Unlike agricultural crops, the expression of economic traits in tree crops would take 8 to 10 years, and the damage caused by bad seeds is irreversible. A large number of Clonal Seed Orchards established during the 1970s are mature enough to produce seeds now, along with the seed production areas maintained by various State Forest Departments. Therefore, there is an urgent need to supply certified seeds from these known sources. As an example, the resources available for certification in the state of Karnataka is given in Table-3, and Table-4. There are around 105 ha of teak seed orchards and 434 ha of seed production areas. These sources can produce about 100 to 120 kg of seeds per ha every year. With 539 ha of CSO and SPA, Karnataka state alone can supply 50 t0 60 tonnes of quality seeds every year.

With the inclusion of 'Forestry' in the proposed Seed Bill 2019 and already notification of Forestry Crops under the PPVFR Act 2010, the certification assumes greater importance. In recent years, there has been great interest among farm communities in planting teak in their fields.

Table 3: List of Clonal Seed Orchards of Teak in Karnataka

Sl. No.	Location	Number of clones	Extent (ha)	Plantation year
1	Majjigehalla Seed orchard 1, Thithimathi, Kodagu	24	12	1978-79
2	Majjigehalla Seed orchard 2, Thithimathi, Kodagu	49	16	1981-82
3	Sakkaraebailu, Seed orchard 1 Shivamogga	24	20	1978-79
4	Sakkaraebailu, Seed orchard 2 Shivamogga	48	25	1983-84
5	Sakkaraebailu, Seed orchard 3 Shivamogga	24	15	1982-83
6	Manchikeri Seed orchard, Yellapur division	16	1	1981-82
7.	Karka, Dandeli Haliyal Division	49	16	1981-82
	Total (ha)		**105**	

Table 4: List of Seed Production Areas of Teak in Karnataka

Sl. No.	No. Seed zones/SPA	SPA Code	Extent (ha)	Year of Plantation	Tree density (ha^{1})	Latitude (N)	Longitude (E)	Altitude (msl)
	Dandeli Seed Zone							
1	Hudsa	D1	20	1927	115	15°08	74°31	510 m
2	Bhagavati	D2	50	1928	138	15°09	74°43	422m
3	Janata colony	D3	20	1950	113	15°13	74°36	513m
4	kulagi	D4	10	1950	173	15°09	74°38	538m
5	Veerampalli plot -1	D5	8.8	1951	133	15°13	74°35	599m
6	Veerampalli plot -1	D6	11.2	1952	113	15°13	74°35	562m
7	Vimoli	D7	20	1957	154	15°13	74°36	513m
	Madikeri seed zone							
8	Moovakal-1	M1	34.4	1930	150	12°15	75°59	899m
9	Moovakal-2	M2	27	1931	173	12°15	75°59	918m
10	Moovakal -3	M3	30	1932	210	12°15	75°59	870m
11	Devamachi -1	M4	25	1936	177	12°16	75°59	933m
12	Devamachi -2	M5	25	1937	152	12°16	75°59	921m
	Shimoga seed zone							
13	Sannivasa	S1	13	1941	206	14°04	75°19	696m
14	Gaddemane	S2	23	1956	183	14°05	75°16	655m
15	Konchosur	S3	22	1959	208	14°05	75°17	711m
16	Halkuni	S4	24	1963	127	14°05	75°21	638m
	Yellapur seed zonE							
17	Ganjavati -1	Y1	21	1937	267	14°59	74°54	500m
18	Ganjavati -2	Y2	20	1937	146	14°59	74°54	508m
19	Kanderayanakoppa -1	Y3	15	1941	202	15°00	74°51	585m
20	Kanderayanakoppa -2	Y4	15	1964	156	15°00	74°51	585m
	Total 434 ha		**105**					

Road map for India

Apicahrt (1991) estimated that the gains from using such orchard seeds are at least 8% over unselected sources. It is reported that every 1% increase in gain will increase the economic returns in the range of US $ 3,500/ha (Rs. 1,50,000.00), justifying the investments in the breeding programme of teak (Kjaer and Foster, 1996). The seed orchards established in the 70s and the seed production areas created can serve as a source of quality seeds. The trees in these orchards are mature enough to produce the seeds. There is an urgent need to revamp these seed orchards by registering them as certified sources. It has been demonstrated that the plantations raised from seeds derived from orchards guarantee an additional yield of 8 to 10%. These sources, created with great vision, need to be brought back to the track envisaged. An immediate action plan that can be followed is given provided below.

A. Management of Seed Sources

1. Creation of a National Register of Seed Sources of Teak: These sources have to be revisited and assessed for the quantity of seeds they can produce every year. Various operations that are required include weeding the plot for easy collection of seeds, labelling the trees with their clonal identity and recording phenological data on flowering and fruiting. This will make each SFD self sufficient in terms of seed requirements for raising plantations.

2. Making it mandatory for state forest departments to use only these seed sources for plantation growth. In general, seed collection is taken as a last minute activity by many SFDs, resulting in sourcing their seed/seedling/stump requirements from private nurseries to meet the target. When we get the seed and planting stock from a private nursery, the quality of the stock is questionable as none of these private nurseries have their own seed sources such as CSOs and SPAs. In fact, these sources are under the control of SFDs and they can make use of them very effectively.
3. Implementation of Seed Certification Scheme: In most seminars, certification of forestry seeds is a hot subject and each SFD is eager to implement it. The certification is possible when these seed sources are managed well and seeds are supplied to the user agencies.

B. Research Issues

1. Testing the genetic superiority of seeds: The clonal seed orchards were established by assembling the phenotypically superior plus trees. These plus trees need to be tested for their genetic superiority by carrying out progeny tests. This will help in the roughing of genetically inferior trees from the orchards and increase the superiority of seeds produced.
2. Rejuvenation of Clonal Multiplication Garden: When seed orchards were established, the plus trees were assembled in the form of a multiplication garden for the production of buds required for grafting. These assemblages of plus trees are an important source of germplasm as most of the plus trees may not exist in their original location when they were selected. Since they are plus trees, they can be subjected to clonal trials and for deployment of clones in large scale clonal plantations.
3. As mentioned earlier, the genetic diversity of teak in India is high and there is scope for selection of seed sources/clones suitable for different agroclimatic regions of India.

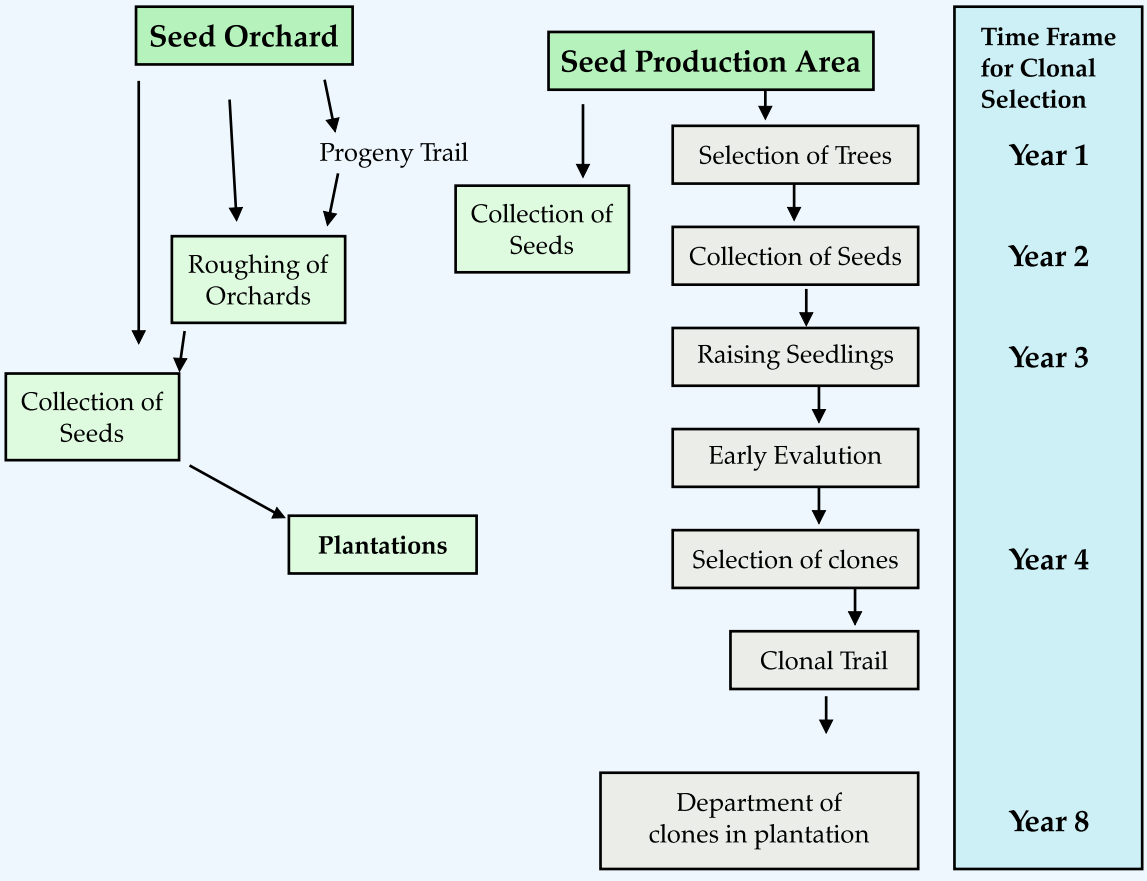

Fig. 1. A scheme for further utilization of genetic resources

In order to address the above issues, the following suggestions are made.

1. To restore teak to its former glory, a long-term programme of breeding, development, and utilisation of teak genetic resources must be developed.
2. Easy access to quality planting stock by the farmers and relaxation of rules on harvesting and transport of teak.
3. Developing high-input, precision silvicultural practises for farm grown clonal teak with a rotation of 18 to 20 years.
4. Using molecular techniques and tools for under standing the genetic resources of teak in the country and employing biotechnological tools in the improvement of teak.
5. The creation of a consortia of Research Institutes, farmers, artisans, wood based industries and exporting the finished products would provide an ideal platform for stepping into the next level in teak improvement and sustained utilisation.
6. To establish a "Teak Mission" to provide guidance for teak timber availability, accessibility, and affordability to all teak users in the near future.

Conclusion

The advancements made in clonal technology and the promotion of teak at a global level warrant India to reorient its approach to cultivation and development of teak. There is significant genetic variation in teak that has yet to be exploited, with potential for expanding plantations in the country's wet and semi-wet zones. If teak can be grown in India, our carpenters and artisans can make furniture and artefacts that have high export value. There are many private firms/industries interested in teak cultivation and manufacturing teak furniture. Thus, there can be mutual understanding and partnership between Industry, Research organizations and farmers. Apart from increasing the economy, it will also create more job opportunities and increase scope for skill development, resulting in "Grow in India, Make in India and Export from India"

References:

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- Mechanical properties of wood (Static Bending, Compression Parallel to Grain, Compression Perpendicular to Grain, Tension Parallel to Grain, Tension Perpendicular to Grain, Hardness, Shear, Nail Holding Power, Screw Holding Power)
- Determination of calorific value of wood
- Thermo gravimetric analysis of lignocellulosic material
- Determination of penetration and retention of preservative in the treated wood
- Wood polymer composites
- Preservative solution analysis
- Proximate analyser (fixed carbon content, volatile content, ash content and moisture content)
- Estimation of percentage of Sandalwood oil and GC analysis of oil
- Distillation of essential oil and estimation of oil yield by hydro distillation method
- Identification services decay fungi/mould
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- Wood Modification
- Field Identification of Important Timbers
- Clonal Propagation of Melia dubia
- Sandalwood: Establishment and Maintenance of Healthy Nurseries and Plantations
- Insect Pest Management
- Bamboo Agarbatti Stick Making

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Silvicultural Practices for Teak: A Revisit

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Teak has been a plantation species since 1846 and the plantation technologies have been well standardized. However, successful teak plantations are limited to discontinuous regions within the tropical climate belt. This fact suggests the importance of site selection for teak plantations (Tanaka et al. 1998) and warrants a clear knowledge on silvicultural requirements of Teak. At present, teak plantations are mostly raised privately by farmers in their farmlands. Further, the harvest age of teak has been shortened from 60 years to 20 years with intensification in plantation management like using of improved planting stocks including clonal / tissue culture teak and adopting of drip irrigation and fertigation technologies. In this context, this paper, re-emphasizes the silvicultural requirements of teak vis-à-vis management strategies for enhancing better establishment of teak plantations and for obtaining optimum productivity. This paper also highlights on the sensitivity of teak to heavy wind and the effect of heavy winds on quantitative and qualitative attributes of teak wood productivity. Mixed plantation of teak with casuarina is proposed in this paper to minimize planting stock requirement for establishing teak plantation.

The first important silvicultural requirement of teak is – being a "Light Demander" – availability of high light intensity from 75 to 100%. The management implication of this well-known fact is that teak is very sensitive to competition and hence, weed management is very crucial particularly in the early establishment period of teak. This aspect is gaining greater importance in the present scenario of rapid invasion of alien weeds in any exposed lands. One strategy to manage the invasive weeds could be establishing of cover crops while planting of teak.

The second important silvicultural characteristics of teak, which is well established through various research results, is its requirement for high calcium availability in the soil, hence teak is known as "Calciphile". Calcium availability is greater in soils having pH range of 5.5 to 8.5. As the calcium availability is strongly related with pH of soil, a simple check on soil pH can be a tool for opting teak for that particular soil. As suggested by Chacko (1995), laterite or lateritic gravel, clays, black cotton, sandy & gravely soils derived from sandstone are NOT GOOD for teak plantations.

Another crucial site conditions impacting establishment of teak plantations is "Water logging", as reported by Morgan (1884) perfect drainage is absolutely required for the health of the teak tree. Water logging gains greater attention in the recent past owing to failure of teak plantations in many farmers fields due to "climate-change driven heavy rainfall (downpour)". In such waterlogging sites, planting of teak in raised bunds of 2-3 feet high could be a good management strategy.

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Wind – an unfavourable factor for Teak:

Though teak is demanding species, it is adapting as well to the poor site conditions. Hence, it misleads that teak can be grown in all site conditions. One another such poor site conditions for teak is locations with heavy wind. Morgan (1884) also reported that Teak grows well on the some of the hills in Wayanad over 3,000 feet in elevation, but does not stand drying easterly winds. A study conducted in IFGTB showed that teak grown in windy locations will have greater branch production. The heavy branching due to wind will lead to greater transpiration of water and the greater need for transpiration by presence of more branches and foliage will result in retaining of more sap wood area (Berthier et al. 2001 Taylor et. al. 2002) and hence, the lesser heartwood content (Plate 1). It is proposed that teak plantations need to be protected from exposure to heavy wind, with windbreaks if required, to assure a better establishment and good growth and also for greater heartwood formation.

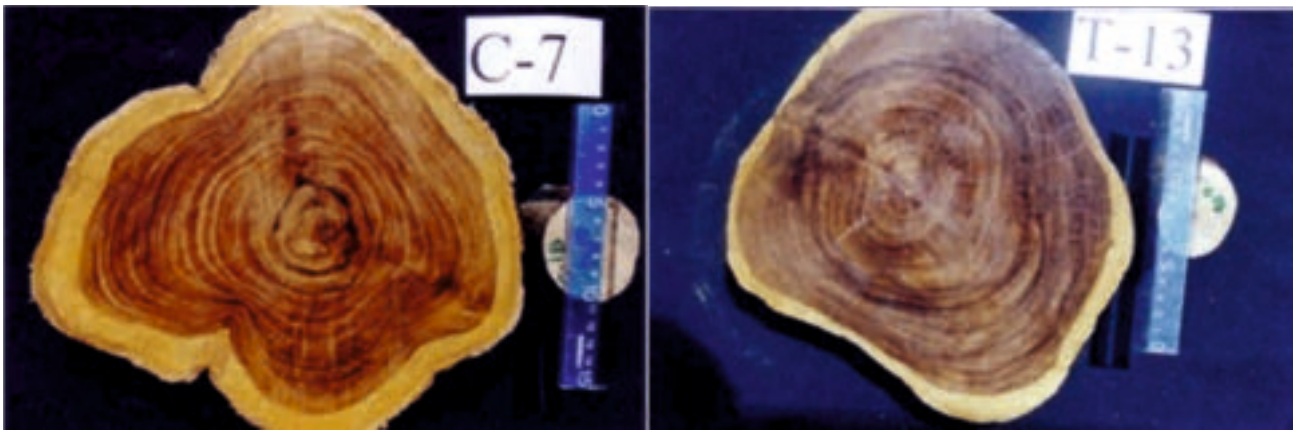

Plate 1: Wood discs from 33-year-old teak plantations with higher sapwood in windy location (C-7) and with lesser sapwood in location not exposed to heavy wind (T-13)

Mixed planting of Teak with Casuarina:

Teak is commonly planted in 2 x 2 m spacing. As reported by Morgan (1884), at this spacing of 2 x 2 m, teak trees cover the ground, prevent weeds and do not throw out the lateral branches. Then, two mechanical thinnings are carried out, in turn the spacing will be 4 x 4 m. This planting technique require 2500 planting stocks for the initial planting. In two mechanical thinnings, 1875 trees will be removed. However, in the present day context, use of superior clones / tissue culture teak planting materials having higher cost per planting stock is gaining momentum. Hence, the mixed planting of teak with casuarina will be a viable option. This mixing of N-fixing trees with Non-N fixing tree species to harness the benefits of association is well studied in other countries with reference to mixing of Acacias with Eucalyptus, sandal with Dalbergias. In a pilot study, IFGTB has demonstrated that growing of Casuarina on either side of teak trees in the boundary planting immensely helped teak to grow taller and with more clear bole height. This successful model of growing teak in the boundary along with Casuarina needs multi-location trials and final technology development. Most importantly, under mixed planting, teak planting stock required will be only 625 per hectare. The cost cutting in the purchase planting stock of teak will be 75%.

Another option to minimize the planting stock requirements could be planting teak at wider spacing of 4 x 4 m. However, if planters wish to grow teak at wider spacing of 4 x 4 m, then manual pruning of branches and mechanized weeding need to be carried out at periodical intervals. Also, the pruning needs to be restricted to 1/3rd height of the tree from the base and 2/3rd of the stem height needs to have foliage for optimum photosynthetic activity and in turn for unhampered growth. It appears that pruning operations will lead to permanently arresting the branch growth at the place of pruning. But there are reports indicating that there will be initiation of production of adventitious branches. To avoid re-branching from pruned woody branch, Balasubramanaian (2020) suggested nipping of branches when they are just emerging from axillary buds in younger teak plantations of one to two years age.

Plate 2: Mixed planting of teak with Casuarina in boundary planting (3-year-old)

To conclude, right selection of sites meeting the silvicultural requirements of teak will aid in better establishment and growth of plantations. As heavy wind is an un-favourable factor for teak, windbreaks need to be established not only for better growth but also for higher heartwood content. Mixed plantation of teak with casuarina can be a viable option for minimizing planting stock requirements of teak in view of present days use of high cost clonal / tissue culture planting stocks of teak.

References: contact the author at buvanesc@icfre.org

Teak Genetic Improvement Program: Roadmap

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Introduction

The Government of India is in the process of formulating and implementing strategies to assist farmers in doubling the income from farmlands. Through agroforestry, agricultural revenue can be enhanced by growing trees alongside agricultural crops. Agroforestry is one of the solutions for increasing wood supply for industries, alternate farming practises to compete in the untapped wood market, coping with the effects of climate change, and improving carbon sequestration. Absentee landowners and small-holding farmers like to grow teak to generate a steady income from their farms. There is a safe market for wood and wood products and huge export potential is available beyond domestic demands. Currently, India is a net wood and wood products importer. The major items included pulp, logs, sawn wood, furniture, veneer and plywood. The major species imported is Teak, Pines and Shorea sp. Indian furniture industry prefers Teak as the first choice of wood because matchless combination of qualities such as, lightness and strength, attractiveness, workability, stability, seasoning ability along with resistance to weather and termites.

India is the pioneer in cultivation of teak and developed protocols for seed handling, nursery establishment, and plantation management. Teak's rotation age was traditionally 80 to 120 years. Vegetative multiplication by grafting of buds produced from phenotypically superior trees and the development of clonal seed orchards (CSO) began five decades ago. However, the yield of Indian Teak plantations is significantly lower than the global average. This is because most of these plantations are raised from unimproved seeds. Hence, it is apparent that we must transition from traditional Teak production practises to contemporary silviculture technologies. We know a lot about Teak, but we don't know much about it. Climate change effects also play a role in teak adaptation and timber yield. Hence we need to develop strategies primarily to produce seeds and clones to meet the goals of immediate planting requirements.

Following the restriction on tree felling in India in the 1990s, the country's wood hunger prompted corporate investors in Latin America and Africa to pursue forestry projects such as Teak plantations in an innovative model. A number of projects were established on 20-year rotations to obtain greater financial returns, despite the fact that the timber sold for less in the market than native produced material. Large plantings by government organisations & smallholders throughout tropical Asia were envisaged to produce this superior wood. This perspective resulted in a booming worldwide Teak sector, with an estate expansion of 300,000 ha in Latin America and 300,000 ha in Africa between 1995 and 2005. The investment-driven revolution absorbed silvicultural expertise from other fast-growing plantation hardwoods, employing more aggressive thinning and fertilisation regimes. Alongside the tree improvements efforts were also made to sustain the returns and the companies started quality seed production, selection of plus trees & mass propagation using tissue culture techniques.

Again, India was a pioneer in tissue culture protocols for teak in the 1970s, but it was the idealistic industrial production of a handful of elite teak clones from a Malaysian laboratory Malaysia's Yayasan Sabah Group (YSG) in the late 1990s. This technology brought the potential of cloning teak into sharp relief and set a new benchmark for genetic gain worldwide. Rooted ex-agar plantlets were shipped to investment-based teak projects all around the world, where they substantially increased timber output. Such scientific contributions made significant impact in teak business and the selected clones were adaptable across different soil types. Thus, it is evident that tree improvement programs, propagation techniques and cultivation practises along with silvicultural interventions, are required to produce commercial teak timber within reasonable time frames.

Although teak is a long gestation crop and breeding is difficult, the internal rate of return is high for teak as the timber is valuable (Kjaer and Foster, 1995). Considering the above facts, genetic improvement programmes for teak was initiated in many countries like Thailand, India, Malaysia, Indonesia, etc. Many tree improvement efforts in teak are currently underway in countries such as Australia, Thailand, Brazil, and Africa in order to quickly increase production from plantations.

Natural distribution of Teak

In India, Teak is mostly confined to the Peninsula region below 24°N latitude. This region is bounded in the north by the Western Arvallis of Rajasthan. The dividing line passes eastward through the districts of Jhansi and Baroda in Uttar Pradesh, finally curving southeast to the Mahanandi river through Madhya Pradesh and Orissa. From this northern limit, teak extends south-wards through the states of Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu, Karnataka and Kerala. Natural teak forest in India covers about 8,900,000 ha (Tewari, 1992); based on rainfall, this forest is classified into five types as shown in Table below (Kumaravelu, 1991).

Table 2. Teak Plantation area in major teak growing districts

Forest type	Rainfall range (mm)	Typical examples
Very dry	< 900	Chittorgath, Ledaipur (Rajasthan); Araungabad (Maharashtra).
Dry	901-1,200	Indore, Kannod, Seoni (MP); Bauswara (Rajasthan); Nirmal (AP); Dharwar (Karnataka); Tamil Nadu.
Semi moist	1,201-1,600	Baster, BetualChedleth, Sultan's Battery (Kerala).
Moist	1,601-2,500	Bori, Hoshangabad (MP); Allapalli (Maharashtra); N. Kanara (Karnataka); Palghat (Kerala).
Very moist	> 2,500	Bhadrawathi (Karnataka); Wynaad, MalayatturThenmala (Kerala); South Coimbatore (Tamil Nadu).

A large amount of natural teak was felled and utilized for construction of building, furniture, ship, etc until eighteenth century. During late eighteenth century, teak plantations were established clear felling the natural forests with miscellaneous species. First teak plantation in India was established in Kerala during 1844 in Nilambur when the then Collector of Malabar, Mr. Conolly fore saw the shortage of teak likely to occur through the depletion of the natural forests. Considering the growing demand, private industries also started planting Teak collecting funds from the public. Although, the requirement of the species for establishment and management of the plantation was considered well, these plantations failed due to use of poor planting materials. About 100,000 hectares are planted with teak annually in India.

Past Teak Improvement in India

Domestication of tree species was started from Teak. Phenotypically superior trees were selected and removed from natural forests for more than a century for utilization leading to dysgenic selection for growth vigour and straight bole. Kedharnath and Matthews initiated a systematic genetic improvement programme for teak. The main objective of teak improvement programmes is to achieve, by selection and breeding, superior stem form and timber quality, fast growth (height and diameter), a trunk free from fluting, buttressing and epicormic branches, resistance to leaf skeletoniser, defoliator, drought and frost.

For achieving the envisaged genetic gain, the variability present between different populations were considered, plus trees were selected at very high intensity, developed clonal multiplication methods, conducted clonal testing, establishment of seed production areas and seed orchards and progeny testing. Subramanian et al. (1994) also reported distinct genetic variation in very dry, dry, semi-moist, moist and very moist types which can be consideration in the improvement programmes. The loss of timber due to branch knots, flutes, bumps, spiral grains and blisters, resistance to insect pests were also considered during selection. About 1000 plus trees were selected from various forests and used for establishment of grafted seed orchards. Vegetative propagation methods were standardized and patch budding was used to multiply the selected plus trees and establish clonal seed orchards. Simultaneous selection for important economic traits cumulatively contributed to increased productivity and quality of timber.

The plus trees were selected in association with the state forest departments. Subsequent to these initiatives, the importance of tree improvement was recognized by the state departments and the selected germplasm was protected and used to establish seed orchards. A national germplasm bank was established in Chandrapur with active support of Maharashtra state

forest department and assembled with plus trees from all the states.

Provenance Variation

Teak is present in a wide range of geographical conditions indicating presence of a large genetic variation. Provenance trials confirm the existence of genetic variation between provenances, which were tested in locations within and outside the natural distribution range of teak. Provenance variations in wood quality, growth rate, stem form, seed morphology and germination and other characters, have been observed in teak. The All-India Provenance trials initiated in 1930 with 11 provenances indicated that the local provenances performed well. Teak wood has showed variation in the quality of the timber, colour, texture and grains according to climatic and edaphic conditions. Teak growing in Malabar coast of Western Ghats attains huge sizes due to high rainfall (2000-3000 mm) and it is preferred for structural needs like ship and boat construction. On the other hand, teak from Central Indian region is known for colour, texture and grains preferred for furniture and other aesthetic needs. Teak from Seoni, Kanker and parts of Bastar, Madhya Pradesh, the timber is golden yellow in colour with the heartwood blending into the sapwood. Teak timber of Chandrapur, Maharashtra is well known for its colour and texture. Teak wood of Godavari valley in Andhra Pradesh is highly priced for furniture and cabinet making for its ornamental figuring. Teak timber from Rajulmadugu of Andhra Pradesh has pink coloured heartwood. Several significant findings were made during international provenances established in the 1970s. One of the findings is that provenances from high rainfall areas outperform those from low rainfall zones.

Plus Tree Selection

Identification of plus trees from natural forests and plantations has been carried out as part of the teak improvement programmes. About 1000 plus trees have been selected throughout the country by the SFDs. Plus trees were selected with very high selection intensity based on phenotypic characters using check tree method. This method is practiced in even-aged plantations. The entire plantation is perambulated for outstanding characters and about 1 in 10,000 trees is marked with a yellow band around the trunk at breast height. Newly formed vegetative buds were collected from these trees and clone banks are established by grafting the buds to stocks raised from locally available seeds.

Proposed Tree Improvement in Teak

During the past, attempts have been made to develop a written breeding program for Teak and execute the same. However, many of these efforts could not be sustained due to various reasons. Because success of tree breeding program in Teak has many challenges viz., low seed yield, poor germination of seeds, less availability of quality planting stock for raising seed orchards, problem of flowering synchronization, low average productivity, narrowing of the Genetic base, difficulties in performing controlled pollination, long rotation age and fairly late flowering. As a result, many of the breeding efforts become fragmented in Teak.

During the recent past, Callister (2013) has proposed different tree improvement strategies for teak in Australia for establishment of progeny trials and select new clones at the age of three years for tree height, DBH, stem straightness, CBH and flowering. This program aims at deployment of clones at the age of 12, 13 and 16 years. This proposal is one of the fastest proposed genetic improvement program for such a long gestation crop like Teak.

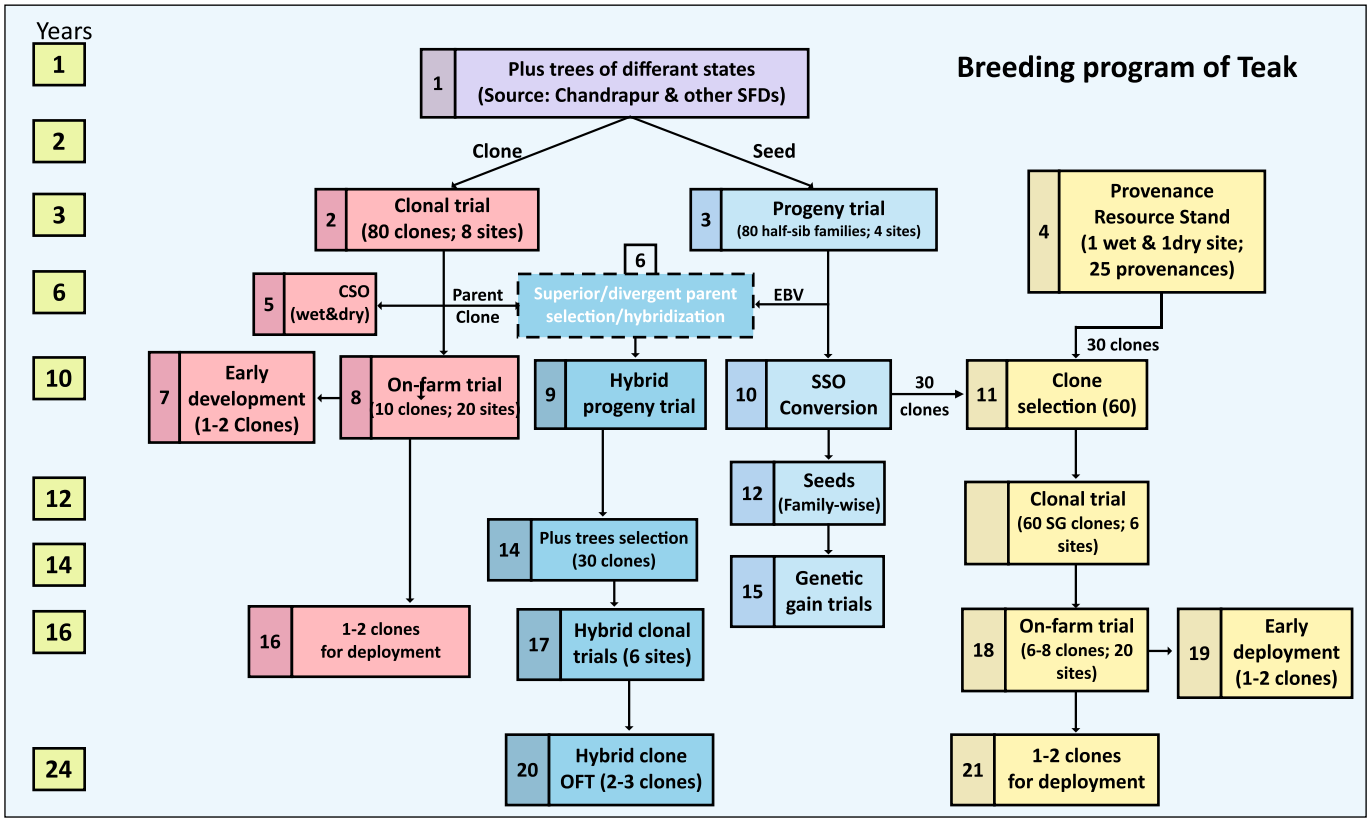
Many of the target traits like height, DBH, CBH, etc have low to moderate heritability. The branching characters, heartwood density, proportion and floral character have moderate heritability values. Further, these characters are controlled by thousands of genes. Clonal propagation is a tool to harness the selected characters to the varieties. Again, the clones also affected by the environmental characters hence required testing in multiple sites.

The clients for the quality planting material of teak is both farmers and SFDs. Farmers prefer tested superior clonal varieties of teak. With intensive silvicultural practices and input, the clones perform better in farmlands. However, on the other hand, SFDs would prefer to have genetically improved seeds for planting in the forest areas where teak is already planted as per the working plan. Although the seeds obtained from the seeds orchards will have growth vigour, there will be a considerable variability between trees. Such variation between trees is acceptable and good for planting in forest areas. Again, the choice of the Forest Development corporation will be clonal varieties for higher productivity. The present program equally considered both clonal as well as seed programs equally to meet the requirement of the farmers and SFDs.

Objectives of the program

The program aims to assemble base populations for immediate and future breeding, conduct Clonal and Progeny trials to improve the quality of planting stock and release improved clonal varieties for cultivation by farmers and SFDs. The following are the specific objectives of the over-all program.

1. To assemble and catalogue the Plus trees selected by various SFDs.
2. To establish multilocational clonal trials and select superior clones.
3. To establish base populations for future breeding.
4. To develop quality seed production system in teak.



Genetic improvement of Teak

1. Plus trees of different states

Teak is present in many states naturally stating from Kerala, Tamil Nadu, Karnataka, Maharashtra, Madhya Pradesh, Odissa, Telangana (South of Gothavari), Andhra Pradesh (North of Gothavari), Chhattisgarh (Bastar), Jharkhand, Rajesthan, Uttar Pradesh, Biharand Uttarakhand. The state forest departments have selected plus trees from the plantations raised in the respective states. Although the seed source for these plantations are not know, possibly they could be collected from nearby forest areas. It is presumed that no much translocation of seedlots have been taken place within India. During those days most of these selections have been taken place during 1980s from about 50 years old plantations which were raised during 1930s. Most of the Plus trees have been selected with very high selection intensity of 1 in 10,000 to 1 in 1,00,000. These plus tree can be considered as representative for the respective state/population.

These plus trees have been multiplied through bud grafting and assembled in National Germplasm Bank for Teak (NGBT) at Chandrapur. Further these Plus trees have been multiplied and planted as Clonal Seed Orchard in many part of the Country by Dr. Ketharnath.

These selected plus trees can be part of the basic breeding population. The NGBT at Chandrapur has about 235 clones assembled from various states of India. They all have been collected as grafts and hence the juvenility is a question, although these grafts have put up satisfactory growth and form in the CSOs established in Tamil Nadu and Kerala. On the other hand, genetically they all are divergent and sufficient to establish a breeding population. So now, we have few options in front of us to have a base population.

One is, collect seeds from these 235 Plus trees when the flowering is profuse (At least >50% of the trees are under flowering). Establish a progeny trial for more than 80 Plus trees and use them as base population for

further breeding. When we use the Plus tree as mother trees, we lose one generation of genotype selection.

The second one is that we try to reach the original Plus trees and try to induce coppice shoots by girdling. Experiments made to induce coppice shoots by complete girdling induced coppice shoots after 6-8 weeks period of time with sufficient light around the damaged area. Cambium get regenerated and cover the girdled area within a period of 4-6 months. However, it requires a huge field work to reach each and every tree in different states.In case, we could multiply the selected plus trees from their original ortet, then we gain one generation of genotype selection.

The third option is that to use tissue culture method to rejuvenate the similar coppice shoot cuttings from Chandrapur. In this method, we will have the risk that the juvenility might not be completely achieved.

Possibly, we may try to collect Single tree seeds from maximum number of clones present in Chandrapur and try to collect coppice shoots from the original ortet of the clones. In case we could not collect the coppice shoots from the Ortet, then those clones may be multiplied through TC method.

Individual tree pedigree must be retained and recorded for calculation of family as well as individual tree Breeding Values (BV).

2. Clonal trial

The available Plus trees as clones must be tested in 8 siteswhere Teak is planted already or suitable. Typical Teak growing regions must be identified for the trial. About 80 clones may be envisaged for establishment of the Clonal trial. These clones may be multiplied from the available populations and planted as Vegetative Multiplication Garden (VMG) in the premises of the participating Institute for further multiplication. The clones may be planted in Randomised Block Design with minimum of five replications. Each replication must be represented by three ramets continuously. A spacing of 3 meters between rows and 2 meters between plants may be adopted.Such similar set of clones tested across multiple sites for comparison and shortlisting are called Multi-locational test (MLT). Care must be given to replicate similar set of clones across the sites.

3. Progeny trial

The Plus trees must be tested for their breeding value. Seeds of open pollinated half-sib progenies may be collected. The seeds must be collected when a minimum of 50% of the trees under flowering. Eighty single tree seed collections must be made for raising progeny trials in four different places. The composition of the families may be divergent considering all the state clones proportional to the extent of Teak forest in the respective state. The site for test must be selected where Teak will have satisfactory vegetative as well as reproductive growth. The trees must be planted at 3 x 2 meter spacing. In each family,6 trees may be planted in 2 rows, each row with 3 trees. Eight replications may be planted in Row Column design for randomizing the families.

4. Provenance Resource Stand (PRS)

A systematic germplasm collection from all the natural ranges of Teak must be collected for selection of plus trees as well as serve the future breeding. In addition to the Breeding populations established under Step-2 and Step-3 in the form of CSO and SSO from Plus trees already selected from different states, PRS is essential. Most of these Plus trees have been selected from the plantations. The variability existing in the natural Teak forest must be collected and made a part of the breeding program. Hence PRS are established under the program. Further, these PRS will serve as a germplasm of all the variability exist in the species for future selection of any other trait other than growth superiority like pest or disease resistance, etc.

It is envisaged to collect seeds from about 25-30 natural provenances of India covering about 14 states. Unique natural populations must be identified within each state, like Nilambur, Konni, Wynad in Kerala, Topslip and Sengotai from Tamil Nadu. Within each provenance/population, about 20-25 healthy trees may be identified and seeds may be collected and bulked. Two Provenance Resource Stands (PRS) may be established one in MP and another one in Kerala. Each provenance will be represented by about 225 trees in a single block as 15 rows by 15 columns. Trees shall be planted at a spacing of 3 x 3 meters. The blocks must be 100% stocking by carrying out casuality replacement.

5. Clonal Seed Orchard (CSO)

The clonal seed orchard could be established using the clonally propagated propagules from the already selected plus trees present in Chandrapur or from other Forest Department selections. Depending on the species distribution area, the number of plus trees may

be added from each population/state. About 60-80 clones may be planted in the orchard. Each clone may be represented by single ramet in each replication. About 20 replications may be established. The randomization may be made using row column design. The trees may be planted at 3x 3meter spacing. The clones may be matched with clones considered for progeny testing. Breeding values estimated for the Clone through progeny test can be used to cull the inferior clones in the CSO. Based on the Breeding value of the clones, half of the clones may be culled. The final spacing shall be altered to have around 300 tree / ha. Culling may be carried out at the age of 6 years (before the closer of the canopy). Genetic gain from the Progeny tested CSOs will further increase. The CSO may be planted with two rows of Melia dubia as boarder trees.

Proper irrigation and fertilization must be provided. Cover crops may be grown for enriching soil fertility and moisture conservation. As the spacing is more, weed growth might suppress the growth of Teak, hence growing cover crop and ploughing once in six months will keep the field clean and support the growth of Teak. Adequate irrigation will help the trees flower and fruit profusely. Apiary may be placed inside the CSO for promotion of cross pollination. Two apiary per ha may be placed at 3 meters height for easy maintenance. Trees must be encourage to grow short by pruning the trees.

6. Hybridization

The progeny trials planted across the sites must be analysed statistically for their Breeding value. The parents for selection of hybridization must be selected based on the Breeding value in one hand and Coefficient of variation % on the other hand. The families with high Breeding value and CV% must be selected for hybridization. About 10-15 parents may be identified for crossing. The parents may be grafted from Chandrapur or original Plus trees to grows as potted plants or hedge seed orchard in the station. Early flowering may be induced for through chemical methods. Partial or full diallel crosses may be made. Emasculated flowers may be cross pollinated and bagged. Seeds may be collected at appropriate maturity stage. It takes minimum of 3 years for production of hybrid seeds.

7. Early deployment

The clonal trials established during the 3rd year of the program under Step-2 shall be evaluated after 6 years of planting for their height, GBH, Clear bole height, stem straightness, less tapering (compare the DBH and mid diameter), branch boldness (less is good; take % of branch diameter to main stem diameter), branch angle (narrow is good), less fluting and less buttress. The uniformity the characters across ramets, coppicing ability and rooting potential of the clones need to be considered for early deployment. In case any clone is found to be superior with respect to growth, tree form, rooting potential, then top 1-2 clones may be considered for early deployment. Pre-requisite for selection of one clone is that the MLTs must have been conducted in minimum of 6 sites with a minimum of 30 clones.Two superior clones may be selected in case more than 60 clones have been tested across 6 sites. These clones can be multiplied and given to farmers and other planting agencies without any further test.

Early deployment is essential as the rotation age is long and associated uncertainty in continuing the breeding program successfully for long period is difficult.

8. On-farm Trial (OFT)

The Clonal trials conducted under Step-2 are analyzed statistically and 10% of the top-ranking clones based on the MLT results may be considered for On-farm trial (OFT). OFT is a clonal trial with limited number of superior clones for proving the uniformity and stability in the farm land conditions. These trials are conducted in relatively large blocks of more than 200 ramets per clone per replication. Clonal plants are multiplied and given to the farmers for planting. The clone/replication layout may be recorded once planting is carried out. About 20,000-30,000 plants may be multiplied for each clone and given to farmers for establishment of OFTs. While multiplying the plants, rooting percentage must be optimized and clone specific clonal propagation method must be optimized to have 80% rooting.

No intervention from the research is done for maintenance. The farmers grow the clones as per the standard cultivation practices. Final growth data is recorded by the responsible researcher and compared. Growth superiority and uniformity of character are mainly considered in the OFTs. Clones released under Step-7 as early deployment variety may also be part of the OFT for the purpose of comparison.

In the OFT, the inputs (water and fertilizer) given by the farmers may be carefully studied to get to know more about the clones to be deployed.

9. Hybrid progeny trial

The basic objective of the Hybrid progeny trial is to screen the individuals for hybrid vigour. As the superior individuals are going to be deployed clonally, Breeding value of the cross or comparison between cross has limited application. We need to identify individual with hybrid vigour. Hence comparison of individuals within each cross is the priority. Hence as far as possible, the individual of a cross must be planted in large blocks. The hybrid progeny trial must be established in sites with uniform soil conditions because larger blocks will be established for selection.

All the cross-pollinated seeds under Step-6 must be germinated. Any malformed and slow growing seedlings must be rejected. All the vigorous plants must be transplanted to polybags. Depending on the availability of plants in all the cross, a base trial and a Primary block must be planted. The base trial will have equal number of plants with replications in RBD. This will enable us to decide which cross may be repeated for subsequent crossing. The Primary blocks will be plants from a particular cross. In case single block could not be made, then 2 or 3 blocks may be made. In case one single block is made, selection of one superior individual is relatively easy when compared to selection of one individual from 2 or 3 blocks.

10. SSO Conversion

The progeny trials established under Step-3 shall be converted in to Seedling seed orchard (SSO) once the progeny growth evaluation is completed. Family level Breeding values may be estimated from the progeny trial established in multiple sites. Further individual tree BV can be estimated using the pedigree details of the parents. All the four progeny trials may be converted in to SSO. The progeny trials were established with 6 trees in 2 rows each with 3 trees. The spacing between rows are 3 meters and between plants are 2 meters. Family breeding value and individual tree breeding values will be calculated and used for culling. The Breeding value may be calculated for single tree volume considering the height, GBH and an approximated common form factor. Culling in the progeny trial must be executed considering the below given norms.

1. Families with high BV- retain 1 or 2 trees among 6 trees in every replication.
2. Families with average BV – retain the trees based on the high individual tree BV across (no need to retain trees for every replication).
3. Family with BV below average – all the trees in the family will be removed (hypothetically about 30 families).

The initial stocking is planned to be 1666 trees per hectare. The approximate final stocking envisaged is 250 trees per hectare (about 6 x 6 meters). Culling must be executed before canopy closure. As the initial spacing of trees are closer (3x2m), culling need to be executed immediately after the evaluation of the Progeny trial (7th Year).

Further, flowering must be enhanced through adequate irrigation and fertigation. All the efforts must be taken to maintain the health of the trees.

11. Clone Selection

Plust rees may be selected from the Provenance Resource Stand established in Step-4. Each provenance is represented by 225 trees in a block. Not more than 2 Plus trees may be selected from each block based on growth and tree form traits viz., Tree height, GBH, Clear bole height, stem straightness, less tapering (compare the DBH and mid diameter), branch boldness (less is good; take % of branch diameter to mainstem diameter), branch angle (narrow is good), less fluting and less buttress.

About 30 plus trees may be selected from the PRS and equally 30 Plus trees may be selected from the Progeny trials established under Step-3. The trees selected as Plus trees need not be felled for cloning them. Girdling may be done to induce coppice shoots. These Plus trees must be part of the original breeding population where are planted, coppicing them for cloning remove the genotype from the breeding population.

12. Collection of seeds

Seeds may be collected from the progeny trial established under Step-3 and subsequently converted in to SSO under Step-10. The SSO possess families and individual trees with high BV. With enhanced flowering and cross pollination, quality seeds are expected to be produced. Seed collection must be carried out when a minimum of 50% of the trees flower and cross pollinate. Synchronoised flowering across the families also affects the seed quality. Family wise seed collection must be made and made available with family identify. Trees must be encouraged to grow short by pruning the trees.

13. Clonal Trial

Clones selected in the Step-11 must be multiplied by inducing shoots from the bottom of the trees. The tissue present in the bottom of the tree will be juvenile when compared to the tissue present in the canopy. Hence complete girdling may be carried out to induce shoots from the bottom of the tree.

Six MLTs may be established in most predominant sites where Teak is commonly planted. Selected clones may be planted in Randomised Block Design with minimum of five replications. Each replication must be represented by three ramets continuously. A spacing of 3 meters between rows and 2 meters between plants may be adopted.

14. Plus tree selection

Trees with hybrid vigour must be selected. The expression of hybrid vigour could be expressed in any of the growth or quality trait. Individual trees with heterotic vigour may be selected. While selecting the trees all the characters mentioned in Step-11 must be considered. A selection intensity of 1 in 500 trees may be considered.

15. Genetic gain trials

The seeds collected with specific family may be tested for their family growth superiority and quantification of realized genetic gain through the breeding program. Seeds of 30 half-sib families may be tested for their genetic gain. The seedlots may be planted as bigger plots of 25 to 36 tree plot each with 4 replications. Local seed source or a clone may be planted as control for quantification of the gain relished. Trees may be planted at 3 x 2 meter spacing. After 8 and 16 years of evaluation, two mechanical thinnings may be carried out.

16. Deployment of clones

The clones which show superiority across the sites, sufficient uniformity in growth as well of tree form traits like CBH, straightness, stem circularity and branching characters must be shortlisted. The early deployed clones must be compared for the growth superiority of the other clones in the OFT. In case any other clone is found superior to the early deployed clone, the previously released clone must be withdrawn and the new clone must be released. Clonal propagation method must be optimized to give 80% rooting potential while releasing a clone.

17. Hybrid clonal trials

Heterotic individuals selected as Plus trees from the Hybrid Progeny Trial (Step-9) following the method described in Step-14, need to be tested for their superiority as a clone. The Hybrid progeny trial will have huge variation between the trees planted. In case the surrounding trees are poor, the centre tree gets advantage of space and nutrient and puts up good growth and might have been selected as plus tree. The competitiveness of the plus tree must be tested with the ramets of the same plus tree.

The selected plus tree shall be coppiced after 5 years. The coppice shoots shall be collected after 6 weeks of coppicing. The initial coppice shoots are vigourous and must be used to establish Vegetative Multiplication Garden (VMG). After taking sufficient coppice shoots the base stump must be allowed to grow and retained alive for future collections. Sufficient number of clonal plants may be produced from the VMG established near the nursery. Clonal trials may be established as per the methods suggested in Step-2. Commonly planted seed source or the commercial clone may be kept as control.

18. On-Farm trials

The plus trees selected tested in the Step-13 shall be shortlisted as per the methods given in Step-8.

19. Early deployment

Similarly, plus trees selected tested in the Step-13 may be shortlisted as per the method given in Step-7.

20. Hybrid clones

Top ranking 2-3 hybrid clones shall be shortlisted and taken to OFT. Hybrid clones require high input for their growth. Silvicultural optimization for spacing, water regime, fertilization requirement and thinning need to be standardized for the superior clone.

21. Clone deployment

The clones may be deployed as per the methods given in Step-16.

Chronological order of the program activities

The entire program activities have been divided in to actionable four phases of the purpose of administrative convenience, creating milestones, reviewing and monitoring.

Phase 1 (2023-2028)	Phase 2 (2029-2034)
1. Plus trees of different states 2. Clonal trial 3. Progeny trial 4. Provenance Resource Stand (PRS)	5. Clonal Seed Orchard 6. Hybridization 7. Early deployment 8. On-farm Trial (OFT) 9. Hybrid progeny trial 10. SSO Conversion 11. Clone Selection
Phase 3 (2035-2039)	**Phase 4 (2040-2045)**
12. Collection of seeds 13. Clonal Trial 14. Plustree selection 15. Genetic gain trials	16. Deployment of clones 17.Hybrid clonal trials 18. On-Farm trials 19. Early deployment 20. Hybrid clones 21. Clone deployment

Next generation silvicultural practices

Innovative silvicultural models need to be developed for teak cultivation outside forest areas. Unlike traditional methods of cultivation of the pure plantations, agroforestry models are being developed. Bund and small block plantations are raised by farmers. Teak grows well along withdifferent typeshorti and agricultural crops and other forest trees. Use of casuarina clones for intercropping brings in early return to the farmers and pruning and thinning expenditure is reduced substantially.

Partner Institutions with Relevant Strengths and Potential Contributions

A countrywide structure of participation in teak improvement program is given below.

To carry out the tasks of various teak improvement program, there is the need for the close networking of the particular agencies involved. These can include the ICFRE institutes, state forest department of respective teak growing states, and the timber-based industries (Plywood and Furniture).Other relevant agencies are the agricultural universities in the region, the forest tree seed centre of the respective state and any private sector partners.

ICFRE institutes are entrusted with promoting and strengthening the sustainable development of teak genetic resources and their industrial uses via research, development, and application initiatives.

In this project, the role of ICFRE institutes is to develop appropriate knowledge and technology for the conservation, management, development and utilisation of teak genetic resources. Also pursue excellence in scientific research and development, and technology transfer to the teak growing sector. A coordinated effort between all the ICFRE institutes will be taken for execution of the program.

IFGTB, Coimbatore can serve as nodel center for execution of teak tree improvement initiative. IFGTB will provide the detailed schedule for launching of breeding and improved planting stock production in short and long-term periods. IFGTB will work with the populations present in Tamil Nadu and Kerala. Likewise, IWST will work in the states of Karnataka and Andhra Pradesh, TFRI to initiate the program with Madhya Pradesh, Orissa and Maharashtra teak populations and RFRI to work with germplasm available in North Eastern States as per the written program on teak improvement.

IFGTB being a nodal institute for the teak improvement program, the activities include, 1. Schedule the teak improvement program, 2. Extend the technical expertise in tree selection, assessment of seed orchards, and seed collection, 3. Devise methodologies for seed handling, nursery techniques (including vegetative propagation and tissue culture techniques) and setting up of seed orchards, 4. Assistance in the execution of scientific teak improvement program for other project partners and 5. Conduct genetic analysis of the field trails and evaluation of research results.

State Forest Departments

There are about 14 State Forest Departments viz., Kerala, Tamil Nadu, Karnataka, Maharashtra, Madhya Pradesh, Odissa, Telangana (South of Gothavari), Andhra Pradesh (North of Gothavari), Chhattisgarh, Jharkhand, Rajesthan, Uttar Pradesh, Bihar and Uttarakhand where Teak is predominantly present either as natural population or plantation. The SFD is responsible for documenting the availability and status of seed orchards and clones in their respective states in co-ordination with ICFRE institutes. SFD will also be entrusted with planning, development and operation of the teak seed nursery.

The role of the forest department in the teak improvement program may include:

- Making the selected plus trees available for the program.
- Assist in germplasm collection in the natural teak areas.
- Providing land for establishment of the research trial plots.
- Maintenance and protection of the trial plots during and after completion of the project.
- Adoption of the tested and certified clonal varieties / seed sources for establishment of plantations within and outside the forest through the department nurseries.

The program will support establishment of clonal trials or seed orchards limited to 1 or 2 orchards in a state. The SFD may make additional funds available to the program for making more seed orchards or clonal trials.

The seed center can assist in the teak improvement program in maintaining the seed orchards, collection of family wise seeds for supply to SFDs. Dissemination of knowledge and technology gained in teak improvements program.

Private Sector

There is a setback for the involvement of private sector in Teak plantation establishment after failure of venture capital programs of Teak during 1990s. The failure was basically lack of availability of quality planting materials. Presently, the program envisages to work on the same aspect for development of quality planting materials. Hence, the private sector could contribute to the teak improvement programme by establishment of production nurseries and plantations.

State agricultural universities

The SAUs present in the mandated states can also participate in establishment and further observations on the clonal as well as progeny trials.

Conclusion and Expected Outcome

The genetic improvement initiatives taken during 1960s have not been taken to subsequent levels. Although the SFDs shown lot of interest in selection more than 1000 clones, the efforts ended with selection of plus trees and assemblage of few selected clones in National Germplasm Bank at Chandrapur and within the state germplasms. No further initiatives has been taken for cloning them, conducting MLTs for the selection plus trees and their progeny testing. The present program envisages to take the program from the selected plus trees available with different SFDs, evaluate them in MLTs for their superiority and their progeny superiority. Further a consorted effort will be made to collect different natural populations and establish a Provenance Resource Stand for the purpose of future breeding. The program aims to come out with clonal varieties for the farmers and Forest corporations after 10, 16, 24 years and seed varieties for the SFDs after 10 years.

References: contact the authors at yasodha@icfre.org

Role of Silviculture in Timber Production India with special reference to Teak

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In this paper, I would like present my views about role of silviculture in forest management to augment timber production with special reference to Teak. In fact, forest officer never fells a tree for timber production, rather timber is produced from a forest only as a by-product as a result of silvicultural operations taken up to make conditions favourable for the reproduction and appropriate growth of the trees of the species of choice, i.e. principal species. This helps to reduce the extra Growing Stock (GS) of over stocked immature forests to appropriate levels. A person felling a tree in a forest cannot be called a forester, if he does so with the only intention of getting timber for revenue. Silvicultural operation is done in a scientific manner in a forest is not at all a luxury for earning revenue at will, but it is necessity to maintain the forests in such a manner that they continue to provide all direct and indirect benefits to the society. When timber is obtained as a result of such silvicultural operations, the Government is ethically as well as legally entitled to it for being the rightful owner of these forests, and therefore, there is no reason why the government should shy away from selling the same to get appropriate amount of revenue for the benefit of the state.

Very often, we find people talking about production forestry and conservation or preservation forestry. In fact, there is nothing like production forestry or conservation forestry. Forestry is only one, which ensures continuous reproduction in perpetuity and appropriate growth of trees of desired species in the forest; i.e. reproduction (either natural or by artificial methods) of species of choice together with maintenance of the GS at such levels which would produce maximum Current Annual Increment (CAI) in cubic volume/ha. Maximisation of per ha CAI of a forest crop directly relates to maximisation of carbon dioxide sequestered by it from the atmosphere in relation to that composition of species and age. This involves knowledge and practice of silviculture and that of forest management which enables the forester to make conditions favourable in the forest in accordance with the silvicultural requirement of the principal species, new reproduction of which is desired to be established on that site and grow satisfactorily. This ordinarily involves felling of mature trees and crops, as may be necessary.

It is painful to say that while granting approval to Working Plans, on many occasions, the Government of India refers to felling operations as a negative activity. Not withstanding the extent of over stocking in a forest under silvicultural treatment, they arbitrarily direct without any logic or scientific backing for the removal of only a portion of mature trees across the board. It must be understood that without felling trees, neither new reproduction of shade intolerant species can successfully be introduced nor stocking of the forest can be regulated to maximise CAI. It is important to mention here that the presence of old and mature trees or over-stocking in a forest neither optimally produces wood (CAI in volume) nor permits new reproduction to establish under their shade. Besides this, non-availability of space, both above and below the ground, also discourages new reproduction of trees to come up and grow satisfactorily. This in turn paralyses the whole process of carbon sequestration as reflected in the form of volume of wood produced annually.

It is a matter of fact that no tree individually or a forest as such grows in volume indefinitely. After it attains an age (specific to the species) or a level of stocking (specific to the site and composition of species), CAI starts diminishing rapidly until it becomes negligible, indicating thereby that carbon dioxide from the atmosphere is not being sequestered efficiently.

The popular perception that substituting timber with other materials like aluminium, steel etc. is good for the protection of the environment, as by using them we save trees from being cut, but without the smallest qualification, it is erroneous. In fact, the situation is reverse. By simple logic we can observe that while any timber item in the form of industrial wood or building material, or furniture would keep certain amount of carbon dioxide blocked inside it until it is burnt. Any substitute of it like steel, aluminium etc. always produces some carbon dioxide during its manufacturing process.

Importance of teak timber and its role in the country's economy, needs no elaboration. However,

I wish to add that one of the efforts to reduce global warming involves sequestration of greenhouse gases, of which carbon dioxide is a component from atmosphere responsible for over half the enhancement of the greenhouse effect. As forest-officers having control over about 22% of total geographical area of the country, it is our responsibility to manage them in such a manner that they sequester maximum amount of carbon dioxide from the atmosphere, which they are capable of, duly manifested in the form of production of wood of species which have long period of silvicultural rotation. This wood must also be capable of keeping the sequestered carbon locked in it for long period of time without getting destroyed by rot or by other means. Teak is one such species which richly meets this requirement as rotation period for teak happens to be around 80 years, and thereafter, when used as timber, it is known to have remained as such for several centuries.

Most of the unworked forests are over stocked, unbalanced, and irregular. Such forests are matured and have over matured trees. Non-working of most of such forests (which are otherwise productive forests) in various states over last several decades have turned them into useless jungles infested with undesirable weeds, climbers and shrubs. There is no control either over composition of species or their distribution in age or girth classes. These forests have no defined pattern of the age class distribution with many of the age classes/girth classes completely missing or suppressed. This has also made such forests incapable of sequestering carbon dioxide from the atmosphere efficiently on account of their over stocking.

Over stocking has also resulted into failure of reproduction, especially of intolerant species like teak, thereby reducing the proportion of teak and its other shade intolerant associates (which are mostly valuable species) in the forest. Tolerant species (mostly having no utility except as firewood) get encouraged, and over a period of time they too fail to reproduce as the site gets captured by more tolerant species and more photo efficient shrubs and woody climbers. This results in the loss of biodiversity as well. CAI in such overstocked jungles is negligible as compared to what the site is, in fact, capable of producing, had stocking been appropriate. In other words, such forests are useless from the view point of environment as they do not sequester carbon dioxide from the atmosphere in an efficient manner.

Similar is the case of teak plantations. Though, balanced and even aged stands of teak were successfully raised by the forest officers in the past, but as a result of long neglect and our failure to maintain them subsequently by appropriate thinning operations, have turned them also into useless unmanaged jungles. Though such stands do not have mature trees, but as a result of congestion, promotion to higher girth classes has suffered miserably. Stems are concentrated in lower girth classes. They are weak and suffer from disease and insect attacks. Also, they are not able to put up the desired amount of CAI.

Conclusion

Silviculture is a technique of managing forest tracts through scientific and judicious human intervention involving felling of trees to ensure reproduction of species of choice and its appropriate growth, such that the forests continue to render all direct and indirect benefits to the society in perpetuity. In this regard, an excerpt from Chapter-1 of the Book titled "The Practice of Silviculture" by David M. Smith is reproduced below:

Paradoxical as it may seem, and repugnant as it may be to certain influential segments of public opinion, useful forests are created and maintained chiefly by the destruction of judiciously chosen parts of them. One of the characteristics of life is death; if there were no death, there would be no space for the new life.

We are growing forest. Not those where CAI per ha is negligible or too small as is the case in most of the Protected Areas on account of, they being over-stocked.I would humbly suggest and request the senior foresters of teak producing to carry out survey, both in old teak plantations (of even aged stands) and natural forests, to find out the actual GS / ha existing there together with the pattern of distribution of trees in various girth classes. This can be done by enumerating entire tree population (100% enumeration of trees) in carefully laid sample plots of one ha and classifying the entire population in 15 cms. girth intervals starting from 0-15, 16-30, 31-45 cms and so on. From this enumeration data, GS per ha can be computed and pattern of distribution of trees in various girth classes can be seen by drawing N-G Curves. Then the desired distribution of stems in various girth classes corresponding to that Teak Site Quality Class, age and composition (available tables relate to pure teak) can be super imposed on N-G Curve so drawn together with desired volume (GS) computed there from. This will enable us to compare the extent of current stocking with that of the stocking desired to be maintained in case of a normal forest to produce maximum CAI in terms of volume of wood-reflecting maximum sequestration of carbon dioxide from the atmosphere.

Teak Forests of Karnataka – Stranger at Home

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Peninsular India is one of the four regions of the world harbouring natural teak trees; the other three regions are Myanmar, Thailand, and Laos. Karnataka is one of the states in the Indian Peninsula blessed with extensive teak forests. In fact, teak was the most widely distributed natural tree species in the forests of the state. Natural teak in varying proportions and with different growth parameters has been found to occur in all the districts, with the sole exception of Udupi, Bagalkote and Vijayapura. Teak attains fairly good growth in the moist deciduous forests, prominently in the districts of Uttara Kannada, Belagavi, Shivamogga, Chikkamagaluru, Mysuru, Chamarajanagar and Kodagu, with a limited presence in the Dakshina Kannada district as well. Teak trees of mediocre growth (pole-sized trees) are found in the dry deciduous forests, in Belagavi, Uttara Kannada, Dharwar, Haveri, Shivamogga, Davanagere, Chikkamagaluru, Mysuru and Chamarajanagar districts. These two stretches of forest are located primarily in the Western Ghats (malnad) region, with a small portion in the interior Karnataka (semi-malnad) region, in Dharwar, Haveri and Davanagere districts. The forests of Hassan district are not included in the above-mentioned forest stretches, as the district practically has no moist deciduous forests, most of these having been converted to coffee plantations long ago, and the dry deciduous forests of the district have been too severely degraded to support any promising growth of teak. As regards the Udupi district, its moist deciduous forests are very moist, almost tending to semi-evergreen, and do not harbour natural teak trees; the district does not have any dry deciduous forests.

Teak normally occurs in association with a number of deciduous hardwood species besides bamboo. Its gregarious occurrence is very rare. As regards the proportion of teak in the two above-mentioned productive forest stretches of Karnataka, it ranges from about 5 to 20 per cent of the tree crop in moist deciduous forest and from about 20 to 40 per cent in dry deciduous (teak pole) forest. The teak and its principal associates in the moist deciduous forests are very well-grown, attaining a girth of about 4-5 meters (12-15 feet) or even more, whereas the trees in the dry deciduous or teak pole forest are smaller, with a girth generally not exceeding 1.2 meters (4 feet).

The teak-bearing moist deciduous forests of Karnataka primarily belong to the sub-type 'Moist teak forest (3B/C1b)'. Some excellent patches of the sub-type 'Very moist teak forest (3B/C1a)' are found in the districts of Chikkamagaluru (Muthodi/Lakkavalli), Uttara Kannada (Gund/Virnoli) and Kodagu (Nalkeri/Hatgat). Towards the drier end, the sub-type 'Moist teak forest (3B/C1b)' turns into a 'Slightly moist teak forest (3B/C1c)' with a relatively lower proportion of teak than normally found in this sub-type (3B/C1c) i.e. (20-60%). The teak-bearing dry deciduous (teak pole) forests occurring in and adjacent to the Western Ghats region primarily belong to the sub-type 'Dry teak forest (5A/C1b)'.

The principal associates of teak in the moist deciduous forest are: *Lagerstroemia lanceolata, Terminaliapaniculata, Terminalia tomentosa, Dalbergia latifolia, Xylia xylocarpa, Schleichera trijuga, Dillenia pentagyna, Grewiatiliifolia, Adina cordifolia, Pterocarpus marsupium, Terminalia bellirica, Lannea coromandelica, Meliadubia, Madhuca longifolia, Mitragyna parvifolia, Kydiaca lycina, Bombax ceiba, Stereospermum* Spp., etc. The proportion of *Lagerstroemia lanceolata, Xylia xylocarpa, Schleichera trijuga, Dillenia pentagyna, Grewia tiliifolia, Kydia calycina,* etc. comes down towards the drier parts, where species such as *Anogeissus latifolia, Lagerstroemia parviflora, Albizia odoratissima, Diospyros melanoxylon, Madhuca latifolia, Buchanania lanzan, Semecarpus anacardium,* etc. start appearing. The typical bamboo is *Bambusa bambos; Dendrocalamus strictus* of very good growth, appears towards the drier end. Most of the teak associates that occur in the drier end of the moist deciduous forest continue to occur in the dry deciduous forest (5A/C1b) where, as already mentioned, the trees are of smaller dimensions. Santalum album starts appearing. *Dendrocalamus strictus* is common; Bambusa bambos is restricted to moister localities such as stream-banks.

Stunted, malformed or multi-stemmed, coppice growth of natural teak is found in the remaining districts, including Hassan district. In some districts, such as Ballari, Bidar, Kalaburagi, Ramanagara, Yadgiri, Hassan, etc., teak is even now conspicuous in a number

of dry deciduous or scrub forests. However, the species is occasional or sporadic in some of the dry deciduous or scrub forests of the remaining districts, namely, Chikkaballapur, Kolar, Tumkur, Chitradurga, Gadag, Bengaluru (Rural), Bengaluru (Urban), Mandya, Raichur, and Koppal. It is probable that in the distant past, teak occurred in the majority of the dry deciduous forests in the Eastern Plains and the interior Karnataka regions, but due to centuries of anthropogenic pressure, these forests have degraded severely, resulting in their transformation into scrub forests, from where teak has been virtually wiped out. It must be mentioned that the teak trees occurring in these regions are not known to have grown up to large timber-yielding dimensions, although some quantities of small timber were reportedly available when they were worked about a century ago.Therefore, planting teak in the forests of these districts may not give any tangible return. However, it is necessary to protect whatever natural teak is present in these forests for the conservation of the biodiversity of the tract. Most of the forests of the dry districts now belong to the types 'Southern dry mixed deciduous forest (5A/C3)' or 'Dry deciduous scrub (5A/DS1)' although remnant patches of the sub-type 'Very dry teak forest (5A/C1a)' are occasionally found in some of the districts such as Bidar, Kalaburagi, Kolar, Chitradurga, Bellary, etc. Prominent species occurring in these forests include, *Anogeissus latifolia, Terminalia tomentosa, Terminalia bellirica, Boswellia serrata, Chloroxylon swietenia, Sterculiaurens, Hardwickia binata, Dalbergia paniculata, Madhuca latifolia, Diospyros melanoxylon, Phyllanthus emblica, Cochlospermum religiosum, Acacia catechu, Buchananialanzan, Lagerstroemia parviflora, Lannea coromandelica, Bridelia retusa, Garugapinnata, Santalum album, Soymida febrifuga, Gymnosporiamontana, Butea monosperma, Albizia amara, Cleistanthus collinus, Cassia fistula, Wrightia tinctoria, Cassia carandas, Ziziphus, Spp., RandiaSpp.*, etc. Single clumps of *Dendrocalamus strictus* are met with sporadically, especially in sheltered localities.

Owing to their highly prized wood, teak trees from the forests of Karnataka have been in demand for many centuries. Most of the teak forests in the Western Ghats region were subjected to heavy exploitation that reached its peak in the early 19th century. Efforts to replenish the depleted stock in the natural habitat gave rise to the establishment of plantations. The need to raise teak plantations in the forests arose not only because of the rapid depletion of the existing stock of mature trees due to heavy exploitation but also because of the inadequacy or absence of natural regeneration of the species in its native tract. Although teak planting started as early as the mid-1850s, the momentum of planting picked up during the beginning of the 20th century, after the First World War. The scale of planting received a boost during the 1920s when the prevailing method of sowing seed and/or planting naked seedlings was replaced by the "stump planting" or 'root-shoot cutting' technique. The level of planting rose further after Independence (1947), when large-scale plantations were taken up. Most of the planting was done after clear-felling the moist deciduous or high forests and, to some extent, the dry deciduous or teak pole forests. The enthusiasm for planting teak was so high that it was taken in almost all the teak-bearing forests and also in some of the adjoining very moist deciduous and semi-evergreen forests that did not harbour teak. Planting teak in these non-teak-bearing areas provided discouraging results, as some of the indigenous species vigorously grew and competed with the teak plants.

In 1983, the Karnataka Forest Department took a policy decision to stop felling natural forests for the purpose of establishing plantations. With this shift in policy, the earlier system of raising teak plantations in clear-felled and burnt forest areas came to an end. By that time, the total extent of teak plantations in the state was about 1,20,000 hectares. From 1984 onwards, there was a sharp decline in the tempo of raising pure teak plantations, and the system was changed to that of carrying out diffused planting of teak along with other miscellaneous species in open or blank areas. Teak was also introduced in some relatively open high forest blocks by taking up under-planting or gap planting after salvaging the dead and fallen timber and firewood available in the regeneration area (RA). One important feature of these plantations was that burning was not resorted to in the RA before taking up planting operations. Another redeeming feature was the introduction of the method of planting pre-sprouted poly-bagged seedlings of teak in place of the traditional stump-planting method. The total extent of teak plantations raised so far in the state (up to 2019-20) is about 1,62,000 hectares, out of which about 42,000 hectares of plantations that were raised after 1984 have teak as the main species and a number of native miscellaneous species.

Teak plantations established before 1984 were primarily monoculture plantations, and on that account, they were often criticised as being detrimental to the biodiversity of the pristine forests. Pure teak plantations are also very prone to fire, which at times causes enormous damage to the forest ecosystem. With the focus of forest management shifting towards

biodiversity conservation, there was a growing demand for transforming these plantations back to natural forest. Within the Forest Department as well, there was a growing desire to do away with the culture of developing monoculture plantations and to take up mixed plantations as a step towards recreating natural forest. It was found that a number of miscellaneous trees had emerged as a result of the delayed or non-execution of the prescribed thinning works, interfering with the growth of the planted teak trees.The ban imposed on felling naturally growing trees also got in the way of carrying out the prescribed thinning work properly.

The emergence of miscellaneous native trees in the teak plantations has actually been a blessing in disguise, as it provides an opportunity for transforming the plantations to their original state by taking up thinning of the trees in a manner that focuses on the removal of certain teak trees and on the retention of the promising miscellaneous trees so that, in due course of time, the plantations will have sufficient well grown miscellaneous trees in association with a reasonable number of well distributed and well grown teak trees. This method of thinning, known as 'Crown thinning', is somewhat different from the conventional 'D-grade thinning' in which importance is given to the retention of the dominant and co-dominant trees and the removal of the dominated and suppressed ones. Crown thinning is considered suitable for reducing congestion in a mixed plantation while at the same time retaining or improving its mixed composition. Its basic principle involves the sacrifice of the less promising dominants and co-dominants in favour of the promising dominated and suppressed trees.

Out of the 162,000 hectares of teak plantation that have been raised so far in the state, about 40,000 hectares are located in the protected areas (Pas) i.e., national parks, tiger reserves, wildlife sanctuaries, etc. In fact, some of the best teak plantations in Karnataka are located in protected areas like Bhadra tiger reserve, Kali tiger reserve, Nagarahole tiger reserve, Shettihalli wildlife sanctuary, etc. As per an order dated 14-02-2000 of the Hon'ble Supreme Court of India, no forest produce, including grass, can be removed from the protected areas. In view of this, no thinning operations are possible in the teak plantations located in the protected areas. Fortunately, a sizeable number of these plantations are old and have already been subjected to at least the first three or four thinnings out of a total of six or seven. Besides, a good number of teak trees in the plantations are damaged every year by wild elephants. Spontaneous growth of various native species such as *Terminalia paniculata, Xylia xylocarpa, Lagerstroemia lanceolata, Chukrasia tabularis, Adina cordifolia, Lagerstroemia parviflora, Pterocarpus marsupium,* etc. is quite encouraging in the gaps created inside the plantations. Thus, congestion of trees is not a serious problem in the plantations located in the PAs and their transformation into a stage of natural forest is discernible in many of these plantations.

As regards teak plantations located outside the protected areas, the working plans of various forest divisions have identified about 80,000 hectares of plantation. These plantations have a sizeable number of teak trees, although, as already mentioned, most of the plantations have miscellaneous native trees in varying proportions. It is roughly estimated that out of these 80,000 hectares of plantation, about 55,000 hectares are dominated by teak, and the remaining 25,000 hectares have lost the characteristics of pure teak plantation due to reasons such as partial failure of teak, dominance of native species, planting teak in combination with other species, etc. The 80,000 hectares of identifiable teak plantations located in the territorial divisions constitute a very important asset that needs to be managed to its optimum potential growth. As already suggested, these plantations should be subjected to crown thinning with a view to arriving at a combination that more or less resembles a natural teak-bearing forest. In other words, if the plantation is located in a teak bearing moist deciduous forest, the proportion of teak at the end of the final thinning should be brought down to at most 20 per cent of the tree crop, and if the plantation is located in a dry deciduous forest, the proportion of teak should be brought down to at most 40 per cent of the tree crop. In respect of plantations raised in semi-evergreen or non-teak moist deciduous forests, the aim should be to gradually do away with teak, ensuring that no teak trees are left in the plantation after the last thinning or at the end of rotation.

With reference to the final harvest of teak, the 80,000 hectares of plantation with the territorial divisions should be closely monitored with respect to their prescribed rotation age, which is 120 years in respect of the moist deciduous forests (high forests) and 60/80 years in respect of the dry deciduous (teak pole) forests. However, even after the completion of the rotation, the plantations should not be subjected to clear-felling. It is also quite probable that all the teak trees in a plantation will not have attained the prescribed exploitable girth even after completion of the rotation age because the trees will have had a chequered growth history. Felling of teak trees should therefore be on a selection basis, i.e., only the teak trees that have reached the exploitable girth limit as prescribed in the working plan should be

removed. From then on, the plantation area should be treated as a natural forest and mature teak trees should be removed as per prescriptions provided in the working plans, preferably under the silvicultural system of Selection or Selection-cum-Improvement.

In the case of planting teak in the moist deciduous forests, the present practise of under-planting or gap planting with pre-sprouted polybagged seedlings should be continued, as this method of planting has given fairly satisfactory results. However, it must be ensured that planting of teak is taken up only in the teak-bearing moist deciduous forests and, under no circumstances, in semi-evergreen or non-teak-bearing moist deciduous forests where the planted teak has never been comfortable. Teak should be planted only in open and well-drained patches where light conditions are conducive to its growth and development. While considering the planting of other local miscellaneous species, a decision should be made based on the status of natural regeneration in the RA. Planting of teak has been suggested as its natural regeneration is poor or non-existent and artificial introduction is the only way to ensure continued perpetuation of the species in its native tract. With rigid protection measures, including fire protection, most of the local miscellaneous species, along with bamboo, will start appearing in the tract. Even teak planting should be widely dispersed so that the proportion of teak does not exceed its normal proportion in a teak-bearing natural forest, which is typically less than 20% of the tree crop in moist deciduous forests.

With regard to the planting of teak in the dry deciduous (teak pole) forests, anthropogenic pressure on these forests has been so high that most of these areas have considerably degraded, and the introduction of teak in these degraded areas may not give satisfactory results. Forest areas away from human settlements, on the other hand, have been relatively less affected by biotic interference. These areas may be considered for enrichment planting with pre-sprouted poly-bagged teak seedlings along with *Dendrocalamus strictus* and a few hardy miscellaneous species such as *Azadirachta indica, Pongamia pinnata, Holoptelea integrifolia, Phyllanthus emblica, Wrightia tinctoria, Alangium lamarckii, Sapindus emarginatus,* etc. In these areas, the proportion of teak may be kept as high as 40 per cent, which is the normal proportion of natural teak in a teak-bearing dry deciduous forest. It is also quite likely that with rigid protection, including fire protection, some of the local miscellaneous species such as *Anogeissus latifolia, Terminalia tomentosa, Diospyros melanoxylon, Cassia fistula, Butea monosperma, Lagerstroemia parviflora, Madhuca latifolia, etc.* would start appearing in these areas. Dibbling of sandalwood seed should also be done under the bushes just prior to the pre monsoon showers.

As already mentioned, teak was present in the forests of most of the districts in the Eastern Plains and interior Karnataka. However, these forests, except those from Dharwar, Haveri, and Davanagere districts, were not known to harbour teak trees of reasonable dimensions even in the distant past. The present condition of most of these forests is so degraded that teak has either been wiped out or become very scarce. As a matter of fact, the existence of these forests is highly threatened due to anthropogenic pressure resulting from centuries of use, overuse, and abuse. Ensuring the protection of these forests by any means is of the utmost priority. Therefore, the introduction of teak in these forests may not serve any purpose at this stage. However, this shortfall can be made good by planting teak in portions of the adjoining agricultural lands. As we are aware, the extent of agricultural land in these districts is very high, ranging from about 75 per cent to about 90 per cent of the geographical area of the respective districts. As teak is a native species of the tract and since the soil and light conditions of the farmlands are ideal for growing teak, it is advisable to earmark a portion of these lands for agroforestry with teak as an important tree species along with others such as *Azadirachta indica, Pongamia pinnata,* etc. Fortunately, the farmers of Karnataka, including those from interior Karnataka and the Eastern Plains, have already evinced a keen interest in planting teak on the borders and bunds of their agricultural lands. These initiatives augur well for the perpetuation of teak in its homeland.

Note: This article is a condensed version of the author's book titled, 'Stranger at Home – Teak Forests of Karnataka', published by Notion Press (2021).]

Status of Augmentation of Teak Resource in Gujarat

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1. Introduction:

In India Teak is predominantly grown in Gujarat, Kerala, Andhra Pradesh (A.P), Karnataka, Madhya Pradesh, (M.P) and Rajasthan. Nevertheless, teak is one of the few emerging valuable hardwood species that has been grown increasingly in planted forests in about 70 tropical countries throughout tropical Asia, Africa, Latin America and Oceania. For most of these countries, albeit being an introduced species, teak represents a good opportunity to produce quality timber and is a major asset for the forestry economy attracting large investments from the private sector. Planted teak forests according to various estimates cover between 4.35 to 6.89 million ha. They are known to exhibit a wide range of origin related variation in growth and wood characteristics. Breeding programs continue to be developed in many countries aiming at improving timber quality of teak planted forests. Most of them, however, are established with seeds of uncertain origin and quality and more recently with clones being produced in countries such as Brazil, Costa Rica, Côte d'Ivoire, India, Indonesia, Malaysia, Tanzania or Thailand. Increasing plantation area under teak is not sufficient solution to narrow demand and supply gap (FAO, 2011). The success and economic realization of any plantation is largely dependent on the quality of planting material used. Hence, it is necessary to take initiative in development of quality planting materials and its distribution to the farmers.

2. Significance of Teak And Teak Forest in Gujarat

Historically Gujarat played a prominent role in teak trade, evidences of Indus valley civilization shows that Gujarat as important place for teak trade with Greek and Mesopotamia. Gujarat ranks fourth among Teak growing states in India with an area of 121580 ha. Main source of teak sold in the name of 'Valsadi' Teak or Sag as the tree is locally called is a measure of wealth for the tribals who now have rights (with caveats) to harvest them. Sag tree was also the single most important reason for the British to lay claim to the Dang area. (The Hindu,2017). Teak is Highly decorative and grain quality is excellent.

Table 1. Natural Teak Forest distribution in Gujarat:

Sr. No.	Sub-type	Proportion of teak	Distribution In District	% Of Forest cover
1	3B/C 1b Moist teak forest	Teak constitutes fair to medium proportion (10-25%)	Valsad, Dangs, Navsari, Shoolpaneshwar Sanctuary	4.48
2	3B/C 1c –SlightIy moist	Teak constitutes medium to high proportion (20-60%)	Surat, Tapi,	3.86
3	3B/C2 - Southern moist mixed	Teak present sparsely	Surat, Tapi, Bharuch, Valsad, Ratanmahal and Dangs	6.75
4	5A/C1a Very Dry Teak Forest	Teak is present in high proportion	Panchmahal, Sabarkantha, Ginar and Gir, Dahod and Sabarkantha	4.32
5	5A/C1b Dry Teak Forest	Teak is present in high proportion, sometime in pure stand	Vadodara, Chota Udepur, Dahod, Panchmahal, Gir and Girnar	11.43

According to Champion and Sheth classification all forest types found in Gujarat, harbours teak. However, based on natural distribution of teak, teak forests can be classified into five subtypes as shown in Table.1. The Dry Teak Forest (5A/C1b) present in highest proportion of forest cover (11.43 %) where teak is present in high proportion and sometime as pure stand. These forests

are found in the district of Vadodara, Chota Udepur, Dahod, Panchmahal, Gir and Girnar (Table 1). About 30.84 percent of forest of Gujarat harbours teak with significant diversity and different ecotypes. 24.09 percent forest area is teak forest and another 6.75 percent forest area where teak is found sparsely. Moreover, Teak is among top five tree species for Trees Outside Forest (TOF). Popularity of teak is high among the farmers.

3. Efforts of Gujarat Forest Department For Augmentation In Teak Production Area

The higher volume of import in teak suggests the challenge of meeting the growing demand between demand and supply of teak wood in country as well as Gujarat state. The main challenge is to increase plantation under teak, however, the long rotation age of teak and comparative short-term gain from cultivating fast growing trees has diverted the land resource under teak in last decades. However, Gujarat Forest Department in close collaboration with farmers and Research and academic Institutes within state, are putting continuous effort in growing the area under teak. Some of the approach taken by Gujarat is presented below.

3.1 Developing Quality Planting Material to Increase Productivity

3.1.1 Candidate Plus Trees (CPT) selection

Plus trees are a superior phenotype that has been identified at a particular selection intensity (often 1: 500 to 5000) for growth, form, and other important attributes. They were then employed in breeding programmes or as a way to harvest better seeds to satisfy an immediate need. The chosen candidate and the trees will be helpful in creating planting material of the highest calibre for mass propagation and subsequent tree improvement programmes. By taking into account qualitative and quantitative qualities of economic relevance, such as stem straightness, roundness, tree height, clear bole height, girth at breast height, and disease resistance, the selection was made using the individual selection method. The provided Fig. 1 shows the effort of Gujarat Forest Department for year-by-year CPT marking. The Fig. 2 makes it obvious that the CPT marking for teak has an upward tendency from 2015 to 2021. There were 250 CPT entries marked in the year 2021. The chosen CPT will be helpful in creating planting materials of the highest calibre for mass propagation and upcoming tree improvement programmes. Additionally, the department at Navsari Agricultural University is working closely with the college of forestry on the evaluation of particular CPT of teak.

Fig. 1 CPT marking by Research Division of Gujarat Forest Department

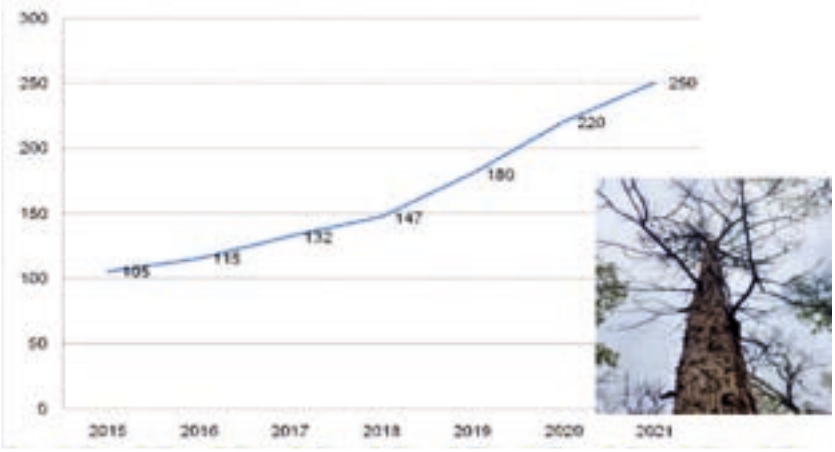

Fig. 2 Year-wise teak CPT selection by Gujarat Forest Department

3.1.2 Seed production areas (SPA) establishment

A seed production area is an upgraded plantation or natural stand where undesirable trees are removed and only desirable trees are kept to interbreed to produce large quantities of genetically superior seeds. The majority of the country's seed production areas were formerly upgraded plantations. SPAs have now been built on more than 5000 hectares around the nation. According to FSI (2001) report, Gujarat's SPA covers a

total of around 100 hectares. Gujarat Forest department has established many SPA specifically designated for teak. These SPA meet immediate seed demand of forest nursery and distribution to the farmers. Compared to seed form unidentified source, these seeds provide higher genetic gain in teak stem straightness and growth rate.

3.1.3 Clonal teak seed orchards (CSO)

Clonal Seed orchard grown from chosen clones propagated using grafting, cutting, air layering, or tissue culture. CSOs have been developed to produce genetically improved seeds. The CSO employs clones replicated by grafting. The greatest feasible profits are obtained in the shortest amount of time. The genetic base remains limited. Clones that have gone through multiple-trait selection methods are becoming increasingly superior. Gujarat forest Department has established six clonal seed orchards in different regions to meet the demand of improved seed.

3.1.4 Progeny Trials

Progeny trial is basis for identification of tree with higher genetic potential. The data from progeny trial is foundation for converting seed orchard to advance generation seed orchard and sometime progeny trial itself can be converted in to seedling seed orchard. Around two large scale and few other progeny trial of teak has been established for teak by Gujarat Forest Department (Fig. 3).

Clones that have gone through multiple-trait selection methods are becoming increasingly superior. Gujarat forest Department has established six clonal seed orchards in different regions to meet the demand of improved seed.

3.2. Mass Production of Quality Planting Material of Teak

Gujarat Forest Department has taken up initiatives in 2010 to establish high quality seedlings production centres at over a dozen sites to increase productivity and yield of teak wood in plantation and agroforestry. A tissue culture lab for production of teak seedlings has been established at Gandhinagar. Plants are supplied to farmers at concessional rate and stumps are prepared from superior trees and distributed to the farmers for the increasing of the quality plant production. Department has established 5 Hit-Tech nurseries where teak along with other important tree species of Gujarat are produced. Moreover, to meet the local demand of farmers, in each teak growing region, average 10-15 local nurseries are strengthened to produce quality planting material of teak (Fig. 4). These seedlings and stumps used for departmental plantation, under different schemes of Gujarat Forest Department and distributed to the farmers of Gujarat.

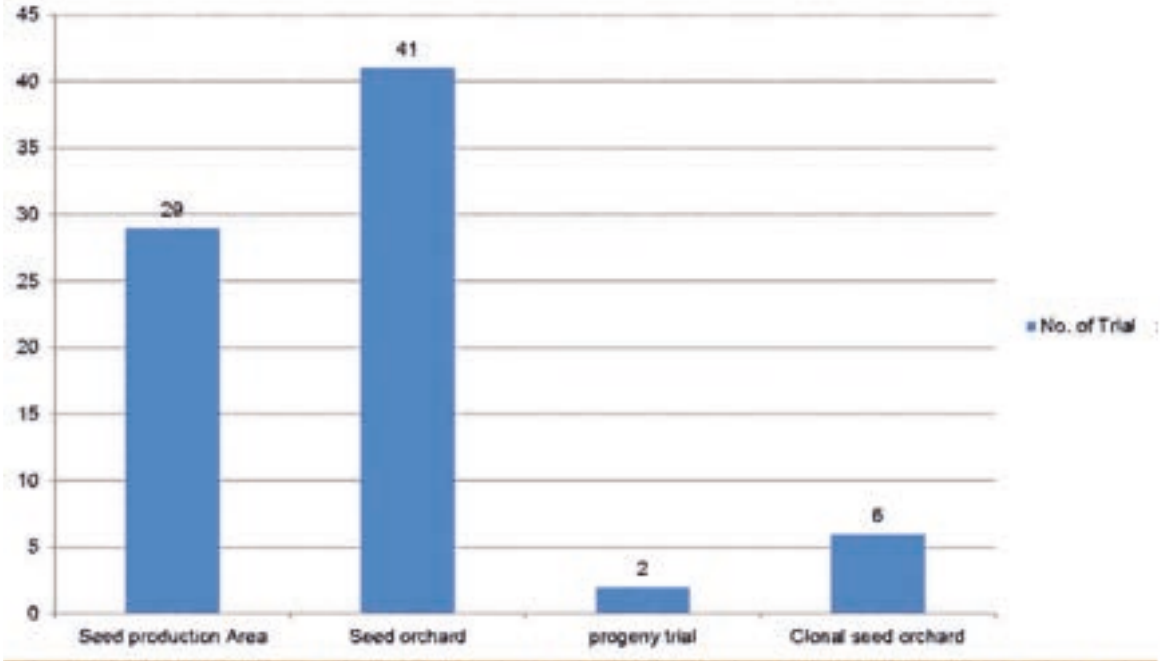

Fig. 3 Number of Teak trials by Research Division of Gujarat Forest Department

Fig.4 Teak nurseries established from improved seed of SPA and SO for seedling and stump production

3.3 Augmenting Teak Growing Area Establishment of Departmental Plantations

Teak plantation area in major teak growing districts of Gujarat represented in table. The highest plantation in last three years has been undertaken in The Dang district (3596.17 ha), other major district where teak plantation has been established by Gujarat Forest Department are Valsad, Navsari, Chota Udepur, Dahod and Godhara (Table 2).

Table.2 Teak Plantation area in major teak growing districts of Gujarat

Sr No.	District	Plantation year 2018-19 (ha.)	Plantation year 2019-20 (ha.)	Plantation year 2020-21 (ha.)	Average area in a year
1	Dang	1662.141	1079.6	854.43	3596.17
2	Valsad	551.89	279.15	222.96	1054
3	Navsari	112.43	80.16	56.56	249.15
4	Chhota Udepur	1620	930	1081	3631
5	Dahod	1614	1295	945	3854
6	Godhra	1520	995	688	3203
Total					15587.31

3.4. Augmenting Teak Growing Area by Distribution Of Teak Seedlings Under Different Schemes

About 90 million seedlings of all trees and around 5-6 million seedlings of teak are supplied annually at nominal charges under Van Mahotsav programme, and about half of them are planted by the farmers on their lands and the rest were distributed among industries, institutions, cooperatives, schools, individuals and other such sectors.

3.4.1 Teak Farm forestry scheme in The Dangs district

A scheme to raise teak plantations on tribal's lands was implemented in the Dangs district. Under this scheme, tree crop will be raised on the tribal's land at the cost of the Government and a provision for adequate assistance every month has been kept for the farmer for twenty years. Objective of the scheme is to restore tree cover on the private lands.

3.4.2 Maliki Yojana in The Dangs

Protected forest (PF) areas were converted into Maliki lands given as new Tenural lands to framers of the Dangs. In order to regulate felling on these PF areas and give monetary benefits to locals, Maliki scheme was implemented. Benefit of harvesting 10 tree, once in five years is given to a Maliki beneficiary in the Dang. E auction is organized by forest department to give a best price in transparency to Maliki beneficiaries (Table 3).

Table 3. No of Beneficiaries in Maliki Yojana 2017-2022

Year	No. of Beneficiaries	Amount (Cr)
2017-18	810	19.12
2018-19	665	15.76
2019-20	1548	33.55
2020-21	474	13.46
2021-22	298	11.28
Total	**3795**	**13.17**

3.5 Researches For Augmentation of Teak

Despite having ancient history of teak trade from Gujarat and currently sold with trade name of 'Valsadi' Teak, the GI tag is has yet to be obtained for 'Valsadi' Teak. Seed production and seed germination from seed orchards is low. Despite having diverse gene pool, population characterization for molecular, wood and morphology of teak of Gujarat is still in infancy. Number of CPTs selected are large, however genetic worth is yet to be confirmed for most of the CPTs. Development of suitable teak-based agroforestry model

3.5.1 Characterization for GI tagging the'Valsadi'

The GI tag is a precise identification of a geographical location. It is employed in the production of agricultural, natural, and manufactured items. For a product to be GI-tagged, it must be created, processed, or prepared in that region. It is also critical that the product possess a distinct quality or reputation. Local manufacturing is supported and protected by GIs (as opposed to global production) and create jobs for the local your community. They originated in villages or small towns and were mostly unaffected by industrialisation. This identification aids in the prevention of unauthorised use of a registered GI. The GI tag increases national and international marketability, hence increasing regional economic growth.

Gujarat was historically vital for teak commerce with Greece and Mesopotamia, as revealed by evidences from the Indus Valley civilization. The primary source of teak sold under the brand name 'Valsadi' Teak. Teak, or sag as the tree is known locally, is a measure of wealth for the tribals who now have harvesting rights (with limitations). The single most essential reason for the British to seize the Dang region was the Sag tree. South Gujarat was an important location where the Valsadi teak trade began in ancient times. It is still awaiting GI Tag. If it gets GI tag it can contribute to the increase in the trading value of Valsadi teak. The Gujarat Forest Department has initiated a study to characterize "Valsadi" teak for its potential for GI tagging, which is being coordinated by Dr. S. S. Jha, Head of the Department of Forest Biology and Tree Improvement at Navsari Agricultural University.

3.5.2 Dendroclimatic analysis of teak (*Tectona grandis* L. f.) annual rings:

Dendroclimatic analysis of tree ring will deliver perspective for many silvicultural and management practices in teak. Presently Gujarat Forest Department in association with Navsari Agricultural university (Dr S.K. Sinha) has been working on this aspect which is immensely helpful to the teak research. Moreover, Navsari Agricultural University, with the keen effort of Dr S.K. Sinha has developed AI model for teak identification on Xylorix platform.

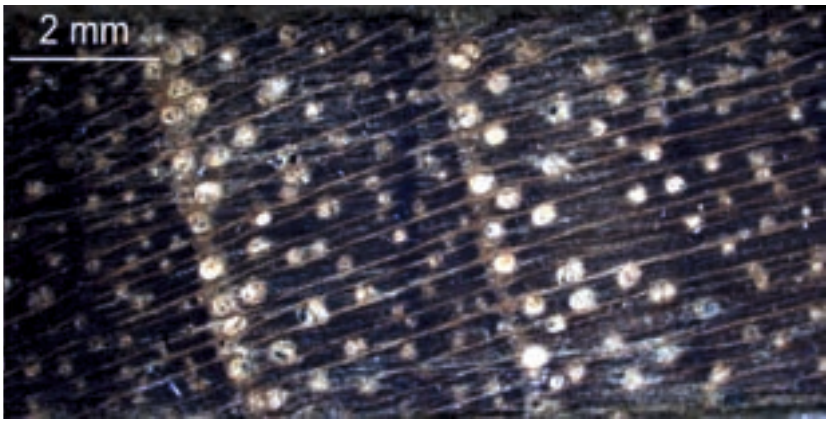

Fig. 5 Wood Identification AI models for Teak on Xylorix platform (developed under ICAR-NAHEP CAAST project, NAU, Navsari)

3.5.3 Molecular characterization of teak of Gujarat

Despite having diverse gene pool, population characterization of teak of Gujarat is still in infancy. Gujarat Forest Department in close association with College of Forestry, Navsari is working on characterization of teak of Gujarat. In initial investigation a large variation was revealed by molecular marker.

3.5.4 Suitable teak-based agroforestry model

Agroforestry has a significant potential to provide employment and additional income to farmers as well as to increase the forest/tree cover to meet specific national targets, reduce pressure on forests, more efficient recycling of nutrients by deep-rooted trees on the site, and better protection of ecological systems. Region specific teak-based agroforestry model development is under progress.

3.6 Other Initiatives By Gujarat Forest Department For Augmentation of Teak

3.6.1 Rehabilitation of degraded farm land using teak

Forest Department supports small and marginal farmers to take up teak plantation on their lands, especially degraded lands. These degraded farm lands are planted every year at the cost of the Government. In addition to the cost of plantation, assistance is also provided for three years as a part of subsidy.

3.6.2 Popularization of Teak farming through Farm forestry extension activities:

Farmer camps to transfer technology and also to promote adoption of teak under farm forestry scheme have been organised in every district for popularization of the species. Annually, about 750 farmer camps are conducted in the state.

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Status of Teak in Karnataka

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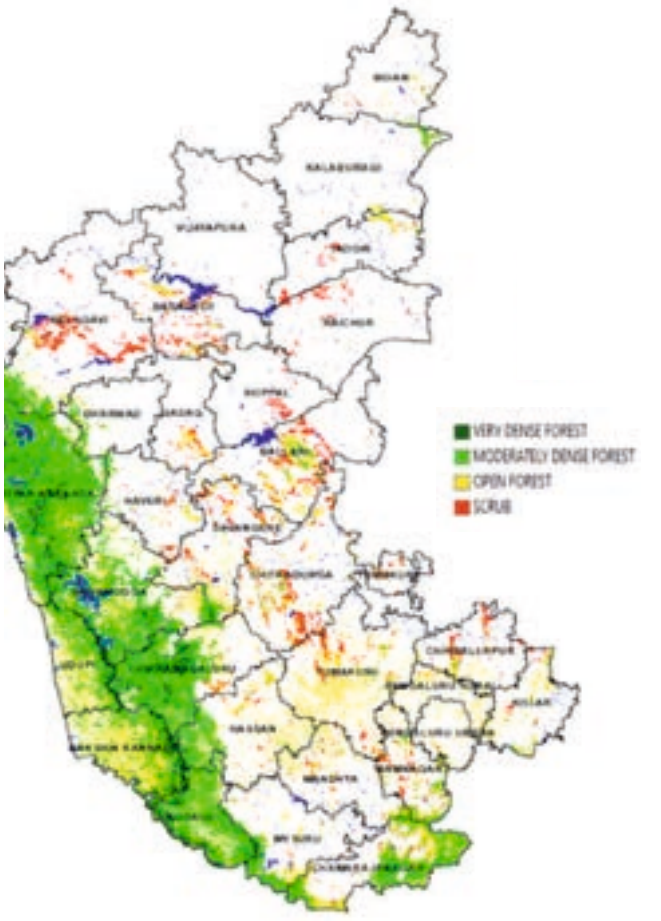
Teak Forests of Karnataka:

The natural teak has widespread presence in the forests of Karnataka. The districts in the Western Ghats bearing Moist Deciduous forests like Shivamogga, Chikkamagaluru, Belagavi, Mysuru, Uttara Kannada and Kodagu harbour excellent teak growth. In Moist Deciduous forests of Chamarajanagar and Dakshin Kannada district has localized presence of natural teak. The dry deciduous forests of the Western Ghats region also had moderate to fairly good growth of natural teak.

In the past, natural teak was present in many dry deciduous forests of interior Karnataka and the Eastern Plains, even the arid districts such as Ballari, Tumkur, Chitradurga, Gadag, Kolar, etc. had patches of teak in the hills such as Sandur, Devarayanadurga, Jogimatti, Kappatagudda, Royalpad, etc. However, due to anthropogenic pressures as well as removal of whatever came up for its prized wood, teak has more or less disappeared from these forests, with only a few patches still retaining some residual, stunted growth. Similar patches are also seen in Bengaluru Rural, Bengaluru Urban, Ramanagara, Mandya, Tumkur, Chitra-durga, Hassan districts. Sporadic and scattered coppice shoots of teak are found in the scrub forests throughout the state including the Eastern Plains and interior Karnataka.



Although rainfall and soil drainage are two important factors that determine the presence of natural teak, its growth and distribution are to a large extent controlled by the nature of soil and the underlying rock from which it is derived. Teak grows on a variety of geological formations but the quality depends on the physical properties of the soil such as depth, drainage, structure, porosity and moisture conditions.

Teak Plantations:

The history of teak plantation in Karnataka dates back to the early 1800s. The need to raise teak plantations in the forests arose because of rapid depletion of the existing stock of mature teak trees due to heavy exploitation and also because of inadequacy or absence of natural regeneration of the species in the forests. The tempo of teak planting picked up during the mid-1920s after the First World War and it received further boost after the Independence. As of now, Karnataka has about 1,62,000 hectares of plantation with teak as the primary species. Out of these, about 1,20,000 hectares which had been raised up to 1983 are more or less pure teak plantations. For various reasons including policy changes, court directives, lack of adequate funds, manpower, etc., management of the

* The views expressed in this article is of author only and writer is indebted to Shri Dipak Sarmah, retired PCCF (HoFF), Karnataka for permitting the use of any material from his book "Stranger at Home – Teak Forest of Karnataka"

teak plantations of the state have been a challenging task. More particularly, a policy decision taken in 1983 to do away with clear-felling of natural forest for regeneration purposes necessitated certain changes in the method of raising new plantations and in the management of the already raised ones.

Issues relating to loss of biodiversity in natural forest due to monoculture of teak also came in for sharper scrutiny and severe criticism. The overall impact of all these developments has been a slowdown in the activities related to the management of the teak plantations, at times bordering on inaction. A major problem relating to management of the teak plantations of Karnataka has been congestion of the trees due partly to inadequacy or lack of thinning and partly to spontaneous emergence of miscellaneous indigenous trees in the plantations. The trees occurring naturally in the plantations cannot be removed as per the present policy of forest conservation that was initiated in 1983. For various reasons including lack of sufficient staff/funds/time, more pressing activities such as plantation development and forest protection, highly conservative approach, etc., many teak plantations have either not been thinned at all or have been thinned inadequately or behind schedule. This has resulted in poorer growth of the trees. Adequate and timely removal of some selected trees from a plantation is of paramount importance for the continued growth and development of the trees that are retained in the plantation.

Karnataka has around 1,20,000 Ha of area under Teak plantations, out of about 80,000 ha falls under various territorial divisions and 40,000 ha under the Protected areas (National Parks and Wildlife Sanctuaries). The areas being worked as per Sanctioned Working Plans is given below-

Prescriptions under the Working Circles

The usual planting technique used for raising the pure teak plantation in Karnataka were in clear-felled areas after burning the debris from the area. The area was planted with teak stumps using crowbar method. This method is called as RAB planting method. The initial number of plants (during time of planting) taken for teak pole area was 1600 (at spacement of 2.5 m x 2.5 m) and for High Forest area was 2500 (at spacement 2m x 2m). The site quality for most teak plantations is taken as III/IV.

The Thinning regime in plantation was either 5 or 6 thinning. First two thinning being mechanical in nature whereas third thinning onwards silvicultural thinning was taken up. The cycle followed was 8th, 14th, 23rd, 32nd, 40th, 48th year or 10th, 20th, 30th, 40th, 50th year depending on final felling age. The thinning was executed in following ways-

1. First mechanical thinning: This thinning is mechanical in nature. The stems in the alternate diagonal lines have to be removed (50% will be removed).
2. Second mechanical thinning: In Second thinning stems in the alternate lines would be removed. Here also once again 50% of the stems will be removed.
3. Third thinning: (First silvicultural thinning). While marking for thinning, sound and promising trees at the rate of 395/ha to be retained by marking the rest for felling. The resultant average spacement will be 5.03 m (16 ft).
4. Fourth thinning: (Second silvicultural thinning). Second silvicultural thinning is done for retaining 321 trees/ ha. Sound and long clear-boled trees, which are promising, are retained and other trees are marked for felling. The selection for felling is from pre-dominants and co-dominants. The spacement after this felling will be 5.58 m (18 ft).
5. Fifth thinning: (Third Silviculture thinning). 267 trees/ ha are selected (best ones) and are retained. Rest is removed. The resultant spacement will be 6.12 m.
6. Sixth thinning: (Fourth or final silvicultural thinning) 198 trees / ha, which are sound healthy and vigorously growing, are selected and retained. The remaining 69 to be removed. The resultant spacement will be 7.10 m (23ft).

Mixed Teak Plantations

The pure teak plantations when not worked for several years tend to turn into mixed crop as the native root stock as well as regeneration of native species take over the weak teak and suppresses it. Many areas have turned into such mixed crop teak plantations. Not all native species are desirable to be retained in such plantations as the growth of robust teak trees gets affected. It is great challenge to carryout thinning operation in such areas. The usual prescription is for a thinning of one or other of the methods and grades already considered, supplemented by a list of species or groups of species in the order in which they are to be favoured when their interests clash; there is also often a

further proviso with regard to certain species which it is considered desirable to retain in certain proportion in the crop from silvicultural or site conservation priorities.

Similarly, since the early 1980s Karnataka had adopted a very conservative approach to forest management. In 1983, a ban was imposed on clear-felling of forest for the purpose of regeneration. With this ban, it was not possible to continue with the earlier system of raising teak plantation in clear-felled and burnt area. From 1984 onwards, plantations were raised by adopting a method of under-planting or gap planting using pre-sprouted teak seedlings raised in polythene bags in relatively open forest areas primarily with teak, along with other miscellaneous indigenous species; teak was planted in the open parts of the plantation sites and the miscellaneous species in the partially shaded parts. Although teak was the main species for planting, its proportion varied depending upon the openness and status of degradation of the plantation sites.

Future of Teak in Karnataka:

The demand of Teak as a source of building timber as well as for furniture is ever growing and with large quantities of timber being imported in lieu of its non-availability or non-affordability. The imported timber is an inferior substitute even if called by the same name. It is in the interest of forest management that the pure teak plantations are reintroduced in forests of the country so as to partially meet the demand for this wonder timber. In Karnataka's three major depots around 7000 cum of teak timber was sold in past three years with average rate of around Rs 100,000/- (Rupees One Lakh) per cum.

Following suggestions are made to maximize the yield from teak plantations-

1. The productivity of these teak plantations can be assessed by using sampling methodologies.
2. The plantations can be earmarked either for 'Conservation' purpose or 'Production' purpose.
3. Conservation purpose plantations should be aided to be converted into natural forests along with associated species by giving tending and cultural operations.
4. Production purpose plantations should be given heavy thinning including to associate species if necessary to aid growth of healthy teak trees in the plantation.

Karnataka has large tracts that can produce commercially available teak. The operations need to be timely and protection needs to be perfect. It is suggested that at least an area of 20,000 ha across the state is selected for the purpose of taking up pure teak plantations. The State has more than 3,50,000 ha of area under various plantations mainly monocultures like Acacia spp as well as Eucalyptus spp. The *Acacia auriculiformis* plantations in Moist deciduous and Dry deciduous areas that could be suitable location for teak plantations can be identified and pure patches of teak plantations raised on such locations.

Referances :

contact author at apccfworkingplan@gmail.com

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INDIAN LAMINATE MANUFACTURERS ASSOCIATION

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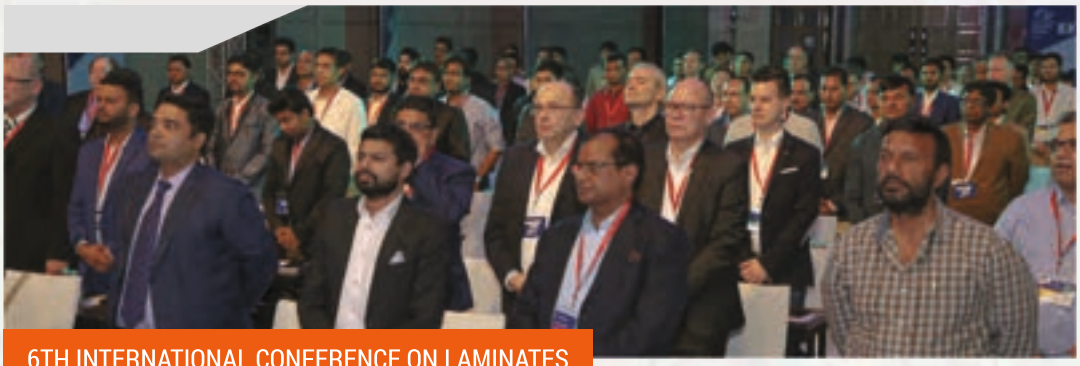

6TH INTERNATIONAL CONFERENCE ON LAMINATES

Strength of Unity

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

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

Key Achievements

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

Upcoming Events

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

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In Pursuit of the Lost Glory; a Paradigm Shift in Teak Management Protocols in Kerala

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Teak (*Tectona grandis*) is considered to be the cynosure of all timbers in the world. Kerala has an enviable status in the long history of nurturing this credited species with several milestones in its favour in the history of the teak plantations, be it the first teak plantation raised during the 1840s in Nilambur or the first stump planting done during the 1890's in Aryankavu. During the 20th century, there was an exponential growth in teak plantations, and until a few decades ago, Kerala had a clear edge over other states, with 30 per cent of the planted teak in India and a lead role in the trade of the much sought-after timber.

Bottlenecks in management

Though the system of raising artificial plantations of teak in the State had commenced long back, the annual target for raising teak plantations in the State was not more than 200 ha till the launch of the 5 Year Plan Schemes. Therefore, the site selection for teak plantations was strictly in conformity with the accepted principles, i.e., avoiding steep slopes, selecting sites where soil conditions are conducive for teak etc. Later, during the period from 1960 to 1980, there was an exponential increase in the annual target pegged at 2000 to 3000 ha to achieve the targets envisaged in the Plan schemes. Consequently, the quality of the plantations started declining over time.

Ever since the commencement of raising artificial teak plantations, the planting technique followed was stump planting in crowbar holes. But during the implementation of the World Bank aided Kerala Forestry Project i.e., by 1997, to be precise, a changeover in the planting techniques had taken place with the introduction of Root Trainer seedlings and pit planting. The result of the changeover is yet to be assessed notwithstanding.

The teak plantations hitherto were affected overtime by many debilitating factors and the chief ailing factors are identified as below.

1. Administrative chinks such as timely release of funds, availability of enough staff to supervise work timely.
2. Selection of unsuitable localities for plantations.

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Fig. 1: Conolly's Plot: world first manmade teak Plantation.

3. Untimely plantings and a lack of proper maintenance.
4. The diseases caused by Loranthus, borer attacks, invasive climbers etc.
5. Ignorance of edaphic factors and readiness for mitigation of natural calamities
6. Substandard and genetically inferior planting stocks
7. Anthropogenic factors such as grazing, fires, lopping etc.

Inappropriate species-site matching, substandard planting stock, untimely planting, improper land management, unscientific post-planting care and management, callousness to pest and disease management, domestic and wild animal damage, forest fire incidences etc. are also having a bearing on the poor performance of teak plantations.

Fig.2: Planting stock getting ready in a Central Nursery in Kerala

Priority changes

As per the statistics published by the Kerala Forest Department, as of 2020, the state has an extent of 76350 ha of teak plantations. This works out to almost 8% of the total area of the state. Also, this is about 50% of the total extent of plantations of various species raised till now. In general, the age of plantations varies from zero to 60 years and some of the plantations are more than 60 years old, the maximum age limit for final felling. Management of teak plantations normally follow 50/60 year rotation with a thinning regime of 5, 10, 15... years. Mechanical thinning begins in the fifth year, while silvicultural thinning starts in the tenth year. The plantations are spread over the five working circles and three wildlife circles of the state. A few plantations are being managed by the Research wing also.

In the 1980s, clear felling of natural forests came to an end, which limited teak plantations only to final felled areas i.e., areas clear felled on completion of rotation. The present teak plantations, by and large, consist of those which have not attained the rotation age, some of which have exceeded the rotation age, and those in the various stages of rotation.

With the passage of time, a fundamental change in the very objectives of forest management has occurred. The government-owned forests of Kerala were originally established to meet the increasing demand for timber, accruing benefits to the public exchequer. But in the light of the emerging precarious situation of dwindling water sources, there was a volte-face in the managerial perspectives, particularly with the conversion or rather reversion of the less promising and failed plantations to natural flora. Maintenance of robust plantations with best silvicultural practises and reverting of the failed woodlots to natural vegetation with the sole goal of conserving water sources are scrupulously being Implemented at present.

Fig.3: A well-managed teak plantation in Kerala

However, it is learnt that the stocking and productivity of several teak plantations managed by the Forest Department could be improved by proper scientific inputs. The future interventions on teak plantations will be focused on soil and moisture conservation going by the principles in vogue, and those teak plantations owned by the government, which are either failing or showing poor growth because of unfavourable climate/poor soil nutrition, and those located in wildlife corridors, disaster-prone areas or river-banks are to be restored to natural forests. However, the healthy and robust ones will be brought under intensive scientific management.

Eco-restoration.

Eco-restoration is suggested for teak plantations classified under low quality sites (subclass B.2: cannot improve). Eco-restoration can be achieved by either natural regeneration or species augmentation approaches or a combination of both. Low-quality sites may be directly added to the list of natural forests and permitted to undergo natural succession overtime.

Ecologically, teak belongs to moist deciduous forests, and hence preference should be given to natural associates of teak while contemplating replenishment. As a thumb rule, give preference to moist deciduous species of early seral stages, such as sturdy indigenous deciduous ones, which have a better survival percentage in harsh conditions. Augmentation with ecologically compatible plant species is recommended, with the planting of miscellaneous species (other than teak) already established in such plantations to be precise.

In low quality sites with scanty natural regeneration, an augmentation approach should be followed with indigenous species with a minimum of 3 years of maintenance. Uncontrolled fires and infestation by wild animals may deter the succession too. Strategies for checking fire ravages and wild animal attacks for 5 years should also be seriously considered.

Seeds, the fulcrum of success

It is a known fact that apart from factors like site selection, arresting soil erosion, avoiding replanting in unsuitable or elephant prone areas, timely completion of harvest operations, casualty replacement, weeding, soil working, manuring, thinning, etc., the most important factors that determine the prospects of teak plantations are the quality of seeds and planting materials. Good quality seeds collected at the right time from the right provenance, providing appropriate seed treatment and nursery practices are critical for good stumps or root trainer seedlings.

The Kerala Forest Department is leaving no stone unturned to ensure that genuine seeds are collected from identified Teak Seed Production Areas (TSPAs) for the next generation. With the age-old practice of using stumps as planting material giving way to root trainer seedlings, it has become mandatory to modify the silvicultural practices in vogue. However, teak seed production frequently experiences large fluctuations in quantity, quality, and even seed year.

Kerala is now poised not only to reclaim the imperial diadem as the leading producer of eminent wood available in Indian markets, but also to demonstrate the foresight and peerless managerial skills of the doyens in the arena aimed at salvaging the dwindling soil moisture regimes in the years ahead.

References: contact authors at : jpdusi@gmail.com

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 Farmers, 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 “ATAMNIRBHAR” 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-meets for taking forward initiatives of the industry.

WTA is a member of:

1. Bureau of Indian Standards (BIS) CED-9 CED-20 Committees.
2. President WTA (Shri S.C. Jolly) is a Member of Managing Committee of FIPPI.
3. President WTA (Shri S.C. Jolly) is a Member of Steering Committee of IPRITI.
4. President WTA (Shri S.C. Jolly) is a Life Member of IWST, Bangalore.
5. 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.
6. 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.
7. WTA and FRI (Dehradun) collaborated under Green India Mission to organize Industry-Institute- Farmer- Meets at Ludhiana (Punjab), Yamunanagar (Haryana) and Pantnagar (U.P).
8. 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 organized at Forest Research Institute, Dehradun.
9. 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.
10. 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.
11. WTA participated and organized multiple webinars in which leading subject-experts shared views / opinion about how to tackle the problems being faced by each stakeholder
12. WTA (Shri G. Rajput, V.P) participated in R&D work with Senior Scientist Shri D.P. Khali, FRI.
13. WTA organized numerous hands-on trainings with the Industry for aspiring Technologists.
14. WTA assists in industry placement of Technologists pan-India as per their skill-set.

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

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Raising of Teak Plantations in Telangana

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Teak (Tectona grandis) enjoys worldwide reputation as a quality timber on account of its remarkable physical and mechanical properties, particularly elasticity, strength and durability. Teak has a great demand in trade and hence it is imperative to develop its effective management strategies for obtaining good quality seedlings through silvicultural techniques.

Traditionally in Telangana, teak plantations were raised by clear felling, burning and planting root-shoot stumps in crowbar holes with a spacing of 2x2 m just after the first monsoon rain in the month of June. The initial stocking of 2500 plants per ha was subjected to thinning for the increment of height and diameter of the crop because teak is a strong light demander and does not tolerate root competition. The thinning regime in teak plantation was 7th, 14th, 22nd, and 32nd years reducing successively the number of stems per ha from 2500 at the time of initial planting to 1250, 650, 450 and 300. In 7th and 14th year (mechanical thinning without considering the quality of the stem form with prime purpose to provide proper growing space) and 22nd and 32nd year (silvicultural thinning depending on the site condition, rotation and objective of management) respectively. It is very crucial to provide appropriate space by executing proper thinning and retaining the target number of plants at the last thinning which should get a growing period of at least one third of the rotation before the crop is harvested. The rotation of 50-60 years is fixed for teak plantations when final extraction is taken up.

Most of the plantations in undivided AP were raised in site quality II/III and III in dry deciduous and moist deciduous forests of average annual rainfall of 1000 – 1200 mm and maximum temperature of 35 – 400 C. The average productivity of the teak plantations harvested during 1990 – 2005 after 50-60 years in undivided AP was 1.2 – 1.4 m^3 ha/year - which is against the national average of 2.54 m^3 ha/year -. The analysis of the final harvest indicates that there is a decline in the productivity over the years and the performance of teak plantations after 2000 is poor in traditional teak-bearing areas of Telangana in the form of survival, initial height growth and Mean Annual Increment (MAI) because of poor quality of planting stock raised from genetically inferior seeds, low organic content of the site, poor sub-soil moisture, repeated fires and heavy grazing, enormous soil and water erosion year after year making the soil compact and impoverished. Added to that, the initial competition of gregarious weeds, attack by teak defoliators, and untimely thinning led to the decline in productivity.

Intensive cultivation Strategy for high productive teak plantation in next 25 years

1. Site selection and site preparation

The major technical reasons that affected the commercial teak plantations were choice of unsuitable sites for teak cultivation and unrealistic projection of timber production. It has been seen that most of the plantations by private enterprises were located in unsuitable sites for teak, especially for the enterprises which promised high productivity from such plantations. Teak needs deep, well drained and fertile soils with an optimum pH of 6.5 to 7.5 soils, ameliorated with appropriate cultural practices to improve teak growth. With good monsoon and efficient management of rain and ground water, vast areas of degraded forest and fallow lands can be profitably put to use for teak cultivation.

To make the hard soil of degraded forest porous, the soil needs to be deep ploughed, sun-hemp seeds may be broadcasted and the same should be cut back before flowering and ploughed back into the soil. This process will enhance the nitrogen content of the soil. The pits of 45 cm^3 size pits can be dug up for the plants to be planted.

2. Quality Planting Stock

Productivity of teak plantation depends on the genetic and physiological quality of the planting material deployed in the field. Planting propagule may be either genetically improved seedling or of a tissue-culture origin of genetically improved clones. One can

use F1 hybrid seeds from a seedling seed orchard or Clonal seed orchard and germinate in primary beds. The germinants can be further culled intensively by using only 30-50% of the physiologically dominant seedlings for the production of root-shoot stumps. These stumps can be put in containers to have the stump-sprouted seedlings. They can be utilized as planting stock. Root trainer planting stock of genetically improved seeds do have the potential of better survival rate and better growth rate in the initial stages as compared to normal teak stumps.

The other alternative is deployment of high-yielding clones. While selecting the clones for planting, it has to be ensured that the climatic condition (broadly rainfall and temperature) of the planting area should broadly match with the area from which the clone originated. A

Fig.1: Teak clonal seed production area in Telengana.

great deal of research work was done to shortlist 5 top-ranking clones in terms of productivity and physical quality of stem. Clone APNBV-1 is the top-ranking clone followed by APNPMP-2, APSBC-1, APNDG-1 and APNPMP-1 from different agroclimatic regions of erstwhile Andhra Pradesh like Bhadrachalam (V R Puram), Narsipatnam (Maripakala) and Nandyal.

These clones can be mass-propagated by tissue culture or rooting of juvenile cuttings like Eucalyptus clonal propagation and planted in the field.

3. Irrigation

Drip irrigation system needs to be installed and the amount of water per day may have to be worked out. Fertification system should be in place to provide nutrients through the drip system or extensive water harvesting cum soil and moisture conservation measures has to be provided inside the plot.

4. Nutrient Management

Evidently, teak prefers fertile deep riverine alluviums; clay content, pH, nitrogen, moisture content, silica-sesquioxide ratio, drainage, soil texture, base saturation and root-available depth are major determinants of productivity. Teak is an exacting species and intensively managed plantations are expected to place large demands on soil nutrient reserves. In case of teak, generally the stand basal area and volume increment increases with increasing foliar N, P, K or Ca levels.

Another important issue to take into consideration is that mineral fertilizer application at the time of planting is only intended to help seedlings with rooting and early development and not to sustain the stand all along the rotation length. During the initial stages of development of a plantation up to canopy closure, the demands for the nutrients from the site will be very high and requirement of a wide range of nutrients are expected. In the early stages of stand development prior to the canopy enclosure, the annual rate of nutrient accumulation increases rapidly and the tree growth becomes very much dependent on the current nutrient uptake. Once the canopy is closed, the reduction in the rate of nutrient accumulation is associated with attaining maximum foliage biomass, high internal retranslocation of mobile nutrients (N; nitrate form, Mg, K., less mobile elements: Ca, Si, Mn, Fe) as well as increasing amounts of nutrients in litter fall and by capture from the atmosphere. This will decrease the nutrient contribution by the soil reserves. Therefore,

fertilizer response will be unlikely during the second stage, unless thinning is done to return the stand to its first stage prior to the canopy closure.

Application of 163 kg urea, 375 kg of Mussorie phosphate, 105 kg of Muriate of potash, 105 kg of quick lime and 373 kg of magnesium sulphate per ha is recommended for young plantations – two splits in first year and 4 splits in second and third year. Such applications generally aim at ameliorating soil conditions, especially the poor sites.

Using Nitrogen fixing trees like Leuacena could be a viable silvicultural option for stimulating early teak growth, especially on unfertilized sites. In very poor sites, it makes sense to mix teak with a nitrogen fixing tree species even upto 50 - 67% of the total stand density (one row of teak for every two rows of N^2 fixing tree on such sites) without any appropriate loss of teak yield due to the reduced initial density. Nonetheless factors such as site quality and managerial considerations are perhaps important determinants of the proportion of N^2 fixing species to be included in the mixture. Teak, being a strong light demander, the intercropped fast-growing multipurpose trees also must be managed (pruned/lopped etc.) to avoid any suppression of teak. Besides, many leguminous trees perform well when inoculated with appropriate strains of Rhizobia and the culture of vesicular arbuscular mycorrhizal fungi (VAM), implying the need for judiciously managing the N^2-fixing tree components.

5. Cultural Operation

Initial intensive soil working, elimination of competition from competing weeds in the early stages improves the establishment and stocking of the plants. Secondly Pruning and thinning are key silvicultural activities in a high intensive teak plantations, and together with the rotational length, are decisive factors for achieving different levels of quality and yield of round logs.

A. Pruning of side branch initials at the early stages of the growth of the plants makes the timber knot free and improves the stem form. Pruning produces considerable amounts of litter fall which will be recycled and taken up again by the stand trees. Practically three prunings are recommended for high input teak plantations: the first pruning should take place between the ages of two and three when the majority of the trees reach 5 meters in height and have a diameter of 6-7 cm. On an average, half of the total height of the tree should be pruned. Anything more can damage the total photosynthetic capacity (consequently growth will slow) and make the plants top-heavy leading to susceptibly for wind damage. The second pruning should take place in 5th year or when the trees reach 10 m in height. The last pruning should remove 60% of the total height when the tree reaches 12 m or 7 years in age.

B. Thinning in intensively managed plantations should be viewed by far the most beneficial operation to increase the productivity. This is because it reduces the competitive effect among trees through a plan of operations that remove a number of selected trees, allowing the remainder ones to increase the productivity in diameter. Hence the aim of increasing the teak plantation= productivity is to optimize the stand density and rotation age. The strategy adopted in teak plantation is to plant teak with initial stocking of 2500 plants / ha (2x2 m spacing) and allow to compete for height growth (for expression of the attribute of apical dominance) in the first quarter of the rotation and then carry out moderate to heavy thinning because teak is a strong light demander and also does not tolerate root competition. In case of irrigated plantations with additional inputs, the growth is faster than that in the rain fed plantation, hence thinning regime has to be early and intensive. The subsequent thinnings, which are silvicultural based on selection, are done to improve the diameter of the remainder trees.

A thinning regime has to be developed with an aim to give progressively higher diameter measurement in the retained crop. It is proposed to have 4 thinnings out of which first 2 thinnings are mechanically done without considering the quality of the stem form to provide proper growing space. Next 2 thinning are silvicultural in a rotation of 20 years and they are done on selection basis depending on site conditions, tree growth and objectives of management. According to the silvicultural needs of the teak plantation, it is very crucial to provide optimum space by executing proper thinnings and retaining the target number of plants at the last thinning which should get a growing period of at least one third of the rotation before the crop is harvested. Ultimately, the final harvested crop has to be reduced to a minimum of 200 in plants / ha in 15th year. Apart from rescheduling thinning regime, consideration may be given to preparation of stock map based on site quality, enumeration of crop in

the sample plot, computation of actual growing stock and application of yield and stand table. This is to ensure appropriate distribution of stems of various diameter classes such that the stocking of the crop at an age and for a specific site quality is maintained after thinning at a level where CAI is optimum and diameter is maximized.

C. **Plant Protection:** The appropriate protection measures for prevention of attack by leaf skeletonizer, Hyblea purea has to be adopted.

Probable Yield and Financial Return

I. Assuming an average of 5 m^3 ha - year - in a 20 year rotation, the production would be 100 m^3 in a hectare (with a stocking of 200 stems ha -). In other words, 0.5 m^3 per tree is the probable yield in 20 years.

II. The price of teak logs increased substantially in the market. As on today, the teak of average quality sells at Rs. 1,00,000/- per m^3. With a conservative estimate of doubling of current price, t is expected a market price of Rs. 2,00,000/- per m^3. With this projection, one can expect Rs. 2,00,00,000/- per ha after 20 years.

III. Commercial teak cultivation is profitable provided all necessary inputs are properly taken care of and the programmes monitored carefully.

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Augmenting Teak Timber in India: Way forward - A perspective from Chhattisgarh

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Introduction

From the beginning of 18th century, when the British started to exploit the natural teak in the Western Ghats for ship building to the present day furniture industry, teak has always been the queen of timbers. Though a native of Burma, India, Thailand and Laos, teak is flourishing as a plantation species in many Asian, African and Latin American countries. India has a history of professional management of teak for commercial purposes by German and British foresters, where the major objective was earning more and more revenue for the Crown in England. Over the years, over exploitation of teak has led to a mismatch between the demand and supply in the domestic market. In the recent past, India has become a major importer of wood, especially teak. India's import bill of wood and wood products for the year 2021 stood at a staggering 32,900 crore rupees (Statista, 2022).

Timber production in Chhattisgarh

As a continuation of the British style of scientific management of teak forests for timber, the Chhattisgarh part of erstwhile Madhya Pradesh too inherited that legacy. Though sal is the major timber species in Chhattisgarh, commercial harvest of sal by raising plantations has not found much favour and success. Therefore, harvest of sal is limited to natural forests through different silvicultural systems.

There are a few regions of natural teak forests in Chhattisgarh and the species comes up very well when raised as plantation across the State. Several teak plantations were raised in Chhattisgarh post-independence and the first commercial plantation by the State Development Corporation commenced in 1970s. Harvesting timber as a management practice is still practiced by the Chhattisgarh Forest Department and the production figures for the past 20 years are provided in table 1.

Table 1: Timber production for the period between 2001-02 to 2020-2021 by Chhattisgarh Forest Department.

Year	Production (in lakh cum)	Year	Production (in lakh cum)
2001-02	1.15	2011-12	1.69
2002-03	1.56	2012-13	1.75
2003-04	1.41	2013-14	1.78
2004-05	1.61	2014-15	1.66
2005-06	1.23	2015-16	1.34
2006-07	2.38	2016-17	0.79
2007-08	2.12	2017-18	0.76
2008-09	1.86	2018-19	0.80
2009-10	1.75	2019-20	1.20
2010-11	1.54	2020-21	1.09

(Source - Chhattisgarh Forest Department)

The Chhattisgarh State Forest Development Corporation or Rajya Van Vikas Nigam (RVVN) was carved out of its Madhya Pradesh counterpart in the year 2001. It is the major organisation in teak production business in Chhattisgarh.The major activity of RVVN is raising teak plantations, silvicultural management, harvest and sale of teak wood. RVVN is a self-sustaining corporate body which does not take any funds from the government to run its operations and pays the salaries of its entire staff from its own earnings. The production figures of RVVN for the past 20 years are provided in figure 1.

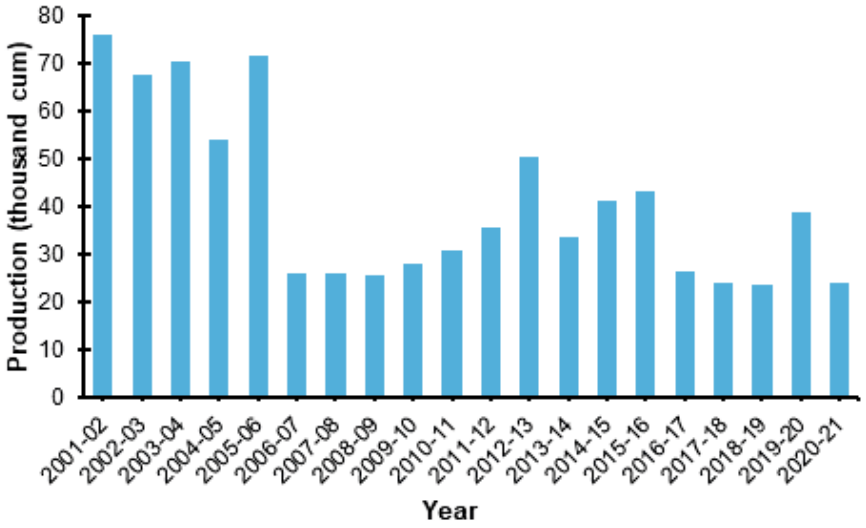

Figure 1.Teakwood production for the period between 2001-02 to 2020-2021 by Rajya Van Vikas Nigam, Chhattisgarh (Source- Chhattisgarh Forest Development Corporation.)

The production has reduced in the past few years as the Working Plans for some divisions are yet to be approved. The total area under teak plantations in RVVN is 1,25,000 ha. The production figures mentioned in table 2 below mainly represent teak wood production and sal and other species comprise not more than 10-20 percentage of the total timber production.

The current scenario

1. Chhattisgarh has a forest cover of 44 percent and there are not many avenues for block plantation of teak in the State.
2. The RVVN has only a small leeway to increase the area under teak plantation. From the biodiversity point of view, it is not advisable to convert natural forest into any kind of monoculture.
3. The Forest Department has several teak plantations of varied age gradations. The total area under pure teak plantation in the Forest Department is about 11,000 hectares spread across 400 different sites. Many of these plantations are good but there are also some plantations which are unsuccessful or of average quality. These are managed silviculturally but not as commercially and efficiently as the RVNN.

Table 2: Teakwood production for the period between 2001-02 to 2020-2021 by Rajya Van Vikas Nigam, Chhattisgarh

Year	Production (in cum)	Year	Production (in cum)
2001-02	787	2011-12	4700
2002-03	2086	2012-13	4102
2003-04	2817	2013-14	6323
2004-05	3128	2014-15	4128
2005-06	3344	2015-16	3991
2006-07	6917	2016-17	6401
2007-08	10275	2017-18	4278
2008-09	11147	2018-19	6112
2009-10	4770	2019-20	9755
2010-11	4066	2020-21	7341

(Source- Chhattisgarh Forest Department)

Augmenting teak production: The way forwards

1. Transferring the teak block plantations under the State Forest Department to RVNN: The block plantations of teak under the forest department can add an additional 11000 hectares to the existing teak forests of RVNN. This would result in an additional production of at least 10 – 20 percent of teak timber.

2. Reducing the felling cycle of teak plantations: To showcase a model to the farmers and entrepreneurs, RVVN can reduce the final felling of the teak plantation from the current 60 65 years to 30-35 years. This can be achieved by opting for high yielding tissue culture plants and comparing the performances of difference clones and choosing the best after a 5-10 year trial. This will also prove to the interested that we can start harvesting a timber species from the 11^{th} year through thinning, followed by regular thinning in the 16^{th}, 21^{st}, 26^{th} and 31^{st} year, and final harvest in the 35^{th} year. The farmers can even harvest between 15-25 years.

3. Promoting Agroforestry: Different types of agroforestry models such as agri-silviculture model, silvi-pasture model, horti-silvicuture, boundary plantations etc., are practiced by the farmers in Chhattisgarh in order to meet their diverse needs (Abhishek Raj etal, 2016). The trees mostly planted in these system are Acacia nilotica, arjun, neem, mango, karanj, etc. There is a great potential for introducing teak as an agroforestry species to the small and medium farmers and as a block plantation species to the large farmers. A small number of farmers have already started procuring superior tissue culture plants from Institute for Forest Genetics and Tree Breeding (IFGTB), Coimbatore and in the rainy season of 2022, more than 100 farmers have asked the forest department to provide them with high quality tissue culture seedlings. The Forest Department of Chhattisgarh is planning to take this up on a larger scale over the years.

Conclusion

These three initiatives of transfer of existing teak block plantation to RVVN, shorter rotation and high yielding clones and promoting agroforestry will definitely give a greater impetus for increasing the production of teak wood in Chhattisgarh.

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Working Office: Institute of Wood Science & Technology Campus,
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(To be Photocopied for Use)

Teak Cultivation in Tamilnadu : An Innovative Approach to Raise Quality Plantations

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Distribution of teak in Tamilnadu

Teak (Tectona grandis) is one of the most valuable trees of Tamil Nadu and it is indigenous to the State. Teak planting in Tamil Nadu was initiated during the early years of the last century in selected, suitable places. Attempts were made to raise teak plantations earlier in Mudumalai forests of Gudalur Division, between 1863 and 1875. It is documented that the natural teak population spread to many parts of the southern tracts from Parambikulam, Anamalai belt, i.e., the Seechally area of the present Indira Gandhi Wildlife Sanctuary.

Teak occurs in the moist deciduous forests of Coimbatore, Nilgiris, Madurai, Kanyakumari and Tirunelveli. Teak forests of the State are divided into Southern Tropical moist deciduous forests and Dry Teak forests.

Teak grows typically in the moist and dry hilly tracts of the Western and Eastern Ghats, between an elevations of 200mt to 1000metres.Teak is found mostly in the south Indian moist deciduous forest and southern tropical moist deciduous forest.

The South Indian Moist deciduous forests are found in the lower slopes of Anamalai, Nilgiris and Palani hills. Rainfall varies from 1500 to 2000 mm with dry season of four to five months. The chief features of this forest type are the prevalence of a leaf less period in dry season from February to April.

The southern tropical dry deciduous forest is usually found in lower slopes of Nilgiris, Anamalai, Palani and also on plateaus of Javvadis, Hasanur and Hosur. The annual rainfall is 1000 to 1200mm.

Silvicultural character

Teak is a strong light demander. Seedling require an intensity of light to the over 90%.It is sensitive to frost and drought. It coppices and pollards vigorously, up to about middle age.

Site factors: Teak grows well in alluvial soils, fairly moist, warm, tropical climate with pH ranges from 6.5 to 7.5. Teak showed poor growth and form on dry sandy soil, shallow or hard pan soil, acidic, laterite, black cotton and waterlogged soils. It occurs from sea level to an altitude of about 1200 m with 800- 2500 mm rainfall regime and also grows in very moist areas with the annual rainfall of over 3,500 mm. In the moist parts of the Southern India (west coast), the maximum and minimum temperatures of teak distribution ranges from 43˚C and 13˚C.

Rotation of Teak : In natural forest, rotation is 100-120 years In artificial regeneration it is 70-80 years and in coppice regeneration it is 40-60 years.

Planting stock

Generally stumps or seedlings are used as planting material. Stumps are prepared from the seedlings raised in the nursery for about one year. Then the seedlings are uprooted, all the leaves and secondary roots are removed and stumps (4 to 6 cm shoot with 15 to 20 cm tap root portion) are prepared. Stump planting is generally preferred and it is easy for transport. Stumps are prepared out of seedlings that are of 2.5 cm long, collar (2-3 cm) and 22-23 cm of tap root.

For seedling plantation:

Young seedlings are shifted to polythene bags containing soil mixture and maintained in the nursery for 3 to 6 months.

Seed collection, processing and Nursery techniques

Generally teak starts flowering 6 years after planting, but profuse flowering occurs after 15 years. **Flowering:** June to September and **Seed collection:** November to January. The number of fruits varies from 1150 to 2800 per kg. Teak fruit contains 4 seeds, but mostly filled with 1 or 2 seeds only. After collection, the fruits are cleaned and then sun dried for 2-3 days and stored in bags. Teak seeds can be stored for up to two years around 12% moisture content in airtight containers.

Seed treatment

Germination of teak is often poor due to dormancy. Pretreatment of the seeds by alternate wetting and drying of the seed for a week is required to break the dormancy before sowing. The seeds are kept in a gunny bag and dock the bag in water, preferably in a running stream, for 12 hours, then spread the seed in the sunlight to dry for 12 hours. This has to be repeated for one week. Further grading of fruits according to size help in improving germination.

Nursery techniques

The germination percentage varies from 30 to 50 % in moist teak and 5 to 10 % in dry teak. The seeds were sown in the raised nursery beds (10 x 1 x 0.3 m) prepared with soil and sand mixture. Germination starts 10 to 15 days after sowing and continues up to 35 to 45 days. The seedlings can be transplanted to polythene bags or it can be maintained in the nursery beds for 10 to 12 months for preparation of stumps.

Seedling Root System

Planting

It is done in pre monsoon period which has high success. Square or line planting is done in 45-60 cm^3 size pits for seedlings and for stump planting, 15 cm diameter holes and 30 cm depth are prepared. Spacing: 1.8x1.8 m, 2x2 m is generally initially applied. (Subsequently thinned in stages).

Plantation Management

A suitable land with good soil and rain fall of > 1200 mm may be selected for raising teak plantation. The land should be ploughed thoroughly and prepare pits (45 x 45 x 45 cm) in 2 x 2 m or 3 x 3 m or 3 x 4 m spacing before rainy season. Farm yard manure with soil mixture has to be prepared and filled in the pits. Seedlings are planted in the pits during rainy season. For stump planting crowbar may be used and pitting is not required. In the initial stage the plants have to be watered weekly, and regular weeding and pruning have to be done.

The branches have to be removed periodically without affecting the main stem. Drip irrigation is beneficial in farm lands. Irrigation reduce the rotation period and also enhance the productivity. Application of 50 g of urea and 30 g of super phosphate after six months and 75 g of urea and 60 g of super phosphate after 24 months of planting increases the growth rates. The fertilizers are effective for enhancement of growth in young teak trees than mature trees. Thinning (removing alternate rows) is done 5 years and 10 years after planting in plantation raised with closer spacing (2 x 2m).

Mechanical thinning is also needed. Teak can also be planted in bunds in south and north direction in such way the agricultural crops get sufficient light. Therefore teak plantation raised with good quality planting material or clones in good soil with limited irrigation and dry period with silivicultural practices can be harvested within 20 to 25 years. The teak growing in the canal areas in Thanjavur and Tiruvarur (Tamil Nadu) showed fast growth with good girth (> 150 cm) within 20 years and canal teak is harvested at the age of 30 years.

Tree improvement work

The teak improvement work in Tamil Nadu included the following works like, formation of seed stands, seed production areas, selection of plus trees, provenance trials and progeny trials, standardization of vegetative methods of propagation in many research centers.

The performance of teak have been evaluated in the various research centers, which are located in the 7 agro climatic zones of the state. Tree improvement work in Tamil Nadu commenced during 1967. Tamil Nadu is the home for many distinctively different native provenance of teak populations found in areas like asanur, Kalakad, Topslip and Annamalai. Establishment of seed production areas started in Tamil Nadu in 1970's.

Superior performing plus trees were propagated vegetatively and clones from different localities were assembled to form Clonal seed orchards. Teak seeds are one of the important species handled in the tree seed center at Coimbatore by Deputy Conservator of Forests, Forest Genetics Division, Coimbatore. Over 10 tonnes of teak seeds are handed annually in the seed center at Coimbatore.

Yield

It yields a volume of 1.58 cu.m of timber per year per tree (increment). The average productivity of teak in Nilambur teak plantations was 2.85 m^3/ ha/year in 53 years rotation period. The trees grown in farm lands, grow faster and produce more biomass when compared to plantations in the forest areas. The quality of teak timber in farm land at 12 years was found to be similar to that of 20 years in forest land.

Technological intervention for successful cultivation of Teak:

Considering the fact that, the success of present day plantation models are largely driven by technology, it is high time that the same strategy has to be explored for the forest plantations of the state such as the teak plantations, in which Internet of Things (IoT) enabled technologies like 'smart forest' can be considered. Incorporation of futuristic technological models in teak plantations will ensure better efficient management of the plantations as well as the sustenance of the scheme.

(a) Smart forest

Current management of Forests are done manually with less or no technological intervention. There is very little or negligible data available presently in inventories, the improvement of which will lead to better manage-ment of forest plantations. Also, increasing Green Cover in the current context is even more possible if we concentrate on tree outside forests.

Components of Smart Forest

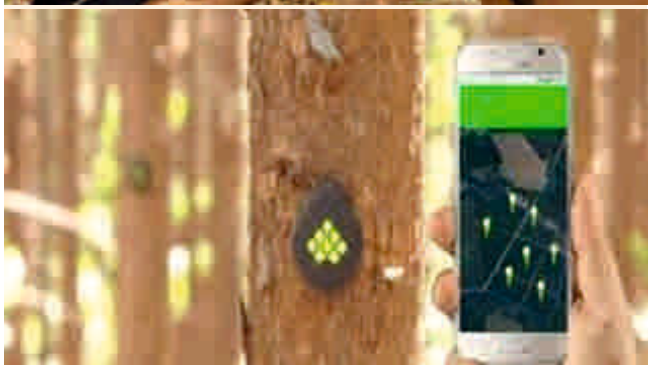
There are three main components of smart forest viz. Forestry Big Data, Forestry software and Digital forest inventory.

1. Forestry Big Data

Big Data is a concept that describes the large volume of structured and unstructured forest data that is generated every minute.

Components of Big Data

1. Volume – Massive volume of data generated.
2. Speed – Transport huge amount of information in matter of minutes.
3. Variety and Variability - Data on the entire forestry asset and different types of information (genetic material, diameter, height, location, etc.)



4. Data analysis - Data has to be correlated or linked wherever needed.

2. Forestry software

Forestry software is a system that integrates and maintains centralized data on both forestry asset and the department.

Functionalities Example - The software is integrated with the field App and automated locks to prevent collection from taking place in an improper place. These features are known as geofence, which is nothing more than a distance limit (security) set by the user.

3. Digital Forest Inventory

Traditionally, forest inventory is carried out without adequate planning and guidance, with poorly prepared workers or with insufficient training, this may not only lead to low accuracy and errors in volume estimates, but it will also prevent the department from intervening in a way effective, not reaching the potential productivity of the forest plantation.

Technologies in forest inventory

1. Use of tablets to collect data in the field.
2. Data collection applications.
3. Using a database digital forest as a basis for calculation algorithms.
4. Online Monitoring Systems.

Operation of a Smart forest

A smart forest works with certain number of specialized dendrometers (smart forest device) and concentrators, the numbers of which vary according to the sample plot size.

Dendrometer

A dendrometer is an instrument used to measure the diameter of the stems of trees.

Technologies in forest inventory

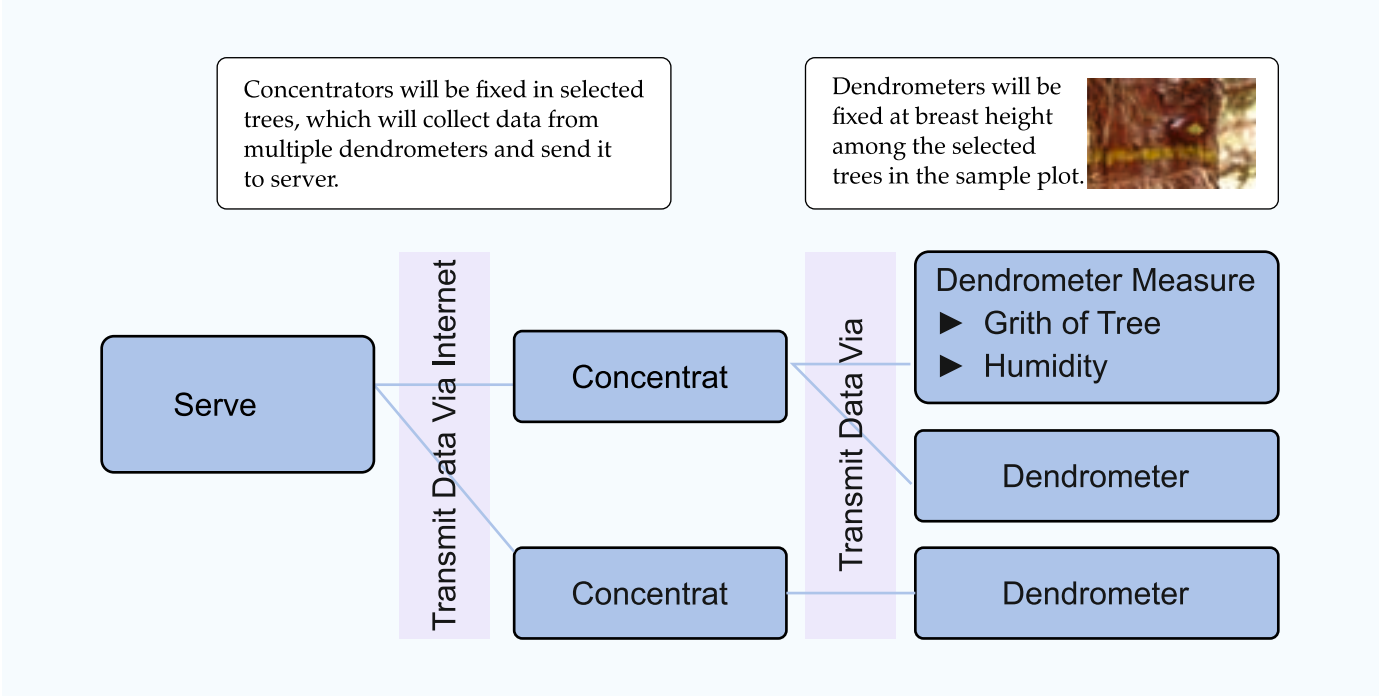
1. Use of tablets to collect data in the field.
2. Data collection applications.
3. Using a database digital forest as a basis for calculation algorithms.
4. Online Monitoring Systems.

Concentrator: A concentrator is a device which collects the data from a set of dendrometers and disseminates it to the server for data analysis.

Working:

Dendrometers will be fixed at breast height among the selected trees in the sample plot. These specialized dendrometers will have temperature and humidity sensors as well. Concentrators will be fixed in selected trees, which will collect data from multiple dendrometers and send it to server. The specialized dendrometers will collect vital data such as; Girth of tree, Humidity, and Temperature.

The dendrometers will collect this information through strategically located sensors across the designated forest area/plantation. Further, transmit this data periodically to a hub/server via Bluetooth or LoRA WAN gateway which in turn send it to the cloud. This data over cloud can then be used to build further analytics. This will help in understanding the growth patterns and helping to arrive at better decision making with regards to forest plantations.



Advantages of smart forest with respect to teak plantations

a) Daily, weekly or monthly change in the girth value is sent immediately from the dendrometers.

b) Calculate the local seasonal changes using the humidity (rainfall pattern) and the temperature and how the growth of tree is affected by the above factors.

c) Finds the rate of growth at different ages and seasons correlated with the local soil factors.

d) Better analysis and decision making of forest plantations with regards to spacing & thinning of trees. (eg: the ideal time to carry out the thinning process).

e) Realization of better revenue through achievement of a higher yield of teak plantation.

f) Better growth of trees leading to better carbon sequestration.

g) Creation of a digital inventory for the plantations and better, accurate documentation of the scheme.

h) When smart forest technology is practiced widely, the health of a forest plantation can be assessed without physical inspection, leading to saving in cost and time.

I) Detect forest fire (Temperature sensor).

j) Detect bacterial or pest attack which inhibits the growth of the plantation. i.e. No considerable increase in a particular tree when compared to other trees.

k) Generated data to farmers, scientific community, open data, promotion of farm forestry.

Popularizing the idea of smart forests to raise quality plantations.

The project will start to create its own digital database with factors such as; Periodical growth of the tree – Species specific, Soil factors, Humidity factors, Temperature factors, and Altitude factors. This database can be shared with the public. Once the data values are shared with the public, they themselves can make smart decisions by correlating the factors and analysing them. And it can be implemented in their respective farms and fields.

The Smart Forest project in itself is a novel idea of bringing latest technology into the forestry sector. This will be the first step to bring startups to see the vast potential of coupling latest technology and forestry. A huge thrust needs to be given to the technology-oriented management of forests. When startups see the potential revenue generation capacity in certain forestry sectors, they will automatically join the race in developing the means to reach the end.

The Smart Forest project will develop a technology to manage the production forests. Once the project is successfully implemented by the state department, it will enable more people to adopt the same technology in private farms as well. This will help in increasing overall productivity of the production forests in India and increased forest cover.

Conclusion:

As mandated by the National Forest policy, it is necessary to increase the country's green cover to 33%. To achieve this target there is a need to raise quality plantations in the forest area and also through various agro forestry models. In this direction, interventions like promotion of smart forest can help the state governments to achieve the target at the earliest.

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Augmenting Teak in Andhra Pradesh: Overview, Scope and Future Strategy

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Year 2022, India is celebrating 76th Inde pendence Day and the country is overjoyed with Azadi ka Amrit Mahotsav. We have come a long way from the 'stroke of midnight' and it is a matter of great pride for every Indian. What begins next is the 'Amrit Kaal' i.e. the period of next 25 years to 2047, the hallmark of which is going to be the 'Atmanirbhar Bharat'. 'Atmanirbhar' i.e., self-dependence and achieving it will be the major focus of the country be it economy, defence or any other sector. With this same objective, the forestry sector too is expected to respond and rise with additional responsibility of sustaining the ecosystems and environment.

Timber demand is continuously going to rise with increase in population and change in living standards. This demand is going to be met by domestic supply and imports of various kinds of timber, round logs, sawn timber, plywood & veneer and furniture etc. Among all timbers, Teak is in great demand due to its durability, strength, appearance and easy working. Given this gap the import of teak is rising continuously and the burden on exchequer is huge. For instance, in 2019 alone, India imported more than 1 million m^3 of teak roundwood logs. Compared to this, the production of teak from domestic sources including natural forests and plantations etc. is only about 50,000 m^3 annually. The gap is enormous and the forestry sector needs to address the issue boldly. In this article an attempt has been made to highlight and suggest measures to improve teakwood productivity and also increase production with special focus on the state of Andhra Pradesh.

Status of Teak in Andhra Pradesh

Andhra Pradesh, the 8th largest State of the country with geographical area of 1,62,968 sq km which is 4.96% of the geographical area of the country is situated on the southeast coast. It has the second longest coastline after Gujarat. Physiographically, the State can be divided into coastal Andhra and the comparatively drier Rayalaseema region. The state experiences hot and humid climate with annual rainfall between 1,100 mm to 1,250 mm and the annual temperature varies from 15°C to 45°C. The State has a variety of vegetation types rich in flora and fauna. Its varied topography ranging from the hills of Eastern Ghats and Nallamala to the shores of Bay of Bengal, supports varied ecosystems. Total forest area of the state is 37,258 sq km which is 22.86% of its geographical area. Eastern Ghats region of the State is home to dense tropical forests, while the vegetation becomes sparse as the Ghats give way to the Deccan Plateau, where shrub vegetation is more common. The vegetation is largely dry deciduous type with a mixture of teak, and species of the genera Terminalia, Dalbergia, Pterocarpus, Anogeissus etc. Red Sanders (*Pterocarpus santalinus*) is endemic to Andhra Pradesh and is highly valued for its rich red colour and grain pattern.

Teak is naturally available in the Forests of Nallamala and Eastern Ghats in Andhra Pradesh. It is naturally spread in Visakhapatnam, Rajahmundry and in small areas in Kurnool and FDPT Srisailam Circles. According to Champion & Seth classification and as per ISFR,2021 5A/C 1b Dry teak forest is spread over 551.72 sq.km in Andhra Pradesh.

In A.P., a large extent of Teak plantations has been raised in Visakhapatnam and Rajahmundry Circles as the area is suitable for raising teak. Kakinada, Chintur (East Godavari), Narsipatnam (Visakhapatnam) and Eluru (West Godavari) divisions have 95% of teak plantations in the state. In other areas like Nandyal, Prakasham, Chittoor etc., teak grows naturally but monoculture plantation of Teak is not possible due to climatic conditions. As of now around 25,289.97 ha of area is under teak plantation. The rotation period is 50 to 60 years. However the production has been less in recent times. For instance, taking the data of last 5 years, on an average only 1600 m^3 of timber has been extracted from plantations which is meagre.

The Silvicultural operations employed by AP Forest Department are as follows: -

1. Planting technique: Well grown and pest resistant teak stumps / bag plants are planted in blocks at an espacement of 2M x 2M in 30 cms. cube pits/crow

bar holes. Replacement of casualties upto 15% will be done in the year of planting.

2. Thinnings: Four thinnings are prescribed i.e., at the age of 7th year, 14th year and 21st year and 32nd year. The first being mechanical thinning, the balance three are silvicultural thinnings. At the end of 1st, 2nd 3rd and 4th thinnings, the stems to be retained will be 550, 300, 200 and 125 per hectare respectively.
3. Rotation: Age of 50-60 years is considered for rotation.
4. Silvicultural System followed: Clear felling followed by regeneration through planting or coppicing is practiced.

Given the unique climatic conditions and site suitability to grow teak, Andhra Pradesh is strategically placed to harness the potential of teak production and contribute to self-reliance. However several limitations need to be overcome and strategies designed to achieve the target of increasing productivity meeting demand. A few have been discussed in detail here.

Issues and Challenges for increasing Teak Production

Problem of augmentation from natural forests can be broken into three parts:

a) Existing well stocked teak areas: Well stocked areas need to be demarcated and there is immediate need to sustainably harvest and manage well available growing stock. These are the low hanging fruits which need to be harvested to promote further regeneration of Teak. Due to non working of these areas, high forest nature is almost lost and we are moving back to coppiced base regeneration. We have to let these areas regenerate again by making appropriating prescriptions and provisions in working plans.

b) Existing poorly stocked teak areas and failed plantations: Teak doesn't like competitions and we need to immediately follow right thinning and cultural operations in these areas.

For example, reason for failure of Ahobilam Teak plantations in Nandyal WL division is not onducting any thinning at right time. Competition have to be removed to allow these teak trees to put on girth. Regeneration is poor in such areas and suppressed, for example, bamboo regeneration has taken over and Regeneration of teak, rosewood etc. is suppressed in historical heritage teak plantations of GBM. These lapses we must address to develop well stocked teak forests whichcan be harvested in near future.

c) Artificially stocking new areas with teak: Teak plantations can be grown with miscellaneous species as well as monoculture methods. Open and degraded forests can be identified and artificial regeneration can be taken up with high quality planting material to rehabilitate them. ANR and gap planting too can help in increasing productivity. We need to identify and demarcate special areas within reserved forests for production forestry.

First and foremost, the main reason of the decreased productivity is the shifted focus on conservation forestry and restrictions on felling in natural forest especially after the National Forest Policy 1988 and more so after Godavarman judgment of Hon'ble Supreme Court in 1996. With no harvesting in natural forests, not enough carbon is captured as forest increments are becoming insufficient. The core of above all arguments is the scientific management of forests. Sustainably managing teak forests and plantations is the need of the hour for which forest services are created rather than leaving potential production forests unmanaged.

To share the burden and infuse intensive management more areas to Forest Development Corporations (FDCs) can be allotted. FDCs have to be utilized optimally and it is a lesson that where ever FDCs are strong good production results are achieved. However, it shall be kept in mind that as the areas suitable for teak are already very less, site quality deterioration should not be allowed.

Strategies for increasing Teak Production

Strategies to augment teak can be designed based on target area, supply of quality planting material, focusing on research and development and creating marketing linkages. Further, to achieve the production goal we need to focus on both natural forest areas as well as Tree Outside Forests (TOF).

1. Tree Improvement and Supply of Quality planting material

Quality planting material (QPM) needs to be supplied for departmental as well as plantations by farmers. The planting material must be suitable to the local conditions and hence a new concept of Target Planting (TP) and TP material (TPM) is being adopted. The two basic criteria for success of teak plantations are

the yield and quality both of which are regulated by site and inputs. QPM or TPM must target yield by reducing the rotation age. Present rotation age of teak for plantations by the forest department is 50-60 years and for the farmers 20-25 years in Agri-Silvicultural systems. Superior clones can be identified and propagation by various means can be practiced. AP Forest Department has conducted successful research in which 18 clones were tested and 5 have been found highly successful with yields of upto 8 m^3/ha/yr (compare it with average Teak productivity in India which is 1.41 to 2.83 m^3/ha/yr whereas in African countries it is 15 m^3/ha/yr) with rotation of 20-25 years. This is an excellent result and must be replicated by large scale propagation. Further these clones were tested and certified by IWST for the wood quality too. State Silviculturist, Tirupathi has raised the nursery from these clones and these can be replicated throughout other divisions too.

For future course of action, apart from above, tree improvement needs to take benefits from genetic modification methods especially and biotechnology. These would allow researchers to manipulate the product and planting material quality based on requirements. This would go a long way in adopting TPM and farmer centric approaches.

With regards to seeds, quality seed collection, locations, and sources for each variety need to be clearly established, documented and well disseminated by making information readily available and procurement easy. Various supply chains such as of NSC, APSSDC, RBKs, KCCs etc can be utilized for this purpose. Online databases such as repositories of seed sources with their attributes can be developed and widely publicized.

Further research labs need to be connected to potential growers in the field so that new clones/seeds etc. can be tested and adopted quickly. Each clone with its site specificity, growth parameters, input requirements and availability of planting material nearby should be documented in online/offline methods and widely disseminated to farmers, public etc.

2. Promoting Agro-Forestry and Tree Outside Forests (TOF)

Andhra Pradesh has a good potential area for promoting cultivation of teak in farmlands. Site is suitable, a market is available nearby and there is already a considerable production of teak from agricultural lands. However to meet the demand locally it is required to expand the area under teak cultivation sharply. It is important to mention here that almost 85% farmers in India and AP too are small and marginal with land holdings less than 2.5 Ha and getting smaller with generation. With high dependency on land and less efficiency pressure is many fold on the smaller land holdings. Since the gestation period is high, these farmers cannot afford to lock their lands for 20-25 years. To incentivize such small holders plantations, which is the only option majorly, policies must provide for subsistence during the lock in period.

Secondly, once farmers agree to take up teak plantations they must be supplied with Target Planting Material (TPM) of fast growing certified varieties, right guidance on planting techniques, agro forestry models, silvicultural and cultural operations. In Rayalaseema region for instance it has been observed that many farmers who grow teak in bund or block plantations end up getting low growth, poor stocking due to lack of above inputs. Rayuthu Bharosa Kendras (RBKs), Village secretariats and volunteer system, Kisan Call Centres (KCCs) etc can be utilized by linking with local forest departments. Farmer Producer Organizations (FPOs) as a Special Purpose Vehicle (SPV) can be formed and motivated for production and marketing of Teak. Publicity material on each stage can be made available through banners, pamphlets, wall paintings, print and electronic media. During Kisan Mela in Nandyal we organized a stall and workshop for farmers to demonstrate different wood and motivate them to take up tree plantations. On this occasion a questionnaire was put voluntarily before farmers pertaining to willingness to plant trees and preferred species. Surprisingly, the majority of the sample wanted to plant trees like Teak, fruit bearing trees etc. but supply of good planting material from forest department nurseries was a common ask. Small holder plantations will not only augment teakwood supply but also locally fulfil the demand leading to less transport costs and overheads.

3. Forest based Enterprises and Private Entities Plantations

Since the land holdings are small and the gestation period is long for cultivation of teak, serious financial difficulties are created in the short to medium term. However the market for teakwood is readily available with growing demand and rising prices of quality timber. This situation creates a perfect place for the market to take over provided the right policies are framed. Private entities, corporations, FPOs, entrepreneurs and forest based industries can provide

the investment & finance in short to mid term. This however requires changes in policies especially land tenure system and land laws. Andhra Pradesh has successfully shown the leadership role in the similar situation of pulpwood where investors such as ITC have created success stories. Involvement of private investment through corporations and enterprises will attract farmers too and take the burden off the shoulders of the Forest Department, especially outside forest areas. Thus promotion, raising and success of such companies should be supported by our policy changes if we want to achieve scale and sustainability in teakwood supply. Carbon Emissions Trading (ET) based regimes leading to ensuring finance for farmers and teak growers too can be promoted with the participation of industry.

4. Markets, Certifications & Supply Chain

Due to easy availability and high productivity, the timber imported from Africa and Southeast Asia is comparatively cheaper to domestic produce of quality. In order to provide the right incentives from the market, major reforms need to be taken up in teak markets or timber in general. Most important among them is the issue of certifications. Major countries from where India receives timber are prone to heavy illegal felling and it may be contributing to our timber imports. This leads to an image where illegal forest destruction is part of our products which is unwanted and should be dealt with strictly. Thus, certification of any international and domestic produce material should be ensured by following common standards which would not only lead to removing illegal timber from our imports but also create demand for Indian timber exports. This would bring down the deficit and balance out the prices of domestic and imported products. Presently our timber exports are meagre. Further duty on such imported timber can be raised while the domestic one can be subsidized either as green box or amber box based on WTO terminology.

Secondly, since most of the teak is going to come from TOF, right price discovery and market linkages are required. Small holder plantations such as from farmers can be linked to markets which ensure fair prices for their produce. Presently local sawmills procure the timber at prices which may be opportunistic to farmers. A detailed study needs to be conducted on these markets so that right interventions can be devised. Online marketing is a good solution but it requires quality assurance and optimized service delivery. For the QA, institutes like IWST can provide certifications and self-certifications too can be promoted. For optimized service delivery supply chains need to be smoothened, major part of which is the regulatory framework remodelling. The felling, transit and storage should be hassle free without the bureaucratic impediments. For instance, presently in AP, the process of harvesting and transportation is regulated by Transit rules, 1970 and Storage & Depot Rules, 1989 which require multiple visits by forest officials leading to delay and unnecessary interference. This can be changed through citizen charter showing time bound permissions, self-certifications, online permits etc. by adopting Ease of Doing Business (EoDB) principles.

5. Research and development

Andhra Pradesh has been a leader in the adoption of R&D and development of technological tools in forestry. Development of superior clones of teak from Nandyal, Chintur, Marripakala (Narsipatnam), successful research in divisions such as State Silviculturist (SS), Tirupathi and SS Rajahmundry on propagation techniques and raising quality planting material of local variants etc. needs to be harnessed for raising successful teak plantations. Tying up research institutes with field nurseries in divisions and taking nursery raising on a large scale of TPM shall be taken up going forward. Tissue culture, biotechnology and DNA based research needs to be further taken up to achieve state of art facility. Mother trees of superior qualities can be further identified in each region and seed collection can be taken up systematically. Quality seed material can be preserved and propagated. Seeds can be certified by research labs like BIO-TRIM, Tirupati or the help of ICFRE institutes like IFGTB can be taken up. Geo-tagging of seeds and clones can be done for better targeting. R&D and SS divisions can be allotted a few plots in different regions for raising trial plantations. Development of Targeted silvicultural practices (TSP) also needs to be taken up. Teak requires early and heavy thinning. Standard protocols can be developed and disseminated to teak growers individually.

Farmers can be linked through extension centres which can be opened by R&D wing at selected Village secretariats and RBKs. Separate helpline for guidance on teak can be opened. R&D institutes need to play a central role in design and publications of information and awareness material. Small holders need to be motivated and successful farmers can be shown as role models. Local markets and demand analysis needs to be taken by involving private consultants so that action points for specific interventions can be obtained.

Technology has a huge role to play in promotion of teak plantations. Few interventions which come to mind are development of online marketing at national level, database of teak producers, repositories of seed banks and clones, portals for availability of TPM at local levels, information education & communication (IEC) activities on right practices, timely guidance etc can be made available. Online regulatory, certifications and self-declaration modules can be developed. Data on imports, their certification, rates and quality standards needs to be made public so that choice is available to buyers.

Organizational reforming is as important as the front end objectives as far as forestry setup is concerned. Flexibility and freedom of FDC can be utilized fully. AP forest department can be strengthened with engaging contractual staff for research and awareness at field level. Regular forest staff is over burdened with territorial duties and hence cannot take enough intensive interest in extension and promotion of teak plantations. Research labs and SS divisions can be linked to private investments which will ensure finance, resources and quick adoption. Dedicated teak promotion cell can be started at state level to work on a mission mode to address the problems of teak growers.

Conclusion

Teak of Godavari valley in AP is an extension of central Indian teak variety. It is used for furniture and cabinet making for its ornamental figuring. Need of the hour is to sustainably manage this resource. AP has 25289.97 Ha of teak plantations of which only 321.41 Ha has been harvested in last 5 years leading to production of 8557.56 m^3 timber which is very low. It is proposed to produce around 63742.43 m^3 of timber over the next 5 years by sustainably harvesting the plantations. Shortcomings in the working plans will be addressed to allow for thinning of the plantations and allow them to put on girth. In the last 5 years 2477 Ha of teak plantations has been raised and this will be further continued. Teak is a strong light demander and does not tolerate competition and is site specific. Emphasis should be laid on improved planting stock and early deployment of silviculture methods so that fast growth can be achieved. Success and prosperity due to the green revolution will be built upon to further extend tree planting in farmlands through bund planting, intercropping, block planting models in the coastal region. In the relatively drier parts of Rayalaseema teak will be promoted with agriculture or horticulture crops. Further local species in demand will also be promoted to reduce requirement for teak. Market based approaches to fill the loose gaps will be taken up at state level. Socio-economic studies and livelihood improvement of farmers through teakwood production would be taken up.

With the focus being solely on conservation forestry and total neglect of production forestry throughout the country for last 3 decades, 'Azadi ka Amrit Mahotsav' is a good course correction moment if we want to sustainably manage our forest resources and achieve self-dependence in timber. Awareness among young forest officers needs to be created along with subordinate staff. Forestry is a science and art. Scientific forest management needs to be reclaimed to achieve dual goals of production and protection. Ecological and economical value of teak forests need to be highlighted. Only then foresters will be able to generate sustainable solutions for our demands to make 'Atmanirbhar Bharat' in timber production too.

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FEDERATION OF INDIAN PLYWOOD & PANEL INDUSTRY (FIPPI)

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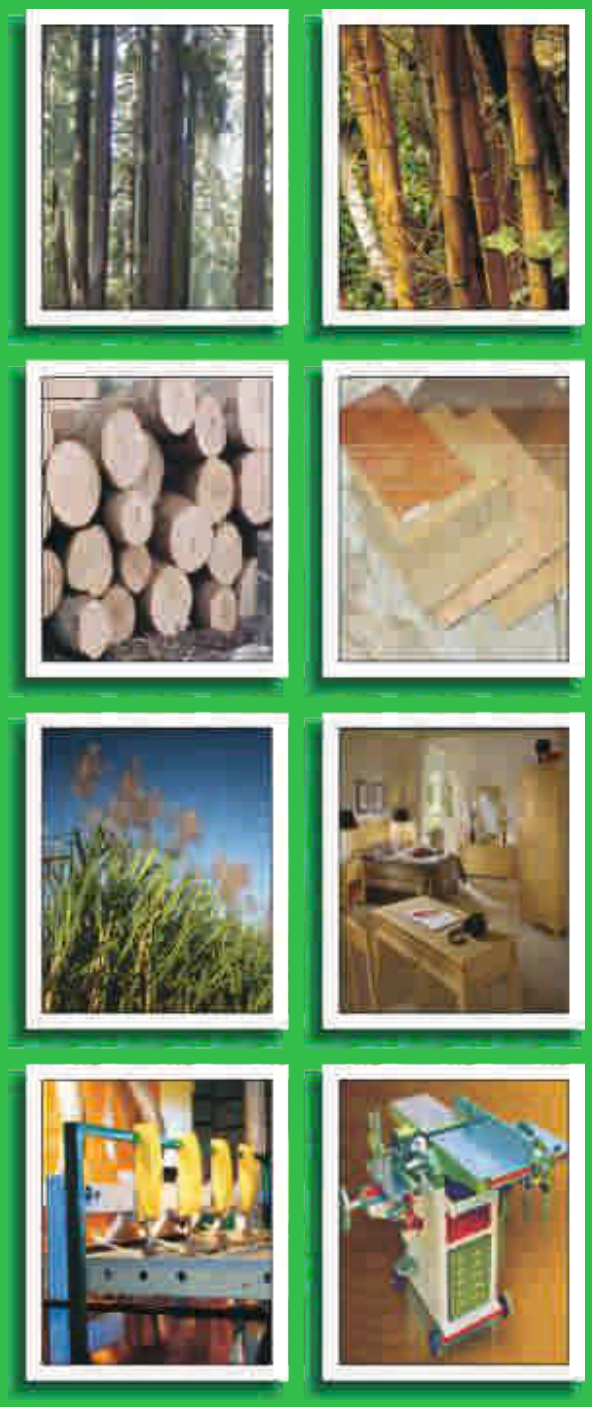

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Geographical Indication (GI) Tagging of Nilambur Teak – The Success Story

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It is common knowledge among connoisseurs across the world that teak is the most important global hard wood resource. Teak is one of the tropical hardwoods in high demand for the luxury market and for heavy duty applications, though its hare in the volume of world timber production and trade is meagre (Kollert and Cherubini, 2012).

There is a general realisation that the teak market has gone through a dramatic change with the Myanmar Government imposing a ban on the export of round logs of teak and other hard woods from 31st March, 2014. Myanmar was the world's largest supplier of high quality teak logs with an annual export of 300,000 ht (Hoppus tons), or about 425,000 cu.m. of teak. This huge deficit is expected to bring about significant changes in the international supply and demand for teak and will most likely have a lasting impact on both the exporting and importing countries. The world's largest importer and consumer of teak, India, will be the most affected. There are signs of some changes in preferences in India due to the very high prices of Myanmar teak.

Since 1980's, teak has attracted large-scale investments from the private sector in approximately 70 countries across tropical Asia, Africa, Latin America and Oceania. Increasing private investment in teak plantations is a clear indication of the perceived potential of the species, even though deforestation and poor management practises have substantially reduced the area of natural stands. Global teak plantations are estimated to cover approximately 4 million ha, with Asia accounting for more than 90% of the total. Teak exports, including shipments of plantation logs and sawn timber from Africa and Latin America are directed towards India, which accounts for 70 to 100% of global teak trade. However, one of the issues is the wide variation in teak wood quality from plantation grown trees raised across the world targeting the principal consumers of international teak, viz., India and other countries. The international teak wood trade is now 'India facing' since the major destination country for most teak trade inflows from producer countries is India as it is the second only to China.

Interestingly, in India, the tiny state of Kerala, which is home to premium quality teak grown in plantations (about 7500 ha) is the major consumer where there is a market invasion by international teak, primarily small girth plantation teak from Latin America, Asia and Oceania. Though one of the greenest states in India, with 29 % of its total area under forest, it is heavily dependent on imports, particularly from Southeast Asia, Africa and other Indian states, for timber. Imported timber for construction was mostly sourced from Myanmar, where round wood (log) exports were banned as of 2014. With the construction business booming, wood is precious, although 11,309 km^2 of its 38,863 km^2 area is forested. Roughly, 35 % of the timber demand of the state is met from homestead sources (Krishnan kutty and Mammen, 2012).Teak and mahogany, suited for solid wood uses continues to be the most preferred timber species for planting in homesteads throughout the state (Kumar et al 1994; Krishnan kutty & Mammen, 2012).

Quality of teak between homesteads and plantations:

There is a widely held view among small holders that teak timber produced from small-scale agroforestry systems, especially home-garden forestry, fetches a lower price than that from conventional plantation forestry. To examine the veracity of this view, the wood quality attributes of teak from two home gardens in the district of Ernakulum (wet site) and Palakkad (dry site) in India were compared to those of a forest plantation in Nilambur (Thulasidas et al, 2006; Thulasidas & Bhat, 2009). The colour of teak wood from homesteads was characterised in comparison with that grown in forest plantations by two methods of colour determination, namely, the Munsell system and the CIE 1976 (L* a* b*) system, in order to precisely interpret the colour variation. As per the Munsell hue system, the heartwood colour of home garden teak from wet sites was comparable with that of dry sites and forest plantation specimens. However, the chroma value indicated less saturation of colour in the former. The chromaticiness index b* (yellowness) of wet site samples as determined by the CIE.1976 (L* a* b*) system differed significantly ($p<0.05$) from dry site and plantation specimens with more yellowness. No

significant difference was observed among the samples collected from the different localities with regard to brightness (L*) and redness (a*) ($p<0.05$). The results suggest that the paler colour (less yellowness) of wet site teak wood is the limiting factor of the timber price of home garden teak as compared with forest plantation.

HW content and wood density:

"The general notion that home garden teak has a large proportion of sapwood seems to be baseless, with no significant difference being found between the heartwood-sapwood ratio of home-garden and forest plantation teak" (Thulasidas & Bhat, 2009). Lack of appropriate silvicultural practices in home-garden forestry caused the production of more defective logs, adversely affecting the market price of timber". Of Home garden teak logs aged 35 years from wet and dry sites, 59% belonged to timber Grade II–IV and the rest were classified as poles. Grade I logs (export quality) with a girth above 150 cm were not available from either of the homesteads. In contrast, the average diameter of each tree measured at breast height (DBH) for teak grown in the dry site was 24 cm, compared to 31 cm for teak grown in the same aged forest plantation in Nilambur. It was found that only 10% of logs belonged to Grade II timber and the rest fell under grades III and IV with more frequent visual defects. Faster-grown teak in the wet site produced large diameter logs (dbh 1.37 m) with an average diameter of 39.6 cm, which is comparable to that of the best site quality in India. The sawn timber recovery percentage was lower for the dry site (66.8%), whereas there was no significant difference in grade between the wet and forest plantation sites, with recovery rates of 76.5% and 78.8%, respectively.

Dry site home-garden teak exhibited a higher compressive strength parallel to grain (60.6 N/mm^2) and differed significantly between wet and plantation sites ($P = 0.05$). The higher MCS value was correlated with higher air-dry density (691 kg/m^3) recorded coupled with a thick fibre wall and smaller fibre lumen as elucidated by anatomical study. The microfibrillar angle also showed a non-significant difference between the three localities ($P = 0.05$) and the value of 12.5° was quite small to affect the timber strength adversely in its utilization potential. The study revealed that "the farmer's choice to fell homestead teak at a short-rotation of 35 years in no way affects the wood quality attributes such as density and strength."

Harvesting age v/s wood quality:

A rotation period of 25–40 years may be taken as the optimum cycle to achieve a balance between economic returns and the production of good quality timber (Centeno, 2011). There are also reports that the rotation period of fast grown plantation teak could be lower than the usual gestation period, i.e., farm teak can be utilized at less than 20 years of age (Pandey and Brown 2000; Tewari 1992). However, do trees harvested at such a young age contain significant quantities of juvenile wood?

The microfibrillar angle also showed a non-significant difference between the three localities (P = 0.05) and the value of 12.5° was quite small to affect the timber strength adversely in its utilization potential. The study revealed that "the farmer's choice to fell homestead teak at a short-rotation of 35 years in no way affects the wood quality attributes such as density and strength."

Juvenile wood properties were studied in teak by Bhat et al. (2001) to assess the utilisation potential of short rotation timber. Compared to mature wood, TW was characterised by wide rings, short fibres, small diameter, low vessel percentage, larger cell wall, wide microfibrillar angle, and relatively low or almost similar mechanical properties. While the average modulus of elasticity and modulus of rupture in juvenile wood were 85% and 82%, respectively, of the mature wood value, the longitudinal compression strength was similar. With a relatively small fibrillar angle of 15° and the scope for genetic selection of individual trees, teak juvenile wood has the potential for desired dimensional stability. The segmented regression models and visual interpretation of radial patterns of variation in anatomical properties reveal that juvenility in plantation grown teak extends up to 15, 20–25 years depending on the property, growth rate, and individual tree and plantation site. Fibre length, microfibrillar angle, vesseldiameter /percentage, and ring width appear to be the best anatomical indicators of age demarcation between juvenile and mature wood, although maturation age often varies among the properties. The projected figures for the proportion of juvenile wood in plantation grown teak at breast height are 80–100% and 25% at ages of 20 and 60 years, respectively.

Contrary to common opinion, fast-growing trees were found to yield a higher percentage of heartwood per tree during the juvenile period (up to 21 years), whereas the differences were not significant in the mature period (55 and 65 years). The following salient findings from the above studies assume importance while devising international grading rules for international teak wood originating from various sources.

(1) Teak offers potential for producing timber of optimum strength with relatively short rotations of 21 years.

(2) Fast-growing provenances/clones can be selected for teak management without reducing wood specific gravity.

(3) Selection of individual trees for the purpose of improving wood specific gravity within a specific provenance offers greater potential than selection of provenances in breeding programmes.

(4) Wood specific gravity is not always the best single indicator of overall genetic improvement of timber quality.

(5) Faster growth in relatively young forest plantations with judicious fertilizer application/genetic inputs can be advantageous in terms of heartwood volume per tree and timber strength.

(6) Juvenile wood from intensively managed plantations will likely differ from traditional teakwood with respect to grain and texture, thus influencing the market value of the timber.

Innumerable literature is available on the wood property variations in teak grown in India. The visually apparent and other kinds of inherent variability in the properties and resultant quality variation due to the particular geographical region in which they grow are fairly well known now. For example, the luxuriant growth of the teak grown in the Malabar region nestled in the Western Ghats, producing straight, large sized logs, coupled with the beautiful and attractive figure of dark brown streaks within the golden brown colour, gives it its uniqueness and international fame. Because of this very high quality, Nilambur teak (synonymously called Malabar teak) is also famous for making large sail boats, or dhows. By giving adequate global publicity, which of late has dwindled, partly due to the low availability and partly due to the availability of teak from other countries, this local variety of teak can help regain the lost glory of Indian teak.

What is a GI tag?

The GI tag is an indication that is specific to a geographical territory. It is used for agricultural, natural, and manufactured goods. For a product to get a GI tag, the goods need to be produced, processed, or prepared in that region. It is also essential that the product have a special quality or reputation. The superiority of teak from Nilambur and surrounding regions for ship building and structural purposes is due to the large size and form of the tree, beautiful colour, workability, and durability. Teak grows fast in Nilambur and yields large diameter logs. Nilambur teak wood has straight grains with a golden yellow brown colour, often with darker chocolate-brown streaks. The durability of Nilambur teak is the result of the synergetic effect of total extractive compounds, especially the polyphenolic compounds, mainly tectoquinone & naphthoquinone. Tectoquinone present in Nilambur teak (heartwood) is repellent to dry wood termites. The resistance to fungal decay is mainly due to naphthoquinone, and the hydrophobic (water repellent) and antioxidant properties are due to caoutchoue compounds. The low shrinkage properties of Nilambur teak indicate its dimensional stability.

Conferring Geographical Indication (GI) status for Nilambur teak

Nilambur teak is the first tree species in the world to be conferred with Geographical Indication (GI) status. The GI tag ensures that the product name can be used only by those who are authorised as the beneficiaries. The GI registration will give growers and users of Nilambur teak the legal right to exclusive use. This is expected to encourage more people to take up teak planting and improve the prosperity of the region through the export of teak timber. Nilambur holds a special status as the home of the world's first commercial teak plantation, established in the 1840's. Conolly's plot and the ChathuMenon plot remain preserved to this day and attract tourists from far and wide. The Teak Museum, the first of its kind in the world, set up by the Kerala Forest Research Institute, is also located in Nilambur in recognition of the region's contribution to teak cultivation.

Approved Logo of GI Tag

Due to its superior physical and mechanical properties, durability as well as aesthetic appearance, Nilamber teak was exported to England ans other parts of the world since time immemorial. As its fame crossed the boundaries of India, Nilambur in Malappuram district of Kerala was christened as 'Mecca of Teak', The British were the first to identify the superior and unique quality of teak from Nilambur forests. Later the region became the major supplier of quality teak inthe world.

GI registration certificate and approved logo of the GI tagged Nilambur

Members of the Nilambur Teak Heritage Society along with scientists of KAU before the GI registry, Chennai.

References: contact the author at anoop.ev@kau.in

Genetic Improvement of *Tectona grandis* at Tropical Forest Research Institute, Jabalpur

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Genetic improvement in Teak was initiated during the 1960s. An extensive programme was undertaken during the 70s to collect the variability by selecting phenotypically superior trees (plus trees) from all the teak-growing states of the country. The Tropical Forest Research Institute (TFRI), Jabalpur caters to the forest research needs of central Indian states such as Madhya Pradesh, Chhattisgarh, and Maharashtra (Orissa for a certain period).

TFRI has conducted extensive research to augment and improve teak on the following aspects: establishing and managing seed orchards; identifying and marking plus trees in M.P., Chhattisgarh, Maharashtra, and Odisha; surveying SPA, CSO, and SSO in M.P., Chhattisgarh, and Maharashtra for flower and fruit status; and providing assistance and technical guidance to SFDs in the establishment and management of SPA, SSOs and CSOs of teak.

Seed production in sufficient quantity for field planting is a logical extension of a successful tree breeding program. A planted area of genetically improved trees, i.e. seed orchard managed for seed production, is one of the more intensive methods for producing such seed. The purpose of a seed orchard is to supply seed of improved genetic quality for the establishment of forest stands. The genetic quality of the seed produced is determined by the parent trees used in its establishment. TFRI has implemented teak improvement activities and assisted central Indian states in establishing seed orchards. During the implementation of the World Bank Project, an area of about 1400 ha was selected as a seed production area (SPA) for teak in natural stands as well as in plantations. Clonal seed orchards (CSO) established (Table 1) are not producing seeds in the expected quantity and thus failed the purpose of their establishment.

Table 1 : Tree improvement activities carried out by TFRI under World Bank aided F.R.E.E.

Sl. No.	State	Area (ha)	Year of establishment
A	**Seed production area**		
1	Madhya Pradesh	175	1995-96
2	Maharashtra	203	1995-96
B	**Seedling Seed Orchard**		
1	Madhya Pradesh	4.0	1995-97
2	Maharashtra	2.5	1998-2000
C	**Clonal Seedling Orchard**		
1	Madhya Pradesh	22.5	1995-98
2	Maharashtra	3.5	1998-2000
3	Orissa	5.5	1997-99
D	**Vegetative Multiplication Garden**		
1	Madhya Pradesh	4.0	1995-97
2	Orissa	0,5	1997-99

This poor seed production is mainly attributed to asynchronized flowering among clones of different geo-climatic origins. Other factors affecting seed production include poor flowering, a lack of pollinators, a short period of stigma receptivity, heavy rains during peak flowering, a closed canopy/spacing, and immature fruit fall. Consolidated tree improvement trials conducted in Central India are provided in table 2.

Table 2 : Tree improvement trials of Teak in Central India

States	Seed production area (ha)	Seedling seed orchard (ha)	Clonal seed orchard (ha)
Madhya Pradesh	1647	203	169.6
Chhattisgarh	421	37	66.5
Maharashtra	-	-	552.32
Total	2068	240	788.42

Considering these shortfalls, this institute started a teak improvement programme in 2012-13 with a refined strategy and 153 Plus Trees of teak from M.P. (84), Chhattisgarh (43), Maharashtra (15) and Odisha (11) were selected. These plus trees were selected on phenotypic traits like height, GBH, clear bole height, branching, free from diseases and pests, and seed production status in comparison to check trees. Open pollinated seeds were collected from some of the selected trees, and a progeny trial was established in 2019 representing 28 progenies from 4 central Indian states. Besides, a germplasm bank of 31 accessions from these four states was also established in 2020. A clonal seed orchard (CSO) with ramets of 15 clones from 5 nearby agroclimatic zones of M.P. and a seedling seed orchard consisting of 33 families from Madhya Pradesh, Chhattisgarh, and Maharashtra has also been established. The origin of the genotypes is from almost similar geoclimatic conditions, and therefore, after 5-6 years, synchronized flowering is expected in CSO. These trials/orchards are assets for the next generation breeding strategy for further improvement.

Genetic diversity studies were conducted and the results reveal that - teak in India harbors more genetic diversity within locations than across locations; The NJ tree, PCoA, and no-admixture and admixture structure analyses reveal two distinct centers of teak diversity, i.e., central India and peninsular India. Further, the very high proportion of genetic diversity residing within locations encourages intensive selection and (or) collection of diverse superior genotypes from each location for the conservation of germplasm and genetic improvement of teak.

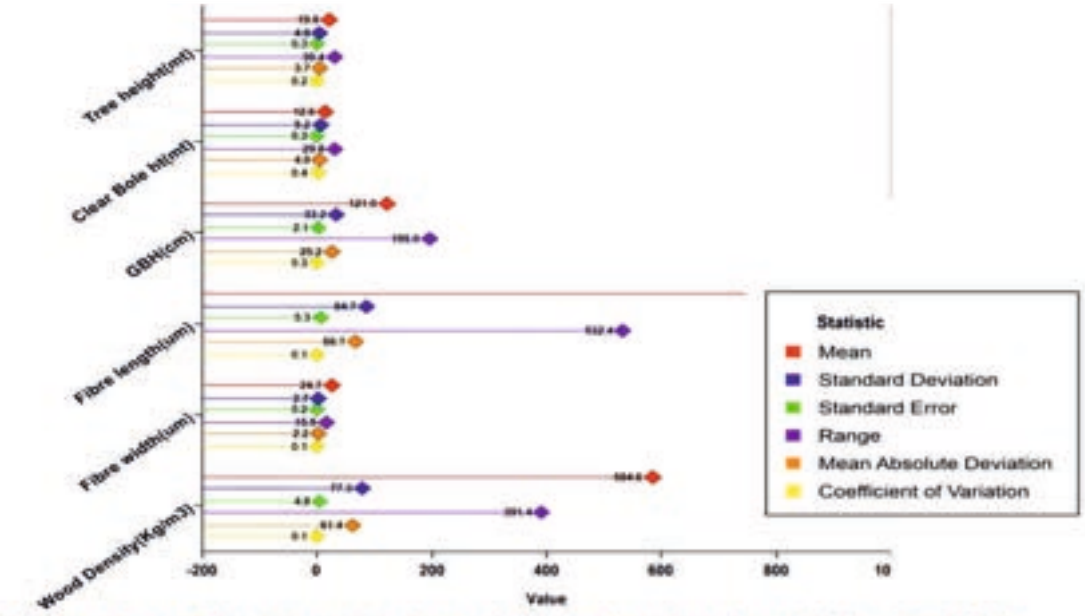
NTGB consists of 238 accessions, each with three ramets belonging to eleven different states of the country. The national germplasm bank was assessed for genetic diversity through molecular marker studies.

A Plus tree of Teak

National Teak Germplasm Bank (NTGB) in Chandrapurat Maharashtra.

This was established in seven phases i.e., in 1979, 1982, 1983, 1984, 1989, 1991, 1991 over an area of 5.09 ha. The NTGB consists of 238 accessions, each with three ramets belonging to eleven different states of the country. The national germplasm bank was assessed for genetic diversity through molecular marker studies. Analysis of molecular variance revealed that highly significant genetic differentiation in teak germplasm maintained at NTGB, Maharashtra. 85% of the total genetic variation was attributed to differentiation within genetic clusters and the remainder to between clusters and within individuals. It has been suggested that for enriching this NTGB emphasis should be given to select more accessions per population rather than sampling more localities/states.

National Teak Germplasm Bank in Chandrapur, Maharashtra



Bar chart for overall descriptive statistics for morpho and wood traits in teak sampled from Central India

Micropropagation of *Tectona grandis* :

TFRI has standardized micro propagation of teak through shoot multiplication, in vitro rooting and ex vitro rooting of shoots.

Biological Control of *Hyblaeapuera* and Eutectonamachaeralis through TFRI Tricho card

Teak Defoliator – *Hyblaeapuera* is a well-known pest of teak plantations in India because of which 44% of the potential volume growth is lost. The classical symptom of it is that there are irregular skeletonization and defoliation, irregular large holes on leaf lamina and with onset of monsoon rain the attack commences.

Teak skelotonizer: *Eutectona machaeralis* is a caterpillar that skeletonize leaf uniformly leaving veins and veinlets. The Larva is green with lateral bands and the adult moth with forewings have transverse markings and hind wings with bands.

Management of *H. purea & E. machaeralis* through egg parasitoid *Trichogramma raoi:*

The defoliator and skeletonizer is managed through egg parasitoid *Trichogramma raoi. Trichogramma raoi,* are minute insects (0.3 to 1.0 mm long) with three segmented tarsi and broad and elongated fore wings with rows of microscopic hairs on them. The egg

parasitoid is multiplied in laboratory on eggs of factitious host, Corcyra cephalonica. The host insect is mass cultured. The parasitoids emerge 7 days after parasitization under room temperature. When cold stored, the cards are taken out and kept in room temperature for a day before field release. The egg card's cut into smaller cards along the lines and stapled on the teak tree. The eggs of *H. Pueraand E. machaeralis* will be collected from teak plantations fifteen days after release and brought to laboratory to observe the emergence of T. raoi.

Recommendations for enhancing seed production:

- Future orchards should be established with clones of similar geo-climatic regions.
- Sub soiling associated root pruning enhances seed production and can be repeated in alternate years in months of March-April in existing orchards.
- Fertilizer application (N fertilizer @500g/tree, P fertilizer @350g/tree, K fertilizer @120g/tree) at the onset of rains can increase seed production up to 20% in trees of younger age (< 30 years).
- Pollination can be increased by keeping honeybee boxes (02 Nos./ha) at the onset of flowering, it will help to increase seed setting.
- Release of 4 TFRI Tricho cards 2 times in one hectare of teak forest, 2 cards at the time of onset of monsoon and 2 during first week of September can control attack of skeletonizer. Dose can be increased during heavy infestation. One egg card (1cc) cost is Rs. 200/- only at TFRI, Jabalpur.

Future Direction of Research at TFRI, Jabalpur:

- Evaluation of established Progeny Trials, SSO and CSO.
- Identification and Multiplication of clones and evaluation through multi-location trials.
- Identification of molecular markers for economically important traits.
- Establishment of germplasm conservation systems.

References :

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How are we Killing the Productivity of the King of Timber

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Teak is one of the favourite timbers all over the world and it has been used for many centuries for a wide range of products and services. It is known for its strength, durability, and attractive appearance due to its remarkable resistance to termites, fungi, and other wood destroying agents. These characteristics make it very popular, and there is regular demand from Indian traders and consumers. Domestication of teak and the ever increasing need for teak timber has resulted in large-scale plantations, both within and outside its range of distribution, and it is a species of significant ecological and socio-economic importance throughout the tropics. The worldwide demand for teak is much greater than the availability of resources, and it is a reference species for end-use classification of a number of tropical hardwoods. India, being a timber deficient country, imports wood, and of the wood imported into India, about 50% is teak. As the indigenous supply of teak diminishes and the demand continues to increase, it is vital to grow teak towards increasing production. It is likely that teak will continue to be the choice of Indians and will occupy the top position in solid wood usage in India (Manickam and Sundararaj, 2011). Somaiya (2005) commented that the list of countries supplying teak to India is exhaustive and, thanks to the demand for teak in India, those countries are able to sell their products.

Teak plantations in India

Teak is indigenous to India and the South-east Asian region and in India it is distributed naturally in the peninsular region below 24°N latitude. Teak forests are found in Madhya Pradesh, Maharashtra, Tamil Nadu,Karnataka, Kerala, Uttar Pradesh, Gujarat, Orissa, Rajasthan, Andhra Pradesh and Manipur. Teak planting in India began in the 1840s, and presently 1.5 million ha. of teak plantations exists in India with around 50,000 ha of teak plantations being raised annually (Subramanian et al., 2000). It grows in the dry moist deciduous forests of Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Chhattisgarh, Madhya Pradesh, Rajasthan, Uttar Pradesh, Manipur and Orissa. Much effort has been put into perfecting the technique of establishing teak plantations, giving thrust to make them successful in terms of silviculture and profitability.

Trees outside forests (TOF) form a significant part of the forest and tree cover of the country and have emerged as a major source of timber in India. In the national level estimates of the number of trees and their volume for major species by diameter class in forest, and TOF ranked the teak in second place with a total volume of 194.54 m. cum with 4.55% of total growing stock of the country's forests (FSI, 2019).

The science of pruning is the principle of perishing invaluable wood species

Pruning is the practice of removing a specific portion of a tree or shrub that is dead or drying/dying due to pests, diseases, and lack of sunlight. On the contrary, it is commonly practiced on agricultural or horticultural trees like mango, moringa, pomegranate, mulberry, etc., mainly to get more leaves, flowers, or fruits at a comfortable height with easy accessibility. Pruning with a higher level of care is recommended in landscape trees like parks, to maintain their structural integrity and aesthetics. Forest trees grow quite well with only self-pruning and removal of foliage by pruning will reduce growth and store energy reserves.

In contrast to this, pruning invaluable wood species like teak (Fig. 1 to 2) has a strikingly extensive & invisible impact on the trees, and they go unnoticed until they break down or die. Pruning causes loss of structural balance in trees, leading to bending of trees (Fig. 3 to 4) and easy breaking by wind (Fig. 5). Pruning-induced wounds cause significant health stress for the tree because it damages the bark, which is the tree's first line of defense against wood decay fungi and wood borers (Figs. 6 & 7). Pruning or lopping and mechanical injuries induce cankers, cracks in the stem, leading to water blister disease (Fig. 8), top breaking and stem forking (Fig. 9), branch stub and stag-head appearance (Fig. 10) and development of hollowness as the wound or injury portions act as infection courts for the development of pathogenic organisms (Fig. 11 to 12) and the tree dries from the top and slowly dies (Fig. 13 & 14).

Fig. 1 to 2: Severely pruned teak plantations

Fig. 3 to 4: Pruned trees with different levels of bending

Fig. 5 : Top breaking by wind,

Fig. 6 : Cut wounds serving as entry points of bio deteriorating organisms

Fig. 7 : Formation of stem canker & crookedness,

Fig. 8 : Development of crack & water blister disease in main stem

Fig.9: Stem forking,

Fig.10: Development of stag-headed appearance

Fig. 11 to 12: Development of hollowness and fruiting body of fungi

Fig. 13 and **14:** Death of trees due to pruning induced consequences

The causal agents of wood decay are heartwood-rot fungi, and they often manifest with protruding fruiting bodies on living trees, which usually commence with wounds or injuries. The cumulative impact of these effects often lead to total tree destruction (Mohan et al., 2022). The human activities of lopping off the branches and wounding the trees (Fig. 15) are known to attract stem-feeding insects of teak and cause significant levels of wood damage (Veeranna and Remadevi, 2007). The subject of decay associated with wounds or injuries of living hardwood trees has been reviewed by many workers and concluded that stem decay is an important cause of potential damage to trees by creating defects that increase the likelihood of physical failure of tree stands. It is further stated that the decay induced due to wounds or injuries cannot be cured completely by any means (Mohanan, 1994) and in contrast to the short rotation tree species, teak being the long rotation species, the impact of wounding in the prolonged period of its rotation period causes significant wood loss (Fig. 16 and 17). The estimated loss of 30% of wood in timber species due to bio-deteriorating organisms in India can be easily saved and the full inherent potential of valuable timber species can be achieved by avoiding the pruning and wounding of trees.

The science of pruning recommends applications of copper-based fungicides like Bordeaux paste at the cut ends, but its application is found to have no impact on wood decay fungi as it seems that the decay fungi have developed multifold resistance against the commonly used fungicides. The consequent injudicious use of pesticides is found to eliminate more than 90% of the earthworm populations, which are the plausible swinkers found in the mother earth/soil and are called "Nature's ploughs" by Charles Darwin. Their perpetual toiling helps in building numerous tunnels in the soil for water percolation and air passage around the base of the plants. These earthworms feed on the remains of the plants, and their faecal matter is a delicacy for the soil micro-flora. Earthworms along with other soil micro-organisms play a pivotal role in converting the organic materials into nutrients of plants. A nation that destroys its soil destroys itself. Forests are the lungs of our land, purifying the air and giving fresh strength to our people. (Franklin D. Roosevelt). Hence, pruning the trees and application of pesticides jeopardizes our goal of "Save Soil". In addition, insect pollinators are parsed in many ways by pruning, which is especially relevant to the non-availability of nutritional and nesting resources, affecting their foraging and nesting behavior, phenology, sociality, and reproductive potential. The

Fig. 15: Human's insensitiveness of wounding the tree,

Fig. 16: Wound induced hollowness in the growing stage

Fig. 17: In the harvested wood

pollinator losses will lead to a cascading effect on cross-pollinated species like teak (Sundararaj, 2022).

Nair et al. (1985) reported the loss of 44% of the potential volume increment of teak due to defoliation by insects. In contrast to defoliation, pruning will have an additional impact as it causes not only defoliation of the trees and wounds, but also a loss of biomass. Pruning tends to promote apical growth, but it limits diametrical growth (Fig. 18) and affects the inner juvenile wood, resulting in poor wood quality parameters. Teak is a tree (Fig. 19 and 20) that is synonymous with durability and the main active compounds that are responsible for its resistance are tectoquinone, lapachol & deoxylapachol. Naphthoquinones, anthraquinones and isoprenoid quinones. These secondary metabolites are abundant in naturally grown teak, but the wood from severely pruned trees was found to have reduced timber density and durability due to fewer of them. Pruning often leads to "dead knots" (Fig. 21) in the wood, resulting in a less attractive wood. Hence, the calls to "save trees" from killing by pruning or wounding and "love the trees and grow wood" in the era of climate change are the calls to stabilise the health and productivity of valuable wood species and conservation of tree-based ecosystems and ecosystem services.

Fig. 18 : Trees with more apical growth and less diametrical growth,

Fig. 19 : Normal, healthy growth of a tree

Fig. 20: Wood from 25 years old healthy tree.

Fig. 21: Dead knots in the wood from wounded tree

REFERENCES: contact the authors at rsundararaj@icfre.org

Common Facility Centre at IWST

Common Facility Centre (CFC) has been established inside IWST campus during the year 2016. The CFC houses many modern wood working and bamboo processing machines. CFC extends wood and bamboo processing facilities to various stake holders, self-help groups, NGOs, wood based small scale/cottage industries and local artisans. All the machines can be used on payment basis during all working days (Monday to Friday) from 9:00 AM to 5:30 PM. The details of available wood working and bamboo machines and their description are given below.

A. List of Wood and Bamboo Working Machines

No.	Name of Machinery	Description
1	Surface Planer	Suitable for removing rough surface of the wood by planing.
2	Thickness Planer	Suitable for sizing the piece of wood in two dimensions
3	Sliding Table Panel Saw	Suitable to cut a wood lumber/panel board to the required sizes in different cutting like rip cut, & scoring for pre lamboard.
4	Small Table Circular Saw	Suitable for rip cutting, cross cutting, and chamfering of wood.
5	Multi Spindle boring	Suitable for multi boring on wood/panel boards like vertical, horizontal and angular bores.
6	Spindle Molder	Suitable for edge profiling and contouring.
7	Belt Sander	Suitable for sanding the surface
8	Finger Jointing Machine	Suitable for joining small solid wood pieces
9	Seasoning Kiln	Suitable for seasoning the wood(Capacity: 200 cft)
10	Bamboo Cross Cutting	Suitable for cross cutting of Bamboo culms.
11	Bamboo Semi Half Splitting	Suitable for splitting the bamboo culms to rectangular strips.
12	Bamboo Variable Size splitting	Suitable for splitting the bamboo culms to number of strips.
13	Bamboo External Knot Removing	Suitable for removing external knots of bamboo culms.
14	Bamboo Thickness Planning	Suitable for thickness planning of bamboo strips to variable size.
15	Bamboo Slat Gluing	Suitable for gluing the bamboo strips for making panel of different sizes.
16	Bamboo Panel Drier	Suitable for drying glues bamboo panels.

To use the facility and for further details, please contact:
Officer incharge of Common Facility Centre, **Institute of Wood Science and Technology**
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Major Pests of Teak

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Teak is a prominent hardwood speciesof tropical countries. Its highly durable, strong, water and decay resistance features favors the high demand for the timber for manufacturing furniture, housing materials, handicrafts, ships and many others across the world. Growing of Teak on industrial scale is practiced by more than 43 nations. Such requirement of the Teak wood has created wide opportunities for farmers to involve the plant in agroforestry. Industrial producers employ different varieties of teak, based on the end purpose i.e., Teak wood from Godavari valley of Andhra Pradesh, is renowned for its ornamental figuring and been used in furniture's and cabinets, Teak from Western Ghats are used in constructing boats, bridges because of its highly durability feature. Along with the good financial returns and vast applicability, teak is found to be infested by various pests like root feeders, stem borers, sap suckers, defoliators, seed feeders, fruit borers and gall inducers at various stages of its growth. Many of these insects are minor or occasional pests and few are considered as major pests, due to economical threats they pose. Among the latter group, defoliators (*Hyblaea puera*), leaf skeletonizers (*Eutectona machaeralis* and *Paliga damastesalis*), Root and foliage feeder (*Holotrichia spp.*) and wood borers (*Sahyadrassus malbaricus, Alcterogystia cadambae, Zeuzera coffeae* and *Hypsipyla robusta*) are reported widely due to their vast impact. Management strategies like physical, chemical, biological and silviculture methods are practiced. Among them biological and tree improvement techniques aided with IPM is found attractive and feasible nowadays (Roshetkoet al, 2013; TNAU).

The major pests reported above are briefed as follows,

I) Defoliators

Defoliation is a serious and recurring problem that is destructive. Insect herbivory is the reason behind it, and the members of this category feed on leaves and tender parts of the plant, affecting their growth and fruit setting. Leaf skeletonizers also contribute to this phenomenon; they consume lamina parts except the skeletal structure of the leaf. Both the activities affect the host plant, and the damage can be severe (occasionally) if untreated. Some are mentioned below.

a) *Hyblaea puera* (Lepidoptera: Hyblaeidae)

Hyblaea purea popularly known as the teak defoliator, is a polyphagous insect. The pest is involved in the complete defoliation of teak in natural forests, plantations, and also at nursery level. The adult female lays eggs singly on tender leaves, preferably on the undersurface near the veins. All the instars exhibit leaf feeding activity. A matured larva feeds on the entire leaf except the midrib, resulting in complete defoliation. Every year, several outbreaks of teak defoliator are recorded between June and August. It can result in volume losses of up to 44.1% in Indian plantations. As the attack by H. *puera* significantly affects timber production, the management of this pest is very important. Silviculture and biological control methods are advocated and accepted widely for the management of this pest. Using natural enemies such as egg parasitoid, *Trichogramma spp.* aids in reducing the pest population (Joshi et al, 2005). Various entomopathogens infecting pests were recorded by Roy choudhury et al (2010). Studies and employment of baculovirus,

Fig 1: Larvae of *Hyblaea puera* enclosed within an infested leaf roll

Hyblaea puera NPV (HpNPV), serve as the most efficient tool to regulate pests due to their specificity and eco-safety features, mainly in forest environments (Nair et al, 1988).

b) *Eutectona machaeralis* (Lepidoptera: Crambidae)

E. machaeralis, also known as 'teak leaf skeletonizer' is the most widespread and serious pest of teak and an oligophagous insect with teak as the main food plant. A female moth lays eggs on the underside of the leaves. The larvae feed on the whole fleshy tissues of the leaf, leaving the vein network intact and skeletonizing the entire leaf. The larvae generally feed on rough and thick teak leaves at different levels of maturity and quality. Pest larvae majorly prefer tender leaves. Serious attacks of the skeletonizer may cause die-back of leading shoots in young trees, resulting in undesirable forking of saplings. The pest is also reported to feed on the inflorescence of teak, resulting in poor seed formation or seed setting during epidemic periods. The pest menace is obligatorily treated with insecticides, which is a short term solution and also a burning problem in environmental concern. Pest threats can be controlled by biological means like *Trichogramma raoi*, egg parasitoid of *E.machaeralis* (Joshi et al, 2005).

Fig 2: *Eutectona machaeralis* A. Larvae feeding on leaf tissues(Left) and B. Moth(Right)

c) *Paliga damastesalis* Walker (Lepidoptera: Crambidae)

P. damastesalisis is an economically important teak skeletonizer in the world. It can cause up to 100% defoliation of teak during outbreaks. The female adult oviposits more than 100 eggs. The larvae feed on the succulent lamina, leaving the leaf veins and ribs intact. Defoliation by the teak skeletonizer is nearly 10 percent and has a negative transient influence on the height increment of the host and also the production of new leaves up to two-three months after attack. The pest is managed through integrated methods (Oi et al 2010).

Fig 3: Moth of *Paliga damastesalis*, feeding on leaf lamina (Source- Sondhi, 2022)

ii) Root and foliar feeders

Some insects feed on various parts of plant according to their life cycle and cause negative impact on host plant and one of them is Holotrichia species.

a) *Holotrichia spp* (Coleoptera – Scarabaeidae)

Holotrichia is the beetle group commonly known as "white grubs" or "June beetles." They dwell in soil and feed on roots and rootlets of teak seedlings. Some of the most prominent among them are *Holotrichia consanguinea, H. insularis, H. fissa, H. serrata and H. problematica*. They appear as major pests of teak at the nursery stage, after 4-5 years of establishment. The pest attack occurs in patches at nurseries, and the infested plant shows wilting symptoms and eventually dies. After moulting, the white grubs are transformed into beetles, also called "Chafer beetles," which are observed to cause considerable damage to the foliage, inflorescence, and fruits of teak plants as they feed on them. Adults are observed to prefer broad-leaved host plants. In Kerala, the grubs caused 20-30% mortality of teak seedlings at various nurseries. In order to manage pests, light traps are used to capture beetles (Roychoudhury and Mishra, 2021).

Fig 4: Holotrichia spp. white grubs infesting roots of host plant (Source-Plantwise)

iii) Wood Borers

Wood boring insects are the most destructive pests of commercial timber crops. Members of certain moths and beetles feed on wood part during their larva (Immature) stage. Their feeding activities through tunneling destroy conducting tissues of host causing branch dieback, structural weakness, and eventual death of susceptible plants. Pest infestation sites also act as entry sources for plant pathogens. Some of the major wood borers are as follows,

a) *Sahyadrassus malbaricus* (Lepidoptera: Hepialidae)

S. malbaricus is also called the Phassus borer / stem borer. The larvae cause damage to saplings of various tree species through boring into the stem. Infested saplings can be easily identified by the dome-shaped mass of woody particles covering the point of attack. The young larva makes a vertical tunnel in the sapling running downwards to the roots, with an exit hole. On the sapwood, the feeding area remains covered by a screen of frass. The stem borer infests the main stem of new trees in the basal region. The infested trees wilt and succumb due to the consequent pest attacks. The pest impact is negligible and only in extreme cases does it result in stem-break off.

Fig 5: Stem borer, *S. malbarzcus* within an infested tree A (left) and Pupa B (right)

b) *Alcterogystia cadambae* (Lepidoptera: Cossidae)

A. cadambae is also named as the teak trunk borer and it moderately attacks teak trees between the ages of 15 and 25 years. It affects unhealthy or mechanically damaged trees. Eggs are laid in small crevices on the bark. The larva feeds on callus tissues, including the outer bark. In the sapwood, it makes a tunnel of about 6-7 cm radially and follows a zig-zag course, reaching the heartwood. The larval feeding results in the girdling of the side shoots, which leads to dieback, which is one of the initial symptoms of attack. During rain, water penetrates inside the damage site and favours a few saprophytic fungi. Due to the action of such fungi, the heartwood gets rotten and ultimately the wood becomes useless. Occurrences of borer holes in timber caused by this pest adversely affect its commercial value. The pest is managed through agri-silviculture techniques and resistant clones.

Fig 6. Larvae of Alcterogystia cadambae

c) *Zeuzera coffeae* Lepidoptera:Cossidae)

Z. coffeae is also known as the coffee borer or red borer. It affects the stems and branches of the host plant. The adult female lays eggs on the bark of stems or branches. Larvae make irregular mines that may completely girdle the infested part. The caterpillar bores into the stem to feed the wood part. Pellet-like excrement of the larva accumulated at the base of the host plant marks the symptom. In early stages of pest attack, wilting of the infested stem/branch occurs, and in advanced stages, the plant will get dried. It is managed through physical, chemical, and biological means to a lesser extent. Biological means, including application of Beauveria bassiana (TNAU) and release of the braconid parasite, *Amyosoma zeuzerae* are also reported as effective. (Gopinath, 1962).

Fig 7: *Zeuzera coffeae* A) Larvae feeding on stem of host plant; (Left) B) Adult moth (Right)

d) Hypsipyla robusta (Lepidoptera: Pyralidae)

The shoot borer, H. robusta, is one of the more serious pests of teak. It is widely distributed in the tropics and subtropics. The caterpillar bores into the tips and shoots, and the female lays eggs on leaves and young shoots of the host. During the course of larval development, it may infest more than one shoot. It destroys the apical shoot, causing the tree to form many side branches and often a deformed trunk. It decreases the value of the timber. The most common natural enemies of the pest include both predators (*Acridotheres tristis, Amorphoscelis indica, and Carabidae spp.*) and pathogens (Beauveria bassiana). Along with biocontrol methods, tree improvement techniques, silviculture, and IPM based methods are advocated.

Fig 8: Larvae of shoot borer, Hypsiphyla robust

Conclusion

Teak is a commercial crop found to be susceptible to several pest attacks. Though most of them cause negligible loss, they can be destructive at higher numbers. Aided by this, they also exploit timber quality. Various methods are used in order to manage them, but they are not commendable due to their negative effects. As a result, more emphasis and research into biological pest control are needed because they are superior to other methods and can be easily adapted in large scale forest systems.

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Wood Properties, Phytochemicals and Various Applications of Teak: The Gold Standard Wood in Indian Agroforestry

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Teak tree is also known as Sagwan in Hindi. Due to its decorative surface and resistance to fungal and termite damage, it is one of the most sought-after timbers in the world. Considering high demand for the Teak timber, it is being grown in the farm of industrial plantations in about 43 countries across the globe. The sustainable production from natural forests cannot keep up with the demand for teak wood on a national and international scale. Hence, there is a great opportunity for the farmers to grow Teak as an agroforestry species.

Agroforestry involves combining tree plantations with agricultural crops. Many tropical nations currently have smallholding agroforestry systems where teak is grown. It is positioned in various models, combinations, and spacing. These systems give farmers the chance to diversify their output, lower agricultural risk, and make much needed money. They also meet the demand for timber from industry and enhance the environment. The World Agroforesty Congress was held in New Delhi in 2014, and India became the first country in the world to implement the National Agroforestry Policy (NAP). Agroforestry supports food, nutritional, and ecological security by producing food, fuel, fodder, wood, fertilizer, and other agricultural products (Awasthi, 2022). The Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore, an institute under Indian Council of Forestry Research and Education (ICFRE), Dehradun has developed various agroforestry models such as,

- Agri-silvicultural models (Teak and Casuarinas with crops such as cotton maize, tomato, turmeric, and chilly)
- Agri-silvi-horticultural models (Teak and Coconut with agricultural crops, vegetables, turmeric, cotton and maize)
- Silvi-horticultural model (Teak with Gauva and Annona).
- A silvipasture model was created for irrigated areas using Napier and Guinea for the pasture and Teak and Casuarina for the tree component.

Wood quality of plantation teak v/s old growth forest (Burmese) teak:

There are various grades of teak on the market, including plantation teak from Indonesia and South America. Due to their rapid growth and early harvest, they are considered inferior in qualities than old-growth (Burmese) teak. Plantation teak has lower silica and oil content which are responsible for vulnerability to termites and rots. Planks from plantation teak tend to warp and crack. The major wood quality differences between old growth forest teak, and plantation teak are shown in the Table 1.

Nevertheless, scientists working in agro-forestry always suggest growing more teak in agroforestry and the most appropriate reasons behind this are as follows-

- Teak is exclusively planted for the purpose of ecological restoration or commercial plantation under forestry management.

Table1: Wood quality of old growth forest teak and plantation teak

Parameters	Old growth forest teak	Plantation teak
Colour	Rich golden-brown luster	Little lighter/less uniform
Oil content	High natural oil content	Low oil content
Silica content	High silica content	Low silica content
Resistance	Resistance to all weather conditions and microbial attack	Less resistant to weather and microbial attack
Durability	Strongest and most durable due to high extractives of all woods	Comparatively less durable due to lower amount of extractive

- Since plantation teak is harvested and managed to generate a consistent supply, it is regarded as a renewable resource.
- When plantation teak is treated properly; it retains most of the qualities of old growth teak.
- Due to the enormous demand for this and the relatively fast growth of teak trees, sustainable production of teak is currently being carried out on plantations in a variety of dry tropical regions throughout Mexico and Costa Rica.
- Since, plantations provide a more nearby source of teak, because teak can be cultivated everywhere on the dry tropical regions of the planet, this ensures lower shipping costs and low carbon footprint.

Handicraft applications:

A crucial property of teak is its extremely good dimensional stability. Teak has a high amount of oil, tight grain and high tensile strength making it suitable where weather resistance is required. Teak is recognized as a high quality timber species with high resistance to insect damage, decay and marine borers attack due to high oil content in the heartwood. Termites eat the sapwood but rarely attack the heartwood due to this reason. The trees that are older, between 40 years, and 80 years old, give the best quality of wood. Teak wood doesn't turn black when it encounters metals. Due to all these qualities, teak has very high demand in global market including India for making various handicraft products.

Teak wood is used in the manufacturing of various handicraft items like boat decks, outdoor furniture (Figure 2), cutting boards, countertops, shower benches and stools. Despite being easily worked, the presence of silica (up to 1.4%) in the wood can severely dull sharp instruments. From this point, plantation teak may be

Figure 2: Beautiful furniture made up teak

one of the best options, as it contains less amount of silica compared to natural grown teak. In India, teak is widely utilized to make furniture, columns, and beams for homes, as well as door and window frames. This species is also utilized in other handicraft items such as wooden plate, Hindu temples, antique teak wood bone inlay box, wooden tile tray, tissue box, wooden carved low table, pure teak wood hand-carved temple, interior décor, teak wood leaf inlay, and wooden god statues.

Wood properties of teak

Anatomical properties:

The photomicrographs (Fig. 3) show the anatomical structure of teak in cross- section (transverse), tangential longitudinal section (TLS), and radial longitudinal section (RLS). Teak is a ring porous wood with distinct growth rings delimited by large early wood pores. Pores in early wood are filled with tyloses, and sometimes with yellow-white deposits. Latewood pores are mostly solitary, moderately large to small, and in radial multiples. Parenchyma is vasicentric, forming a thin layer of sheath around the vessel. Rays are

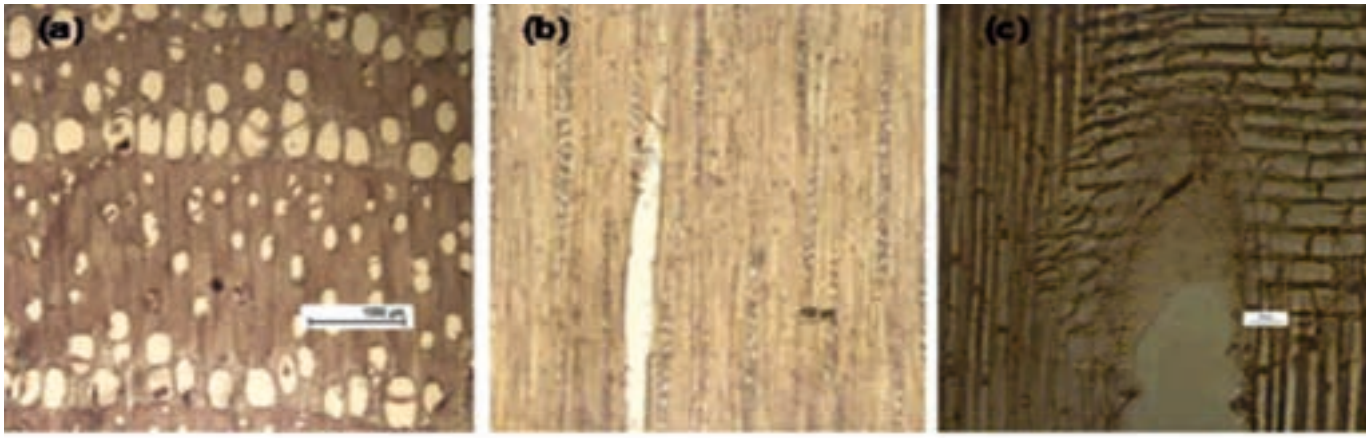

Figure 3: Anatomical structure of teak wood (a) cross section (b) TLS and (c) RLS

generally moderately broad and visible under hand lens. The difference in anatomical properties of natural forest- grown and plantation- grown teak is not well reported.

Physical and mechanical properties:

Wood density/specific gravity and dimensional stability are important properties of teak wood and there is an assumption that older trees would typically have greater wood density values than younger tree. On an average, similar values were noticed between properties of plantation teak wood of different ages. Wanneng et al., (2014) reported that different-aged plantation teak did not significantly differ in wood specific gravity. Teak that was 10 years old had an average specific gravity of 0.64 at 12 % moisture content, while teak that was 15 years old had a mean specific gravity of 0.62. Teak trees of 20 and 25 years old had average specific gravity of 0.63, and 0.59, respectively at 12 % moisture content. However, the specific gravity of standard teak is 0.604 (Shukla & Viswanath, 2014). Similarly, shrinkage values of plantation teak of different ages were also not significantly different from each other. Therefore, based on physical properties, the wood from all the above ages would be acceptable for a number of wood-based products for both outdoor and indoor applications. Apart from this, Shukla & Viswanath, (2014) reported that unmanaged block plantations were shown to have superior wood quality metrics than intensively managed block plantations. Compared to managed and unmanaged block plantations, unmanaged line plantations displayed slightly lower average values of various wood characteristics. However, compared to standard forest teak, these three types of teak plantations were shown to have lower wood quality in respect of mechanical properties. But the value was not significantly different. For example, static bending strength: modulus of rupture (MOR) of intensively managed block (bim), unmanaged block (bum), unmanaged line (lum) of plantation type, and standard teak were 82.1, 84.3, 74.4 and 94.0 MPa. However, modulus of elasticity (MOE) of bim, bum, lum and standard teak were 8.1, 10.1, 6.9 and 11.7 GPa. Finally, they concluded that the block plantation harvesting may be postponed for a few years to maximize economic returns because mechanical properties of wood are anticipated to improve with age.

Secondary metabolites

It is crucial to know that which secondary metabolites are present in the teak because it provides basis information for its traditional uses. Over 100 years of intensive research in photochemistry, diverse compounds have been found in T. grandis from various plant parts. Around 92 different compounds have so far been identified from teak (Vyas el al., 2019), although the existence of a number of compounds may depend on the location and climatic conditions. Quinones are dominant secondary metabolites of teak that are present in the various forms such as naphthoquinon (viz. Lapachol and deoxylapachol), anthraquinones (tectoquinone) and isoprenoid. Other phytochemicals found in teak include triterpenoids, lignans, steroids/ saponins, some fatty esters and phenolic, flavonoids, phenylethanoid glycosides and miscellaneous compounds (Vyas et al., 2019). Lapachol, deoxylapachol, and tectoquinone compounds, originated from heartwood, are accountable for resistance to biological attack, i.e., fungi and termites (Table2) (Vyas el al., 2019). Notably, number and concentration of compounds may varry in plantation teak grown in different geo-climatic conditions.

Medicinal properties

The bark is an astringent and is useful for treating bronchitis. The bark yields a bitter tonic that has been used to treat fever.

Teak is produced by several countries across the tropical and subtropical regions of the world in agroforestry systems. The species is one of the most important trees in home gardens in South Asia due to its medicinal value in folk remedies. The leaves and an extract from them suppress Mycobacterium tuberculosis bacterium. There is evidence to support the use of flowers in the treatment of bronchitis, biliousness, and urine discharge. The leaves have yellow and red dyes that can be used to colour wool, cotton and silk. The bark is an astringent and is useful for treating bronchitis. The bark yields a bitter tonic that has been used to treat fever. Additionally, it helps with headaches and stomach issues (Awasthi, 2022). The wood/ bark of the plant may improve digestion. Different parts of the plant have different types of compounds that diversified its pharmacological importance as given in the table 2, though, medicinal properties of plantation teak may vary due to the change in secondary metabolite profile.

Table 2. Bioactive compounds produced from different parts of plant with their pharmacological properties (Vyas el al., 2019).

Plant parts	Bioactive compounds	Pharmacological activities
Leaf	Rutin , quercitin	Antioxidant activity
Leaf	Ethanol extract (Benzene-1-carboxylic acid-2- hexadeconate)	Antiviral activity (against chikungunya virus)
Leaf	Corosolic acid, 5,8-dihydroxy-2-methy lanthraquinone, hydroxy-sesamone, tectograndone	Anti-plasmodial activity
Dried leaf	2-Oxokovalenic acid, 19-hydroxyferruginol	Phytotoxic activity
Bark	5-Hydroxylapachol, Lapachol	Cytotoxic activity
Heartwood	Lapachol	Antitumor and Anti-metastatic activity
	Lapachol	Gastroprotective activity

Market potential:

The price of teak wood in the market is governed by various parameters such as its country of origin, age of the tree when felled, width of the growth rings, wood colour and proportion of heart wood. Old growth teak always fetches a better price because of higher heartwood content, narrow growth rings, and colour. One of the largest suppliers of old growth teak is Burma (Myanmar) and Burma teak is the most valued teak in India. The price of Burma teak planks in India at present ranges about Rs. 6500-8000 per cubic feet (cft). However, most of the teak wood coming from Ghana, Ecuador, Brazil etc. are from plantations of about 10-25 years old. Wood from such short rotation plantations always contains a higher proportion of juvenile wood. As most of these commercial plantations are well managed, tree growth is faster and as a consequence, the ring widths are comparatively wider. The price of teak wood logs imported to India from these countries ranges between 400-1000 USD per cubic meter depending on the girth and heartwood content and age of the trees. For instance, when the girth is about 50 cm, the price is about 400 USD per cubic meter and when the girth is above 100 cm, the price ranges between 800-1000 USD per cubic meter. The following table shows the price of teak wood logs (5.8 m length) imported from Brazil. The price structure in each girth class may also vary depending on the shape of the logs and the presence of defects, which in turn can affect the recovery after conversion.

Table 3 Price of teak logs imported from Brazil and its estimated price after conversion.

Girth (cm) (USD/CBM)	CFR Price of log (INR/cft)	Approx. CFR Price of log (INR/cft)	Approx. Price of log to the importer (INR/cft)	Approx. Price of planks (assuming 60% recovery)
60-70	410	929	1069	1781
70-80	460	1042	1199	1998
80-90	540	1224	1407	2346
100-104	800	1813	2085	3475
105-109	840	1904	2189	3649
110-114	880	1994	2293	3822
115-119	960	2176	2502	4170
125-129	1000	2266	2606	4344

Teak logs from Ghana

Teak logs from Ecuador

The price shown in the table 3 (column 2 and 3) is the price at the port of import (CFR- Cost and Freight). Custom duty (5% for logs) and the social welfare surcharge (10% of custom duty) are the additional charges that needs to be paid at the port of entry by the importer. Besides, some other miscellaneous charges such as such as custom clearance charge, plant quarantine clearance charges and local transport are the additional charges that needs to be added to the arrive at the price of the logs to the importer. Because of these charges, the price of logs, on an average, increases by about 15% and the cost of logs to the importer with these additional charges is shown in column 4 of table 2. Considering a conversion output of 60%, the price of converted planks increases by about 67% (column 5). The selling price of imported teak wood of lowest quality is about 2500-3000/cft which is about 40-65% higher than the cost price. In-spite of all the expenditures (freight, custom duty, custom clearance etc.), the trade of imported teak in India is still lucrative. If the entire requirement of teak can be met from domestic production, the cost incurred towards freight, custom duty, custom clearance and plant quarantine clearance can be saved and this will add to the profit of the growers as well as sellers. Besides, local production and consumption of teak wood will lead to a significant reduction in its carbon footprint.

Conclusions:

Teak is one of the major tropical plantation species, and their production meets around 1% of the world's yearly demand for lumber. India is leading in teak plantation (43%) throughout the world as the wood is naturally durable and the wood has huge demand in handicraft sectors. Due to its high demand in the various wood-based industries, India is importing around 25% of teak from Myanmar only. As wood imports drain out our foreign reserves, it is important to find an alternative to meet the whole timber demand. Agroforesry is one of the best possible ways to resolve the shortage of teak wood in the country. Teak of different ages can be used for making various products, as the physical and mechanical properties of plantation teak are not significantly different from old growth forest teak. The cost of freight, custom duty, custom clearance, and plant quarantine clearance can be reduced if a domestically produced teak is used, which would increase the profit of both the farmers (growers) and the sellers. Besides, local production and consumption of teak wood will lead to a significant reduction in its carbon footprint.

Teak logs from Brazil

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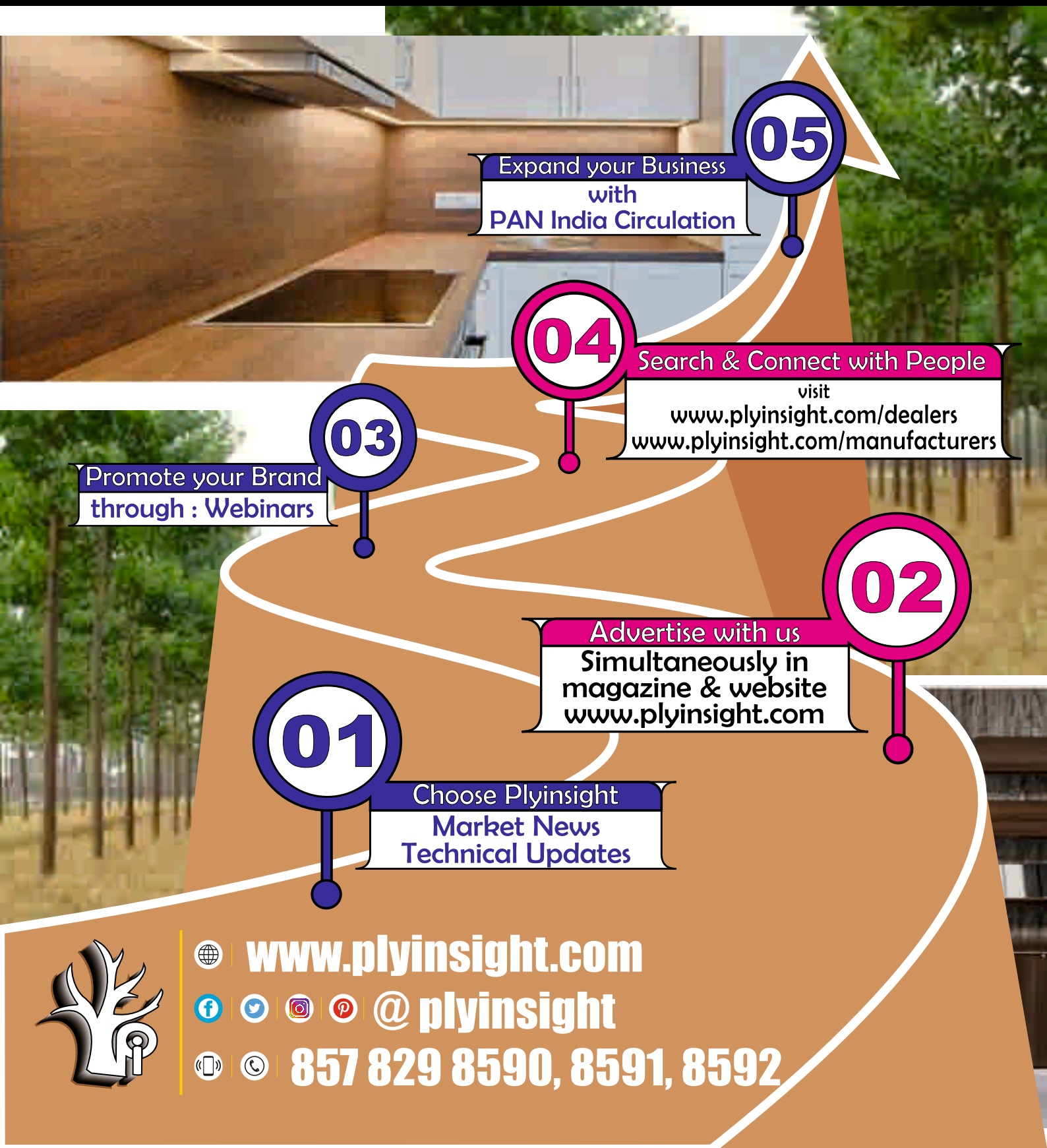

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Dendroclimatological Investigation of Teak (*Tectona grandis* L.f) in South Gujarat

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Introduction

Dendrochronology is a branch of science that aims to understand the forest ecology, climatology, geology, anthropology and the past events of trees. Dendro word that comes from the Greek word dendrum i.e., old wooden log, and chronology is the name of a science that deals with time and the assignment of dates to particular events. Dendroclimatology is one of the important branches of dendrochronology in which tree ring width is studied to establish a relationship with climate. Tree species suitable for dendroclimatic investigation must have annual growth rings (Fritts, 1976). Chowdhury (1940) reported that about one-fourth of total tropical tree species produce growth rings. In a tropical climate, teak (*Tectona grandis* L.f) is largely studied for dendroclimatology due to datability of its growth rings to the exact years of the formation and also because of its large distribution and commercial importance (Sinha et al., 2019).

Pant and Borgaonkar (1983) initiated dendroclimatic studies on teak in India's tropical regions. They developed an annually dated teak ring-width chronology from the Western Ghats of Maharashtra and presented the significant role of post-monsoon rainfall of the previous growing season in maintaining the moisture availability for the current year's growth. Later on, Bhattacharyaa et al. (1992) studied the datable tree-rings of *Tectona grandis* (Teak) and *Cedrela toona* (Toon) and reported the good potential of teak for drought reconstruction and toon for flood reconstruction. In the present scenario, a lot of research has been carried out by many researchers on dendroclimatic analysis of teak from different regions of peninsular India. A brief review of dendroclimatic studies carried out at the Navsari Agricultural University on teak from different sites in South Gujarat is presented

Sampling sites and tree-ring chronology development

Teak is a ring-porous to semi-ring porous tropical tree, producing distinct annual growth rings delimited by large earlywood pores. For the dendroclimatic investigation, a total of 58 increment core samples (4 mm in diameter) were collected at the breast height of thirty-four teak trees from three different locations (Ahwa, Valsad and Navsari) in South Gujarat. The core samples from Ahwa (Dang) and Valsad forest areas were collected during December, 2012, whereas core samples from Navsari were collected from the plantation area during January, 2015. The region is under the strong influence of monsoon precipitation where more than 75% rainfall is received during the monsoon season (June-September) and less during the post monsoon season (October-December). The pre-monsoon season (March-May) is usually hot and dry. Growth rings of all core samples of teak were counted and cross matched within and between trees from three sites using a special cross-matching technique developed by Stokes and Smiley (1968) to detect false rings (Fig.1). Cross dating between core samples of the same tree and between different trees of each site was good for dendroclimatic analysis. Three site tree-ring index chronologies were prepared by standard dendrochronological procedures (Fritts, 1976). A negative exponential or cubic spline fit of wavelength equal to 65% N (N is the length of the tree-ring series) has been used in the standardisation procedure to maximize climatic signals and minimize non-climatic noise from each series using the computer program ARSTAN (Holmes 1992).

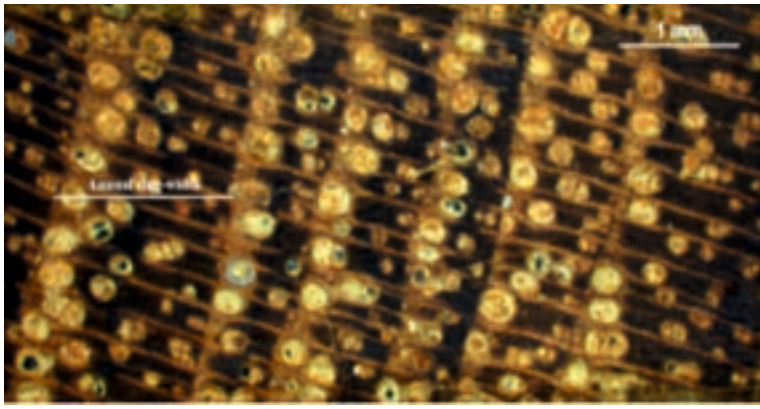

Fig. 1. Photomicrographs showing variation in annual ring-width of teak

After standardization, a ring-width index chronology was prepared from each ring-width series. Indices were derived by dividing the measured ring-width data with the analogous predicted value of ring-width for each year to extract useful climatic signals. A mean tree-ring-width-index chronology was prepared for each site by averaging all individual index series (Fig.2).

The statistical performance of three teak ring-width index chronologies is presented in Table 1. The chronology suitable for dendroclimatic study should have good correlation between trees, low autocorrelation, high standard deviation, high mean sensitivity, high signal to noise ratio (SNR) and high expressed population signal (EPS) and high value of common variance (Fritts 1976). The expressed population signal (EPS) decides the association between the mean chronology derived from the core samples and the population from which they are drawn. According to Wigley et al. (1984) chronologies with an EPS greater than or equal to 0.85 can be acceptable for dendroclimatic analysis. The signal to noise ratio (SNR) greater than one indicates the strength of climatic signal between trees (Briffa and Jones 1990). The common variance indicates the variance due to common forcing factors of a site that may be due to the influence of climatic factors experienced by all the trees over a large area.

Variance due to common forcing factors of a site that may be due to the influence of climatic factors experienced by all the trees over a large area.

Table 1. Statistics of teak ring-width index chronology from three regions of South Gujarat

		Ahwa (Dang)	Valsad	Navsari
Full Chronology Period		AD 1912-2012	AD 1867-2012	AD 1991-2015
1.	Number of cores (radii)	11 (17)	8 (10)	10(10)
2.	Mean tree-ring width (mm)	2.49	2.00	6.52
3.	Standard deviation	0.261	0.351	0.320
4.	Mean sensitivity	0.294	0.390	0.273
5.	Lag-1Autocorrelation	0.052	0.005	0.217
Common Chronology Period		AD 1938 – 2012	AD 1910 – 2012	AD 1996 – 2015
6.	Number of trees (radii)	9 (15)	4(4)	5(5)
7.	Mean correlation (variance)	0.297	0.562	0.244
8.	Signal-to-noise ratio	5.592	5.139	1.613
9.	Expressed population signa	l0.848	0.837	0.617
10.	Variance in first eigen vector	34.73%	67.39%	51.58%

(Source: Sinha et al., 2019)

It is found that moderately high values of standard deviation, mean sensitivity, and low auto-correlation after using autoregressive (AR) modelling indicate the high dendroclimatic potential of tree-ring index chronologies from three sites in South Gujarat. The value of EPS was nearly 0.85 for the tree-ring chronologies of Ahwa and Valsad and 0.62 for the Navsari chronology. The value of SNR was greater than one for all three chronologies. The common variance was high for all three chronologies. These results indicate that tree-ring-index chronologies of three sites have potential for dendroclimatic analysis.

El Niño and drought signals in teak ring width index chronology

Mean tree-ring-index chronologies of teak developed for three sites viz., Ahwa (Dang), Valsad and Navsari showed good relations to most of the El Niño and drought years that occurred in India and especially in Gujarat from 1865 to 2015 (Fig. 2). The drought years over India during AD 1865-2015 that matched with tree-ring index chronologies of teak from three sites of South Gujarat are 1868, 1877, 1911, 1920, 1966, 1968, 1972, 1974, 1979, 1982, 1986, 1991, 2002, 2004 and 2009. Out of these drought years, AD 1968, 1972, 1982,1986,1991,2002, 2004 and 2009 were El Niño years (Saini and Gulati, 2014). The years that coincided with the drought years of Gujarat are 1956, 1986, 1998, 1999, 2000, 2001, 2002, 2008 and 2009 (Rathore and Jasrai, 2013). It reveals that teak is found to have good potential to know rainfall patterns, mostly in drought years.

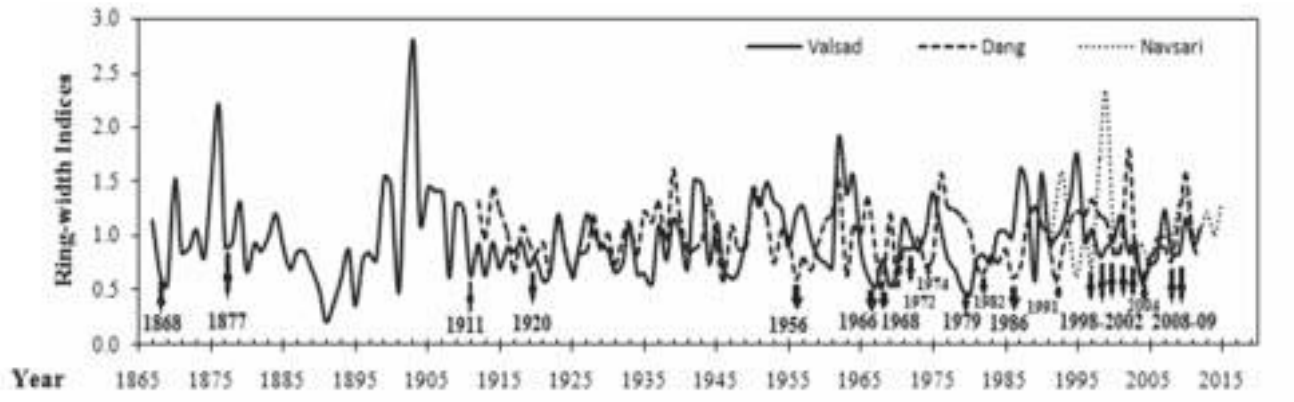

Fig. 2. Mean ring-width index chronologies of teak developed for Ahwa (Dang), Valsad and Navsari showing El Nino and drought years of India and Gujarat

Tree-ring growth and climate relationship

The availability of moisture in the root zone of a tree is primarily a function of monthly rainfall and temperature (Ram et al. 2008). The radial growth in teak begins in March and reaches a peak in June-September and the wood formation gradually declines in October and ceases in November. Defoliation starts in December and trees become completely leafless by March (Rao and Rajput 1999). We have carried out a correlation analysis of all three tree-ring chronologies of teak with the monthly rainfall and temperature of their respective sites.

The current year's tree growth and climate relationship at Ahwa (Dang) showed a positive association with radial growth of teak and rainfall during the months of March, June to July, and September (Table 2). March temperatures during the current year also showed a positive response to tree growth. A positive association between tree growth and climate during March, June to July and September of the current year suggests that the pre-monsoon showers during March and monsoon rainfall during June to September play an important role in the radial growth of teak. The March temperature showed a significantly positive effect on the radial growth, as it favours the initiation of cambial activity for wood formation.

It is reported that tree growth and climate relationships at Navsari exhibited a positive influence of September rainfall of the preceding year and September to November rainfall of the current year on the radial growth of teak (Table 2). From June to August rainfall and temperature did not show any significant relationship at this site. Navsari receives higher rainfall than Valsad and Dang in June to August months, and moisture availability is also high in the root zone due to frequent irrigation of agricultural crops nearby the teak plantation site. Therefore, it seems that when the moisture availability reaches a certain threshold limit, the tree does not respond to extra moisture and this may be the reason that tree growth did not show any significant relationship with June to August rainfall and it showed a positive relationship with September to November rainfall.

Table 2. Correlation analysis of teak ring-width index with monthly rainfall and temperature from August of the previous year (-A) to December of the current year(D); significance $p<0.05$, + = positive relationship, ● = negative relationship

Location	Climatic Factors	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Ahwa	Rainfall								+			+	+		+			
	Temperature								+									
Navsari	Rainfall		+												+	+	+	
	Temperature																	
Valsad	Rainfall	●										●						
	Temperature			●	●	●							●		●	●	●	

We reported that tree growth and climate relationships at Valsad showed a significant negative association with radial growth and August rainfall of the preceding year and June rainfall of the current year (Table 2). Temperatures of the previous year's October to December and current year's July and September to November months also showed a significant negative relationship with radial growth. In the case of Valsad, tree-ring sampling sites, viz., Dharampur, Kaprada and Nanaponda are located on the sloppy terrain of a hilly forest. However, a large amount of rainfall was received during the monsoon but drained down due to the steep topography of tree-ring sites, which resulted in moisture stress in the root zone that may have affected the normal growth of trees. Higher temperatures always promote evaporation and evapotranspiration, which produces severe moisture stress in the root zone, causing narrow ring-width in trees. Therefore, overall rainfall and temperature might have shown a negative relationship with the radial growth of teak. However, in the case of Navsari and Ahwa (Dang) sites, the amount of run-off water is comparatively less due to flat topography, and adequate moisture is available at the root zone for longer periods although the temperature is high. Consequently, the significant effect of temperature on tree growth has not been observed at the Navsari site, and only March temperature showed a positive influence on the radial growth of teak at the Ahwa (Dang) site.

Our general observations on the tree-ring and climate relationship of teak at three sites in South Gujarat reveal that the low growth years (narrow rings) are significantly associated with low rainfall (drought condition) in most cases. However, normal or above normal rainfall is not reflected as a significant higher growth and it helps in maintaining the normal growth of trees in the next two-three years even though the rainfall during these years is scarce. This is mainly because of moisture availability at the root zone of the tree. When the moisture availability reaches a certain threshold limit, the tree does not respond to additional moisture. In contrast, it is also true that inadequate rainfall in any given year creates moisture stress conditions at the root zone in the following one to two years, resulting in below-average tree growth in consecutive years.

Conclusions

1. Mean ring-width-index chronologies of teak developed for the three sites viz., Dang, Valsad and Navsari of South Gujarat are useful to know the information about past drought years of Gujarat as well as major El Niño and drought years of India that could be further used for reconstruction of the past climate, especially rainfall data.
2. Mean ring-width-index chronologies of teak developed for the particular time periods at the three sites in South Gujarat are also useful in determining the unknown year of illegal felling of teak at respective tree-ring sites.
3. Pre-monsoon showers and high temperatures during March and monsoon rainfall from June to September play an important role in the development of radial teak growth. Carry over effect of moisture from the previous year's monsoon as well as post monsoon also contribute to the radial growth of teak. Hence, by knowing the previous year's precipitation and its possible positive or negative influence, plantation activity of teak can be managed so that mortality rates can be minimized and poor growth can be avoided.
4. Low rainfall and high temperatures during the monsoon (June-September) and post-monsoon season (October November) create moisture stress conditions in the root zone of teak. Thus, moisture availability in the root zone either by rainfall or irrigation during the peak growth period in the stress condition boosts the radial growth of teak.

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Teak Wood Quality Research Trail of Kerala

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Teak is the world's most cultivated high-grade tropical hardwood. Since 1842, teak plantations have been extensively raised in different parts of Kerala. Kerala Forest Research Institute (KFRI) is the major R & D institution of the Kerala Government engaged in forestry and forest products research in the state. It has significantly contributed to teak wood quality research in the region and is in its half-century of service in supporting the wood sector of Kerala through R & D inputs from its Wood Science and Technology Division. An attempt is made here to consolidate the contributions made by KFRI during the last four and a half decades in the field of teak wood quality research for generating data on the variation of wood properties and end-use correlation for linking the same with programmes in genetic improvement of wood properties.

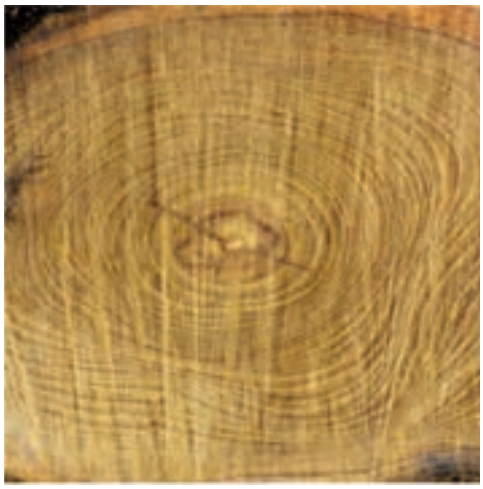
In teak, age is determined by ring number from pith and is found to be the decisive factor in controlling the specific gravity of wood, an important factor as far as wood quality is concerned. However, growth rate is found to be statistically less important. Fast grown teak of 21 years of age (from good sites) is found to attain optimum strength properties with regular heartwood percentage. Wood strength is found to be not associated with ring width. This offers scope for reducing the rotation age of fast-grown wood without affecting timber strength. Growth periodicity and cambial activity (wood formation) in juvenile and mature teak were investigated. Juvenile teak wood was characterized and the information generated was of particular interest to dendrochronologists in tree ring analysis.

It has been observed that in many plantations, standing trees are attacked by the mistletoe, Dendrophthoe falcate var. pubescens. Severe mistletoe attack (10 or more mistletoe clumps per tree) is found to result in a significant reduction in timber strength, as evidenced by the loss of modulus of elasticity (MOE) and work to maximum load (WML). The ultimate strength of mistletoe infested teak can be predicted in machine stress grading by either MOE or fibre stress at the limit of proportionality (FSPL) and by specific gravity in non-machine stress grading. As severe mistletoe attack is being found to affect the modulus of elasticity of wood, for critical structural use, it is suggested to select wood of a density 600 Kg/m3 and above. Between dominant and suppressed trees of the same age (54 years), dominant trees are found yielding timber of more specific gravity to the tune of 14%. Teak planting on river banks is not recommended. Nearly 30% of the teak trees growing

within a distance of 200 m from the river banks are affected by water blisters, causing radial shake in the trunk wood. Water blister in teak is identified as a physiological problem causing serious damage to the main bole of the tree, thereby losing a considerable amount of timber. water blister marks adversely affect the aesthetic value of wood. Water blister was absent in homestead-grown teak, which is usually planted in smallholdings and has adequate drainage. Therefore, it is suggested that teak planting on river banks may be minimized.

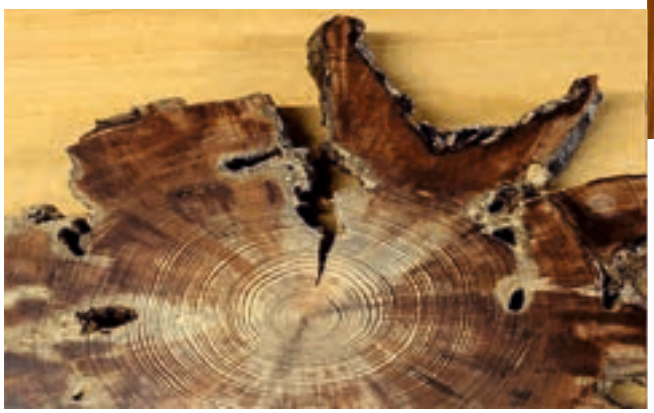
As the sustainable supply of teak wood from the natural forests diminishes and the demand continues to increase, the general trend in the future of teak cultivation will be towards increasing the production and rational utilization of plantation-grown timber with relatively short rotations of 20–30 years, as the timber attains the required strength properties at this age. The mechanical properties of wood from fast-grown plantation teak can be lower than those of wood from slower grown forest trees. As far as the information on the quality of teak logs produced from traditional forest plantations of Kerala is concerned, teak from Konni, Kerala, is found to be the best; 70% of the logs came within the three grades (I, II & III) and the rest 30% belong to Grade I. An appraisal of the timber quality of fast grown teak wood from plantations of low- as well as high-input management was attempted. A higher yield of heartwood per tree by faster growth with judicious fertilizer application and/or genetic inputs in relatively short rotation (high-input) teak plantations is found to be possible. The difference between timber from low and high input plantations is mainly found to be limited to the poor color, grain, and texture of the product. This should be acceptable in the market in the context of reduced supply of quality timber. Even 5-year-old juvenile teak wood from high-input plantations is found to fit into the 'Class II Resistant Timbers' according to the ASTM (American Society for Testing and Materials) classification of timbers on the basis of decay resistance.

A comparison of wood quality attributes of home garden grown teak (35 years) versus those grown in forest plantations has shown that 59% of home garden grown teak is found yielding timber of Grade II-IV and the rest was classified as poles. Grade I logs (export quality) with a girth above 150 cm were not available from homesteads; only 10% of logs belonged to Grade II timber and the rest fell under grades III and IV with more frequent visual defects. Sapwood of around 15% was recorded from trees of an age above 55 years from Nilambur, Kerala, whereas the same from young trees of age 13 and 21 years was 52% and 40%, respectively. Sapwood width decreases with tree age and stabilizes for older trees. The general notion that home garden teak has a large proportion of sapwood seems to be baseless; no significant difference was found between



the heartwood-sapwood ratio of home-garden and forest plantation teak. Homesteads in wet areas were found to produce larger diameter logs without adversely affecting the heartwood yield compared to dry localities and plantation sites.

At the age of 35 years, faster-grown teak in the wet site produced large diameter logs with an average DBH (diameter at breast height of 1.37 m) of around 40 cm, which is comparable to that of best site quality (SQ I prescribed in All India Yield Tables) in India; naturally with higher sawn timber recovery. Sawn timber recovery was lower for the dry site grown home garden teak of smaller dimension, with an average DBH of 24 cm (67%), which qualifies only for SQ II/III and a major share of logs falls into pole classes, compared to the average DBH of above 30 cm from the same aged forest plantations in Nilambur; whereas there was no significant difference in grade from the wet and forest plantation sites, with recovery rates of 77% and 79% respectively. The major structural factors that determine sawn timber grade and recovery in teak are the size and frequency of unsound hollow knots, deep flutes in the log, stem size, bole shape and heartwood proportion. No significant differences were noticed in wood basic density and volumetric shrinkage values among the homesteads of wet and dry localities as well as forest plantations. The teak wood grown in homesteads has almost the same dimensional stability and strength as plantation grown teak of forest sites. Significant differences exist in natural decay resistance between the wet and dry localities. Two brown-rot



fungi, *Polyporus palustris* and *Gloeophyllum trabeum* caused more severe weight loss in wet site teak wood, which can be attributed to the lower extractive content (12.4%) of the wetsite wood. Teak wood from wetsites is paler in color, may be due to the low extractive content. Out of the total extractive content of 12.4% in the wet - site homegarden grown teak, tectoquinone accounts for 0.2% and naphthoquinone 0.6%. The corresponding values for the dry site home garden grown teak are 16%, 0.3% and 1.3%, which is naturally higher than the wet-site homegarden grown teak. The amount of naphthoquinone was more consistently correlated with higher decay resistance (against brown-rot fungi) in the wet than the dry and planted sites, implying that naphthoquinone is the single most important compound which imparts decay resistance to teak wood. Naturally, a word of caution has been pointed out in the use of wetsite homegarden teak wood exposed to outdoor conditions. Plantation teak is found to contain 13% extractive content.

The mature teak wood from forest plantation sites and the shortrotation teak taken from homesteads were found to have similar strength characteristics. The timber stiffness and bending strength of the wood samples evaluated from the three locations were found identical, with the exception of the slightly higher longitudinal compressive stress of dry site home-garden teak. According to anatomical explanation, the increasing fibre wall thickness and smaller fibre lumen caused the observed maximum compressive stress (MCS). The farmer's decision to harvest homestead teak at a short-rotation of 35 years has no negative effects on the wood's quality characteristics, such as density and strength.

In brief, teak wood from homesteads differs from that of forest plantations in log form, extent of natural defects, appearance/ wood color and grain, as well as natural durability in the dry or wet locality, whereas wood density and strength properties are nearly the same. The difference in timber quality may influence the price factor of teak wood coming from homesteads especially in wet localities. Farmers grow teak in homesteads singly or along with other agricultural crops. There is a need for increasing the technology level and its transfer to mechanical wood industries that allows the use of smaller and younger trees; for example, peeling lathes capable of handling logs up to a minimum diameter of 7 cm and modified vertical band saws can process small diameter logs more efficiently. The introduction of small portable or mobile sawmills which can be easily moved from site to site during thinning operations, may be appropriate for improved utilization of small timber. This can further facilitate an improved supply of sawn wood requirements for rural communities, building contractors, and furniture.

The major environmental factors influencing the formation of false rings in teak were rainfall during a dry

period, drought during an active growing season, polybag container field transplantation of seedlings and juvenility. However, sporadic insect defoliation does not always result in the formation of false rings in teak. Whenever there is intervention of the environmental factors occurring during the growing season, it determines the location of false rings within the annual growth increment. These results will have practical implications for better management of teak plantations. Protection against insect defoliation was shown to increase heartwood percentage with enhanced radial

increment in 8-year-old teak. The influences of rainfall, irrigation and age on growth periodicity and wood structure in teak were studied in depth and reported (along with the influence of provenance variation on wood properties) from the Western Ghat region in India. Rainfall impacts cambial activity in teak. Higher rainfall contributes to a greater amount of wood formation. Juvenile teak trees in irrigated plantations tend to produce diffuse porous wood during the first 3–4 years of growth, in contrast to the ring porosity displayed even in the first year of growth in unirrigated plantations.

Within the same age group of 21-year-old plantations of the three major teak provenances of the Western Ghat region, teak from the North Kanara provenance, generally known to display slow growth, had lower values of static bending and longitudinal compressive stress than the Malabar provenance (Nilambur). The weaker timber of North Kanara provenance was attributed to its relatively high percentage of parenchyma and low percentage of fibres in the narrower rings, probably as an adaptation to the nutrient-rich soil condition. Observations on teak wood from a 65-year-old plantation of Konni provenance showed the highest mechanical properties attributed to the greater percentage of cell wall material despite the slower growth rate and well-defined ring-porosity with wider bands of earlywood parenchyma tissue. The study signifies the need to recognize the provenance source of variation to explain the varied growth-structure-property relationships of teak and to utilize the Indian genetic resources to the optimum in future teak improvement programmes. Heritability and genetic gains in wood quality attributes of clonal teak were looked into. The effects of site and clone origin on the basic wood density of teak were studied in 14-year-old trees of 18 clones vegetatively propagated from plus trees and grown at two different locations in Kerala showed that site had a highly significant influence on wood density, while the place of origin of clones had no effect; no evidence of any interaction between site and clones could be detected.

For establishing a germplasm bank in Kerala, the genetic diversity in teak with respect to superior wood characteristics and morphological features was evaluated in 23 natural teak populations in ten teak-growing states in India. Data on age related wood properties such as diameter at breast height (DBH), heartwood and extractive content, basic density, wood color, lignin content, etc. and morphological treeform characters such as straightness, persistence of axis, branch size and branching mode, clear bole ratio, and bole defects like knots, twists, fluting, etc. were collected. DBH showed a positive correlation with age and heartwood percentage. Teak from drier areas had 10-15% less heartwood than from high rainfall areas. Ring width varied within age classes and was significantly different between provenances. A maximum of 7.6 mm was noticed for Nilambur teak provenance, indicating a high growth rate. The densest wood (692 Kg/m^3) was recorded from age class III (35-44 years) in the Banaswara provenance of Rajasthan and the lightest wood (473 Kg/m^3) was obtained from age class I (<25 years) in the Khariar provenance of Orissa. The teak wood with the longest fibre (1.4 mm) was obtained from Konni, Kerala. The Basthar provenance of Chhattisgarh and the Nilambur provenance of Kerala are found to possess teak wood with the highest extractive content (12.3%) and an attractive color. Wood from drier localities in the central parts of India was darker in colour than that of South Indian provenances. Lignin content was found to be high in wood from the Burgi provenance (36.9%) of Madhya Pradesh. The Teli variety of Hudsa provenance from Dandeli, Karnataka was found best for many of the tree form traits and highest in heartwood content (93%) in age class II (25-34 years) and III (35-44 years) in spite of small log size. Higher growth rates with a mean ring width of above 4.7 mm and heartwood content greater than 90% were noted in trees grown in southern states like Kerala, Tamil Nadu and Karnataka. In brief, locations with plus trees were identified; recorded morphological tree form traits along with wood characteristics for future genetic conservation programmes. Ex-situ conservation germplasam bank was established at Nilambur, Kerala with 25 provenances. Development of hybrids between best performers for growth and excellent provenances for better tree form and other wood characteristics (specifically between Hudsa, Nilambur and Basthar) is suggested for helping the improvement of planting stock.

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